B.E. DEGREE (Mechanical Engineering) PROGRAMME

CURRICULUM AND DETAILED SYLLABI FOR

II to VIII SEMESTERS CORE & ELECTIVE COURSES

FOR THE STUDENTS ADMITTED FROM THE

ACADEMIC YEAR 2015 ONWARDS

THIAGARAJAR COLLEGE OF ENGINEERING
(A Government Aided ISO 9001-2008 certified
Autonomous Institution affiliated to Anna University)

MADURAI – 625 015, TAMILNADU

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Passed in Board of Studies Meeting held on 11.11.17 Approved in 55th Academic council meeting held on 16.12.2017

THIAGARAJAR COLLEGE OF ENGINEERING, MADURAI – 625 015
DEPARTMENT OF MECHANICAL ENGINEERING

Vision:

"Be a globally renowned school of engineering in mechanical sciences"

Mission:

As a department, we are committed to

- Develop ethical and competent engineers by synergizing world class teaching, learning and research
- Establish state-of-art laboratories and to provide consultancy services to fulfill the expectations of industry and needs of the society
- Inculcate entrepreneurial qualities for creating, developing and managing global engineering ventures
- Motivate the students to pursue higher studies and research

Programme Educational Objectives (PEOs) of B.E. (Mechanical Engineering)

PEO1: The programme will prepare graduates for successful careers in design, manufacturing, service and process industries, research and development organizations and academic institutions

PEO2: The programme will prepare graduates with aspiration for higher studies and research

PEO3: The programme will prepare graduates with entrepreneurial and self-learning capabilities to excel in their profession

PEO4: The programme will prepare graduates to work with ethical values in diverse teams

Programme Outcomes (POs) of B.E. (Mechanical Engineering)

Graduating Students of B.E. Mechanical Engineering programme will have

1. **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning**: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Programme Specific Outcomes (PSOs) of B.E. (Mechanical Engineering)

Graduating students of B.E.(Mechanical engineering) programme will be able to:

PSO1: Design mechanical components/subsystem(s), prepare production drawings using CAD tools and select suitable manufacturing processes.

PSO2: Formulate and analyze energy and mass flow in thermal devices.

PSO3: Design, analyze, optimize and realize mechanical processes/systems to meet industrial competitiveness.

PEO – PO Matrix

POs PEOs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
PEO1	S	S	S	S	S	M	L	M	M	M	M	M
PEO2	S	S	S	S	S	M	M	S	L	S	M	S
PEO3	S	M	M	M	M	M	L	M	S	S	S	S
PEO4	M	M	M	M	M	M	M	S	S	M	M	M

Correlation: S – Strong; M-Medium; L-Low

SCHEDULING OF COURSES

Semester	Theory							Theory cum Practical	Practical			Credits
	1	2	3	4	5	6	7	8	9	10	11	
I	14MA110 Engineering Mathematics (3)	14PH120 Physics (3)	14CH130 Chemistry (3)	14EG141 English (3)	14ES150 Basics of Civil and Mechanical Engineering (2)	14ES160 Basics of Electrical and Electronics Engineering (2)		14ME170 Engineering Graphics (3)	14PH180 Physics Lab (1)	14CH190 Chemistry Lab (1)	-	**21**
II	14ME210 Engineering Calculus (3)	14ME220 Free Body Mechanics (3)	14ME230 Metal Casting and Forming Processes (3)	14ME240 Engineering Thermodynamics (3)	14ME250 Environmental Science and Engineering (3)	14ME260 Materials Science (3)		-	14ME281 Strength of Material and Material Science Lab (1)	14ME290 Workshop (1)	-	**20**
III	14ME310 Statistical Techniques (3)	14ME320 Mechanics of Materials (3)	14ME330 Metal Joining Processes and Manufacturing Practices (2)	14ME340 Fluid Mechanics (3)	14ME350 Applied Materials and Metallurgy (3)	14ME360 Geometric Modeling (3)		14ME370 Problem solving using Computer (3)	14ME380 Fluid Mechanics and CFD Lab (1)	-	-	**21**
IV	14ME410 Numerical Methods (3)	14ME420 Engineering Design (3)	14ME430 Machining Processes (3)	14ME440 Thermal Engineering (3)	14ME450 Production Drawing (3)			14ME470 Professional Communication (2)	14ME480 Machining Practices Lab (1)	14ME490 Thermal Engineering Lab (1)	14ME4C1 Capstone Course-I (2)	**21**
V	14ME510 Accounting and Finance (3)	14ME520 Design of Machine Elements (2)	14ME530 Manufacturing Systems and Automation (3)	14ME540 Heat and Mass Transfer (3)	14ME550 Mechanical Measurements and Metrology (3)	14ME560 Drives and Control (2)	14MEPX0 Prog. Elec.I (3)	-	14ME580 Computer Aided Modeling Lab (1)	14ME590 Heat Transfer Lab (1)	-	**21**
VI	14ME610 Operations Research (3)	14ME620 Kinematics and Dynamics of Machinery (3)	14ME630 Quality Engineering (2)	14ME640 Design of Transmission Systems (3)	14MEPX0 Prog. Elec.II (3)	14MEGX0 Gen.Elec. (3)		-	14ME680 Computer Aided Manufacturing Lab (1)	14ME691 Mechanical Measurements & Metrology Lab (1)	-	**19**
VII	14ME710 Project Management (3)	14ME720 Industrial Engineering (3)	14MEPX0 Prog. Elec.III (3)	14MEPX0 Prog. Elec.IV (3)	14MEGX0 Gen.Elec. (3)	-		14ME770 Finite Element Analysis (3)	-	-	14ME7C0 Capstone Course-II (2)	**20**
VIII	14MEPX0 Prog. Elec.V (3)	14MEPX0 Prog. Elec.VI (3)	14MEPX0 Prog. Elec.VII (3)	-	-	-		-	14ME880 Project (12)		-	**21**

Total Credits for Curricular Activities: **164**

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CATEGORIZATION OF COURSES
(Choice Based Credit System)

Degree: B.E. **Programme: Mechanical Engineering**

A. Foundation Courses: Credits to be earned: (48-63)

a. Humanities and Social Science (12-15) - 14

S.No	Course Code	Name of the Course	Number of Hours / Week			Credit	Prerequisite
			L	T	P		
THEORY							
1.	14EG141	English	3	0	0	3	Nil
2.	14ME250	Environmental Science and Engineering	3	0	0	3	Nil
3.	14ME510	Accounting and Finance	3	0	0	3	Nil
4.	14ME710	Project Management	3	0	0	3	Nil
THEORY CUM PRACTICAL							
5.	14ME470	Professional Communication	1	0	2	2	Nil
			Total			14	

b. Basic Science (15-21) - 20

S.No	Course Code	Name of the Course	Number of Hours / Week			Credit	Prerequisite
			L	T	P		
THEORY							
6.	14MA110	Engineering Mathematics	2	2	0	3	Nil
7.	14PH120	Physics	3	0	0	3	Nil
8.	14CH130	Chemistry	3	0	0	3	Nil
9.	14ME210	Engineering Calculus	2	2	0	3	Nil
10.	14ME310	Statistical Techniques	2	2	0	3	Nil
11.	14ME410	Numerical Methods	2	2	0	3	Nil
PRACTICAL							
12.	14PH180	Physics Lab	0	0	2	1	Nil
13.	14CH190	Chemistry Lab	0	0	2	1	Nil
			Total			20	

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CATEGORIZATION OF COURSES

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c. Engineering Science (15-21) - 20

S.No	Course Code	Name of the Course	**Number of Hours / Week**			Credit	Prerequisite
			L	T	P		
THEORY							
14.	14ES150	Basics of Civil and Mechanical Engineering	2	0	0	2	Nil
15.	14ES160	Basics of Electrical and Electronics Engineering	2	0	0	2	Nil
16.	14ME260	Materials Science	3	0	0	3	Nil
17.	14ME420	Engineering Design	1	0	2	3	Nil
18.	14ME610	Operations Research	2	2	0	3	Nil
THEORY CUM PRACTICAL							
19.	14ME170	Engineering Graphics	2	0	2	3	Nil
20.	14ME370	Problem solving using Computer	2	0	2	3	Nil
PRACTICAL							
21.	14ME281	Strength of Material and Material Science Lab	0	0	2	1	Nil

Degree: B.E. **Programme: Mechanical Engineering**

d. Elective Foundation Courses (HSS, BS and ES)* **Credits to be earned: 06**

S.No	Course Code	Name of the Course	**Number of Hours / Week**			Credit	Prerequisite
			L	T	P		
THEORY							
1.	14MAFA0	Graph Theory	3	0	0	3	Nil
2.	14MAFB0	Fuzzy Sets and Clustering	3	0	0	3	Nil
3.	14MAFC0	Number Theory	3	0	0	3	Nil
4.	14PHFA0	Smart Materials for	3	0	0	3	Nil

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CATEGORIZATION OF COURSES

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S.No	Course Code	Name of the Course	**Number of Hours / Week**			Credit	Prerequisite
			L	T	P		
		Engineers					
5.	14PHFB0	Thin Flim Technology	3	0	0	3	Nil
6.	14PHFC0	Nanotechnology	3	0	0	3	Nil
7.	14CHFA0	Biology for Engineers	3	0	0	3	Nil
8.	14CHFB0	Chemistry of Engineering Materials	3	0	0	3	Nil
9.	14CHFC0	Battery Technologies	3	0	0	3	Nil

Degree: B.E. **Programme: Mechanical Engineering**

B. Core Courses: **Credits to be earned: (63-72) - 71**

S. No	Course Code	Name of the Course	**Number of Hours / Week**			Credit	Prerequisite	Mandatory
			L	T	P			
THEORY								
1.	14ME220	Free Body Mechanics	2	2	0	3	Nil	Yes
2.	14ME230	Metal Casting and Forming Processes	3	0	0	3	Nil	Yes
3.	14ME240	Engineering Thermodynamics	2	2	0	3	Nil	Yes
4.	14ME320	Mechanics of Materials	2	2	0	3	Nil	Yes
5.	14ME340	Fluid Mechanics	2	2	0	3	Nil	Yes
6.	14ME350	Applied Materials and Metallurgy	3	0	0	3	Nil	Yes
7.	14ME360	Geometric Modeling	3	0	0	3	Nil	No
8.	14ME430	Machining Processes	3	0	0	3	Nil	Yes
9.	14ME440	Thermal Engineering	2	0	2	3	Nil	Yes
10.	14ME520	Design of machine	2	0	0	2	14ME320	Yes

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CATEGORIZATION OF COURSES
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		elements					14ME420	
11.	14ME530	Manufacturing Systems and Automation	3	0	0	3	Nil	Yes
12.	14ME540	Heat and Mass Transfer	2	2	0	3	14ME340	Yes
13.	14ME550	Mechanical Measurements and Metrology	3	0	0	3	Nil	Yes
14.	14ME560	Drives and Control	2	0	0	2	Nil	No
15.	14ME620	Kinematics and Dynamics of Machinery	2	2	0	3	Nil	Yes
16.	14ME630	Quality Engineering	2	0	0	2	14ME310	Yes
17.	14ME640	Design of Transmission Systems	2	2	0	3	14ME320 14ME520	No
18.	14ME720	Industrial Engineering	3	0	0	3	Nil	Yes
						51		
THEORY CUM PRACTICAL								
19.	14ME330	Metal Joining Processes and Manufacturing Practices	1	0	2	2	Nil	Yes
20.	14ME450	Production Drawing	1	0	4	3	Nil	Yes
21.	14ME770	Finite Element Analysis	2	0	2	3	14ME320 14ME520	Yes
						8		
PRACTICAL								
22.	14ME290	Workshop	0	0	2	1		Yes
23.	14ME380	Fluid Mechanics and CFD Lab	0	0	2	1	Nil	Yes
24.	14ME480	Machining Practices Lab	0	0	2	1	Nil	Yes
25.	14ME490	Thermal Engineering Lab	0	0	2	1	Nil	Yes
26.	14ME4C1	Capstone -I	0	0	2	2	Nil	Yes
27.	14ME580	Computer Aided Modeling Laboratory	0	0	2	1	Nil	Yes
28.	14ME590	Heat Transfer Lab	0	0	2	1	Nil	Yes

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29.	14ME680	Computer Aided Manufacturing Lab	0	0	2	1	14ME580	Yes
30.	14ME691	Mechanical Measurement and Metrology Lab	0	0	2	1	14ME550	Yes
31.	14ME7C0	Capstone -II	0	0	2	2	Nil	Yes
						1 2		

C. Elective Courses: (27 - 39)

a. Programme Specific Elective (12- 15)

S.No	Course Code	Name of the Course	**Number of Hours / Week**			Credit	Prerequisite
			L	T	P		
THEORY							
1.	14MEPA0	Product Design and Development	3	0	0	3	14ME420
2.	14MEPC0	Refrigeration and Air Conditioning	3	0	0	3	14ME340 14ME440
3.	14MEPE0	Robotics	3	0	0	3	Nil
4.	14MEPF0	Total Quality Management	3	0	0	3	Nil
5.	14MEPG0	Marketing Management	3	0	0	3	Nil
6.	14MEPJ0	Material Handling Systems Engineering	3	0	0	3	Nil
7.	14MEPK0	Automotive Engine system	3	0	0	3	14ME340 14ME540
8.	14MEPP0	Design for welding	3	0	0	3	14ME330
9.	14MEPQ0	Design for sheet metal manufacturing	3	0	0	3	Nil
10.	14MEPR0	Assembly Engineering	3	0	0	3	14ME330 14ME450 14ME530
11.	14MEPS0	Metal Cutting Engineering	3	0	0	3	14ME430
12.	14MEPT0	Internal	3	0	0	3	14ME340

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CATEGORIZATION OF COURSES

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		Combustion Engines					14ME540
13.	14MEPU0	Spark Ignition Engines - Design	3	0	0	3	14MEPT0
14.	14MEPV0	Vehicle Dynamics	3	0	0	3	14MEPH0
15.	14MEPW0	Motor cycle Dynamics	3	0	0	3	14MEPH0
16.	14MEPY0	Computational Fluid Dynamics	3	0	0	3	14ME340 14ME410
17.	14MEPZ0	Turbo Machines	3	0	0	3	14ME340 14ME440
18.	14MERB0	Integrated Product Development	3	0	0	3	14ME420
19.	14MERD0	Organization Behavior	3	0	0	3	Nil

b. Programme Specific Elective for Expanded Scope (9-12)

S.No	Course Code	Name of the Course	**Number of Hours / Week**			Credit	Prerequisite
			L	T	P		
THEORY							
1.	14MEPH0	Automotive Engineering	3	0	0	3	Nil
2.	14MEPM0	Vehicle Design Engineering	3	0	0	3	14MEPH0
3.	14MEPL0	Manufacturing system Engineering	3	0	0	3	14ME530
4.	14MERA0	Mechanical Vibrations	3	0	0	3	14ME620
5.	14MERE0	Gas turbine & Propulsion systems	3	0	0	3	14ME340 14ME440
6.	14MERC0	Reliability Engineering	3	0	0	3	14ME310
7.	14MERF0	Hydraulics and Pneumatics	3	0	0	3	Nil
8.	14MEPD0	Additive Manufacturing	3	0	0	3	Nil
9.	14MEPB0	Energy Conversion Systems	3	0	0	3	14ME440

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CATEGORIZATION OF COURSES

(Choice Based Credit System)

S.No	Course Code	Name of the Course	**Number of Hours / Week**			Credit	Prerequisite
			L	T	P		
One Credit Courses							
1.	14 ME1A0	Product Life Cycle Management	1	0	0	1	Nil
2.	14ME1B0	Mechanical Engineering Perspective in Rocketry Systems.	1	0	0	1	Nil
3.	14ME1C0	Basics of HVAC	1	0	0	1	Nil
4.	14ME1D0	Nuclear engineering	1	0	0	1	Nil
5.	14ME1F0	Industrial Hydraulics	1	0	0	1	Nil
6.	14ME1G0	3D Printing	1	0	0	1	Nil
7.	14ME1H0	Finite Element Method for Product Development	1	0	0	1	Nil
8.	14ME1K0	Non Destructive Testing	1	0	0	1	Nil
9.	14ME1L0	Gas Turbine Engines	1	0	0	1	Nil
10.	14ME1M0	Value Engineering	1	0	0	1	Nil
11.	14ME1N0	Six Sigma	1	0	0	1	Nil
12.	14ME1P0	Marine Systems and Maintenance	1	0	0	1	14ME440
13.	14ME1Q0	Vision Based Dimensional Measurement	1	0	0	1	Nil

c. Interdisciplinary Elective **Credits to be earned: 09 -12**

S.No	Course Code	Name of the Course	**Number of Hours / Week**			Credit	Prerequisite
			L	T	P		
THEORY							
1.	14MEGA0	Systems approach for engineers	3	0	0	3	Nil

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2.	14MEGB0	Energy Conversion Techniques	3	0	0	3	Nil
3.	14MEGC0	Industrial robotics	3	0	0	3	Nil
4.	14MEGD0	Composite Materials	3	0	0	3	Nil
5.	14MEGE0	Basics of Automobile engineering	3	0	0	3	Nil
6.	14MEGF0	Manufacturing of Automotive Electrical and Electronics parts	3	0	0	3	Nil

D. Project

S.No	Course Code	Name of the Course	**Number of Hours / Week**			Credit	Prerequisite
			L	T	P		
PRACTICAL							
1	14ME880	Project	0	0	0	12	Nil

		Category	L	T	P	Credit
14ME210	**ENGINEERING CALCULUS**	BS	2	1	0	3

Preamble

Engineering, Physics, in general, but particularly Solid Mechanics, Aerodynamics, Fluid Flow, Heat Flow, Robotics have application that require an understanding of Vector Calculus, Complex Analysis and Partial Differential Equations. Also Mathematical tools Fourier, Laplace Transforms are very much essential to solve ordinary and partial differential equations that occurs in the above areas. The course is designed to impart the knowledge and understanding of the above concepts to Mechanical Engineers and apply them in their areas of specialization.

Prerequisite

- Course Code : 14 MA110 Course Name: Engineering Mathematics I

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO1.	Apply the concepts of vector differentiation and vector integration to fluid flow and heat transfer problems.	Apply
CO2.	Apply analyticity to construct stream function, velocity potential and the concept of mapping in fluid flow and heat transfer	Apply
CO3.	Analyze the conformability of various transformations	Analyze
CO4.	Apply the transform tool in solving differential equation and problems in control systems	Apply
CO5.	Develop mathematical model for the given problem and analyse using Laplace transform	Analyze
CO6.	Determine the solutions of 1st order,2nd order p.d.e's	Apply
CO7.	Find the Fourier series of the given functions of length 2l and of length l.	Apply
CO8.	Apply the Fourier series tool to solve one dimensional and two dimensional heat flow problems.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	M	S	S	S	_	_	_	_	_	_	M	_	_	_
CO2.	S	M	S	S	S	_	_	_	_	_	_	M	_	_	_
CO3.	S	L	S	S	S	_	_	_	_	_	_	M	_	_	_
CO4.	S	M	S	S	S	_	_	_	_	_	_	M	_	_	_
CO5.	S	L	S	S	S	_	_	_	_	_	_	M	_	_	_
CO6.	S	M	M	M	S	_	_	_	_	_	_	M	_	_	_
CO7.	S	M	M	M	S	_	_	_	_	_	_	M	_	_	_
CO8.	S	M	M	M	S	_	_	_	_	_	_	M	_	_	_
	S	M	S	S	S	_	_	_	_	_	_	M	_	_	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	12	12	12	09
Understand	18	18	18	21
Apply	70	56	70	56
Analyse	0	14	0	14

Course Level Assessment Questions

(CO1):

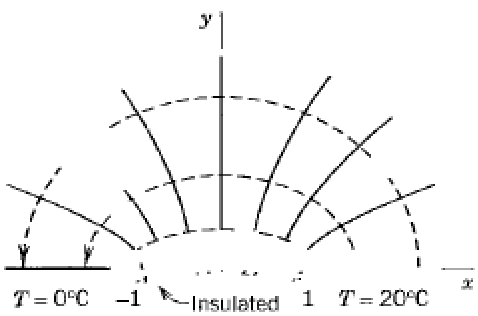
1. Find the angle between the vectors $2i - j + k$ & $i - j + 2k$.
2. A fluid motion is governed by $\varphi = (y+z)i + (z+x)j + (x+y)k$ .Is the motion Irrotational?
3. Find the amount of fluid that crosses the surface in a flow per unit time at any one instant, if the velocity field is $\vec{v} = y\vec{i} + x\vec{j} + z\vec{k}$ over the boundary of the region enclosed by the paraboloid z = 1- x^2 - y^2 and the plane z = 0.

(CO2)

1. Construct an analytic function whose real part is $u = e^{-x} sin2y$
2. Prove that the transformation $w = sin\, z$ maps the family of straight lines x = constant and y = constant in to two families of confocal central conics

(CO3):

1. Analyze the complex potential $w = z + \frac{1}{z}$
2. Find the temperature field in the upper half plane when x-axis is kept at T = 0˚ C for x < -1, is insulated for -1 < x < 1, and is kept at T = 20˚ C for x > 1as given in the fig.

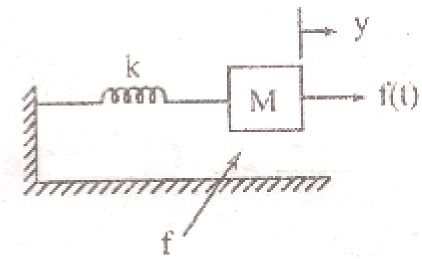


(CO4):

1. Solve the Differential Equation $y''+7y'+6y=e^{2t};\ y(0)=y(1)=1$ using Laplace Transformation.
2. Using Laplace transform solve the equation $y'+3y+2+\int_0^t y(t)=t,$ with y(0) = 0.

(CO5):

1. Develop a mathematical model for the mechanical system as given in the figure. Given the parameters M 100Kg, f = 1000N/m/sec., k = 10000N/m. A step force of 100 N is applied at t = 0 and with initial conditions y(0) = y'(0) = 0. Obtain the transfer function model parameters damping ratio ζ, undamped natural frequency $\omega_{n,}$ and damped natural frequency ω_d . Also obtain step response.



(CO6):

1. Find the Complete integral of $\sqrt{p}+\sqrt{q}=1$
2. Solve the equation (D^3 – 3 D D'^2 + $2D'^3$) = 0
3. Solve (D^3 – 4 D^2 D' + 4 D D'^2) z = sin (3x – 4y)
4. Solve (x^2 – yz)p + (y^2 – xz) q = (z^2 –xy)

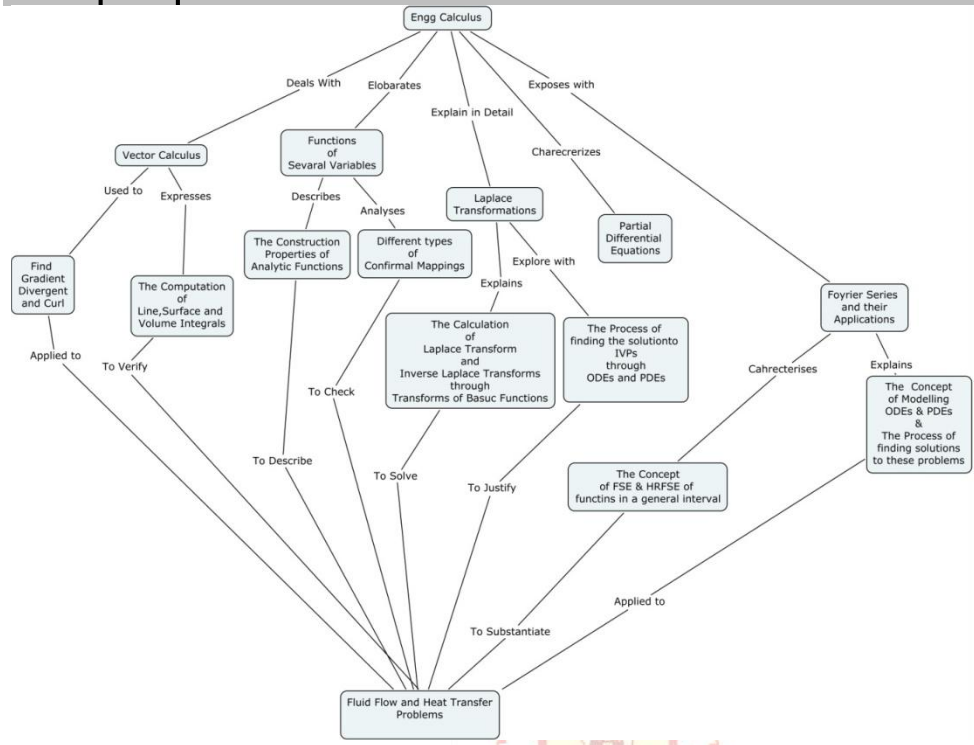
(CO7):

1. Find the Fourier coefficient $f(x)=\begin{cases} l-x & ;0<x<l \\ 0 & ;x>l \end{cases}$ a_0 for in (0, 2l).
2. Obtain the Half Range Fourier series for $f(x)=(x+1)^2$ in (-1,0).

(CO8):

1. A bar of 10 cm long, with insulated sides has its ends A and B maintained at temperatures 50˚ C and 100˚ C respectively, until steady-state conditions prevail. The temperature at A is suddenly raised to 90˚ C and at B is lowered to 60˚ C . Find the temperature distribution in the bar thereafter.
2. Find the steady state temperature distribution in a rectangular plate of sides a and b insulated at the lateral surfaces and satisfying the boundary conditions: u(0, y) = 0, u(a, y) = 0, for 0 < y < b; u(x,b) = 0 and u(x,0) = x(a - x), for 0 < x < a.

Concept Map



Syllabus

Vector Calculus-Introduction to vector algebra - Application to vector Mechanics - Vector Differential Operator- Gradient -Divergent and Curl - _Identities - Solenoidal and Irrotational vectors - Application to fluid flow - Vector Integration - Line, Surface and Volume Integrals - Green's - Stoke's and Gauss's theorems - Application of these theorems on fluid flow problems. **Functions of Complex variables-**Complex differentiation - Analytic functions - Properties - Construction of Analytic functions - applications to Fluid Mechanics - Conformal Mappings - Basic transformations - - Applications to heat transfer and fluid flow problems. **Laplace Transformations-**Definition - Transforms of Basic functions - Shifting theorems, derivatives and integrals of transforms, Transforms of derivatives and Integrals - Inverse Laplace Transforms Using partial fractions and convolution - Initial value and Final value theorems - Solution to Differential and Integral equations by Laplace Transformation - Modeling and Solution of control system problems. **Partial Differential Equations (PDEs)-** Solution to PDEs - Standard forms - Lagrange's differential equation - Higher order equations with constant Coefficients - variable separable method. .**Fourier Series-**General Fourier series of length 2l -Half range series of length l - Harmonic Analysis - Problems on One Dimensional Heat Flow Equation and Two Dimensional Heat flow equations- Fourier Series solution to these problems.

Text Books

1. Grewal B.S, '**Engineering Mathematics**', Khanna Publishers India Ltd, 43rd Edition, 2014.
2. Erwin Kreyszig, '**Advanced Engineering Mathematics**', Wiley India, 10th Edition, 2011.

Reference Books

Lecture Notes prepared by Department of Mathematics, Thiagarajar College Of Engineering , Madurai 15

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Vector Calculus and its Application**	
1.1	Introduction to vector algebra and its applications to Mechanics	1
1.2	Gradient of scalar point functions, Divergent and Curl of vector point functions	2
1.3	Application to fluid flow	1
1.4	Vector Integrals ,Line, Surface and Volume Integrals	3
1.5	Theorems and their applications to fluid flow	3
2	**Functions of Complex variables**	
2.1	Complex differentiation ,analytic functions and their properties	1
2.2	Construction of analytic functions, applications to fluid mechanics	3
2.3	Conformal mappings, basic transformations	2
2.4	Applications of conformal mappings in Heat transfer problems	2
2.4	Applications of conformal mappings in Fluid flow problems	2
3	**Laplace Transforms and its Applications**	
3.1	Transforms of Basic functions, shifting theorems	2
3.2	Transforms of Derivatives and Integrals and Derivatives and Integrals of transforms	2
3.3	Inverse Laplace Transforms by partial fraction method and Convolution method	2
3.4	Solution to Differential and Integral Equations	2
3.5	Modeling and Solution of control system problems	2
4	**Partial Differential equations and their applications**	
4.1	Solution to standard types of equations	2
4.2	Solution to Lagrange's equations	2
4.3	Solution to Higher order PDEs with Constant Coefficients	3
4.4	Solution to Partial Differential equations using variable separable method	2
5	**Fourier Series and its Applications**	
5.1	Fourier Series Expansion of functions of length 2l	2
5.2	Half Range Fourier Series Expansion of length l	2
5.3	Harmonic Analysis	1
5.4	Application of Fourier Series Expansion in One Dimensional Heat Transfer problems	3
5.5	Application of Fourier Series Expansion in Two Dimensional Heat Transfer problems in Cartesian and polar coordinates	3
	Total	**50**

Course Designers:

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		Category	L	T	P	Credit
14ME220	**FREE BODY MECHANICS**	PC	2	1	0	3

(Common with 14MT220- Free Body Mechanics)

Preamble

Mechanics is the branch of physics concerned with the behaviour of physical bodies when subjected to forces or displacements, and the subsequent effect of the bodies on their environment. The discipline has its roots in several ancient civilizations. Scientists such as Galileo, Kepler and especially Newton, during the early modern period, laid the foundation for what is now known as classical mechanics. The often-used term 'body' in the field of mechanics stands for a wide assortment of objects, including particles, projectiles, spacecraft, stars, parts of machinery, parts of solid, parts of fluids (gases and liquids) etc. Distinctions between the various sub-disciplines of mechanics, concern the nature of the bodies being described. Sub-disciplines of mechanics include Newtonian mechanics (dynamics, theory of motion and forces), Lagrangian mechanics (a theoretical formalism based on the principle of conservation of energy), Hamiltonian mechanics (another theoretical formalism based on the principle of the least action), Celestial mechanics (the motion of heavenly bodies: planets, comets, stars, galaxies, etc.), Astrodynamics (spacecraft navigation etc.), Solid mechanics (properties of rigid bodies), Elasticity (properties of semi-rigid bodies), Acoustics (density variation propagation in solids, fluids and gases), Statics (semi-rigid bodies in (mechanical equilibrium), Fluid mechanics (the motion of fluids), Soil mechanics (mechanical behavior of soils), Continuum mechanics (mechanics of continua - both solid and fluid), Hydraulics (mechanical properties of liquids), Fluid statics (liquids in equilibrium)

Prerequisite

- 14MA110 : Engineering Mathematics-I
- 14PH120 : Physics

Course Outcomes

On the successful completion of the course, students will be able to

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Enumerate the basic of concept of mechanics and fundamentals of friction	Understand
CO 2.	Solve problems in engineering systems using the concept of static equilibrium	Apply
CO 3.	Determine the centroid of a line, areas, and volumes, center of mass of body and moment of inertia of composite areas.	Apply
CO 4.	Solve problems involving frictional phenomena in machines	Apply
CO 5.	Solve problems involving kinematics and kinetics of particles in two- and three-dimensions	Apply
CO 6.	Solve problems involving kinematics and kinetics of rigid bodies in plane motion.	Apply
CO 7.	Solve problems using D'Alembertz principles.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	M	M	M	L	_	_	_	_	_	_	_	_	M	_	M
CO2.	S	S	S	M	_	_	_	_	_	_	_	_	M	_	M
CO3.	S	S	S	M	_	_	_	_	_	_	_	_	M	_	M
CO4.	S	S	S	M	_	_	_	_	_	_	_	_	M	_	M
CO5.	S	S	S	M	_	_	_	_	_	_	_	_	M	_	M
CO6.	S	S	S	M	_	_	_	_	_	_	_	_	M	_	M
CO7.	S	S	S	M	_	_	_	_	_	_	_	_	M	_	M
	S	S	S	M	_	_	_	_	_	_	_	_	M	_	M

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	20	20	20	20
Apply	60	60	60	60
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

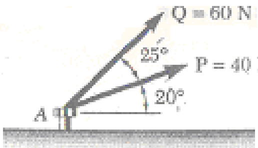
Course Level Assessment Questions

Course Outcome 1 (CO1):

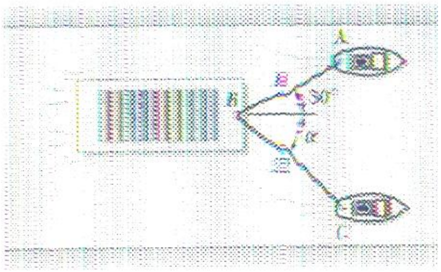
1. State the concept of equilibrium of mechanical system.
2. State law of friction
3. Describe the dynamic equilibrium of a rigid boy in plane motion
4. State the Newton's law of motion

Course Outcome 2 (CO2):

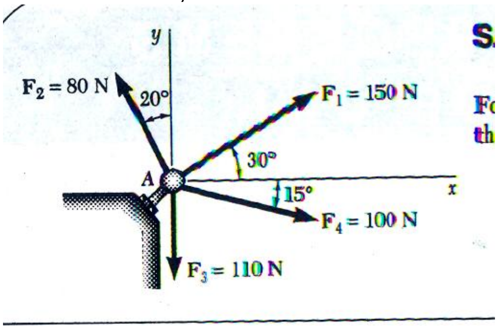
1. Determine the resultant of two force P and Q act on a bolt A



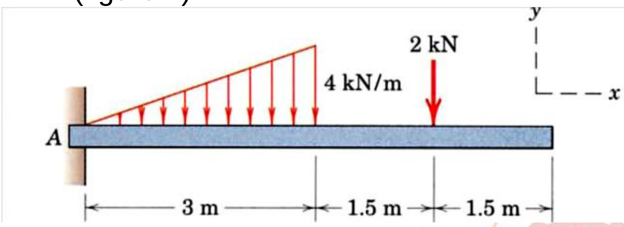
2. A barge is pulled by two tugboats. If the resultant of the forces exerted by the tugboats is a 5000 N force directed along the axis if the barge, determine the a) the tension in each of the ropes knowing that α = 45^o b) the value of α for which the tension in rope 2 is minimum.



3. Four forces act on bolt A shown, Determine the resultant of the forces on the bolt,

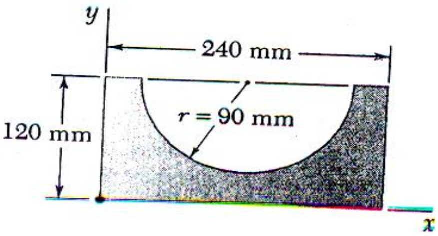


4. Determine the reactions at A for the beam subjected to the following load distribution (figure 1)

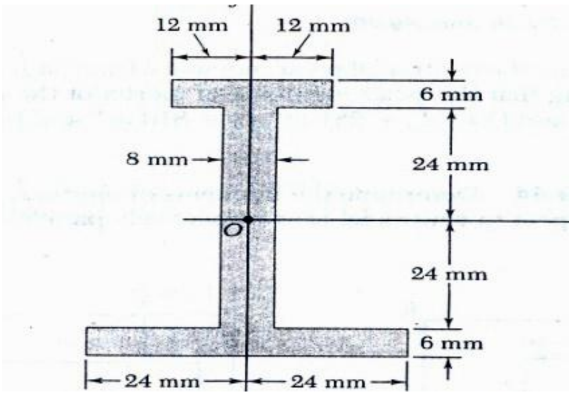


Course Outcome 3 (CO3):

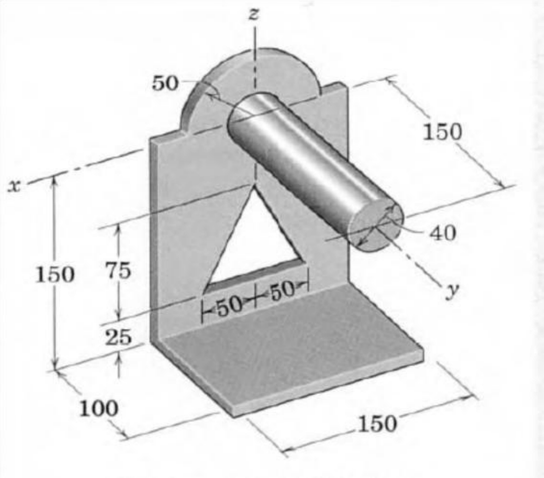
1. Define centroid of an area
2. State parallel axis theorem
3. State perpendicular axis theorem.
4. Determine the moment of inertia of the shaded area with respect to the x axis



5. Determine the moment of inertia and radius of gyration of the shaded area with respect to the x axis



6. Locate the centre of gravity of the given shape as shown in figure .



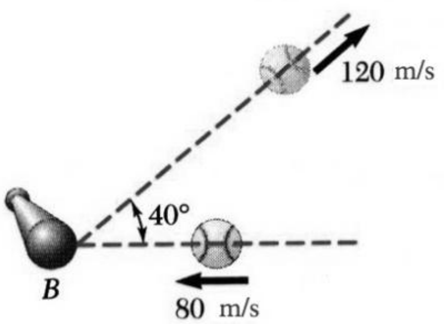
Dimensions in millimeters

Course Outcome 4 (CO4):

1. A body of mass 4 kg lying on a rough horizontal plane is attached to one end of a string. The string passes over a smooth pulley and carries at its other end, a body of mass 10 kg which hangs freely vertically down. If the system starts from rest and attains an acceleration of 6 m/s^2, find the coefficient of friction.
2. Determine the horizontal force P required to raise the 200kg block. The coefficient of friction for all surfaces is 0.40.
3. If the coefficient of friction between the steel wedge and the moist fibers of the newly cut stump is 0.20, determine the maximum angle which the wedge may have and not pop out of the wood after being driven by the sledge.

Course Outcome 5 (CO5):

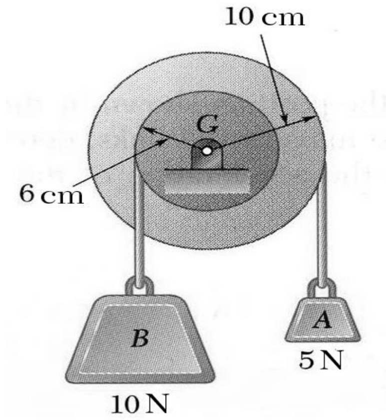
1. Steep safety ramps are built beside mountain highways to enable vehicles with defective brakes to stop safely. A truck enters a 250m ramp at a high speed Vo and travels 180m in 6s at constant deceleration before its speed is reduced to V0/2. Assuming the same constant deceleration, determine a) the additional time required for the truck to stop b) the additional distance travelled by the truck.
2. A flywheel rotates about its centre, and has a mass of 50kg. It rotates freely at an constant angular velocity of 1000 rpm when a brake is applied as shown in fig.. Find the angular acceleration of the flywheel, and determine the time taken T for it to come to rest.
3. A 0.5 kg baseball is pitched with a velocity of 80 m/s. After the ball is hit by the bat, it has a velocity of 120 m/s in the direction shown. If the bat and ball are in contact for 0.015 s, deter-mine the average impulsive force exerted on the ball during the impact.



Course Outcome 6 (CO6):

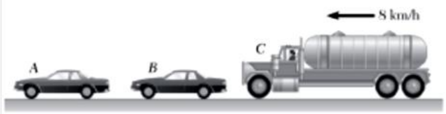
1. A Stone is thrown vertically upwards with a velocity of 40 m/sec. Find its position after 5 seconds.

2. A body of mass 4 kg lying on a rough horizontal plane is attached to one end of a string. The string passes over a smooth pulley and carries at its other end, a body of mass 10 kg which hangs freely vertically down. If the system starts from rest and attains an acceleration of 6 m/s^2 m, find the coefficient of friction.
3. A pulley weighing 12 N and having a radius of gyration of 8 cm is connected to two blocks as shown. Assuming no axle friction, determine the angular acceleration of the pulley and the acceleration of each block.

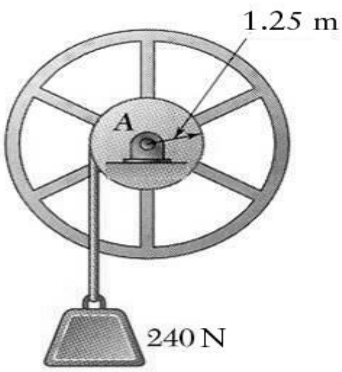


Course Outcome 7 (CO7):

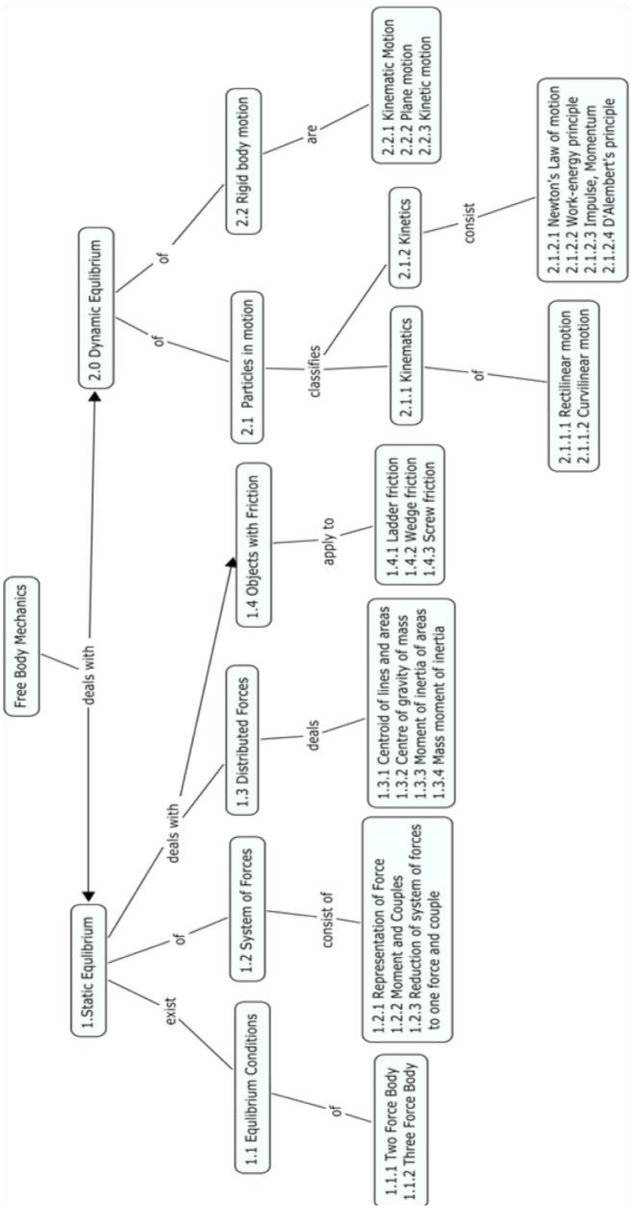
1. A flywheel executes 1800 revolutions while it coasts to rest from speed of 6000 rpm. Assuming uniformly accelerated motion, determine (*a*) the time required for the flywheel to coast to rest, (*b*) the time required for the flywheel to execute the first 900 revolutions.
2. Two identical 1350-kg automobiles *A* and *B* are at rest with their brakes released when *B* is struck by a 5400-kg truck *C* which is moving to the left at 8 km/h. A second collision then occurs when *B* strikes *A*. Assuming the first collision is perfectly plastic and the second collision is perfectly elastic, determine the velocities of the three vehicles just after the second collision.



3. For the drum and flywheel, I=10.5 kg-m2.The bearing friction is equivalent to a couple of 60Nm .At the instant shown, the block is moving downward at 6 m /s. Determine the velocity of the block after it has moved 4 m downward.



Concept Map



Syllabus

Static Equilibrium of Mechanical Systems: Equilibrium conditions-Two force body-Three force body. **System of forces**: Representation of Force, Moment and Couples-Reduction of system of forces to one force and couple. **Distributed forces:** Centroid of lines and areas-Centre of gravity of mass-Moment of inertia of areas-Mass moment of inertia. **Objects with friction**: Ladder friction-Wedge friction-Screw friction-Applications **Dynamic equilibrium:** Particles in motion-Kinematics of particles-Rectilinear motion-Curvilinear motion-Kinetics of particles-Newton's Law of motion-Work-energy principle-Impulse-Momentum principle, D'Alembert's principle. **Rigid body motion:** Kinematic Motion -Rotary motion of rigid bodies-Plane motion-Kinetic motion.

Text Books

1. Beer F.P. and Johnston Jr. E.R., '**Vector Mechanics for Engineers: Statics and Dynamics**', Eighth Edition, Tata McGraw Hill, 2008.
2. Meriam J.L and Kraig L.G, '**Engineering Mechanics-Statics and Dynamics**', John Wiley & sons, Newyork, 2008.

Reference Books

1. Boresi A.P. and Schmidt R.J., '**Engineering Mechanics and Dynamics**', Thomson Asia Press, Singapore, 2004.
2. Shames. I.H, '**Engineering Mechanics – Statics and Dynamics**', Pearson Education, Asia, 2006.
3. Palanichamy and Nagan S., '**Engineering Mechanics – Statics and Dynamics**', Tata McGraw Hill, 2005.
4. Lakshmana Rao, '**Engineering Mechanics– Statics and Dynamics**', Prentice Hall of India, New Delhi, 2003.
5. Timoshenko, S, Young, D, Rao. J, '**Engineering Mechanics**', Fourth Edition, Tata McGraw Hill, 2006.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Static Equilibrium of Mechanical Systems**	
1.1	Equilibrium conditions	1
1.1.1	Two force body	
1.1.2	Three force body	1
1.2	**System of forces**	
1.2.1	Representation of Force,	2
1.2.2	Moment and Couples	2
1.2.3	Reduction of system of forces to one force and couple	1
1.3	**Distributed forces**	
1.3.1	Centroid of lines and areas	2
1.3.2	Centre of gravity of mass	2
1.3.3	Moment of inertia of areas	2
	Tutorial Problems in Moment of Inertia	2
1.3.4	Mass moment of inertia	2
	Tutorial Problems in Mass Moment of Inertia	2
1.4	**Objects with friction**	
1.4.1	Ladder friction	2
1.4.2	Wedge friction	2
1.4.3	Screw friction	2
	Tutorial Problems in Friction	2
2	**Dynamic equilibrium**	
2.1	**Particles in motion**	
2.1.1	Kinematics of particles	1
2.1.1.1	Rectilinear motion	1
2.1.1.2	Curvilinear motion	1
2.1.2	Kinetics of particles	1
2.1.2.1	Newton's Law of motion	2
2.1.2.2	Work-energy principle	2
2.1.2.3	Impulse, Momentum	2
	Tutorial Problems	2
2.1.2.4	D'Alembert's principle	1

2.2	**Rigid body motion**	
2.2.1	Kinematic Motion –Rotary motion of Rigid bodies	1
2.2.2	Plane motion	2
2.2.3	Kinetic motion	2
	Tutorial Problems	2
	Total	**48**

Course Designers:

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14ME230	METAL CASTING AND FORMING PROCESSES	Category	L	T	P	Credit
		PC	3	0	0	3

Preamble

Casting is a manufacturing process by which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mold to complete the process. Casting is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other method. Metal casting is one of the most common casting processes. Products may be discrete products like nails, piston, engine blocks or continuous products like rod, tube and pipes of metal or plastics. Plastics are commonly used in almost all products.

Forming or metal forming, is the metal working process of fashioning metal parts and objects through mechanical deformation; the work piece is reshaped without adding or removing material, and its mass remains unchanged. The rolling is the primary process to produce billets, slabs and sheets, which are subsequently used to produce parts such as tubes, panels, car doors, PC panels, computer casing, utensils, and so on. Rapid prototyping is a group of techniques used to quickly fabricate a scale model of a physical part or assembly using three-dimensional computer aided design (CAD) data.

The first and second parts of this course aim to provide knowledge on the working, advantages, limitations and applications of various metal casting and forming processes.

Prerequisite

- 14MA110 : Engineering Mathematics-I
- 14PH120 : Physics
- 14ES150 : Basics of Civil and Mechanical Engineering

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the principles of various metal casting processes, metal forming, plastic moulding and additive processes.	Understand
CO 2.	Explain the process capabilities of metal casting, forming, plastic moulding and additive processes.	Understand
CO 3.	Explain the process parameters of metal casting, forming, plastic moulding and additive processes.	Understand
CO 4.	Determine the forming forces for various metal forming processes.	Apply
CO 5.	Identify defects and interpret causes in product of metal casting and forming processes.	Apply
CO 6.	Select the suitable material & process for a given product or component.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1.	M	L	L	_	_	_	L	_	_	_	_	_	L	_	L
CO2.	M	L	L	_	_	_	_	_	_	_	_	_	L	_	L
CO3.	M	L	L	_	_	_	_	_	_	_	_	_	L	_	L
CO4.	S	M	M	_	_	_	_	_	_	_	_	_	M	_	L
CO5.	S	M	M	_	_	_	_	_	_	_	_	_	M	_	L
CO6.	S	M	M	_	_	_	_	_	_	_	_	_	S	_	L
	S	M	M	_	_	_	_	_	_	_	_	_	M	_	L

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	**20**	**20**	**20**	**20**
Understand	**40**	**40**	**40**	**40**
Apply	**40**	**40**	**40**	**40**
Analyse	**0**	**0**	**0**	**0**
Evaluate	**0**	**0**	**0**	**0**
Create	**0**	**0**	**0**	**0**

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Give the classification of patterns.
2. What is impact extrusion?
3. State the principle of stereolithography (SLA) processes

Course Outcome 2 (CO2):

1. Discuss the steps involved in investment mould casting process with a neat sketches.
2. Explain with neat sketches the following forging operations: (a) upsetting, (b) drawing down, (c) bending, (d) drifting, (e) punching, (f) fullering, (g) heading and (i) piercing
3. Discuss the working principle of fusion deposition modelling (FDM).

Course Outcome 3 (CO3):

1. Explain the temperature distribution at the interface of the mould wall and the liquid metal during solidification of metals in casting.
2. How does friction force, roll force and tensions affect flat rolling practice?
3. Explain the process to produce plastic sheets.

Course Outcome 4 (CO4):

1. An annealed copper strip 228 mm wide and 25 mm thick is rolled to a thickness of 20 mm. The roll radius is 300 mm and rotates at 100 rpm. Calculate the roll force and the power in this operation.
2. A solid cylindrical work piece made of 304 stainless steel is 150 mm in diameter and 100 mm high. It is forged by open die forging at room temperature with flat dies to a 50 % reduction in height. Assuming that the coefficient of friction is 0.2, calculate the forging force at the end of the stroke.
3. A round billet made of 70-30 brass is extruded at a temperature of 675° C. The billet diameter is 125 mm and the diameter of the extrusion is 50 mm. Calculate the extrusion force required.

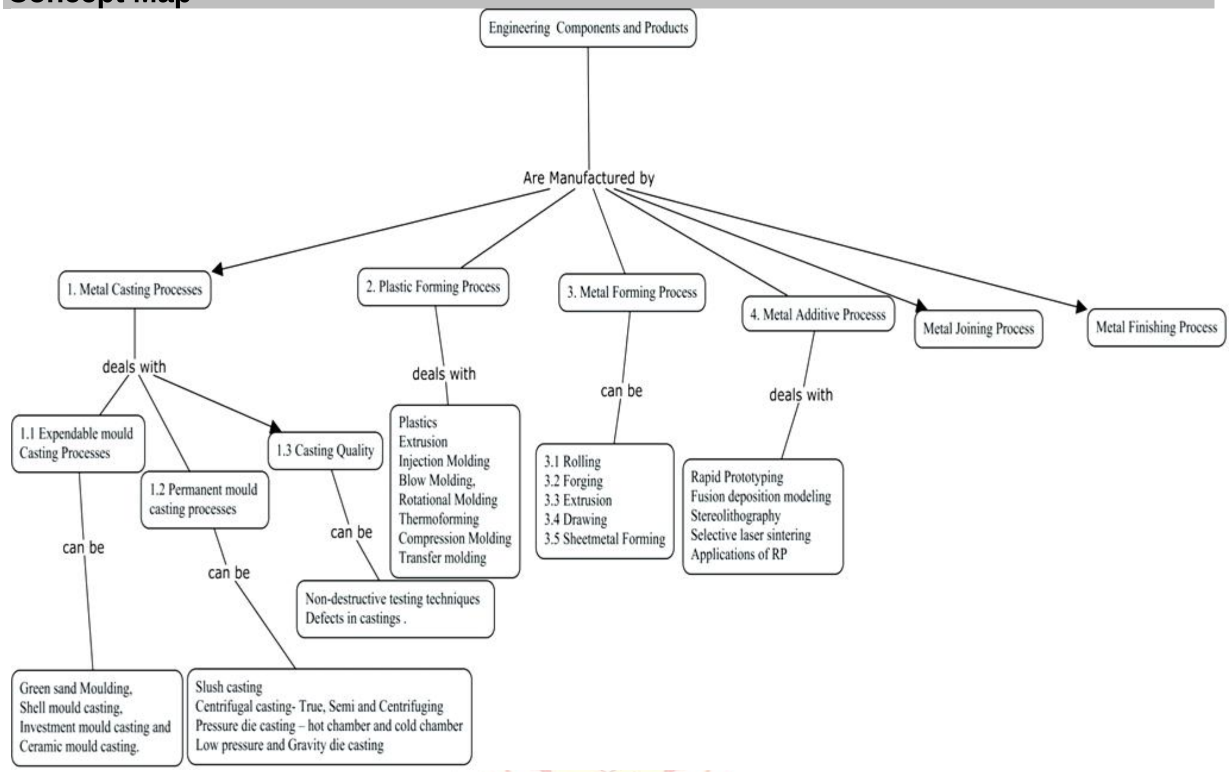
Course Outcome 5 (CO5):

1. List the defects that occur in rolled plates and sheets.
2. Suggest few techniques to minimize incomplete casting and inclusions in casting.
3. Identify a more suitable method to inspect a cast with shrinkage, metallic projections, cavities, discontinuities and describe it. Also, write all the possible causes for those defects and rectification method.

Course Outcome 6 (CO6):

1. Select a suitable pressure die casting process for low melting point materials.
2. Suggest suitable metal forming process along with justification for manufacture of the following products:
   (i) CAM shaft of IC Engine
   (ii) Threaded bolt
   (iii)Spur gears of Al
3. How is the following house hold articles produced? i) Tumblers and ii) Cups
4.

Concept Map



Syllabus

Metal casting:

Expendable mould Casting Processes: Pattern - materials, types, and allowances. Cores, Core prints and Core making. Types of sand moulds - green sand, cold box and no-bake moulds. Steps involved in making a green sand mould. Moulding machines - Squeeze type, Jolt type, and Sand slinger. Procedural steps and applications of Shell mould casting, Investment mould casting and Ceramic mould casting.

Permanent mould casting processes: Procedural steps and applications of Permanent mould casting processes such as Slush casting, Centrifugal casting- True, Semi and Centrifuging, Pressure die casting – hot chamber and cold chamber, Low pressure and Gravity die casting.

Process parameters of sand, shell, ceramic, investment casting, and pressure die casting.

Casting Quality: Defects in castings -Shrinkage, metallic projections, cavities, discontinuities, defective surface, incomplete casting and inclusions and summary of Non-destructive testing techniques.

Plastic forming Processes: Plastics, general properties and applications of thermo plastics and thermosets, Forming/shaping and applications of plastics: Extrusion, Injection Molding, Blow Molding, Rotational Molding, Thermoforming, Compression Molding, Transfer molding, Casting, and Cold forming processes / Equipment.

Metal forming Processes:

Fundamental of Metal forming, Elastic and plastic deformation. Concept of strain hardening. Hot and cold working processes.

Rolling Process: Hot and cold rolling process , process parameters involved, Type of rolling mills, Flat rolling practice, Shape rolling operations, Production of seamless pipe and tubing, Defects in rolled plates, tubes and sheets.

Forging: Outline of forging and related operations, process parameters involved, Various Forging Processes such as open die, closed die, Forging Operations such as Heading, Piercing, coining, Forging presses and dies and defects in forging.

Drawing Process: Wire and tube drawing, process parameter involved, Wire Drawing equipment and dies and defects in drawing.

Extrusion Process: hot, cold, impact and hydro static extrusion, process parameter involved, Extrusion Machines-Horizontal, Vertical hydraulic presses and dies and defects in extrusion.
Sheet metal forming Process: Formability of Sheet metal, Shearing mechanism, Drawabilty, process parameter involved, Shearing operations- Blanking, Piercing, fine Blanking, Slitting, trimming, lancing, cut off, coining, Nibbling, bending, shaving, Forming, Beading, bulging Flanging, Dimpling, Hemming, Tube bending, Stretch Forming, Deep Drawing, Reverse Drawing and defects in sheet metal process.
Metal additive processes: Introduction to Rapid Prototyping – fusion deposition modeling - Stereolithography– Selective laser sintering – applications.

Text Book

1. Serope Kalpakjian and Steven R.Schmid, '**Manufacturing Engineering and Technology**', Sixth Edition, PHI, 2010.
2. Mikell P.Groover, '**Fundamental of Modern Manufacturing**', Wiley India Edition, Third Edition, Reprint, 2012.

Reference Books

1. S.K.HajraChoudhury and A.K. HajraChoudhury, '**Elements of Work shop Technology**', Vol – I Manufacturing Processes, Media Promoters and Publishers Pvt. Ltd, 1986.
2. P.L.Jain, '**Principles of Foundry Technology**', Tata McGraw Hill, Fifth Edition, 2009.
3. Prabodh C. Bolur, '**A Guide to Injection Moulding of Plastics**', Third edition, Sri Prema Sai Printers and Publishers, Mangalore, 2007.
4. P.N.Rao, '**Manufacturing Technology**', Volume-1, Tata McGraw Hill, New Delhi, Third Edition, 2011.
5. P.C. Sharma, '**A Text Book of Production Technology (Manufacturing Processes)**', S. Chand & Company Ltd., New Delhi, Seventh Reprint, 2012.
6. E.Paul Degarmo, J.T.Black, and Ronald A. Konser, '**Materials and Processes in Manufacturing**', 5th Edition, Prentice Hall India Ltd., 1997.
7. Philip F. Oswald, and Jairo Munoz, '**Manufacturing Process and Systems**', John Wiley and Sons, 1992.

Course Contents and Lecture Schedule

No.	Topic	No. of Lectures
1	**Metal casting Processes**	
1.1	**Expendable mould Casting Processes:** Pattern - materials, types, and allowances. Cores, Core prints, and core making. Types of sand moulds.	2
1.1.1	Green sand, cold box and no-bake moulds. Steps involved in making a green sand mould.	1
1.1.2	Moulding machines - Squeeze type, Jolt type, and Sand slinger.	1
1.1.3	Procedural steps and applications of Shell mould casting, Investment mould casting and Ceramic mould casting.	2
1.2	**Permanent mould casting processes:** Procedural steps and applications of Permanent mould casting processes such as Slush casting, Centrifugal casting- True, Semi and Centrifuging,	2
1.2.1	Pressure die casting – hot chamber and cold chamber, Low pressure and Gravity die casting, Process parameters of sand, shell, ceramic, investment casting, and pressure	2

	die casting.	
1.3	**Casting Quality:** Defects in castings -Shrinkage, metallic projections, cavities, discontinuities, defective surface, incomplete casting and inclusions and summary of Non-destructive testing techniques.	2
2	**Plastic forming processes:** Plastics, general properties and applications of thermo plastics and thermosets.	1
2.1	Forming/shaping and applications of plastics: Extrusion, Injection Molding, Blow Molding, Rotational Molding	2
2.1.1	Thermoforming, Compression Molding, Transfer molding, Casting, and Cold forming processes / Equipment.	2
3.	**Metal Forming Process**	
3.1	Fundamental of Metal forming, Elastic and plastic deformation. Concept of strain hardening. Hot and cold working processes.	1
3.2	**Rolling Process**: Hot and cold rolling process , process parameters involved, Type of rolling mills, Flat rolling practice, Shape rolling operations, Production of seamless pipe and tubing.	2
3.2.1	Defects in rolled plates and sheets.	1
3.3	**Forging Processes:** Outline of forging and related operations, process parameters involved, Various Forging Processes such as open die, closed die, Forging Operations such as Heading, Piercing, coining.	2
3.3.1	Forging presses and dies and defects in forging.	1
3.4	**Extrusion Process**: hot, cold, impact and hydro static extrusion, process parameter involved,	2
3.4.1	Extrusion Machines-Horizontal, Vertical hydraulic presses and dies and defects in extrusion.	1
3.5	**Drawing Process:** Wire and tube drawing, process parameter involved, Wire Drawing equipments and dies and defects in drawing.	2
3.6	**Sheet metal forming Process**: Formability of Sheet metal, Shearing mechanism, Drawabilty, process parameter involved.	1
3.6.1	Shearing operations- Blanking, Piercing, fine Blanking, Slitting, trimming, lancing, cut off, coining, Nibbling, bending, shaving, Forming, Beading, bulging Flanging, Dimpling, Hemming.	1
3.6.2	Tube bending, Stretch Forming, Deep Drawing and defects in sheet metal process.	1
4	**Metal additive processes**	
4.1	Introduction to Rapid Prototyping, Fusion deposition modelling.	2
4.2	Stereolithography, Selective laser sintering and applications.	2
	Total	**36**

Course Designers:

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14ME240	**ENGINEERING THERMODYNAMICS**	Category	L	T	P	Credit
		PC	2	1	0	3

Preamble

Thermodynamics is a branch of science that deals with energy and its transfer. All activities in nature involve some interaction between energy and matter. Engineering thermodynamics plays a major part in the design and analysis of automotive engines, rockets, jet engines, refrigeration and air-conditioning systems, and power plants, etc. Therefore, developing a good understanding of the basic principles of engineering thermodynamics is essential for mechanical engineers. This course deals with the basic principles and concepts of thermodynamics, laws of thermodynamics, energy and entropy of ideal gas, steam, and mixture of gases.

Prerequisite

- 14MA110 : Engineering Mathematics-I
- 14PH120 : Physics
- 14ES150 : Basics of Civil and Mechanical Engineering
-

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Determine the change of properties and energy transfer during different thermodynamic processes in closed system such as piston-cylinder arrangement using ideal gas, water or steam.	Apply
CO 2.	Determine the energy transfer (work transfer and heat transfer) and change in properties of ideal gas or steam in thermodynamically open systems namely nozzle, diffuser, turbine, compressor, heat exchanger during different thermodynamic processes.	Apply
CO 3.	Determine the efficiency of heat engine and COP of heat pump or refrigerator.	Apply
CO 4.	Determine the entropy change in ideal gas, water or steam in various reversible and irreversible processes and cycles.	Apply
CO 5.	Determine the available energy and irreversibility of thermodynamic processes.	Apply
CO 6.	Determine the properties of ideal gas mixture.	Apply
CO 7.	Calculate air fuel ratio and percentage of excess air for combustion process.	Apply

Mapping with Programme Outcomes

S- Strong; M-Medium; L-Low

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	M	L	_	_	_	_	_	_	_	_	L	_	M	_
CO2.	S	M	L	_	_	_	_	_	_	_	_	L	_	M	_
CO3.	S	M	L	_	_	_	_	_	_	_	_	L	_	M	_
CO4.	S	M	L	_	_	_	_	_	_	_	_	L	_	L	_
CO5.	S	M	L	_	_	_	_	_	_	_	_	L	_	M	_
CO6.	S	M	L	_	_	_	_	_	_	_	_	L	_	L	_
CO7.	S	M	L	_	_	_	_	_	_	_	_	L	_	L	_

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	30	30	30	30
Apply	50	50	50	50
Analyse	--	--	--	--
Evaluate	--	--	--	--
Create	--	--	--	--

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. State Zeroth law of thermodynamics.
2. Explain open system with an example.
3. a) A stationary mass of gas is compressed without friction from an initial state of 0.3 m^3 and 0.105 MPa to a final state of 0.15m^3 and 0.105 MPa, the pressure remaining constant during the process. There is a heat transfer of 37.6 kJ of heat from the gas during the process. How does the internal energy of the gas change?
4. A perfect gas is compressed according to the law $Pv^{1.25}$ = constant from an initial pressure of 1bar and volume of 0.9 m^3 to a final volume of 0.6 m^3. Determine the final pressure and work done per kg of gas during the process. Take R = 287 J/kgK and □ = 1.4.
5. In a cyclic process, heat transfer are +14.7 kJ, -25 kJ, - 3.56 kJ and + 31.5 kJ. What is the net work for the cyclic process?
6. Determine the heat transfer and its direction for a system in which a perfect gas having molecular weight of 16 is compressed from 101.3 kPa, 20^o C to a pressure of 600 kPa following the law $Pv^{1.3}$ = Constant. Take specific heat at constant pressure of gas as 1.7 kJ/kgK.
7. A gas of mass 1.5 kg undergoes a quasistatic expansion, which follows a relationship P = a + bV, where 'a' and 'b' are constants. The initial and final pressures are 1000 kPa and 200 kPa respectively and the corresponding volumes are 0.2 m^3 and 1.2 m^3. The specific internal energy of the gas is given by the relation U = (1.5 PV – 85), where P is in kPa and V is in m^3. Calculate the net heat transfer and the maximum internal energy of the gas attained during expansion.

8. A vessel of volume 0.04 m^3 contains a mixture of saturated water and saturated steam at a temperature of 250+o C. The mass of the liquid present is 9 kg. Find pressure, mass, specific properties.

Course Outcome 2 (CO2):

1. Define steady flow and write the steady flow energy equation for a turbine.
2. Derive the steady flow energy equation
3. Steam enters a nozzle at 400°C and 800 kPa with a velocity of 10 m/s, and leaves at 300°C and 200 kPa while losing heat at a rate of 25 kW. For an inlet area of 800 cm^2, determine the velocity and the volume flow rate of the steam at the nozzle exit.
4. Calculate the power developed and diameter of the inlet pipe, if a gas enters into the gas turbine at 5 kg/s, 50 m/s with an enthalpy of 0.9 MJ/kg and leaves at 150 m/s with an enthalpy of 0.4 MJ/kg. The heat loss to the surroundings is 0.025 MJ/kg. Assume 100 kPa and 300 K at the inlet.
5. 4 kg/s of steam enters a turbine. The inelt of the turbine is 2.5 m higher than the outlet. The velocity is 132 m/s. Outlet velocity is 327 m/s and heat loss is 9.2 kJ/s.

The enthalpy per kg at inlet and outlet of the turbine are 3127.4 kJ/kg and 2512 kJ/kg respectively. Determine the power output.

Course Outcome 3 (CO3):

1. Write Kelvin Planck's statement of second law of thermodynamics.
2. Show that the efficiency of a reversible heat engine is greater than that of irreversible engine.
3. A Carnot heat engine receives heat from a reservoir at 900°C at a rate of 800 kJ/min and rejects the waste heat to the ambient air at 27°C. The entire work output of the heat engine is used to drive a refrigerator that removes heat from the refrigerated space at - 5°C and transfers it to the same ambient air at 27°C. Determine (*a*) the maximum rate of heat removal from the refrigerated space and (*b*) the total rate of heat rejection to the ambient air.
4. 1200 kJ of heat is supplied to an engine from a source of 20 C, the sink temperature is 2 C. Which of the following cycle represents reversible, irreversible or impossible? (i)275 kJ of heat is rejected to sink, (ii) 825 kJ of heat is rejected and (iii) 350 kJ heat is rejected.
5. Two Carnot engines A and B are operated in series. The Engine A receives heat at 870 K and jrects to a reservoir at T. Engine B receives heat rejected by the Engine A and in turn rejects to a sinki at 300 K. Find the temperature T for (i) Equal work outputs of both engines and (ii) same efficiencie
6. A reversible heat engine operates between two reservoirs at 827^{o}C and 27^{o}C. Engine drives a Carnot refrigerator maintaining –13^{o}C and rejecting heat to reservoir at 27^{o}C. Heat input to the engine is 2000 kJ and the network available is 300 kJ. How much heat is transferred to the refrigerator and total heat rejected to reservoir at 27^{o}C.

Course Outcome 4 (CO4):

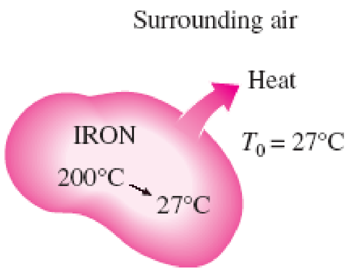
1. State the principle of increase of entropy.
2. Derive the general expressions to determine the change in entropy of an ideal gas in terms of pressure ratio and temperature ratio.
3. Air is flowing steadily in an insulated duct. The pressure and temperature measurements of the air at two stations. A and B are given below. Establish the direction of the flow of air in the duct. Assume that for air, specific heat c_p is constant at 1.005kJ/kg K, $h=c_pT$, and $v/T=0.287/p$, where p,u and T pressure, volume and temperature respectively.

	Station A	Station B
Pressure	130 kPa	100kPa
Temperature	500 ^{o}C	130 ^{o}C

4. The steam initially at a pressure of 15 bar and 250^o C expands reversibly and polytropically to 1.5 bar. Find the temperature, workdone and change in entropy if the index of expansion is 1.25.

Course Outcome 5 (CO5):

1. Define available energy and unavailable energy.
2. Define the term irreversibility
3. A 500-kg iron block shown in Fig. is initially at 200°C and is allowed to cool to 27°C by transferring heat to the surrounding air at 27°C. Determine the reversible work and the irreversibility for this process.
4. 3 kg of air at 500 kPa, 90 C expands adiabatically in a closed system until its volume is doubled and its temperature becomes equal to that of the surroundingsd at 100 kPa and 10^o C. Find the maximum work, irreversibility.



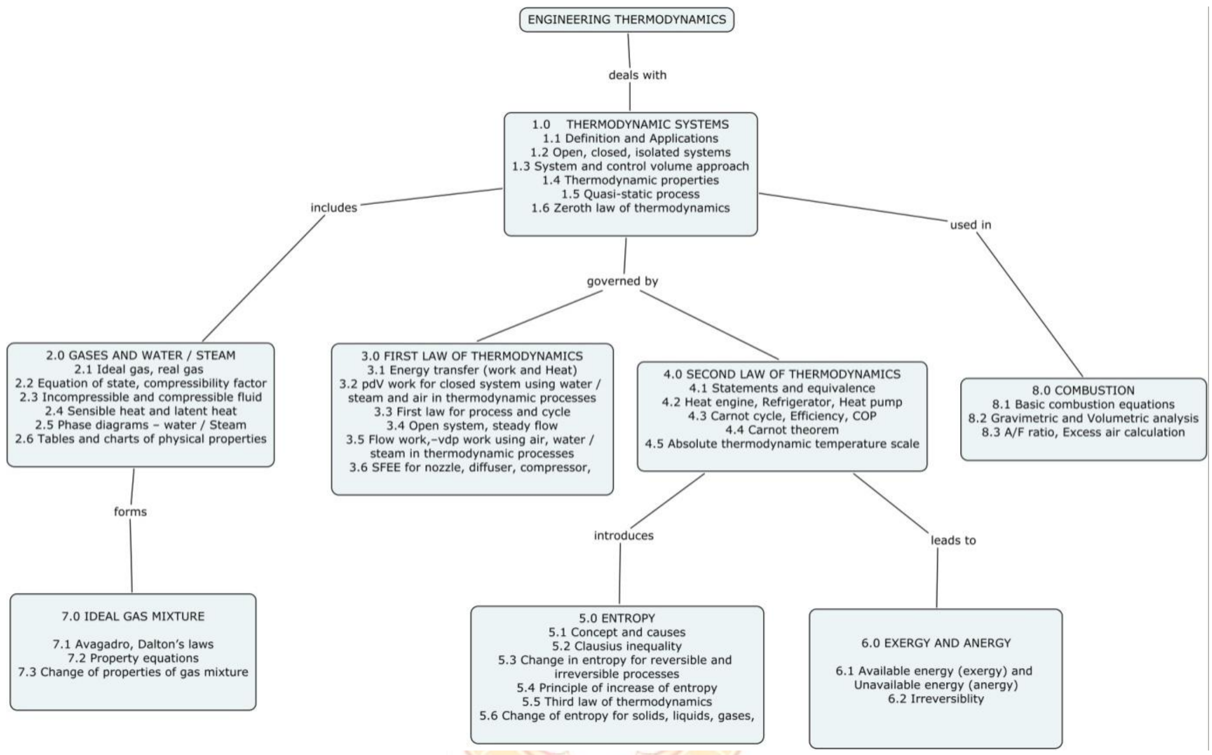
Course Outcome 6 (CO6):

1. State Dalton's law of partial pressure.
2. Define the term mole fraction
3. A mixture of ideal gases consists of 2.5 kg of N2 and 4.5 kg of CO2 at a pressure of 4 bar and a temperature of 25 C. determine, i) mole fraction of each constituent, ii) Equivalent molecular weight of the gas mixture ii) Equivalent gas constant of the mixture iv) the partial pressures and partial volumes and v) the volume and density of the gas mixture.
4. A gas mixture consists of 12 kg of methane, 5 kg of nitrogen ad 3 kg of oxygen. Determine the molecular mass and gas constant of the gas mixture. If the total pressure is 100 kPa, calculate their partial pressures.
5. 0.5 kg of Helium and 0.5 kg of Nitrogen are mixed at wt 20 C and a total pressure of 100 kPa. Find (i) the total volume of the mixture, (ii) the partial volume of the components, (iii) the partial pressure of the components, (iv) mole fraction of the components and (v) specific heats of the mixture

Course Outcome 7 (CO7):

1. Define the term combustion
2. Explain gravimetric analysis
3. Determine the percentage of excess air supplied to boiler for burning the coal having the following composition on mass basis. C = 0.82; H_2 = 0.05; O_2 = 0.08; N_2 = 0.03; S = 0.005; and moisture = 0.015.
   Volumetric analysis of dry flue gases shows the following composition.
   CO_2 = 10%; O_2 = 7 %; CO = 1 % and N_2 = 82 %
4. The products of combustion of hydrocarbon fuel of unknown composition have the following composition as measured by dry basis. CO_2 = 8%; O_2 = 8.8 %; CO = 0.9 % and N_2 = 82.3 %. Calculate (i) Air fuel ratio (ii) Composition of fuel on mass basis and (iii) the percentage of air on mass basis.

Concept Map



Syllabus

Thermodynamic Systems: Definition and applications **-** Open, closed and isolated systems – System and control volume approach - Thermodynamic properties, Quasi-static process- Zeroth Law of thermodynamics. **Gases and water/steam :** - Ideal gas and real gas – Equation of state, compressibility factor – compressible and incompressible fluid - Sensible heat and latent – phase diagrams of water/steam - Tables and charts of physical properties. **First law of Thermodynamics:** Energy Transfer (Work and Heat) –pdv work for closed system using air and water/steam in thermodynamic processes - First law for process and cycle - Open Systems, steady flow and unsteady flow – flow work, -vdp work using steam and air in thermodynamic processes - Steady flow energy equation (SFEE) for nozzle, diffuser, compressor, turbine, heat exchanger. **Second Law of Thermodynamics:** Second law statements and its equivalence - Heat engine, refrigerator and heat pump - Carnot Cycle, Efficiency and COP - Carnot theorem - Absolute thermodynamic temperature scale. **Entropy:** Concept and Causes - Clausius inequality - change in entropy for reversible and irreversible processes - principle of increase of entropy - Third law of thermodynamics – change of entropy for solids, liquids and gases. **Exergy and Anergy:** Available (Exergy) and Unavailable energy (Anergy) - Irreversibility. **Ideal gas mixture:** Avagdro's law, Dalton's law of partial pressure, property equations and change of properties of gas mixture – **Combustion:** Basic combustion equations - Gravimetric analysis and volumetric analysis – Air-fuel ratio and percentage of excess air.

Text Book

1. Yunus A. Cengel and Michael A. Boles, '**Thermodynamics: An Engineering Approach**', Seventh Edition, McGraw Hill, 2011.

Reference Books

1. Richard E. Sonntag, Claus Borgnakke, Gordon J. Vanwylen, '**Fundamental of Thermodynamics**', Wiley, 2002.
2. Rayner Joel, '**Basic Engineering Thermodynamics in SI units**', ELBS, 1998.
3. Nag, P.K., '**Engineering Thermodynamics**', Tata McGraw Hill, 2013.
4. Venkatesh, A., '**Basic Engineering Thermodynamics**', University Press, 2007.
5. Rajput, R.K., '**Engineering Thermodynamics**', Fourth Edition, Laxmi Publications, 2010
6. Valan Arasu, A., '**Engineering Thermodynamics**', Vijay Nicole Imprints Pvt. Ltd., Chennai, 2006.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.0	**Thermodynamic Systems**	
1.1	Definition and applications	1
1.2	Open, Closed and Isolated Systems	
1.3	System and Control volume approach	1
1.4	Thermodynamic Properties	1
1.5	Quasi-static process	1
1.6	Zeroth Law of thermodynamics	1
2.0	**Gases and Water/Steam**	
2.1	Ideal gas and real gas	1
2.2	Equation of state and compressibility factor	
2.3	Incompressible and compressible fluid	1
2.4	sensible heat and latent heat	1
2.5	Phase diagrams – water/steam and Tutorial	**2**
2.6	Tables and charts for physical properties	1
3.0	**First law of thermodynamics**	
3.1	Energy transfer (work and Heat)	1
3.2	pdV work for closed system using water/steam and air in thermodynamic processes and Tutorial	**2**
3.3	First law for process and cycle and Tutorial	**2**
3.4	Open system, steady flow and unsteady flow	1
3.5	Flow work,–vdp work using air, steam in thermodynamic processes and Tutorial	**2**
3.6	SFEE for nozzle, diffuser, compressor, turbine, heat exchanger and Tutorial	**2**
4.0	**Second Law of Thermodynamics**	
4.1	Statements and its equivalence	2
4.2	Heat engine, Refrigerator and Heat Pump and Tutorial	**2**
4.3	Carnot cycle, Efficiency and COP and Tutorial	**2**
4.4	Carnot theorem	1
4.5	Absolute thermodynamic temperature scale	1
5.0	**Entropy**	
5.1	Concept and causes	1
5.2	Clausius inequality	1
5.3	Change of entropy of reversible and irreversible processes and Tutorial	**2**
5.4	Principle of increase of entropy	1
5.5	Third Law of thermodynamics	1
5.6	Change of entropy for solids, liquids and gases and Tutorial	**2**

Module No.	Topic	No. of Lectures
6.0	**Exergy and Anergy**	
6.1	Available energy (Exergy) and Unavailable energy (Anergy)	1
6.2	Irreversibility	1
7.0	**Ideal gas mixture**	
7.1	Avagdro's law, Dalton's law of partial pressure	1
7.2	Property equations	1
7.3	Change of properties of gas mixture and Tutorial	**2**
8.0	**Combustion**	
8.1	Basic combustion equations	1
8.2	Gravimetric analysis and volumetric analysis and Tutorial	**2**
8.3	Air fuel ratio and percentage of excess air and Tutorial	**2**
	Total	**48**

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14ME250	ENVIRONMENTAL SCIENCE AND ENGINEERING	Category	L	T	P	Credit
		HSS	3	0	0	3

(Common With 14MT250-Environmental Science and Engineering)

Preamble

This course provides the basic knowledge of structure and function of ecosystem and better understanding of natural resources, biodiversity and their conservation practices. It describes the need to lead more sustainable lifestyles, to use resources more equitably. It helps to create a concern for our environment that will trigger pro-environmental action, including activities we can do in our daily life to protect it. Furthermore, it deals the social issues and ethics to develop quality engineer in our country.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Comprehend the structure and function of the ecosystem	Understand
CO 2.	Account for ecological succession Of ecosystem	Understand
CO 3.	Illustrate the features of biodiversity	Apply
CO 4.	Recall the uses of natural resources	Remember
CO 5.	Recommend the solution for reduce pollution from automobiles	Apply
CO 6.	Relate the EURO and Bharat stage norms for Pollutants	Understand
CO 7.	Identify the suitable disaster management for natural calamities	Apply
CO 8.	Conserve and follow the environmental ethics and Act	Understand

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	M	L	L	_	S	_	M	M	_	_	_	M	_	_	_
CO2.	M	L	L	_	M	_	M	M	_	_	_	M	_	_	_
CO3.	M	L	L	_	M	_	M	M	_	_	_	M	_	_	_
CO4.	M	L	M	_	S	_	M	M	_	_	_	M	_	_	_
CO5.	S	M	M	_	S	_	S	S	_	_	_	M	_	_	_
CO6.	S	M	M	_	S	_	S	S	_	_	_	M	_	_	_
CO7.	M	L	L	_	M	_	M	M	_	_	_	M	_	_	_
CO8.	M	L	L	_	M	_	M	S	_	_	_	M	_	_	_
	S	M	M	_	S	_	S	S	_	_	_	M	_	_	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	40	30	30	30
Apply	40	50	50	50
Analyse				
Evaluate				
Create				

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Describe the multidisciplinary nature of Madurai district
2. Explain the necessity of food web
3. Account for energy of pyramid of ecosystem always upright

Course Outcome 2 (CO2):

1. List out types of ecological succession
2. Demonstrate the regulation of ecosystem
3. Illustrate process involved in transformation of natural calamity affected place to fertile land

Course Outcome 3 (CO3)

1. Demonstrate bio-geographical classification of biodiversity
2. Distinguish between in situ and ex situ conservation
3. Recall the term hot spots of biodiversity

Course Outcome 4 (CO4)

1. List uses of forest resource
2. Describe the over exploitation of natural resource
3. Report the need of social forestry

Course Outcome 5 (CO5)

1. List out the air pollutants from automobiles
2. Illustrate the consequences of air pollution
3. Identify the suitable method to reduce pollution from mechanical industries

Course Outcome 6 (CO6)

1. Define EURO and Bharath stage norms
2. Explain the salient features of EURO norms
3. Compare EURO and Bharath norms

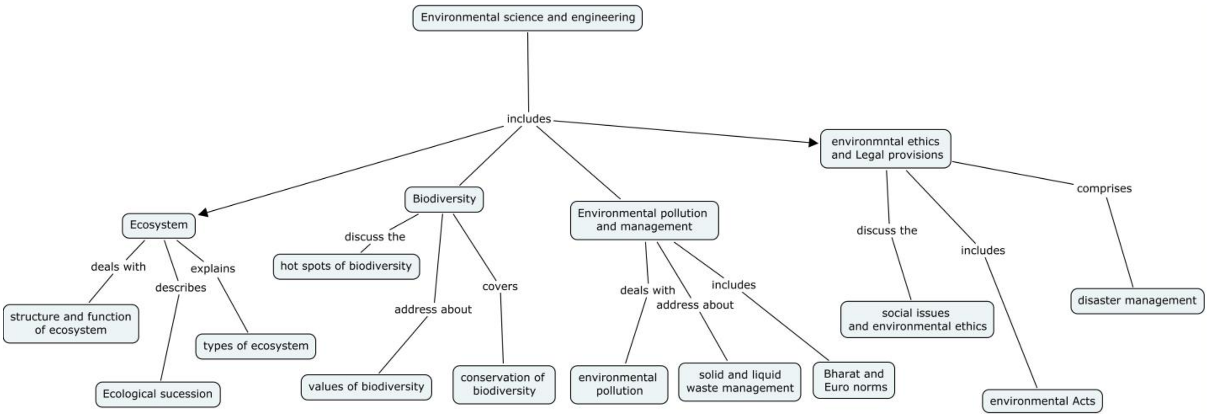
Course Outcome 7 (CO7)

1. Define the term tsunami
2. Explain the various types of natural disaster
3. Asses the control measures of flood

Course Outcome 8 (CO8)

1. Recall the forest act in India
2. Criticise the environmental ethics of our country
3. Compare and contrast ethics and law

Concept Map



Syllabus

Ecosystem: Multidisciplinary nature of environment- need for public awareness-Eco-system-Concept, structure, function, components, laws of Ecology, Energy flow in eco system - Food chains, food webs-Ecological pyramids-Ecological succession. Types of eco system-forest, grass land, desert, aquatic ecosystem, Loss of ecosystem and its estimation. **Biodiversity:** Biodiversity and its conservation-biodiversity types, bio-geographical classification, Values of biodiversity - Hot spots of biodiversity-threats to biodiversity-Biodiversity Indices-Endangered and endemic species- conservation of bio-diversity, Natural resources-Forest-Water-Food-Energy-soil-uses, over exploitation, effects and control. Role of individual in the conservation of natural resources **Environmental pollution and management:** Environmental pollution- air (automobiles and mechanical industries and their case studies), water, soil and noise pollution-causes, effects and control measures, Bio fuels and alternate fuels, biopolymer composties- refregent -Radiation hazards -protection and safety- solid, liquid and e-waste management-sources – treatment & disposal. Global warming-climate change and its effect on Environment- Euro norms- Bharath stage norms for environmental pollution, ISO 14000 standards carbon trading. **Environmental ethics and Legal provision:** Social Issues and the environment-Environmental Ethics - sustainable development - Future aspects - Human and Animal rights-conservation of ethics and traditional value systems of India - Legal provisions-Environmental acts – Air, water, soil and forest and wildlife - Population explosion and environment- family welfare programme - Value education - Disaster management- floods, earthquake, tsunami and landslides.

Text Book

1. Anubha Kaushik, Kaushik, C.P., '**Environmental Science and Engineering**', Third Edition, New age international (p) ltd publishers, 2010.

Learning Resources

1. Eugene Odum, '**Ecosystem Ecologist and Environmentalist**', paperback edition, university of Georgia press, 2002.
2. Naik, S.C., Tiwari, T.N., '**Society and Environment**', Oxford & IBH Publishing, 2011.
3. Susmitha, Baskar, R., '**Environmental Science for Engineering Undergraduates**', Unicorn Books, 2007.
4. http://collegesat.du.ac.in/UG/Envinromental%20Studies_ebook.pdf .

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.	**Ecosystem**	
1.1	Multidisciplinary nature of environment- need for public awareness	1
1.2	Eco-system-Concept, structure, function, components	1
1.3	Laws of Ecology and Energy flow in eco system	1
1.4	Food chains, food webs-Ecological pyramids	2
1.5	Ecological succession and regulation	1
1.6	Types of ecosystem, and their Loss and estimation	2
2.	**Biodiversity**	
2.1	Types of biodiversity and their bio-geographical classification	1
2.3	Hot spots of biodiversity and biodiversity indices	1
2.4	Threats to biodiversity	1
2.2	Values of biodiversity	1
2.3	Endangered and endemic species of India	2
2.4	Conservation of biodiversity	2
3	**Environmental pollution and management**	
3.1	Introduction to environmental pollution (air, water, soil)	1
3.2	Environmental pollution due to automobiles and industries (causes, effects and control measures)	2
3.3	Alternate fuels – bio-fuel	2
3.4	Nuclear hazardous safety and protection	1
3.5	Solid, liquid and e-waste management	2
3.6	Climatic change -Global warming and its effects	1
3.7	Euro and bharath norms for pollution	1
4	**Environmental ethics and Legal provision**	
4.1	Social issues and environmental ethics	2
4.2	Sustainable development for future aspects	1
4.3	Human and animal conservation rights	1
4.4	Traditional value of India and conservation rights	2
4.5	Population explosion and environmental impact	2
4.6	Value education and disaster management	2
	Total	**36**

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		Category	L	T	P	Credit
14ME260	**MATERIALS SCIENCE**	ES	3	0	0	3

Preamble

The course work aims at imparting the fundamental knowledge on Classification of Materials and their properties, Phase diagram, Strengthening Mechanisms in Metals, Non-destructive testing and Characterization pertaining to mechanical engineers.

Prerequisite

Basic course (No prerequisite)

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain different classes of material and their properties	Understand
CO 2.	Select suitable material for specific engineering application	Apply
CO 3.	Compute the thermal and electrical conductivity, coefficient of thermal expansion and specific heat of metals.	Apply
CO 4.	Compute the magnetic properties of magnetic materials	Apply
CO 5.	Calculate the stress, strain and tensile strength of materials	Apply
CO 6.	Explain different type of testing of materials	Understand
CO 7.	Evaluate the hardness, percentage elongation and reduction in area and tensile strength of materials.	Apply
CO 8.	Identify suitable non destructive technique to locate the defect in a material	Apply
CO 9.	Interpret the characterization tools viz., XRD, Optical microscope AFM and Photoelastic effect	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO 3	PO4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PS O2	PSO 3
CO1	M	S	_	_	_	_	_	_	_	_	M	_	M	_	M
CO2	M	M	_	_	_	_	_	_	_	_	M	_	M	_	M
CO3	S	_	_	_	_	_	_	_	_	_	M	_	_	_	_
CO4	S	_	_	M	_	_	_	_	_	_	M	_	_	_	_
CO5	M	M	_	_	_	_	_	_	_	_	M	_	_	_	_
CO6	M	M	_	_	_	_	_	_	_	_	M	_	_	_	_
CO7	M	S	_	_	_	_	_	_	_	_	M	_	_	_	_
CO8	M	M	_	M	_	_	_	_	_	_	M	_	_	_	_
CO9	M	S	_	M	_	_	_	_	_	_	M	_	_	_	_
	S	M	_	L	_	_	_	_	_	_	M	_	L	_	L

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	40	40	40	40
Apply	40	40	40	40
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Compare the properties and applications of metals, polymers, ceramics and composite materials.
2. Identify three important limitations that restrict the use of concrete as a structural material.
3. Explain the advantages of the Composite materials with specific engineering example.
4. Describe the properties and applications of functional materials.

Course Outcome 2 (CO2):

1. Identify the criteria for selecting materials to use in tennis racket. Choose the materials that would satisfy these criteria.
2. In selecting the materials for surgical gloves, what factors should you consider? Identify the appropriate material and justify your answer.
3. Identify the required properties of materials to be selected in the manufacturing of thermally insulated food carriers. Propose a number of candidate materials and identify your best choice, justify your answer.
4. When designing the shaft of a golf club, what mechanical loading conditions should we consider? How cans fibre reinforced composites support these loading conditions. Identify the advantage of replacing stainless steel shafts with composite shafts

Course Outcome 3 (CO3):

2. For aluminium, the heat capacity at constant volume C_v at 30 K is 0.81 J/mol-K and the Debye temperature is 375 K. Compute the specific heat a) at 50 K and b) at 425 K.
4. Calculate the drift velocity of the free electrons in a conductor of area $10^{-4}m^2$, given the electron density to be $8x10^{28}/m^3$when a current of 5A flows through it.
5. Compute the electron density form the if the drift velocity of electrons in a metal wire of diameter 5mm is $6x10^{-4}$m/s and the current is 10A.
6. Calculate the relaxation time of free electrons in a metal of resistivity $1.54x10^{-8}$ ohm-m, if the metal has $5.8x10^{28}$ electrons/m^3.

Course Outcome 4 (CO4):

1. The magnetization within a bar of some metal alloy is $1.2X10^6$ A/m at a magnetic field of 200 A/m. Compute a) the magnetic susceptibility, b) the permeability and c) the magnetic flux density within this material. What type of magnetism would you suggest as being displayed by this material? Why?
2. A magnetic material has a flux density and magnetization of 0.0044 Wb./m^2 and 3300 A/m respectively. Calculate the magnetising force and relative permeability of the material.
3. The magnetic field strength in copper is 10^6 A/m. If the magnetic susceptibility of copper is $-0.8X10^{-5}$, calculate the flux density and magnetization in copper.
4. A Para magnetic material has a magnetic field intensity of 10^4 A/m. If the susceptibility of the material at room temperature is $3.7X10^{-3}$, compute the magnetization and flux density in the material.

Course Outcome 5 (CO5):

1. Calculate the engineering stress in SI units on a bar of 55 cm long and having a cross section of 7.00 mm x 3.00 mm that is subjected to a load of 4000 kg.
2. A 48 mm diameter copper bar is subjected to a force of 35 KN. Calculate the engineering stress in pounds per inch (psi) 0n the bar.
3. A 25 mm diameter copper alloy test bar is subjected to a load of 235 KN. If the diameter of the bar is 20 mm at this load, compute (a) the engineering stress and strain and (b) the true stress and strain.
4. 40 cm longrod with a diameter of 0.56 cm is loaded with 7840 N weight. If the diameter decreases to 0.435 cm, calculate the engineering stress, engineering strain and true stress and true strain at this load.

Course Outcome 6 (CO6):

1. Distinguish between elastic and plastic deformation
2. Explain the rotating beam fatigue test to determine the endurance limit of a ductile material.
3. Demonstrate the Brinell test procedure to determine the hardness of a material.
4. Describe the tensile test procedure to estimate the resilience and toughness of a ductile material

Course Outcome 7 (CO7):

1. A tensile specimen of cartridge brass sheet has a cross section of 8 mm x 3.20 mm and a gage length of 50 mm. Calculate the engineering strain that occurred during a test if the distance between the gage markings is 60 mm, after the test.
2. A 13 mm diameter rod of an aluminium alloy is pulled to failure in a tension test. If the final diameter of the rod at the fractured surface is 11 mm. Compute the percentage reduction in area of the sample due to the test.
3. A 3.8 mm diameter 99.5 percent copper wire is to be cold drawn with a 30 percent cold reduction. Calculate the final diameter of the wire.
4. Calculate the percentage cold reduction when an annealed aluminium wire is cold drawn from a diameter of 2.84 mm to a diameter of 1.37 mm.

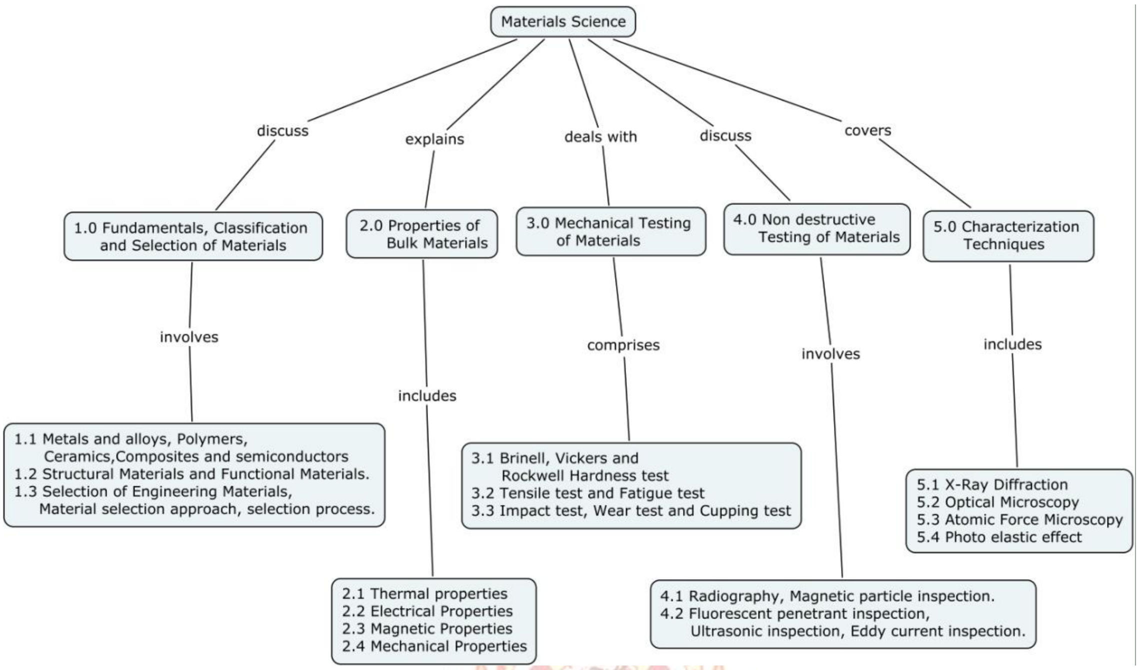
Course Outcome 8 (CO8):

1. Demonstrate an appropriate NDT technique to locate the internal flaw in a ferrous material.
2. Illustrate a suitable method for the detection of surface and near surface discontinuities in ferritic steel and iron.
3. Report an appropriate test procedure to find the internal and surface defects in sound conducting materials.
4. Apply a suitable NDT technique to compute the surface coating thickness of a conducting material.

Course Outcome 9 (CO9):

1. Illustrate the procedure to compute the grain size on the surface of a steel specimen using optical microscopy.
2. Determine the spacing between (i) (100) planes (ii) (110) planes and (111) planes in a NaCl crystal having the lattice constant a=5.64 A^{o}.
3. Demonstrate the methodology to calculate the structural parameters of a crystalline sample using the XRD data.
4. Apply the photoelastic effect to determine the stress distribution in a steel material.

Concept Map



Syllabus

Fundamentals, Classification and Selection of Materials: Metals and Alloys, Polymers, Ceramics, Composites and Semiconductors. Structural Materials and Functional Materials. Selection of Engineering Materials: Material selection approach, selection process. Properties of Bulk Materials: Thermal Properties: Expansion, Heat Capacity and Conductivity. Electrical Properties: Conductivity, Dielectric Constant, Dielectric Strength, Dielectric Loss and Dielectric Breakdown. Magnetic Properties: Permeability, Hysteresis, Susceptibility and Magnetic Intensity. Mechanical Properties: Concept of Stress and Strain, Elastic and Plastic Deformation, Creep, Hardness, Tensile Strength. Mechanical Testing of Materials: Brinell, Vickers and Rockwell Hardness test, Tensile test and Fatigue test, Impact test, Wear test and Cupping test. Non destructive Testing of Materials: Radiography, Magnetic particle inspection, Fluorescent penetrant inspection, Ultrasonic inspection, Eddy current inspection. Characterization Techniques: X-Ray Diffraction, Optical Microscopy, Atomic Force Microscopy, Photoelastic effect.

Text Book

1. Callister W. D., '**Materials Science and Engineering**', John Wiley & Sons, 2007.
2. Sidney H. Avner, '**Introduction to Physical Metallurgy**', Tata McGraw Hill, New Delhi, 1997.

Reference Books

1. Van Vlack L.H., '**Elements of Materials Science and Engineering**', 6th Edition, Addison-Wesley, 1989.
2. William F Smith, Javad Hashemi, Ravi Prakash, '**Materials Science and Engineering**', Tata McGraw Hill Private Limited, 4th Edition, 2008.
3. Van Vlack L.H., '**Elements of Materials Science and Engineering**', 6th Edition, Addison-Wesley, 1989.

4. George T. Austin, '**Shreve's Chemical Process Industries**', McGraw Hill International, 5th Edition, 1984.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.0	**Fundamentals, Classification and Selection of Materials:**	
1.1	Metals and alloys, Polymers, Ceramics, Composites and semiconductors.	5
1.2	Structural Materials and Functional Materials.	3
1.3	Selection of Engineering Materials, Material selection approach, selection process.	2
2.0	**Properties of Bulk Materials:**	
2.1	Thermal Properties: Expansion, Heat Capacity and Conductivity.	3
2.2	Electrical Properties: Conductivity, Dielectric Constant, Dielectric Strength, Dielectric Loss and Dielectric Breakdown.	3
2.3	Mechanical Properties: Concept of Stress and Strain, Elastic and Plastic Deformation, Creep, Hardness, Tensile Strength.	3
2.4	**Mechanical Testing of Materials:**	
3.0	Brinell, Vickers and Rockwell Hardness test.	3
3.1	Tensile test and Fatigue test.	2
3.2	Impact test, Wear test and Cupping test.	2
3.3	**Non destructive Testing of Materials:**	
4.0	Radiography, Magnetic particle inspection.	3
4.1	Fluorescent penetrant inspection, Ultrasonic inspection, Eddy current inspection.	2
4.2	**Characterization Techniques:**	
5.0	X-Ray Diffraction.	2
5.1	Optical Microscopy.	1
5.2	Atomic Force Microscopy.	1
5.3	Photo elastic effect.	2
5.4		
	Total	**40**

Course Designers:

1. N. Sankara Subramanian nssphy@tce.edu
2. T. Mani Chandran tmphy@tce.edu

14ME280	STRENGTH OF MATERIAL AND MATERIAL SCIENCE LAB	Category	L	T	P	Credit
		PC	0	0	2	1

Preamble

Students of Mechanical engineering would get exposure in the properties of engineering materials.

Prerequisite

- 14ME220 : Free body mechanics
- 14ME260 : Material science

Course Outcomes

On the successful completion of the course, students will be able to:

Sl. No	Course Outcomes	Blooms level
CO 1.	Identify different materials based on its properties	Apply
CO 2.	Determine the mechanical properties of different materials.	Apply
CO 3.	Determine the grain size of the materials.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	S	M	M	_	_	_	_	M	_	_	_	S	_	S
CO2.	S	S	S	S	_	_	_	_	M	_	_	_	S	_	S
CO3.	S	S	M	S	_	_	_	_	M	_	_	_	S	_	S
	S	S	S	S	_	_	_	_	M	_	_	_	S	_	S

S- Strong; M-Medium; L-Low

Syllabus

Part A: Strength of Materials Lab. (Any six experiments are to be conducted)

1. Determination of the Young's Modulus of the material of the specimen by conducting the tension test
2. Determination of the Young's Modulus of the material of the beam by conducting the bending test.
3. Determination of the Young's Modulus of the material of the beam by conducting the bending test using HuggenbergerTensometer.
4. Determination of the rigidity modulus of the material of the specimen by conducting the torsion test.
5. Determination of the rigidity modulus of the material of the spring by conducting the test.
6. Determination of the Young's Modulus of the material of the beam by conducting the deflection test in UTM
7. Determination of Brinell hardness and Rockwell hardness

Part B: Material Science Lab (Any six experiments are to be conducted)

1. Hand layup method for preparing composites.
2. Tensile test on composites.
3. Compressive test on composites.
4. Three point bending test on composites.
5. Shear test on composites.
6. Impact Test on composites.

7. Heat treatment and Hardness testing of steel.
8. Microstructure analysis of steel.
9. Microstructure analysis of cast iron.
10.

Evaluation Pattern:

1. Students are examined for 50 marks in strength of materials lab and 50 marks in composite materials lab for terminal examination.
2. **Duration:** 3 Hours (1 Hour 30 minutes for strength of materials lab and 1 Hour 30 minutes for Composite materials lab)

Course Designers:

1. V. Muruganandam vmciv@tce.edu
2. M. Kathiresan umkathir@tce.edu

14ME281	STRENGTH OF MATERIAL AND MATERIAL SCIENCE LAB	Category	L	T	P	Credit
		PC	0	0	2	1

Preamble

Students of Mechanical engineering would get exposure in the properties of engineering materials.

Prerequisite

- 14ME220 : Free body mechanics
- 14ME260 : Material science

Course Outcomes

On the successful completion of the course, students will be able to:

CO1	Identify different materials based on its properties.	Apply
CO2	Determine the mechanical properties of different materials.	Apply
CO3	Determine the grain size of the materials.	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	M	S	L	L	L	L	L	L	L	L
CO2	S	S	M	S	L	L	L	L	L	L	L	L
CO3	S	S	M	S	L	L	L	L	L	L	L	L

S- Strong; M-Medium; L-Low

Syllabus

Part A: Strength of Materials Lab. (Any six experiments are to be conducted)

8. Determination of the Young's Modulus of the material of the specimen by conducting the tension test
9. Determination of the Young's Modulus of the material of the beam by conducting the bending test.
10. Determination of the Young's Modulus of the material of the beam by conducting the bending test using Huggen bergerTensometer.
11. Determination of the rigidity modulus of the material of the specimen by conducting the torsion test.
12. Determination of the rigidity modulus of the material of the spring by conducting the test.

13. Determination of the Young's Modulus of the material of the beam by conducting the deflection test in UTM
14. Determination of Brinell hardness and Rockwell hardness

Part B: Material Science Lab (Any six experiments are to be conducted)

1. Preparation of composite laminate by Hand layup method
2. Determination of the tensile properties of the composite material by conducting tensile test
3. Determination of the flexural properties of the composite material using three point bending test.
4. Determination of shear strength of the composite material by conducing shear test.
5. Determination of Impact properties of the composite material by conducting the Impact test.
6. Identification of the microstructure of the given steel specimen
7. Identification of the microstructure of the given cast iron specimen
8. Sieve analysis of the moulding sand
9. Determination of strength of the moulding sand
10. Determination of the hardenability of steel by conducting Jominy end quench test.
11. Determination of hardness of the steel under different heat treatment techniques.

Evaluation Pattern:

3. Students are examined for 50 marks in strength of materials lab and 50 marks in composite materials lab for terminal examination.
4. Duration:3 Hours(1 Hour 30 minutes for strength of materials lab and 1 Hour 30 minutes for Composite materials lab)

Course Designers:

1. V. Muruganandam vmciv@tce.edu
2. M. Kathiresan umkathir@tce.edu

14ME290	WORK SHOP	Category	L	T	P	Credit
		PC	0	0	2	1

(Common With 14CE290- Workshop and 14MT290- Workshop)

Preamble

Workshop is a hands-on training practice to Mechanical, Civil and Mechatronics engineering students. It deals with fitting, carpentry, sheet metal and related exercises. Also, it will induce the habit of selecting right tools, planning the job and its execution.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to:

Sl. No	Course Outcomes	Blooms level
CO1.	Construct the different laminas of regular shapes.	Apply
CO2.	Build different types of fitting using MS plate.	Apply
CO3.	Model simple sheet metal components.	Apply
CO4.	Build the different types of joints using wooden material.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	M	L	L	L	_	_	_	S	_	_	_	_	_	L
CO2.	S	M	L	L	L	_	_	_	S	_	_	_	_	_	L
CO3.	S	M	L	L	L	_	_	_	S	_	_	_	_	_	L
CO4.	S	M	L	L	L	_	_	_	S	_	_	_	_	_	L
	S	M	L	L	L	_	_	_	S	_	_	_	_	_	L

S- Strong; M-Medium; L-Low

Syllabus

I Card Board Exercises (4 Hours/6 periods)

1. Construction of cube, Triangular, square, Pentagonal and Hexagonal Prisms (Any one solid)
2. Construction of Triangular, square, Pentagonal and Hexagonal Pyramids (Any one solid)

II Fitting (6 Hours/9 periods)

Preparation of Square, V, L, Gauge, Taper, Radius and Dove tail Fitting (Any one Fitting Exercise)

III Sheet Metal Exercises (6 Hours/9 periods)

Preparation of Liter Cone, Dust pan (Straight, Taper) and Tray (Straight, Taper) - (Any one sheet metal Exercise)

IV Carpentry (6 Hours/9 periods)

Preparation of Door frame using Mortise & Tenon joint and Mitered Mortise & Tenon joint.

V Demo on Plumbing (2 Hours/3 periods)

Assessment Pattern

All the exercises are evaluated on continuous assessment basis based on the fit/finish of the component, measurement and record. Students are given with additional attempt on each trade for their better performance (within the specified time of each trade). The distribution of marks in each trade is as follows:

Trade	Fit/Finish	Record	Total (Marks)
Card Board Exercises	15	5	20
Fitting	15	5	20
Sheet Metal	25	5	30
Carpentry	25	5	30

- **Students are evaluated based on continuous assessment only and pass mark should be minimum 50. Also no terminal examination for this course.**
- **If he/she got less than 50 marks, he/she has to undergo the terminal examination for 100 marks in subsequent semester as supplementary examination.**

Course Designers:

1. C. Paramasivam cpmech@tce.edu
2. ML. Mahadevan mlmmech@tce.edu

14ME310	STATISTICAL TECHNIQUES	Category	L	T	P	Credit
		BS	2	2	0	3

Preamble

Statistics, as a subject, is a science of learning from data and provides tools for making decisions when conditions of uncertainty prevail. The mechanical engineers play a significant role in designing and developing new products and manufacturing systems and processes and reliability. Statistical techniques are an important tool in these activities because they provide the engineer with both descriptive and analytical methods for dealing with the variability in observed data. The course is designed to impart the knowledge and understanding of the statistical techniques to Mechanical Engineers and apply them in their areas of specialization.

Prerequisite

- 14 ME210 Engineering Calculus

Course Outcomes

On successful completion of the course, the students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Apply conditional probability, Baye's theorem to solve manufacturing process problems.	Apply
CO 2.	Select an appropriate probability distribution to determine probability mass function for solving engineering problem.	Apply
CO 3.	Test the hypothesis on mean, variance, proportion of small and large samples, for goodness-of-fit and independence of attributes.	Apply
CO 4.	Design and conduct of engineering experiments involving a single factor, two factors and three factors.	Apply
CO 5.	Generate random numbers and random variates and test the randomness using various simulation techniques.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	M	M	M	S	_	_	_	_	_	_	M	_	_	_
CO2.	S	M	M	M	S	_	_	_	_	_	_	M	_	_	_
CO3.	S	M	M	M	S	_	_	_	_	_	_	M	_	_	_
CO4.	S	M	M	M	S	_	_	_	_	_	_	M	_	_	_
CO5.	S	M	M	M	S	_	_	_	_	_	_	M	_	_	_
	S	M	M	M	S	_	_	_	_	_	_	M	_	_	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	8	8	8	10
Understand	24	24	24	20
Apply	68	68	68	70
Analyse	-	-	-	-
Evaluate	-	-	-	-
Create	-	-	-	-

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. State Baye's Theorem.

2. The weekly demand for propane gas (in 1000s of gallons) from a particular facility is an rv X with pdf

a. $f(x) = \begin{cases} 2\left(1-\frac{1}{x^2}\right) & ,1 \le x \le 2 \\ 0, otherwise \end{cases}$

a) Compute the cdf of X. b) Compute $E(X)$ and $V(X)$.

3. Seventy percent of the light aircraft that disappear while in flight in a certain country are subsequently discovered. Of the aircraft that are discovered, 60% have an emergency locator, whereas 90% of the aircraft not discovered do not have such a locator. Suppose a light aircraft has disappeared. **a.** If it has an emergency locator, calculate probability that it will not be discovered? **b.** If it does not have an emergency locator, calculate probability that it will be discovered?

Course Outcome 2 (CO2):

1. State the mean and variance of Weibull distribution

2. Automobiles arrive at a vehicle equipment inspection station according to a Poisson process with rate per hour. Suppose that with probability .5 an arriving vehicle will have no equipment violations. Predict the probability (a) that exactly ten arrive during the hour and all ten have no violations? (b) that y arrive during the hour, of which ten have no violations, for any fixed y ≥ 10? (c) that ten "no-violation" cars arrive during the next hour?

3. If bolt thread length is normally distributed, estimate the probability that the thread length of a randomly selected bolt is a. Within 1.5 SDs of its mean value? b. Farther than 2.5 SDs from its mean value? c. Between 1 and 2 SDs from its mean value?

Course Outcome 3 (CO3):

1. Define Type I and Type II errors.

2. A manufacturer of sprinkler systems used for fire protection in office buildings claims that the true average system-activation temperature is 130°. A sample of n = 9 systems, when tested, yields a sample average activation temperature of 131.08°F. If the distribution

of activation times is normal with standard deviation 1.5°F, does the data contradict the manufacturer's claim at 1% significance level ?

3. In an experiment to compare bearing strengths of pegs inserted in two different types of mounts, a sample of 14 observations on stress limit for red oak mounts resulted in a sample mean and sample standard deviation of 8.48 MPa and .79 MPa, respectively, whereas a sample of 12 observations when Douglas fir mounts were used gave a mean of 9.36 and a standard deviation of 1.52. Test for significance of variances in two types of mounts at 5% l.o.s.

Course Outcome 4 (CO4)**:**

1. Define designed experiment.

2. The following data refers to yield of tomatoes (kg/plot) for four different levels of salinity. *Salinity level* here refers to electrical conductivity (EC), where the chosen levels were EC 1.6, 3.8, 6.0 and 10.2 nmhos/cm.

1.6:	59.5	53.3	56.8	63.1	58.7
3.8:	55.2	59.1	52.8	54.5	
6.0:	51.7	48.8	53.9	49.0	
10.2:	44.6	48.5	41.0	47.3	46.1

Use the *F* test at level to test for any differences in true average yield due to the different salinity levels.

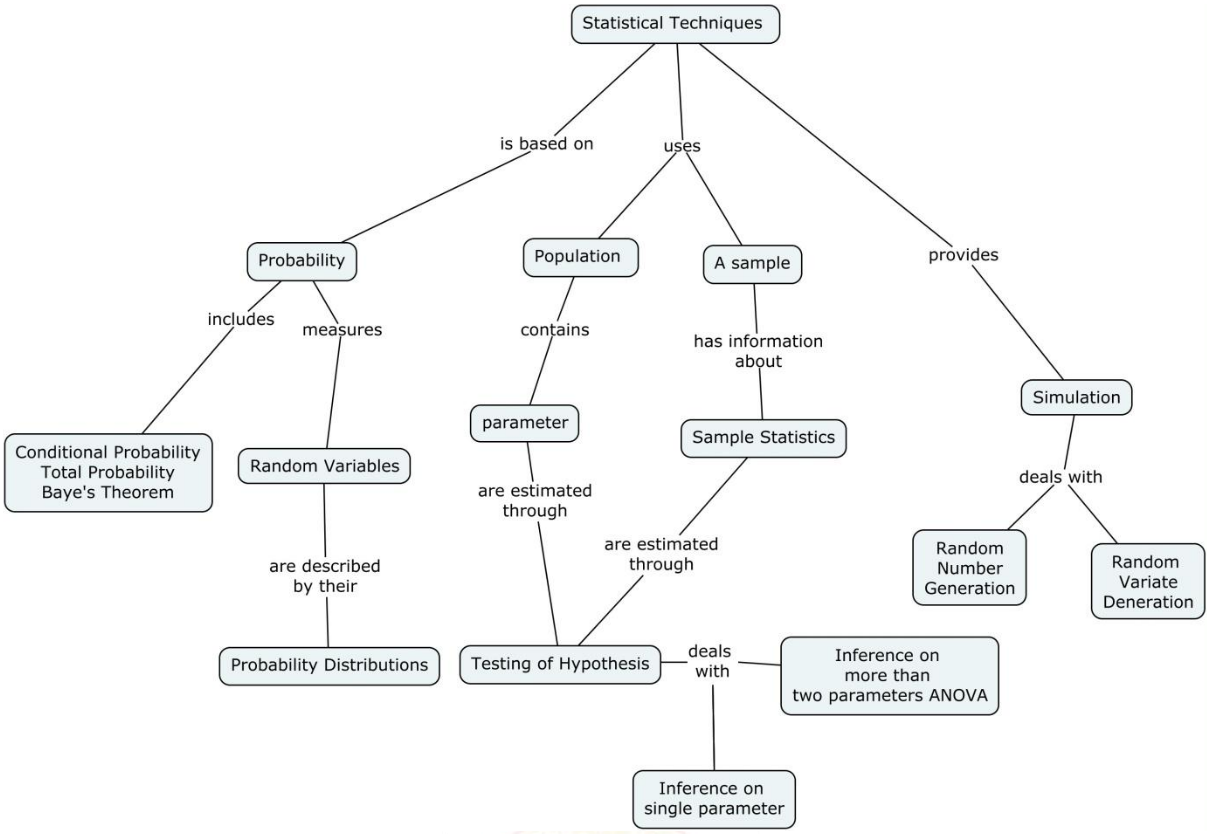
Course Outcome 5 (CO5)**:**

1. Mention the properties of random numbers.

2. Suppose that the five numbers 0.44, 0.81, 0.14, 0.05, 0.93 were generated. Perform a test for uniformity by using the Kolrnogorov-Srnirnov test with the level of significance. α = 0.05.

3. Generate Weibull distributed random variate.

Concept Map



Syllabus

Probability and Random Variables - conditional probability - Baye's theorem - discrete random variables - probability mass function - continuous random variables - probability density functions - cumulative distribution function - expected values for discrete and continuous random variables - **Probability Distributions** - The Binomial probability distribution - hyper geometric - negative Binomial distribution - the Poisson probability distribution - the normal distribution - the exponential distribution gamma distribution - **Tests of Hypotheses -** hypotheses and test procedures - tests concerning a population mean - tests concerning a population proportion - *z* tests and confidence intervals for a difference between two Population means - the two-sample *t* Test and confidence interval - inferences concerning a difference between population proportion - inferences concerning two population variances - **The Analysis of Variance** - Single-Factor ANOVA - Two-Factor ANOVA - Three-Factor ANOVA **Simulation -** random number generation - tests for random numbers - Kolmgorov test - runs tests - exponential, uniform, Weibull random variate generators using inverse transform.

Text Books

1. Jay L. Devore, "**Probability and Statistics for Engineering and the Sciences**", 8th Edition, Cengage Learning India Pvt Ltd, New Delhi, 2012.

2. Jerry Banks, John S. Carson II, Barry L. Nelson, David M. Nicol, "**Discrete-Event System Simulation**", 5th Edition, Pearson Education, New Delhi, 2013. (For module 5, Simulation)

Reference Books

1. Ronald E. Walpole, Sharon L. Myers, Keying Ye, "**Probability & Statistics for Engineers and Scientists**", 9th Edition, Pearson Education, New Delhi, 2012.
2. Mendenhall William, "**Introduction to Probability and Statistics**", 14th Edition, Duxbury Press, New Delhi, 2012.

Course Contents and Lecture Schedule

Module No.	Topic	No.of Lectures
1	**Probability and Random Variables**	
1.1	Conditional probability, Baye's theorem	1
	Tutorial	1
1.2	Discrete Random variables, probability mass function	1
	Tutorial	1
1.3	Continuous random variables probability density functions, cumulative distribution	1
	Tutorial	1
1.4	Expected values for discrete and continuous random variables	1
	Tutorial	1
2	**Probability distributions**	
2.1	The Binomial probability distribution	1
	Tutorial	1
2.2	Hyper geometric, negative binomial distribution	1
	Tutorial	1
2.3	The Poisson probability distribution	1
	Tutorial	1
2.4	The Normal distribution	1
	Tutorial	1
2.5	The Exponential distribution	1
	Tutorial	1
2.6	Gamma distribution	1
	Tutorial	1
3	**Tests of Hypotheses**	
3.1	Hypotheses and test procedures	1
	Tutorial	1
3.2	Tests concerning a population mean	1
	Tutorial	1
3.3	Tests Concerning a population proportion	1
	Tutorial	1
3.4	z Tests and confidence intervals for a difference between two population means	1
	Tutorial	1
3.5	The two-Sample t Test and confidence interval	1
	Tutorial	1
3.6	Inferences concerning a difference between population proportions	1
	Tutorial	1
3.7	Inferences concerning two population variances	1
	Tutorial	1
4	**The Analysis of Variance**	
4.1	Single-Factor ANOVA	1

Module No.	Topic	No.of Lectures
	Tutorial	1
4.2	Two-Factor ANOVA	1
	Tutorial	1
4.3	Three-Factor ANOVA	1
	Tutorial	1
5	**Simulation**	
5.1	Random number generation	1
	Tutorial	1
5.2	Tests for random numbers Kolmgorov test	1
	Tutorial	1
5.3	Test for autocorrelation	1
	Tutorial	1
5.4	Exponential, uniform, Weibull random variate generators using inverse transform technique	1
	Tutorial	1
	Total	**48**

Note: Problems using statistical simulation software will be included in some of the tutorial classes/assignment.

Course Designers:

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14ME320	MECHANICS OF MATERIALS	Category	L	T	P	Credit
		PC	2	2	0	3

Preamble

Mechanics of materials is the study of mechanical properties of engineering materials and the behaviour of structures made thereof. It deals with analysis of structures to find the forces and corresponding stresses at various points. It covers relationships between various types of stresses and strains, deformations of various mechanical members such as beams, shafts, cylinders, etc. This course is concerned with one aspect of engineering design pertaining to the stability of mechanical components under different static loading conditions. It is a decision-making process, in which the mechanical properties of materials, type of stress developed due to a particular type of load are applied to select suitable material in order to meet a stated objective.

Prerequisite

- 14ME220 Free body Mechanics
- 14ME260 Materials Science

Course Outcomes

On successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Determine the simple stresses and strains and relation between elastic constants and principal stresses and strains	Apply
CO 2.	Determine the shear force and bending moment on beams	Apply
CO 3.	Determine the distribution of bending and shear stresses and deflection of beams	Apply
CO 4.	Determine the torsional stresses in shafts	Apply
CO 5.	Determine the crippling load on columns and struts	Apply
CO 6.	Determine stresses in thin cylindrical and spherical vessels	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1.	S	M	M	M	_	_	_	_	_	_	_	L	M	_	_
CO2.	S	M	M	M	_	_	_	_	_	_	_	L	M	_	_
CO3.	S	M	M	M	_	_	_	_	_	_	_	L	M	_	_
CO4.	S	M	M	M	_	_	_	_	_	_	_	L	M	_	_
CO5.	S	M	M	M	_	_	_	_	_	_	_	L	M	_	_
CO6.	S	M	M	M	_	_	_	_	_	_	_	L	M	_	_
	S	M	M	M	_	_	_	_	_	_	_	L	M	_	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	

Remember	10	10	10	10
Understand	10	10	10	30
Apply	80	80	80	60
Analyse	-	-	-	-
Evaluate	-	-	-	-
Create	-	-	-	-

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. A steel bar of rectangular section 25 mm x 40 mm carries an axial load of 40 kN. Determine the average tensile stress over the normal cross section of the bar.
2. A 30 m long wire is subjected to a tensile force of 4.4 kN. It stretches by an amount of 25 mm. Determine the modulus of elasticity of the material if the cross sectional area of the wire is 25.8 mm^2.
3. At a point in an elastic material under strain, there are normal stresses of 50 N/mm^2 and 30 N/mm^2 respectively at right angles to each other with a shearing stress of 25 N/mm^2. Find the principal stresses and the position of principal planes if a) 50 N/mm^2 is tensile and 30 N/mm^2 is also tensile b) 50 N/mm^2 is tensile and 30 N/mm^2 is compressive. Find also the maximum shear stress and its plane in both the cases.

Course Outcome 2 (CO2):

1. Express the relation between load, shear force and bending moment.
2. Define the term: Point of contra flexure.
3. A cantilever beam of span 6m is subjected to a point load of 10 kN at free end and a uniformly distributed load of 12 kN/m over the right half of the span. Draw the shear force and bending moment diagrams.

Course Outcome 3 (CO3):

1. Sketch the bending stress distribution in a simple supported beam of rectangular section.
2. Derive an expression for the slope and deflection of a simply supported beam when subjected to a central point load.
3. A beam is simply supported at its ends over a span of 10 m and carries two concentrated loads of 100 kN and 60 kN at a distance of 2 m and 5 m respectively from the left support. Calculate (i) slope at the left support (ii) slope and deflection under the 100 kN load. Assume EI = 36 x 104 kN-m2

Course Outcome 4 (CO4):

1. Explain the method of calculating angle of twist in a shaft.
2. A solid shaft has to transmit 337.5 kW at 100 rpm. If the shear stress is not to exceed 65 N/mm^2 and the internal diameter is 0.6 times external diameter, find the external and internal diameters assuming that the maximum torque is 1.3 times the mean.
3. Determine the diameter of a solid shaft which will transmit 300 kN at 250 rpm. The maximum shear stress should not exceed 30 N/mm^2 and twist should not be more than 10^0 in a shaft length of 2 m. Take modulus of rigidity = 1 x 10^5 N/mm^2.

Course Outcome 5 (CO5):

1. Determine the crippling loads given by Euler's and Rankine's formula for a tubular steel strut 2.3 m long having outer and inner diameter 38 mm and 33 mm respectively, loaded through pin joints at each end. Take the yield stress as 335 N/mm^2. The

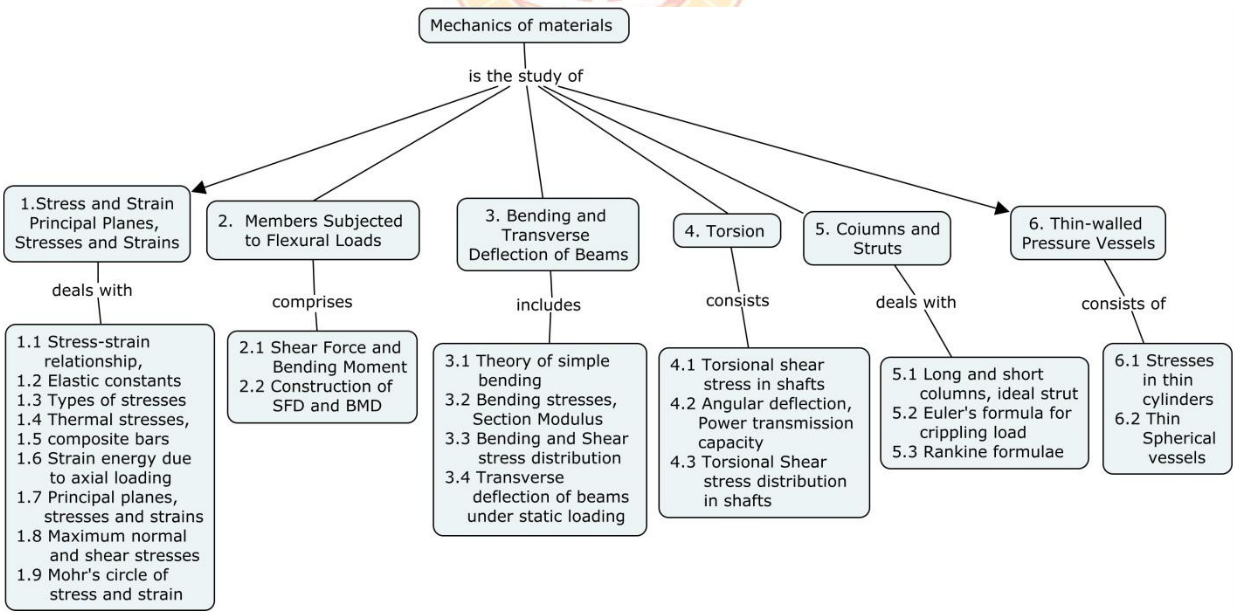
Rankine's constant = 1/7500 and E=0.205 x 10^6 N/mm^2.

2. A 1.2 m long column has a circular cross section of 45 mm diameter. One of the ends of the column is fixed in direction and position and other end is free. Taking factor of safety as 3, calculate the safe load using (i) Rankine's formula, taking yield stress = 560 N/mm^2 and *a* = 1/1600 for pinned ends. (ii) Euler's formula, taking Young's modulus for cast iron = 1.2 x 105 N/mm^2.
3. Find the Euler critical load for a hollow cylindrical cast iron column of 150 mm external diameter, 20 mm wall thickness, when it is 6 m long with hinged at both ends. Assume Young's modulus of cast iron as 80 kN/mm^2. Compare this load with that given by Rankine formula. Using Rankine constants, *a* = 1/1600 and yield stress = 567 N/mm^2.

Course Outcome 6 (CO6)**:**

1. A spherical shell of 1 m diameter is subjected to an internal pressure 0.5 N/mm^2. Find the thickness of the shell, if the allowable stress in the material of the shell is 75 N/mm^2.
2. A thin cylindrical shell 3 m long has 1 m internal diameter and 15 mm metal thickness. Calculate the circumferential and longitudinal stresses induced and also the change in the dimensions of the shell, if it is subjected to an internal pressure of 1.5 N/mm^2. Take E = 2x10^5 N/mm^2 and Poisson's ratio = 0.3. Also calculate change in volume.
3. A steel cylindrical shell 3 m long which is closed at its ends, has an internal diameter of 1.5 m and a wall thickness of 20 mm. Calculate the circumferential and longitudinal stress induced and also the change in dimensions of the shell if it is subjected to an internal pressure of 1.0 N/mm^2. Assume the modulus of elasticity and Poisson's ratio for steel as 200 kN/mm^2 and 0.3 respectively.

Concept Map



Syllabus

Stress and Strain: Elementary definition of stress and strain, tension, compression, shearing stress and strain, stress-strain relationship, Hooke's law, Poisson's ratio, elastic constants and their relations, thermal stresses, composite bars, strain energy due to axial loading. Principal planes, stresses and strains, maximum normal and shear stresses, Mohr's circle of stress and strain.

Members Subjected to Flexural Loads: Shear force and bending moment. Relation between load, shear force and bending moment. Construction of Shear force diagrams and Bending moment diagrams for different types of static loading on cantilever, simply supported and overhanging beams. **Bending and Transverse Deflection of Beams:** Theory of simple bending, bending stresses, section modulus, bending stress and shear stress distribution, transverse deflection of beams under static loading. **Torsion:** Torsional shear stress in solid and hollow circular shafts, angular displacement and power transmission capacity, Torsional Shear stress distribution in shafts. **Columns and struts:** Long and short columns, ideal strut, Euler's formula for crippling load for columns of different ends, concept of equivalent length, eccentric loading, Rankine formulae and other empirical relations. **Thin-walled Pressure Vessels:** Stresses in thin cylindrical and spherical vessels.

Text Books

1. Ferdinand P. Beer and E. Russell Johnston Jr., "**Mechanics of Materials**", McGraw Hill Book Company, 2004.
2. Bansal, R.K., "**A Text Book of Strength of Materials**", Laxmi Publications (P) Ltd. New Delhi, 2010.

Reference Books

1. James M. Gere and Stephen P. Timoshenko, "**Mechanics of Materials**", 3rd edition, McGraw Hill Book Company, 2002.
2. Timoshenko, S.P. and D.H. Young, "**Elements of Strength of Materials**", 5th edition. East-West Press, 2011.
3. Rajput, R.K., "**Strength of Materials**", S. Chand Publications, 2010.
4. Egor P. Popov, "**Engineering Mechanics of Solids**", Second Edition, Pearson Education Ltd, 2001.
5. NPTEL Video Lectures – Engineering Mechanics: Statics and Dynamics, Prof. Mahesh Panchagnula, IIT Madras. URL: www.nptel.ac.in/courses/112106180
6. MIT Open Courseware – Mechanics of Materials – Prof. Carol Livermore URL: http://ocw.mit.edu/courses/mechanical-engineering/2-001-mechanics-materials-i-fall-2006/syllabus

Course Contents and Lecture Schedule

Module Number	Topic	No. of Lectures
1.0	**Stress and Strain:**	
1.1	Elementary definition of stress and strain, tension, compression, shearing stress and strain	1
1.2	Stress-strain relationship, Hooke's law, Poisson's ratio	1
1.3	Elastic constants and their relations	1
1.4	Thermal stresses	1
1.5	Composite bars	
1.6	Strain energy due to axial loading	1
1.7	Principal planes, stresses and strains	1
1.8	Maximum normal and shear stresses	1
1.9	Mohr's circle of stress and strain	1
	Tutorials	6
2.0	**Members Subjected to Flexural Loads:**	
2.1	Shear force and bending moment. Relation between load, shear force and bending moment.	1
2.2.1	Shear force and bending moment diagrams for cantilever subjected to various types of loading	1
2.2.2	Shear force and bending moment diagrams for simply supported beam subjected to various types of loading	1

Module Number	Topic	No. of Lectures
2.2.3	Shear force and bending moment diagrams for overhanging beam subjected to various types of loading	1
	Tutorials	6
3.0	**Bending and Transverse Deflection of Beams:**	
3.1	Theory of simple bending,	1
3.2	Bending stresses, section modulus,	1
3.3	Bending stress and Shear stress distribution	1
3.4	Transverse deflection of beams under static loading	1
	Tutorials	4
4.0	**Torsion:**	
4.1	Torsional shear stress in solid and hollow circular shafts	1
4.2	Angular deflection and power transmission capacity	1
4.3	Torsional Shear stress distribution in shafts	1
	Tutorials	3
5.0	**Columns and struts:**	
5.1	Long and short columns, ideal strut,	1
5.2	Euler's formula for crippling load for columns of different ends, concept of equivalent length, eccentric loading	1
5.3	Rankine formulae and other empirical relations	1
	Tutorials	3
6.0	**Thin-walled Pressure Vessels:**	
6.1	Stresses in thin cylindrical vessels	1
6.2	Stresses in thin spherical vessels.	1
	Tutorials	2
	Total	**48**

Course Designers:

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14ME330	METAL JOINING PROCESSES AND MANUFACTURING PRACTICES	Category	L	T	P	Credit
		PC	1	0	2	2

Preamble

Metal joining is an inevitable process in the fabrication of parts. The theory part of this course aims to provide knowledge on the working, advantages, limitations and applications of various metal joining processes.

It is essential to have hands on practice of the fundamental manufacturing processes of metal casting, injection moulding, metal joining, metal forging, metal forming and Inspection through material study and NDT. This would supplement the understanding of the theory courses on Metal casting and forming processes (14ME230), and Metal joining processes (14ME330).

Prerequisite

- 14PH120 : Physics
- 14ME230- Metal casting and forming processes

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the principles of metal joining processes.	**Understand**
CO 2.	Explain the working principles of machines/equipments used for metal joining processes	**Understand**
CO 3.	Explain the process parameters involved in metal joining processes.	**Understand**
CO 4.	Select the suitable joining methods for fabrication/ assembly of products.	**Apply**
CO 5.	Organise suitable experiment to identify defects and interpret causes in manufacturing process such as metal casting, forming and joining processes	**Apply**

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1.	S	_	_	_	_	_	_	_	_	_	L	_	S	_	L
CO2.	S	_	_	_	_	_	_	_	_	_	L	_	S	_	L
CO3.	S	_	_	_	_	_	_	_	_	_	M	_	S	_	L
CO4.	S	M	_	_	_	_	_	_	_	_	M	_	S	_	M
CO5.	S	M	_	_	_	_	M	_	_	_	M	_	S	_	M
	S	L	_	_	_	_	L	_	_	_	M	_	S	_	M

Assessment Pattern

Theory (70 marks)					Practical (30 marks)		
Bloom's Category	Continuous Assessment Tests (20)		Terminal Examination (50)		Valuation category	Continuous Assessment (10)	Continuous Assessment Test 3 (20)
	1	2					
Remember	20	20	20		Class work/ Exercise	90	90
Understand	60	60	60		Record / Viva-voce	10	10
Apply	20	20	20				
Analyse	0	0	0				
Evaluate	0	0	0				
Create	0	0	0				

Theory cum Practical Courses:

There shall be three tests: the first two tests (Maximum 50 marks for each test) will be from theory component and the third test (Maximum 50 Marks) will be for practical component. The sum of marks of first two tests shall be reduced to 20 Marks and the third test mark shall be reduced to 20 marks. Average mark awarded for viva – voce, conduct of experiments, observation & results, record work in regular class works shall be reduced to 10 marks. The sum of these 50 Marks would be rounded to the nearest integer.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define Edge preparation in welding.
2. List the principles governing design of good welding fixtures.
3. State the principle of solid state welding processes

Course Outcome 2 (CO2):

1. Discuss the steps involved in thermit welding process with a neat sketches.
2. Explain the principle and operations of MIG welding and give their advantages, limitations and specific applications.
3. Describe and explain (1) Brazing and (2) Soldering. State the principal difference between them. Also state their specific applications.

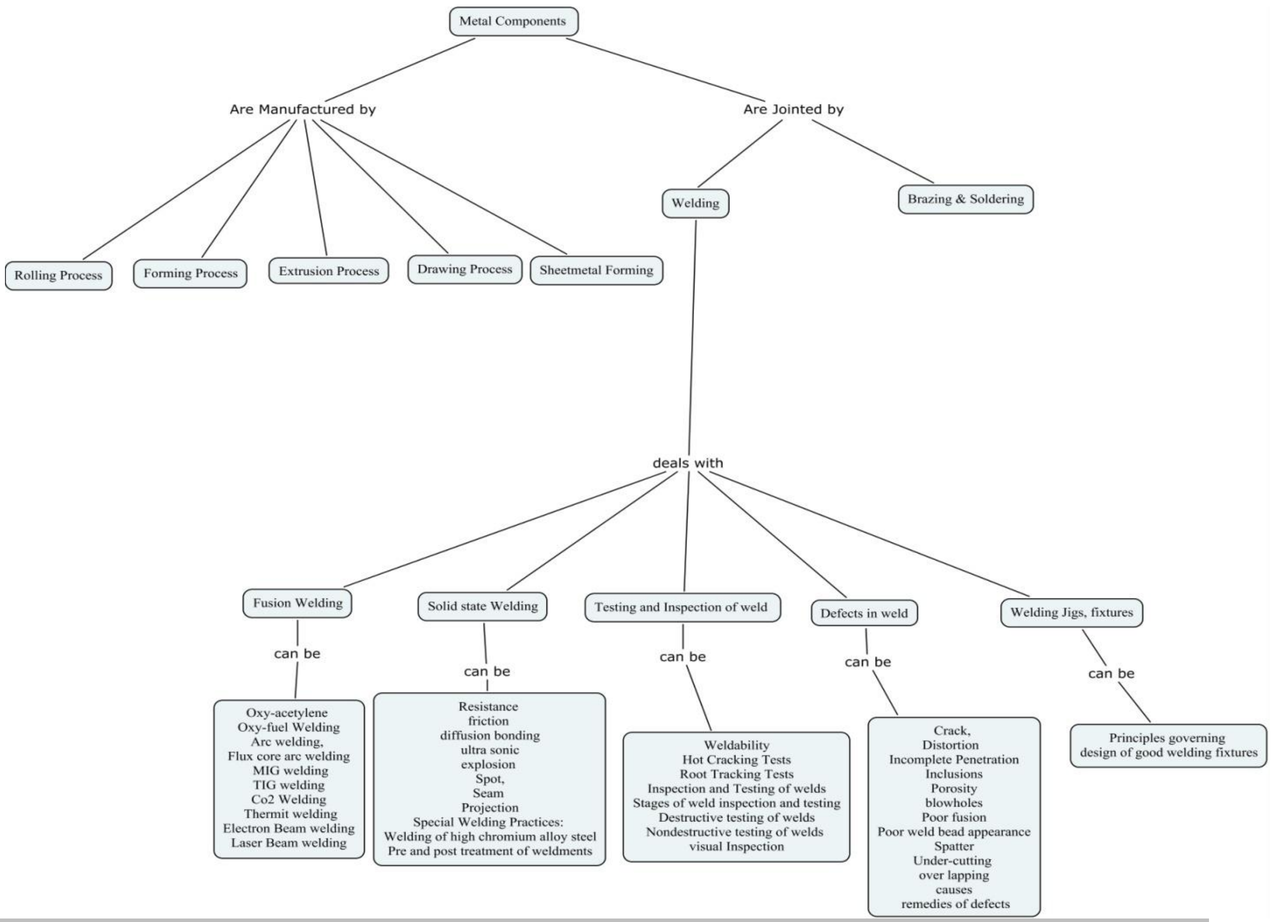
Course Outcome 3 (CO3):

1. Explain the process variables involved in electric arc welding processes.
2. Suggest few techniques to minimize distortion and warpage in welding.
3. Two flat copper sheets 1.0 mm thick are being spot welded by the use of a current of 5000 A and a current flow time of 0.25 sec. The electrodes are 5 mm in diameter. Estimate the heat generated in the weld zone. Assume that the resistance is 100 micron ohms.

Course Outcome 4 (CO4):

1. Identify a more suitable method to inspect a weld with cracks and internal blow holes and describe it. Also, write all the possible causes for those defects and rectification method.
2. Suggest the suitable joining process for the manufacture of i) funnel made of MS sheet of 22 Gauge thickness and ii) PCB used in electronic products.
3. Suggest the suitable welding process for the following: i) Cast iron; ii) Aluminum alloy

Concept Map



Syllabus

Theory Component:

Metal joining Process - Introduction:
Solidification of the weld metal, base metal, heat affected zone, weld metal, shielding gases, filler metal, fluxes.

Fusion welding: Oxy-fuel gas Welding, Arc welding, Flux core arc welding, MIG welding, TIG welding, Co_2 Welding, Thermit welding, Plasma arc welding, Electron Beam welding, Laser Beam welding.

Solid State welding: Resistance Welding-spot, seam, projection welding , friction welding, diffusion bonding, ultra sonic welding, explosion welding.

Special Welding Practices: Welding of high chromium alloy steel and Pre and post treatment of weldments.

Defects in welding: Crack, Distortion (Distortion and residual stresses, Concept of distortion, Types of distortion, Control of welding distortion), Incomplete Penetration, Inclusions, Porosity and blowholes, Poor fusion, Poor weld bead appearance, Spatter, Under-cutting and over lapping, causes and remedies of defects.

Testing and Inspection of welding : Weldability, Hot Cracking Tests, Root Tracking Tests, Inspection and Testing of welds, Stages of weld inspection and testing, Destructive testing of welds, Non-destructive testing of welds and visual Inspection.

Welding fixtures: Principles governing design of good welding fixtures

Brazing and soldering: Principle of Operation, advantages, Limitations and application.

Text Books

1. Serope Kalpakjian and Steven R.Schmid, "**Manufacturing Engineering and Technology**", Sixth Edition, PHI, 2010.
2. Mikell P.Groover, "**Fundamental of Modern Manufacturing**", Wiley India Edition, Third Edition, Reprint, 2012.

Reference Books

1. E. Paul DeGarmo, J.T. Black and Ronald A. Kohser, "**Degarmo's Materials and Processes in Manufacturing** ", John Wiley & Sons, 11th Edition 2011.
2. Philip F. Oswald, and Jairo Munoz, "**Manufacturing Process and Systems**", John Wiley India Edition, 9th Edition, Reprint 2008.
3. Richard.L,Little, "**Welding and Welding Technology**" - McGraw Hill Education (India) Private Limited , New Delhi, 42nd Reprint 2013.
4. Parmer R.S, "**Welding Engineering and Technology**", 2nd Edition, Khanna publishers, Delhi, 2010.
5. S. K. Hajra Choudhury, Nirjhar Roy, A. K. Hajra Choudhury, **"Elements of Work shop Technology, Vol – I Manufacturing Processes**", Media Promoters and Publishers Pvt. Ltd, 2009.
6. P.N.Rao, "**Manufacturing Technology**", Volume-1, Tata McGraw Hill, New Delhi, Third Edition, 2011.
7. P.C. Sharma, "**A Text Book of Production Technology (Manufacturing Processes)**", S. Chand & Company Ltd., New Delhi, Seventh Reprint, 2012.
8. AWS Welding Handbook, Volume 1, Welding Science & Technology, American Welding Society, 2001.
9. AWS Welding Handbook, Volume 2, Welding Processes, Part 1, American Welding Society, 2004.
10. AWS Welding Handbook, Volume 3, Welding Processes, Part 2, American Welding Society, 2004.
11. NPTEL Video Lectures –Manufacturing Processes I, Prof. Pradeep Kumar, IIT Roorkee. URL: www.nptel.ac.in/courses/112107144
12. MIT Open Course Ware – Welding and Joining Processes, Prof. Thomas Eagar, MIT. URL: http://ocw.mit.edu/courses/materials-science-and-engineering/3-37-welding-and-joining-processes-fall-2002/download-course-materials

Course Contents and Lecture Schedule

S.No.	Topic	No. of Lectures
1	Metal Joining Process- Introduction, Solidification of the weld metal, base metal, heat affected zone, weld metal, shielding gases, filler metal, fluxes.	1
2	Fusion welding	
2.1	Oxy-fuel gas Welding, Arc welding, SMAW	1
2.2	GTAW, GMAW and SAW, Thermit welding	1
2.3	Plasma arc welding, Electron Beam welding, Laser Beam welding	1
3	Solid State welding	
3.1	Resistance Welding-spot, seam, projection welding, friction welding	1
3.2	Friction stir welding, diffusion bonding, ultra sonic welding, explosive welding	1
3.3	Special welding practices: Welding of high chromium alloy steel and Pre and post treatment of weldments.	2
4	Defects in welding	
4.1	Cold and hot cracks, hydrogen induced cracking, Lamellar tearing, Incomplete Penetration, Inclusions / Porosity and blowholes	1
4.2	Improper fusion, Poor weld bead appearance, Spatter, Under-cutting and over lapping, causes and remedies of defects	1
5	Testing and Inspection of welding	
5.1	Weldability, Stages of weld inspection and testing, Hot Cracking Tests	1
5.2	Destructive and Non-destructive testing of welds and visual Inspection.	1
6	Welding fixtures- Principles governing design of good welding fixtures	1

7	Brazing- Principle of Operation, advantages, Limitations and application	1
8	Soldering- Principle of Operation, advantages, Limitations and application	1
	Total	**15**

Practical Component:

Ex. No	List of Experiments	No of Hrs.
	Molding and Casting Practices	
1.	Preparation of the mould using single piece pattern.	2
2.	Preparation of the mould using split pattern.	2
3.	Melting, pouring and finishing.	2
4.	Exercise in Plastic Injection Moulding (Horizontal/Vertical Machine).	2
	Metal Joining Practices	
5.	Exercises in Arc Welding with use of appropriate fixtures for welding.	2
6.	Exercises in MIG Welding with use of appropriate fixtures for welding.	2
7.	Exercises in Spot Welding different thickness by selecting appropriate current settings.	2
8.	Brazing and soldering in the sheet metal parts like- Dust Bin, Dust Pan, Taper Tray).	2
	Non Destructive Inspection of Casting and Welding	
9.	Inspection of castings using NDT Methods	1
10.	Inspection of weldment (Surface Cracks) using Dye Penetrant Test.	1
11.	Demonstration of inspection of weldment (Internal Cracks) using Ultrasonic Flaw Detector.	1
	Smith Forging Practices	
12.	Preparation of Square / Hexagonal Head Bolt.	2
13.	Preparation of tool for shaping machine / Chisel.	2
14.	Preparation of Z – Clamp / S – Hook.	1
	Total	**24**

NOTE:

- Any two practices will be given for the final practical examination.
- Minimum 12 Exercises are to be conducted.
-

Course Designers:

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		Category	L	T	P	Credit
14ME340	**FLUID MECHANICS**	PC	2	2	0	3

Preamble

Fluid mechanics is defined as the science that deals with the behavior of fluids at rest (fluid statics) or in motion (fluid dynamics) and the interaction of fluids with solids or other fluids at the boundaries. Fluid mechanics itself is also divided in to several categories. The study of the motion of fluids that are practically incompressible (such as liquids, especially water and gases at low speeds) is usually referred to as hydrodynamics. Gas dynamics deals with the flow of fluids that undergo significant density changes such as the flow of gases through the nozzle at high speeds. The occurrence of normal shocks and constant area flow with friction (Fanno flow) and constant area flow with heat transfer (Rayleigh flow) are the branches of gas dynamics used to acquire knowledge in compressible flow.

Prerequisite

- 14MA110 - Engineering Mathematics-I
- 14PH120 - Physics

Course Outcomes

On successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the effect of fluid properties on a flow system and solving fluid flow problems.	**Apply**
CO 2.	Apply the kinematic concepts and dynamic concepts which relates to the conservation principles of mass and energy	**Apply**
CO 3.	Predict the losses and pressure drop in pipe flow	**Apply**
CO 4.	Compute the compressible flow properties with variation in area	**Apply**
CO 5.	Analyze the occurrence of shock in compressible flow and its property variation across the shock	**Analyze**
CO 6.	Analyze the effects of friction (Fanno flow) and heat transfer (Rayleigh flow) on compressible fluids in constant area duct.	**Analyze**

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	M	L	_	_	_	_	_	_	_	_	_	_	M	_
CO2.	S	M	L	_	_	_	_	_	_	_	_	_	_	M	_
CO3.	S	M	L	_	_	_	_	_	_	_	_	_	_	M	_
CO4.	S	M	L	_	_	_	_	_	_	_	_	_	_	M	_
CO5.	S	M	L	L	_	_	_	_	_	_	_	_	_	S	L
CO6.	S	M	L	L	_	_	_	_	_	_	_	_	_	S	L
	S	M	L	L	_	_	_	_	_	_	_	_	_	S	L

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	30	30	30	30
Apply	50	40	40	40
Analyse	--	10	10	10
Evaluate	--	--	--	--
Create	--	--	--	--

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Derive an expression for capillary rise or fall of a liquid
2. The velocity distribution over a plate is given by $u = \frac{3}{4}y - y^2$ where u is the velocity in m/s and at a depth y in metre above the plate. Determine the shear stress at a distance of 0.3 m from the top of the plate. Assume the dynamic viscosity of the fluid is taken as 0.96 NS/m^2.
3. A manometer is used to measure the pressure of a gas in a tank. The fluid used has a specific gravity of 0.85, and the manometer column height is 55 cm. If the atmospheric pressure is 96 kPa, determine the absolute pressure within the tank

Course Outcome 2 (CO2):

1. Differentiate between local and convective acceleration.
2. For the two dimensional stream function for a flow in ψ = 9 + 6 x – 4 y + 7 xy, determine the velocity potential.
3. Velocity for a two dimensional flow field is given by, V = $(3 + 2xy + 4t^2)$ **i** + $(x y^2 + 3 t)$ **j**. Find the acceleration at a point (1,2) after 2 seconds.

Course Outcome 3 (CO3):

1. Water flows in a pipe of 150 mm diameter and at a sudden enlargement the loss of head is found to be 2/3 of the velocity head in the pipe 160 mm diameter. Find the diameter of the enlarged pipe, if flow rate is 150 litre/s.
2. Derive the relation for loss of head due to sudden enlargement in a pipe.
3. The diameter of a horizontal pipe which is 300 mm is suddenly enlarged to 600 mm. The rate of flow of water through this pipe is 0.4 m^3/s. If the intensity of pressure in the smaller pipe is 125 kPa, determine (i) loss of head due to sudden enlargement and (ii) intensity of pressure in the larger pipe. .

Course Outcome 4 (CO4):

1. A sonic velocity air jet has a temperature of 280 K. Determine (i) velocity of sound in the jet, (ii) stagnation temperature and stagnation enthalpy of the jet, (iii) stagnation velocity of sound, (iv) critical speed of sound, (v) stagnation to static pressure ratio, (vi) maximum isentropic speed and (vii) Crocco number.
2. Air is discharged from a reservoir at 1 MPa and 500 K through a nozzle to an exit pressure of 0.09 MPa. If the flow rate through the nozzle is 3600 kg/h, determine for isentropic flow (i) throat area, pressure and velocity (ii) exit area and Mach number.
3. Derive an expression for Mach number in terms of stagnation to static temperature ratio.

Course Outcome 5 (CO5):

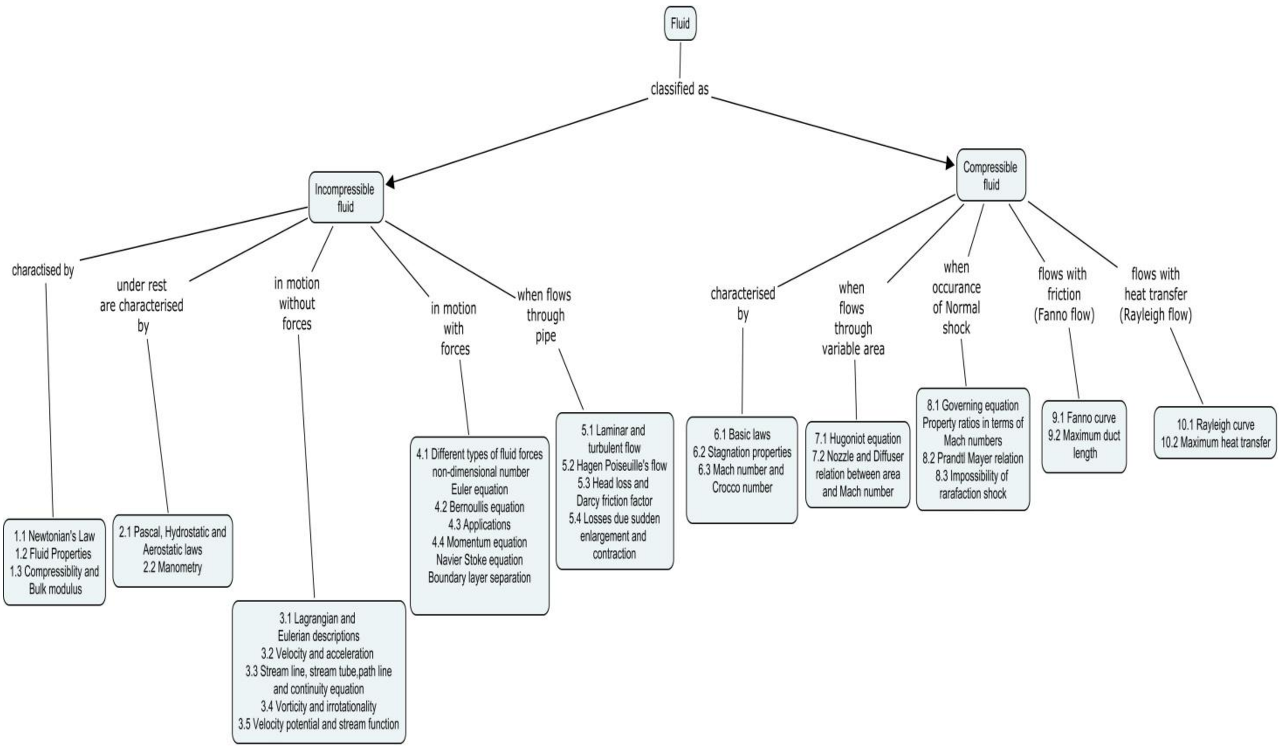
1. Air flows isentropically through a duct. At a particular section in the passage, the cross sectional area is 400 mm^2 and M = 0.4. At another section the area is 300 mm^2. What is the Mach number at the second section? What would be the area at the section where M = 1?

2. During the occurrence of shock, is the stagnation temperature varying? Why?
3. Air flows isentropically through a duct. At a particular section in the passage, the cross sectional area is 400 mm^2 and M = 0.4. At another section the area is 300 mm^2. What is the Mach number at the second section? What would be the area at the section where M = 1?

Course Outcome 6 (CO6)**:**

1. The average friction factor of a 25 mm diameter, 12 meter long pipe is 0.004. The conditions of air at entry are 2 bar and 300 K. Determine the pressure, temperature and the Mach number at exit, if the Mach number at inlet is 0.25.
2. Air at inlet to an insulated constant area duct of diameter 160 mm has a Mach number of 0.36. The mean friction factor of the duct for the flow conditions is 0.0025. What length of the pipe would give a 10 % loss in stagnation pressure? What is the Mach number at the corresponding exit section? What is the percentage loss in stagnation pressure, if the flow extends to sonic condition?
3. Differentiate between Fanno and Rayleigh flow.

Concept Map



Syllabus

Basic Concepts: Concept of fluid - Dimensions and Units- Thermodynamic properties of Fluids: Pressure, Density, Specific Gravity, Viscosity, Surface Tension, Capillarity, Compressibility and Bulk Modulus. **Fluid Statics**: Pressure at a Point: Pascal's Law - Pressure force on a fluid element: Hydrostatic law and aerostatic law – Manometry.

Fluid Kinematics: Lagrangian and Eulerian Descriptions – Velocity and Acceleration of a fluid particle-Stream line, stream tubes and path line- Continuity Equation in Cartesian Co-ordinates – Vorticity and irrotationality- Velocity Potential and Stream Function. **Fluid Dynamics:** Different types of fluid forces- non-dimensional number: Reynolds number, Froude number, Euler number, Weber number and Mach number- Euler's Equation for Motion - Bernoulli's Equation - Applications of Bernoulli's Equation, Venturimeter and orifice meter – Momentum equation - Navier Stokes Equation – Boundary layer separation.

Pipe Flow: Laminar and turbulent flow - Reynolds Experiment - Significance of Reynolds Number - Laminar Flow in Pipes: Hagen Poiseuille's flow, Darcy-Weisbach equation, losses due sudden enlargement and contraction.
Gas Dynamics: Definition - Basic laws and Governing equations - Stagnation state and properties- Velocity of sound - Mach number – critical Mach number –Effect of compressibility on Mach number- Crocco number. **Isentropic Flow with variable area:** Hugoniot equation – Nozzle and Diffuser -relation between area and mach number.
Normal Shocks in one dimensional flow: Governing equations- Property ratios in terms of Mach numbers across the shock- Prandtl Mayer relation –impossibility of rarefaction shock.
Fanno Flow: Fanno curve - Fanno flow governing equations - Maximum duct length. **Rayleigh Flow:** Rayleigh curve - Rayleigh flow governing equations - Maximum heat transfer.

Text Books

1. Bruce R. Munson, Theodore H. Okiishi, Wade W. Huebsch, Rothmayer, **"Fluid Mechanics**", Seventh Edition, Wiley India Pvt. Ltd, 2015.
2. S.M. Yahya, **"Gas tables for Compressible Flow Calculations"**, Sixth Edition, New Age International (P) Ltd, 2011.

Reference Books

1. S.M. Yahya, **"Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion"**, Fourth Edition, New Age International (P) Ltd, 2010.

2. S. K. Som, G. Biswas, Suman Chakraborty, **"Introduction to Fluid Mechanics and Fluid Machines"**, Third Edition, Tata McGraw - Hill Publishing Company Limited - New Delhi, 2011.
3. Yunus A. Cengel, John M. Cimbala, "**Fluid Mechanics: Fundamental and Applications**", Third Edition, McGraw-Hill Education (India) Pvt. Ltd, 2014**.**
4. Frank White, "**Fluid Mechanics**", Seventh Edition, McGraw Hill Education (India) Pvt. Ltd, 2011.
5. R.K. Bansal, "**A Text Book of Fluid Mechanics and Hydraulic Machines**", Ninth Edition, Laxmi Publications (P) Ltd., 2011.
6. R.K. Rajput, "**Fluid Mechanics and Hydraulic machines**", S.Chand & Company Ltd, 2010.
7. NPTEL Video Lectures – Introduction to Fluid Mechanics and Fluid Engineering, Prof.S.Chakraborty, IIT Kharagpur. URL: www.nptel.ac.in/courses/112105183
8. MIT Open Courseware – Fluid Mechanics, Prof. Mark Drela, MIT. URL: http://ocw.mit.edu/courses/aeronautics-and-astronautics/16-01-unified-engineering-i-ii-iii-iv-fall-2005-spring-2006/fluid-mechanics/
9. NPTEL Video Lectures – Gas Dynamics and Propulsion, Prof. V. Babu, IIT Madras. URL: www.nptel.ac.in/courses/112106166
10. MIT Open Courseware – Hydrodynamics, Prof. Alexandra Techet, MIT. URL: http://ocw.mit.edu/courses/mechanical-engineering/2-016-hydrodynamics-13-012-fall-2005/index.htm

Course Contents and Lecture Schedule

Module No	Topic	No. of Lectures
1.	**Basic Concepts**	
1.1	Introduction - Liquids and Gases, Ideal and real fluids, Newtonian and Non-Newtonian fluids	1

1.2	Properties of Fluids, Pressure, Density, Specific Gravity, Viscosity, Surface Tension and Capillarity	1
1.3	Compressibility and Bulk Modulus	1
	Tutorials	2
2	**Fluid Statics**	
2.1	Pascal's Law, hydrostatic law and aerostatic law	1
2.2	Manometry	1
	Tutorials	2
3.	**Fluid Kinematics**	
3.1	Lagrangian and Eulerian Descriptions	1
3.2	Velocity and Acceleration of a fluid particle	1
3.3	Stream line, stream tubes and path line, Continuity Equation in Cartesian Co-ordinates	1
3.4	Vorticity and irrotationality,	1
3.5	Velocity Potential and Stream Function	1
	Tutorials	2
4.	**Fluid Dynamics**	
4.1	Different types of fluid forces- non-dimensional number, Reynolds number, Froude number, Euler number, Weber number and Mach number - Euler's equation of motion	1
4.2	Bernoulli's equation	1
4.3	Applications of Bernoulli's Equation, Venturimeter and orifice meter	1
4.4	Momentum Equation, Navier Stokes Equation, Boundary Layer separation	1
	Tutorials	2
5.	**Pipe Flow**	
5.1	Laminar and turbulent flow, Reynolds Experiment and Significance of Reynolds Number	1
5.2	Laminar Flow in Pipes, Hagen Poiseuille's flow,	1
5.3	Head loss and Darcy friction factor	1
5.4	Losses due sudden enlargement and contraction.	1
	Tutorials	2
6.	**Gas Dynamics**	
6.1	Definition - Basic laws and Governing equations	1
6.2	Stagnation state and properties - Velocity of sound	1
6.3	Mach number – critical Mach number – Crocco number	1
	Tutorials	2
7	**Isentropic Flow with variable area**	
7.1	Hugoniot equation	1
7.2	Nozzle and Diffuser -Relation between area and Mach number	1
	Tutorials	2
8.	**Normal Shocks in One dimensional flow**	
8.1	Governing equations- Property ratios in terms of Mach numbers across the shock	1
8.2	Prandtl Mayer relation	1
8.3	Impossibility of rarefaction shock	1
	Tutorials	2
9.	**Fanno Flow**	
9.1	Fanno curve - Fanno flow equations	1

9.2	Maximum duct length	
	Tutorials	2
10.	**Rayleigh Flow**	
10.1	Rayleigh curve - Rayleigh flow equations	1
10.2	Maximum heat transfer	
	Tutorials	2
	Total	**48**

Course Designers:

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14ME350	APPLIED MATERIALS AND METALLURGY	Category	L	T	P	Credit
		PC	3	0	0	3

Preamble

Applied Materials and Metallurgy imparts knowledge on the defects and deformation in crystalline solids, strengthening mechanisms in crystalline solid materials, ferrous alloys, heat treatment and surface hardening of Steel, nonferrous alloys and surface treatments pertaining to mechanical engineers.

Prerequisite

- 14ME260 Materials Science

Course Outcomes

On successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain various types of defects and deformation in crystalline solids.	Understand
CO 2.	Select suitable strengthening mechanism and its effects for a crystalline material.	Apply
CO 3.	Explain the Iron-Iron carbide equilibrium diagram and outline various types of steel and iron.	Understand
CO 4.	Select appropriate heat treatment and surface hardening process for steel.	Apply
CO 5.	Illustrate the phase diagram of copper, aluminum, nickel and titanium alloys.	Apply
CO 6.	Demonstrate suitable surface treatment methods for metals and alloys.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1.	M	L	_	_	_	_	_	_	_	_	_	_	M	_	M
CO2.	S	M	L	L	_	_	_	_	_	_	_	_	S	_	S
CO3.	M	L	_	_	_	_	_	_	_	_	_	_	M	_	M
CO4.	S	M	L	L	_	_	_	_	_	_	_	_	S	_	S
CO5.	S	M	L	L	_	_	_	_	_	_	_	_	S	_	S
CO6.	S	M	L	L	_	_	_	_	_	_	_	_	S	_	S
	S	M	L	L	_	_	_	_	_	_	_	_	S	_	S

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	40	40	40	40
Apply	40	40	40	40
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Outcomes

Course Outcome 1 (CO1):

1. Illustrate different types of point defect in crystalline solid materials.
2. Distinguish between screw and edge dislocation.
3. Explain the various classes of surface defects.
4. Outline any four differences between deformation by twinning and deformation by slip relative to mechanism, conditions of occurrence and final result.

Course Outcome 2 (CO2):

1. Illustrate the effect of annealing on the structure and mechanical properties of a cold worked metal.
2. Illustrate the solid solution strengthening of metals.
3. Sequence five important factors that affect the recrystallization process in metals.
4. Interpret the microscopic changes that occur when a cold worked sheet of metal such as aluminium undergoes a recovery heat treatment.

Course Outcome 3 (CO3):

2. Illustrate the Iron - Iron carbide phase diagram and discuss the various phases and invariant reactions that take place in it.
1. Explain the affect of various alloying elements on the properties of steel.
2. Annotate the composition properties and applications of various types of carbon steel.
3. Distinguish between white and nodular cast iron with respect to its a) composition and heat treatment, b) microstructure and c) mechanical characteristics.

Course Outcome 4 (CO4):

1. Draw an isothermal transformation diagram for plain-carbon eutectoid steel and exhibit the various decomposition products in it.
2. Illustrate the types of microstructure that are produced by tempering plain carbon steel with more than 0.2 percent carbon in the temperature ranges a) 20-250 ^{0}C, b) 250-350 ^{0}C and c) 400-600 ^{0}C.
3. Demonstrate a suitable process for surface hardening of gears after machining.
4. Choose appropriate hardening processes for steel using necessary TTT diagram.

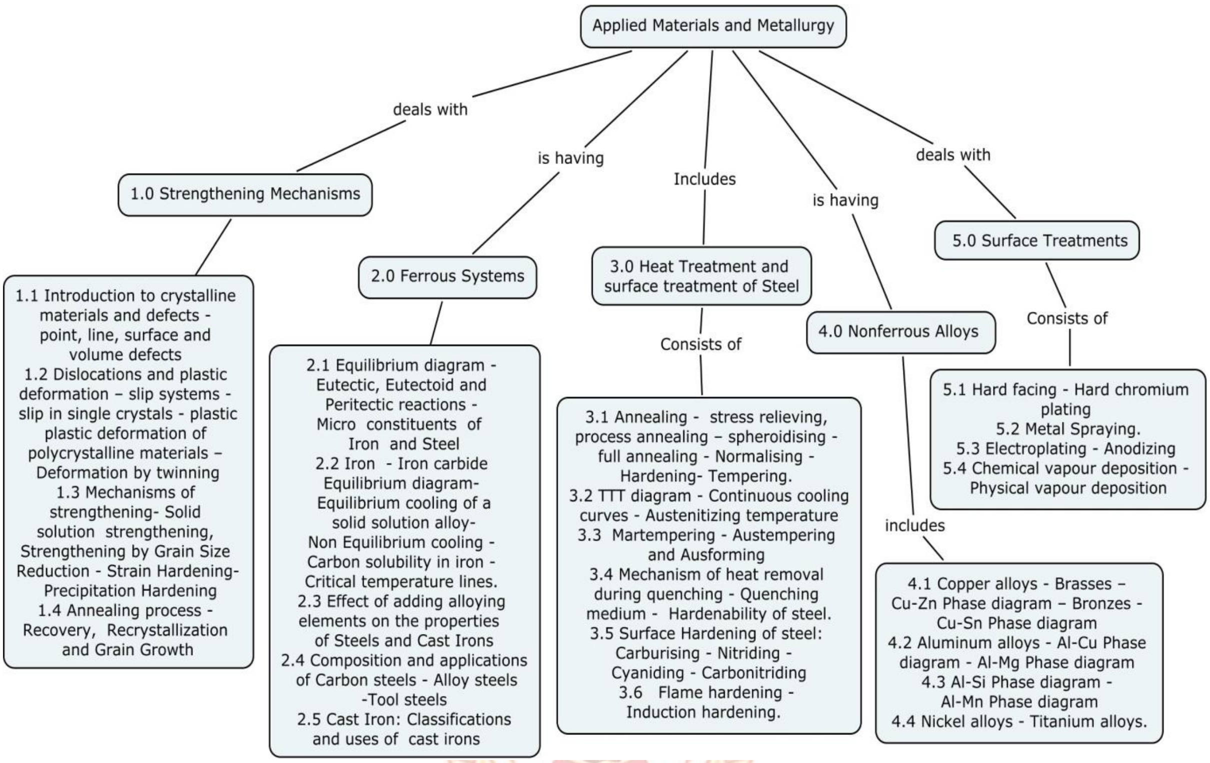
Course Outcome 5 (CO5):

1. Illustrate the binary Cu-Zn phase diagram and demonstrate the effect of zinc concentration on the properties of Cu-Zn alloys.
2. Draw the phase diagram of Al-Mg alloy system and interpret the significance of various phase present in it.
3. Demonstrate the development of microstructure during the equilibrium solidification of a 35 wt% Ni – 65 wt % Cu, using suitable phase diagram.
4. Draw the Ti-Al phase diagram and demonstrate the importance of various phases of this alloy system.

Course Outcome 6 (CO6):

1. Demonstrate a suitable method to minimize the surface roughness of coarse grained steel.
2. Illustrate an appropriate method to achieve wear resistance surfaces.
3. Demonstrate a surface treatment technique with regard to anticorrosion surfaces.
4. Interpret the properties and applications of thin film TiN surface coatings.

Concept Map



Syllabus

Strengthening Mechanisms: Introduction to crystalline materials and defects - point, line, surface and volume defects - Dislocations and plastic deformation – slip systems - slip in single crystals - plastic deformation of polycrystalline materials – Deformation by twinning - Mechanisms of strengthening - solid solution strengthening, Strengthening by Grain Size Reduction - Strain Hardening and Precipitation Hardening - Annealing process - Recovery, Recrystallization and Grain Growth. **Ferrous Systems:** Equilibrium diagram - Eutectic, Eutectoid and Peritectic reactions - Micro constituents of Iron and Steel - Iron - Iron carbide Equilibrium diagram- Equilibrium cooling of a solid solution alloy- Non Equilibrium cooling - Carbon solubility in iron - Critical temperature lines. Effect of adding alloying elements on the properties of Steels and Cast Irons- Composition and applications of Carbon steels, Alloy steels, Tool steels - Cast Iron: Classifications and uses of cast irons. **Heat Treatment and Surface treatment of Steel:** Annealing - stress relieving, process annealing, spheroidising, full annealing - Normalising - Hardening- Tempering - TTT diagram - Continuous cooling curves - Austenitizing temperature - Martempering, Austempering and Ausforming - Mechanism of heat removal during quenching - Quenching medium- Hardenability of steel. Surface Hardening of steel: Carburising - Nitriding - Cyaniding - Carbonitriding – Flame hardening - Induction hardening. **Nonferrous Alloys:** Copper alloys - Brasses – Cu-Zn Phase diagram – Bronzes - Cu-Sn Phase diagram - Aluminum alloys - Al-Cu Phase diagram - Al-Mg Phase diagram - Al-Si Phase diagram - Al-Mn Phase diagram - Nickel alloys - Titanium alloys. **Surface Treatments:** Hard facing - Hard chromium plating – Metal Spraying - Electroplating - Anodizing – Chemical vapour deposition - Physical vapour deposition.

Text Books

1. Callister W. D., "**Materials Science and Engineering**", John Wiley & Sons, 2007.

2. Sidney H. Avner, "**Introduction to Physical Metallurgy**", Tata McGraw Hill, New Delhi, 1997.

Reference Books:

1. Vijayendra Singh, "**Physical Metallurgy**", Standard Publishers distributors, Delhi, 2005.
2. Rajan.T.V, Sharma C.P., Ashok Sharma, "**Heat Treatment Principles and Techniques**", Prentice-Hall of India Pvt. Ltd., New Delhi, 2002.
3. Serope Kalpakjian, Steven Schmid, "**Manufacturing Engineering and Technology**", Pearson Education, New Delhi, 2001.
4. George Dieter, "**Mechanical Metallurgy**", 3rd Edition, Tata McGraw-Hill, New Delhi, 2013.
5. NPTEL Video Lectures – Introduction to Material Science and Engineering, Prof.RanjitBauri, IIT Madras. URL: www.nptel.ac.in/courses/113106032
6. NPTEL Video Lectures – Principles of Physical Metallurgy, Prof.R.N.Ghosh, IIT Kharagpur. URL: www.nptel.ac.in/courses/113105023
7. MIT Open Course Ware – Iron Carbide Phase Diagram. URL: http://ocw.mit.edu/courses/materials-science-and-engineering/3-40j-physical-metallurgy-fall-2009/lecture-notes/MIT3_40JF09_lec21.pdf

Course Contents and Lecture Schedule:

Module No.	Topic	No. of Lectures
1.0	**Strengthening Mechanisms:**	
1.1	Introduction to crystalline materials and defects - point, line, surface and volume defects	2
1.2	Dislocations and plastic deformation – slip systems - slip in single crystals - plastic deformation of polycrystalline materials – Deformation by twinning	2
1.3	Mechanisms of strengthening - Solid solution strengthening, Strengthening by Grain Size Reduction - Strain Hardening - Precipitation Hardening	2
1.4	Annealing process - Recovery, Recrystallization and Grain Growth	1
2.0	**Ferrous Systems:**	
2.1	Equilibrium diagram - Eutectic, Eutectoid and Peritectic reactions - Micro constituents of Iron and Steel	2
2.2	Iron - Iron carbide Equilibrium diagram- Equilibrium cooling of a solid solution alloy- Non Equilibrium cooling - Carbon solubility in iron - Critical temperature lines.	2
2.3	Effect of adding alloying elements on the properties of Steels and Cast Irons	1
2.4	Composition and applications of Carbon steels - Alloy steels -Tool steels	2
2.5	Cast Iron: Classifications and uses of cast irons	2
3.0	**Heat Treatment and Surface treatment of Steel:**	
3.1	Annealing - stress relieving, process annealing – spheroidising - full annealing - Normalising - Hardening- Tempering.	2
3.2	TTT diagram - Continuous cooling curves - Austenitizing temperature	2
3.3	Martempering - Austempering and Ausforming	1
3.4	Mechanism of heat removal during quenching - Quenching medium- Hardenability of steel.	1

Module No.	Topic	No. of Lectures
3.5	Surface Hardening of steel: Carburising - Nitriding - Cyaniding - Carbonitriding	2
3.6	Flame hardening - Induction hardening.	1
4.0	**Nonferrous Alloys :**	
4.1	Copper alloys - Brasses – Cu-Zn Phase diagram – Bronzes - Cu-Sn Phase diagram	2
4.2	Aluminum alloys - Al-Cu Phase diagram - Al-Mg Phase diagram	2
4.3	Al-Si Phase diagram - Al-Mn Phase diagram	1
4.4	Nickel alloys - Titanium alloys.	2
5.0	**Surface Treatments:**	
5.1	Hard facing - Hard chromium plating	1
5.2	Metal Spraying.	1
5.3	Electroplating - Anodizing	1
5.4	Chemical vapour deposition - Physical vapour deposition	1
	Total	**36**

Course Designers:

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		Category	L	T	P	Credit
14ME360	**GEOMETRIC MODELING**	PC	3	0	0	3

Preamble

The concept of geometric modeling is evolved rapidly due to the development of computer graphics, computer aided design and manufacturing technologies. Geometric modeling is the base for the computer aided design (CAD) and it embraces computational geometry and extends to the field of solid modeling, creating an elegant synthesis of geometry. The construction of an entity is usually a computer aided operation. Computer graphics, Computer aided design and computer aided manufacturing have been the driving forces behind the rapid development of geometric modeling schemes. Robotics, computer vision and artificial intelligence are also making increasing demands on geometric modeling capabilities.

Prerequisite

- 14MA110 - Engineering Mathematics

Course Outcomes

On successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the coordinate system for the development of geometric models	**Understand**
CO 2.	Develop and manipulate the curves and surfaces using parametric equations	**Apply**
CO 3.	Develop and manipulate the solid models using different modeling approaches	**Apply**
CO 4.	Apply the transformation and projection principles over the given geometric models.	**Apply**
CO 5.	Build the neutral file formats over 2D wireframe models	**Apply**

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1.	M	L	L	L	L	_	_	L	_	_	_	_	_	_	_
CO2.	S	M	L	L	L	_	_	L	_	_	_	_	_	_	_
CO3.	S	M	L	L	L	_	_	L	_	_	_	_	_	_	_
CO4.	S	M	L	L	L	_	_	L	_	_	_	_	_	_	_
CO5.	S	M	L	L	L	_	_	L	_	_	_	_	_	_	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	40	40	40	40
Apply	40	40	40	40
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Differentiate geometric and display coordinate system.
2. List the desirable properties of curve modeling.
3. Write down any two Euler operators.

Course Outcome 2 (CO2):

1. Plot the resultant shape of hermite cubic spline curve using P_0(0, 20) and P_1(50, 50) with 30^0 inclination at the starting point and -45^0 inclination at the end point.
2. Generate a segment of Bezier curve using (0, 0), (15, 0), (10, 10) and (5, 10) using polynomial equation.
3. Find the equation of a cubic B-spline surface defined by (4 x 5) control points. Find out all the entire knot vectors.

Course Outcome 3 (CO3):

1. Develop a solid model of hollow cylinder of 20 mm thickness with ASM and sweep schemes.
2. Suggest a suitable manipulation technique for joining two different solids.
3. Illustrate the Boundary representation and CSG technique with suitable solid model and compare complexity of the two techniques used.

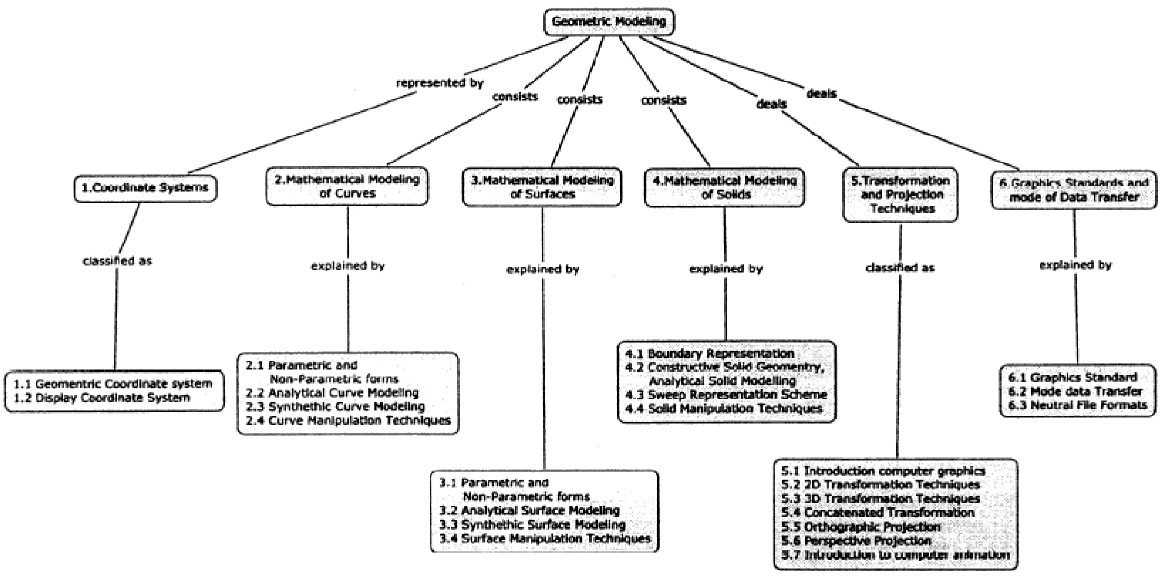
Course Outcome 4 (CO4):

1. Consider a line with (5,5) and (5,0) points. Rotate the line with respect to another point (0, 2.5) by 45 degrees in CW direction and get the transformed position.
2. A point P(2,5,10) is rotated 30° in CCW about z-axis then followed by scaling 200% and refection about Y=0 plane. What happens if this point P transformed in reverse sequence?
3. Obtain the perspective view of a point in space (2,5,8) when projecting along z-direction at a distance of 75 mm.

Course Outcome 5 (CO5):

1. Obtain the IGES format for circle of diameter 30 mm located at (0, 0) and line segment of (10, 5) and (20, 0).
2. Illustrate the structure of DXF neutral file format with a suitable wire frame drawing.
3. Write IGES and DXF code structure for an arc with starting point (0,5) end point (5,0) with center of (0,0)

Concept Map



Syllabus

Coordinate systems: Geometric co-ordinate systems - Cartesian, Cylindrical and Spherical coordinate systems. Display co-ordinate systems - Global, Local, View and Screen coordinate systems. **Mathematical modelling of Curves:** Definition - Parametric and non-parametric forms of analytical and synthetic curves. Analytical Curve modelling - Line Segment, Circle, Ellipse. Synthetic Curve modelling - Hermite Cubic Spline, Bezier, B-spline and Rational Curves. Curve manipulation techniques. **Mathematical modelling of Surfaces:** Definition - Parametric and non- parametric forms of analytical and synthetic surfaces. Analytical surface modelling - Parametric form of plane, loft, Cylindrical, Surface of revolution. Synthetic Surface modelling - Hermite Bicubic Spline, Bezier, B-spline, Coon's, triangular, blending Surfaces. Surface Manipulation techniques. **Mathematical modelling of Solids:** Properties of solid model, Solid modelling Techniques - Boundary representation, Constructive Solid Geometry, Analytical Solid Modelling, Sweep representation schemes. Solid Manipulation Techniques. **Transformation and Projection techniques:** Introduction to computer graphics, Non-interactive Vs interactive computer graphics, applications, graphics system configuration. 2D and 3D transformation techniques - Translation, Rotation, Scaling and Reflection principles. Principle of concatenated transformation. Orthographic and Perspective Projections of Geometric Models. Introduction to computer aided animation system. **Graphic Standards and mode of data transfer:** Definition of graphics standard, geometrical data, direct and indirect data transfer. Neutral file formats - Data Exchange Format (DXF) and Initial Graphics Exchange Specification (IGES).

Text Books

1. Ibrahim Zeid, "**Mastering CAD/CAM**", Tata McGraw Hill Education (P) Ltd., Special Indian Edition, 2008.
2. Amarendra N Sinha and Arun D Udai, "**Computer Graphics**", Second reprint, Tata McGraw Hill Education (P) Ltd., 2009.

Reference Books

1. Michael E. Mortenson, "**Geometric Modeling**", Third edition, Industrial Press, 2006.
2. Rogers, **"Mathematical Elements for computer Graphics"**, Tata Mcgraw Hill Education Private Limited, 2009.
3. Rajiv Chopra, **"Computer Graphics: A Practical Approach, Concepts, Principles, Case Studies"**, First Edition, S.Chand and Company Ltd., 2011.
4. NPTEL Video Lectures – Computer Aided Design and Manufacturing-I, Prof. Anup Chawla, IIT Delhi.URL:http://nptel.ac.in/courses/Webcourse-contents/IIT-Delhi/Computer%20Aided%20Design%20&%20ManufacturingI/index.htm
5. MIT Open Course Ware – Computational Geometry, Prof. Nicholas Patrikalakis, Prof. Takashi Maekawa, MIT. URL: http://ocw.mit.edu/courses/mechanical-engineering/2-158j-computational-geometry-spring-2003/calendar/

Course Contents and Lecture Schedule

Module No.	Topics	No. of Lectures
1	Coordinate systems	
1.1	Geometric co-ordinate systems - Cartesian, Cylindrical and Spherical coordinate systems	1
1.2	Display co-ordinate systems - Global, Local, View and Screen coordinate systems	1
2	Mathematical modeling of Curves	
2.1	Parametric and non-parametric forms of analytical and synthetic curves	1

Module No.	Topics	No. of Lectures
2.2	Analytical Curve modeling - Line Segment, Circle, Ellipse.	1
2.3	Synthetic Curve modeling - Hermite cubic spline, Bezier curve	2
	Synthetic Curve modeling - B-spline and Rational Curves	1
2.4	Curve manipulation techniques	1
3	Mathematical modeling of Surfaces	
3.1	Parametric and non-parametric forms of analytical and synthetic surfaces	1
3.2	Analytical surface modeling - Parametric form of plane, loft surface	1
	Analytical surface modeling - Cylindrical, Surface of revolution	1
3.3	Synthetic Surface modeling - Hermite bicubic spline, Bezier surface	2
	Synthetic Surface modeling - B-spline, Coon's, Triangular, Blending Surfaces	2
	Synthetic Surface modeling - triangular, blending Surfaces	1
3.4	Surface manipulation techniques	1
4	Mathematical modeling of Solids	
4.1	Boundary representation scheme	1
4.2	Constructive Solid Geometry, Analytical Solid Modeling	1
4.3	Sweep representation scheme	1
4.4	Solid Manipulation Techniques	1
	Demonstration of solids using modeling package	2
5	Transformation and Projection techniques	
5.1	Introduction computer graphics - Non-interactive Vs Interactive computer graphics, applications, graphics system configuration	1
5.2	2D transformation techniques - Translation, Rotation	1
	2D transformation techniques - Scaling and Reflection	1
5.3	3D transformation techniques - Translation, Rotation	1
	3D transformation techniques - Scaling and Reflection	1
5.4	Principle of concatenated transformation	1
5.5	Orthographic Projections of Geometric Models	1
5.6	Perspective Projections of Geometric Models	1
5.7	Introduction to computer aided animation system	1
6	Graphic Standards and mode of data transfer	
6.1	Graphics standard	1
	Geometrical data	1
6.2	Mode of data transfer - Direct and indirect data transfer	1
6.3	Neutral file formats - Data Exchange Format (DXF) and Initial Graphics Exchange Specification (IGES)	1
	Total	**36**

Course Designers:

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14ME370	PROBLEM SOLVING USING COMPUTER	Category	L	T	P	Credit
		PC	2	0	2	3

Preamble

This syllabus is intended for the candidate who desires to learn problem-solving techniques and the design of computer solutions in a precise manner. The syllabus emphasizes problem-solving methodologies, algorithm designs and developments and computer-programming skills. The intention is to provide sufficient depth in these topics to enable candidates to achieve better understanding of problem solving using computers. Besides the written papers, lab-based examinations are included as part of the assessment requirements for the study. The lab-based examinations will test the candidate's ability to develop computer-programming solutions for a series of programming tasks of varying complexity.

The modules in the syllabus reflect solving general problems via programming solution. Thus, modules collectively focus on programming concepts, strategies and techniques; and the application of these toward the development of programming solutions.

Prerequisite

- Nil

Course Outcomes

On successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO1.	Construct algorithms for solving simple mathematical and engineering problems using appropriate control structures like repetition and selection.	Apply
CO2.	Build flow charts for modelling solutions to solve numerical and engineering problems.	Apply
CO3.	Construct solutions for problems related to merging, searching, sorting and string manipulation using either iteration or recursion as applicable.	Apply
CO4.	Construct solutions involving structures to store, manipulate and retrieve records of data.	Apply
CO5.	Develop programs in a precedential language for numerical and engineering problems	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	S	M	_	_	_	_	_	M	_	_	M	L	_	_
CO2.	S	S	M	_	_	_	_	_	M	_	_	M	L	_	_
CO3.	S	S	M	_	_	_	_	_	M	_	_	M	L	_	_
CO4.	S	S	M	_	_	_	_	_	M	_	_	M	L	_	_
CO5.	S	S	M	_	_	_	_	_	M	_	_	M	L	_	_
	S	S	M	_	_	_	_	_	M	_	_	M	L	_	_

Assessment Pattern

Theory (70 marks)					Practical (30 marks)		
Bloom's Category	Continuous Assessment Tests (20)		Terminal Examination (50)		Valuation category	Continuous Assessment (10)	Continuous Assessment Test 3 (20)
	1	2					
Remember	20	20	20		Class work/ Exercise	90	90
Understand	20	20	20		Record / Viva-voce	10	10
Apply	60	60	60				
Analyse	0	0	0				
Evaluate	0	0	0				
Create	0	0	0				

* **Theory Cum Practical Courses:**
There shall be three continuous assessment tests: the first two tests (Maximum 50 marks for each test) will be from theory component and the third test (Maximum 50 Marks) will be for practical component. The sum of marks of first two tests shall be reduced to 20 Marks and the third test mark shall be reduced to 20 marks. Average mark awarded for viva – voce, conduct of experiments, observation & results, record work in regular class work shall be reduced to 10 marks. The sum of these 50 Marks would be rounded to the nearest integer.

Course Level Assessment Questions

Course Outcome 1 (CO1)**:**

1. Recall the list of symbols used in flowcharts for various purposes. (Remember)
2. Summarize the steps involved in exchanging values of variables. (Understand)
3. Choose proper selection control structures to solve area of rectangle, triangle and circle. (Apply)

Course Outcome 2 (CO2)**:**

1. What is the use of an array? (Remember)
2. Compare function call and recursive call. (Understand)
3. Make use of arrays and functions to transpose an mxn matrix. (Apply)
4. Analyze the performance of search algorithms. (Analyze)

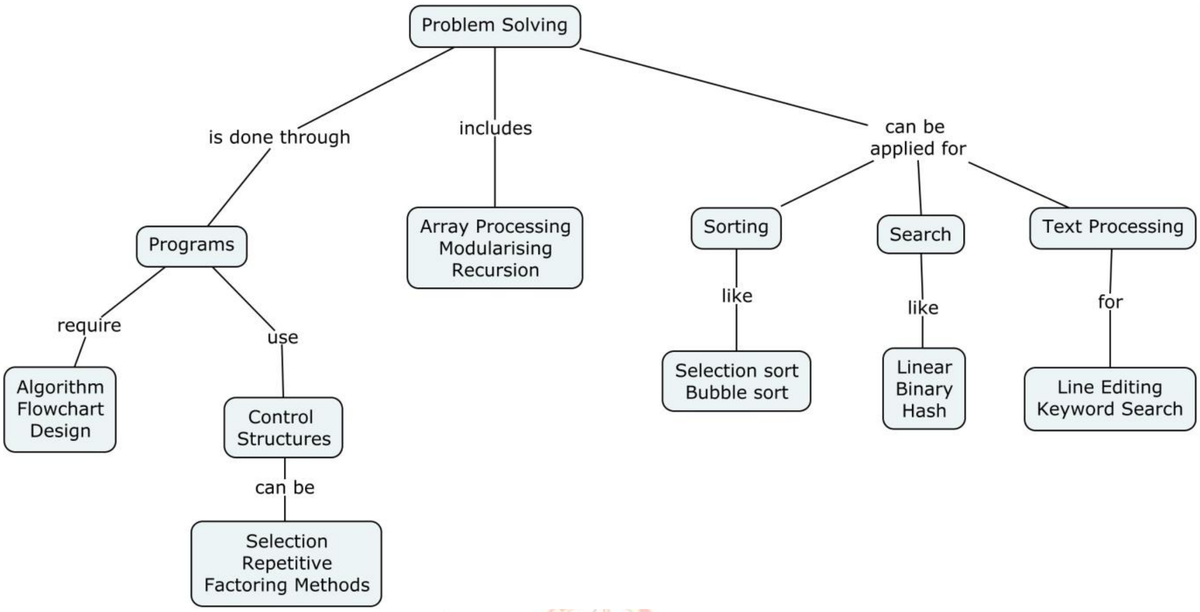
Course Outcome 3 (CO3):

1. What is text processing?
2. Explain the algorithm for linear pattern searching
3. Develop an algorithm for comparing two strings.

Course Outcome 4 (CO4)**:**

1. Develop a C program to convert decimal to binary of a given number using non recursive and recursive techniques. (Apply)
2. Develop a C program to multiply two nxn matrices using arrays and pointers. (Apply)
3. Develop a C program to create a text file to store records of addresses of N persons and retrieve and display the records with city="Madurai". (Apply)

Concept Map



Syllabus

Theory Component:

Introduction to Computer Problem Solving - Introduction to Computer - Program Design - Developing an Algorithm – Flowcharts - Efficiency of algorithms - Analysis of algorithms - Fundamentals Algorithms - Exchanging values of variables – Counting.Control structures - Selection Control Structures - Repetition Control Structures - Summation of set of numbers - Factorial computation - Sine function computation - Fibonacci sequence generation - Reversing the digits of an Integer - Base conversion - Character to number conversion. Factoring Methods - Finding square root of a number -The smallest divisor of an integerGenerating Prime numbers - Generating Pseudo-random numbers - Computing n^{th} Fibonacci number.Array Processing and Techniques - Array technique - Finding the maximum number in a set - Finding k^{th} smallest number - Removal of duplicates from an ordered array - Partitioning array - Matrix manipulations - Modularization and recursion - Sorting by selection. Text Processing - String Manipulations – Structures – Union.

Text Books

1. R.G Dromey, "**How to solve it by Computer?**", Pearson education, Delhi, 2008.
2. Lesley Anne Robertson, "**Simple Program Design, A Step-by-Step Approach**", 5th Edition, Thomson, 2007.

Reference Books

1. Yashavant P. Kanetkar, "**Let us C**", 12th edition, BPB Publications, 2012.
2. Daniel Weller,ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-087-practical-programming-in-c-january-iap-2010/download-course-materials.
3. C Programming Examples – URL: www.programmingsimplified.com
4. NPTEL Video Lectures – Introduction to Programming in C, Prof. Satyadev Nandakumar, IIT Kanpur. URL: www.nptel.ac.in/courses/106104128

Course Contents and Lecture Schedule for Theory

Module No.	Topic	No. of Lectures
1	Introduction to Computer Problem Solving	
1.1	Introduction to Computer, Program Design, Developing an Algorithm	1
1.2	Flowcharts	1
1.3	Efficiency of algorithms, Analysis of algorithms	2
1.4	Fundamentals Algorithms	1
1.5	Exchanging values of variables, Counting	1
2	Control structures	
2.1	Selection Control Structures, Repetition Control Structures	1
2.1.1	Summation of set of numbers, Factorial computation, Sine function computation	2
2.1.2	Fibonacci sequence generation, Reversing the digits of an Integer	1
2.1.3	Base conversion, Character to number conversion	1
2.2	Factoring Methods	
2.2.1	Finding square root of a number, The smallest divisor of an integer	1
2.2.2	Generating Prime numbers	1
2.2.3	Generating Pseudo-random numbers, Computing n^{th} Fibonacci number	1
3	Array Processing and Techniques	
3.1.1	Array technique, Finding the maximum number in a set, Finding k^{th} smallest number	2
3.1.2	Removal of duplicates from an ordered array, Partitioning array,	1
3.2	Matrix manipulations (add, subtract, multiply)	2
3.3	Modularization and recursion, Sorting by selection,	1
4	Text Processing	
4.1	String Manipulations	1
4.2	Structures	2
4.2.1	Union	1
	Total	**24**

Syllabus

Practical Component:
Problem Solving with Fundamental Algorithms (use data types and expressions)

Problem solving with Selection Control Structures and Decision Statements (use if-else, switch-case, break, and continue)

Problem solving with Repetition Control Structures and Loop Statements (use while, do-while and for loops)

Problem solving with array based problems (use 1D and 2D arrays) and function oriented problems (functions and recursive functions

Problem solving using text and strings (use string, structures)

Course Contents and Lecture Schedule for Practical Component

Module No.	Topic	No. of Lectures
1	Introduction to C components	1
2	Problems on Fundamentals Algorithms	2
3	Factoring Methods in C	2
4	Problems on Factoring Methods	2
5	Selection Control Structures, Repetition Control Structures in C	2
6	Problems on Selection Control Structures, Repetition Control Structures	2
7	Array techniques in C	2
8	Problems on Array techniques	2
9	Functions and recursion in C	1
10	Problems on Functions and recursion	2
11	Concepts of String in C	1
12	Problems on Strings	2
13	Concepts of structures in C	1
14	Problems on structures	2
	Total	**24**

Course Designers:

1. Mrs. S. Sudha ssj@tce.edu
2. Mr. S. Prasanna sprcse@tce.edu

14ME380	FLUID MECHANICS AND CFD LAB	Category	L	T	P	Credit
		PC	0	0	2	1

Preamble

The laboratory exercises aim at imparting practical knowledge on concepts of fluid mechanics by conducting experiments in flow through pipes/pumps and turbine, over/between parallel plates and numerical simulation using modelling and simulation software. This would supplement the understanding of the theory course on Fluid Mechanics.

Prerequisite

- 14ME240:Thermodynamics
-

Course Outcomes

On successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	**Determine the rate of flow of water through Orificemeter and Venturimeter**	**Apply**
CO 2.	**Determine the head losses due to friction in pipe line**	**Apply**
CO 3.	**Determine the performance of hydraulic turbines and pumps**	**Apply**
CO 4.	**Determine numerically the properties of compressible /incompressible fluid during flow through a pipe / between two parallel plates**	**Apply**
CO 5.	**Determine numerically the properties of fluid flowing over a streamlined/bluff body**	**Apply**

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1.	S	M	L	_	_	_	_	_	_	L	_	_	_	M	_
CO2.	S	M	L	_	_	_	_	_	_	L	_	_	_	M	_
CO3.	S	M	L	_	_	_	_	_	_	L	_	_	_	M	_
CO4.	S	M	L	_	S	_	_	_	_	L	_	_	L	S	_
CO5.	S	M	L	_	S	_	_	_	_	L	_	_	L	S	_
	S	M	L	_	M	_	_	_	_	L	_	_	L	S	_

Syllabus

The following are the list of experiments. Minimum of 12 experiments are to be given. (At least six experiments in each Lab.)

Fluid Mechanics Lab.

1. Determination of rate of fluid flow through a uniorm diameter pipe using orificemeter.
2. Determination of rate offluid flow through a uniorm diameter pipe using venturimeter.
3. Experimental verification Bernoulli's theorem.

4. Determination of losses in pipe section.
5. Verification of Reynolds experiment to determine the type of flow in pipe
6. Performance test on Pelton wheel/Francis turbine.
7. Performance test on centrifugal pump / reciprocating pump.

CFD Lab.

1. Determination of pressure, velocity distribution and losses in laminar flow between two parallel plates using numerical simulation software.
2. a) Determination of pressure, velocity distribution and losses in larminar fluid flow through a circular pipe using numerical simulation software.
   b) Determination of pressure, velocity distribution and losses in turbulent fluid flow through a circular pipe using numerical simulation software.
3. Determination of pressure, velocity distribution and losses in incompressible fluid flow through a venturimeter using numerical simulation software.
4. Determination of pressure, velocity temperature, Mach numbner distribution in a compressible fluid flow through a convergent-divergent nozzle,using numerical simulation software.
5. Determination ofFlow behaviour of fluid laminar flow over a flat plate numerical simulation software.
6. Determination of pressure, velocity distribution and losses in behaviour of fluid flowing over cylinder / air foil blade using numerical simulation software.
7. Determination of pressure, velocity distribution and losses in flow distribution in a pipe circuit using numerical simulation software.

Terminal Examination: Students would be tested in both labs each 1½ hours duration.

Course Designers:

1. Mr. M. Ramasamy mrciv@tce.edu
2. Dr. P. Maran pmmech@.tce.edu

		Category	L	T	P	Credit
14ME410	**NUMERICAL METHODS**	BS	2	2	0	3

Preamble

A Mechanical engineering student needs to know sufficient numerical tools and techniques for solving engineering problems arises in their field. This course aims at developing the ability to formulate an engineering problem in a mathematical form appropriate for subsequent computational treatment and to choose an appropriate numerical approach.

Prerequisite

- 14MA110 Engineering Mathematics
- 14ME210 Engineering Calculus

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Solve the system of linear algebraic equations and single non linear equations arising in the field of Mechanical Engineering	Analyze
CO 2.	Interpolate discrete data by means of continuous function.	Apply
CO 3.	Evaluate the integration of one and two variable functions using numerical tools and calculate derivatives using interpolation polynomial.	Apply
CO 4.	Find the solution for the IVPs in ODE using single step and multistep methods and BVPs in PDE using finite difference methods.	Analyze

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	M	S	S	S	_	_	_	_	_	_	M	_	_	_
CO2.	S	M	M	M	S	_	_	_	_	_	_	M	_	_	_
CO3.	S	M	M	M	S	_	_	_	_	_	_	M	_	_	_
CO4.	S	M	S	S	S	_	_	_	_	_	_	M	_	_	_
	S	M	S	S	S	_	_	_	_	_	_	M	_	_	_

S- Strong; M-Medium; L-Low

Assessment Pattern

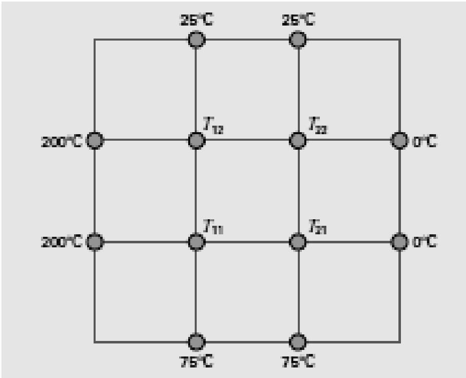
Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	12	12	12	10
Understand	20	20	20	20
Apply	34	68	34	30
Analyse	34	-	34	40
Evaluate	-	-	-	-
Create	-	-	-	-

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Give the physical significance of Newton's method.

2. If the plate is represented by a series of nodes as in the Fig., centered finite divided differences can be substituted for the second derivatives, which results in a system of linear algebraic equations. Use the Gauss-Seidel method to solve for the temperatures of the nodes in Fig.



3. The volume V of liquid in a hollow cylinder of radius r and length L is related to the depth of the liquid by $[r^2 Cos^{-1}(\frac{r-h}{r}) - (r-h)\sqrt{2rh-h^2}]L$. Determine h when r = 2m, L = 5m, V = 8 m^3. Using secant method.

Course Outcome 2 (CO2):

1. Write the recurrence formula used in cubic spline interpolation.
2. Use the portion of the given steam table for superheated H2O at 200 MPa to find the corresponding entropy *s* for a specific volume *v* of 0.108 m3/ kg with cubic spline interpolation

v [m^3/kg]	: 0.10377	0.11144	0.1254
s [kJ/kg.K]	: 6.4147	6.5453	6.7664

3. A sinusoidal function is described by $y(t) = A_0 + C_1 \cos(\omega_0 t + \theta)$.GIven $A_0 = 1.7$, $C_1 = 1$, $\omega_0 = 4.189$. Calculate 10 discrete values of for this curve at interval $\Delta t = 15$ for the range *t* = 0 to 1.35. Use this information to evaluate the coefficients A_0, A_1, B_1.

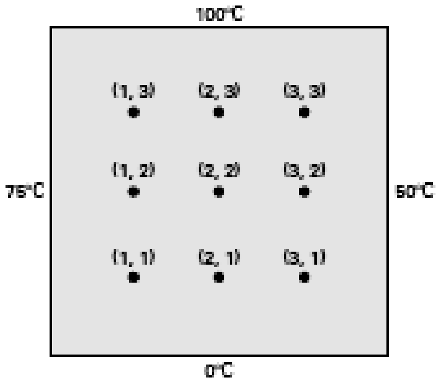
Course Outcome 3 (CO3):

1. Mention the formula for computing the first two derivatives using Newton's forward difference formula.
2. The amount of mass transported via a pipe over a period of time can be computed as $M = \int_{t_1}^{t_2} Q(t).C(t).dt$, where M = mass (mg), t_1 = the initial time (min), t_2 = the final time (min), *Q*(*t*) = flow rate (m^3/min), and *c*(*t*) = concentration (mg/ m^3). The following functional representations define the temporal variations in flow and concentration: *Q(t)* = 9 + 4 cos2(0.4*t*), *c(t)* = 5 $e^{-0.5t}$ + 2 $e^{0.15t}$. Determine the mass transported between t_1 = 2 and t_2 = 8 min with Simpson's rule.
3. Evaluate the integral $\int_1^2\int_1^2 \frac{dxdy}{x+y}$ using Simpson's cubature formula for integration.

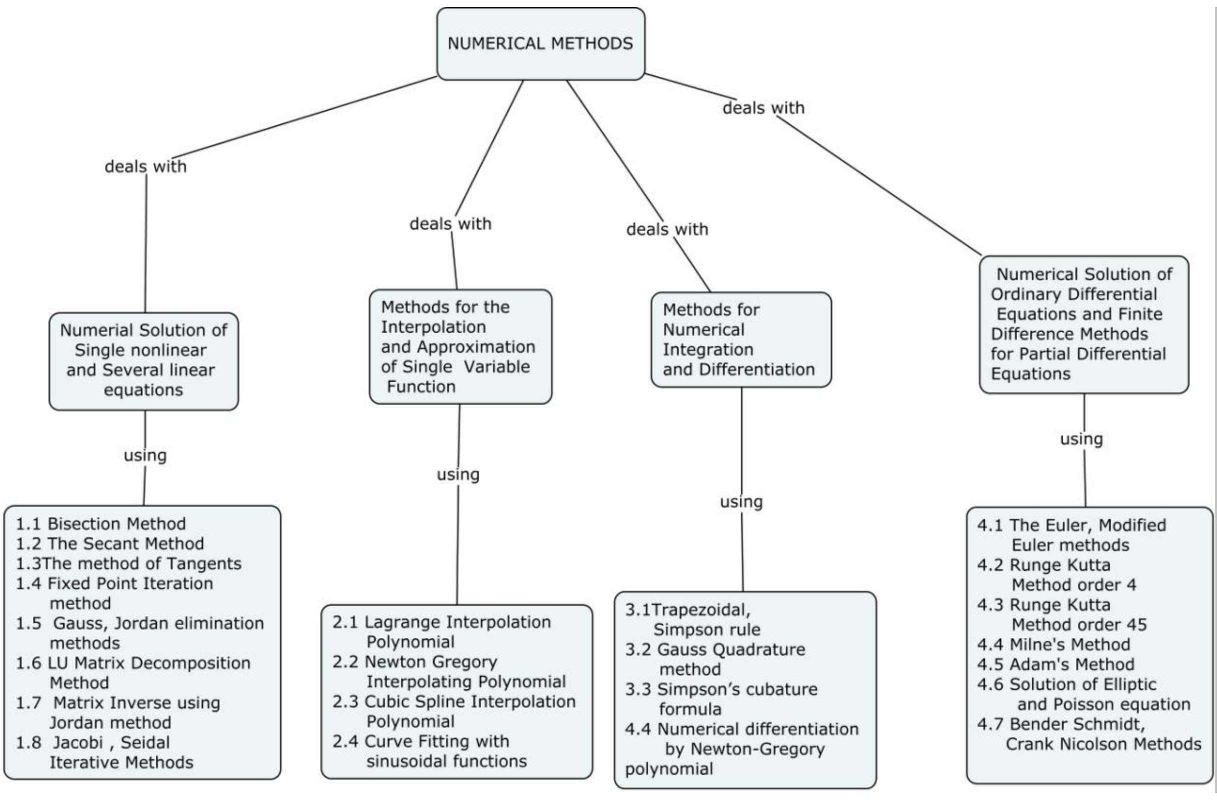
Course Outcome 4 (CO4):

1. Differentiate between single step and multistep method in solving ordinary differential equations.
2. Use the explicit method to solve for the temperature distribution of a long, thin rod with a length of 10 cm and the following values: k'= 0.49 cal/(s · cm ·^{0}C), Δx = 2 cm, and Δt = 0.1s. At t = 0, the temperature of the rod is zero and the boundary conditions are fixed for all times at T(0) = 100˚C and T(10) = 50˚C. Note that the rod is aluminum with C = 0.2174 cal/(g· ^{0}C) and ρ = 2.7 g/cm^3. Therefore, $k = k'/(\rho \cdot C)$ = 0.835 cm^2/s and λ = k/(Δt)/(Δx)^2 .

3. Use Liebmann's method to solve for the temperature of the square heated plate in Figure given below.



Concept Map



Syllabus

Methods for Numerical solution of Single Nonlinear Equations: Bisection Method - The Secant Method - The method of Tangents (Newton-Raphson),convergence - Fixed Point Iteration method, convergence. **Methods for Numerical solution of Several Linear Equations:** Gauss, Jordan elimination methods - LU Matrix Decomposition Method, Method of Inverse of a Matrix using Jordan method - Jacobi , Seidal Iterative Methods,convergence .

Methods for the Interpolation and Approximation of Single Variable Function: Lagrange Interpolation Polynomial - Newton Gregory Interpolating Polynomial - Cubic Spline Interpolation Polynomial - Curve Fitting with sinusoidal functions.

Methods for Numerical Integration and Differentiation
Newton Cote's methods of Integration,Trapezoidal, Simpson rule - Gauss Quadrature method - Simpson's cubature formula for Integration of Two variable Functions - Numerical differentiation by using Newton-Gregory polynomial.

Methods for Numerical Solution of Ordinary Differential Equations and Finite Difference Methods for Partial Differential Equations: The Euler, Modified Euler methods - Runge Kutta Method RK4 & RK45- Milne' smethod - Adam - Bashforth method - Solution of Elliptic equation for Laplace and Poisson equation - Parabolic equation by Bender Schmidt Method, Crank-Nicolson Scheme .

Text Books

1. Steven C. Chapra, Raymond P. Canale, "**Numerical Methods for Engineers**", MC Graw Hill Higher Education, 2016.
2. S. R. K. Iyengar, R. K. Jain, Mahinder Kumar Jain, "**Numerical methods for Scientific and Engineering Computations**", New Age International publishers , 6th Edition, 2012.

Reference Books

1. S.K Gupta, "**Numerical Methods for Engineers**", New Age International Pvt Ltd Publishers, 2015.
2. Joe D. Hoffman , Steven Frankel, "**Numerical Methods for Engineers and Scientists**", Third Edition, 2015.

Course Contents and Lecture Schedule

Module No	Topic	No.of Lectures
1	**Methods for Numerical solution of Single Nonlinear Equations and Several Linear Equations**	
1.1	Introduction to Numerical Methods, Bisection Method	1
	Tutorial	1
1.2	The Secant Method	1
	Tutorial	1
1.3	The method of Tangents (Newton-Raphson), convergence	1
	Tutorial	1
1.4	Fixed Point Iteration method, convergence	1
	Tutorial	1
1.5	Gauss, Jordan elimination methods	1
	Tutorial	1
1.6	LU Matrix Decomposition Method	1
	Tutorial	1
1.7	Method of Inverse of a Matrix using Jordan method	1

Module No	Topic	No.of Lectures
	Tutorial	1
1.8	Jacobi , Seidal Iterative Methods, , convergence	1
	Tutorial	1
2	**Methods for the Interpolation and Approximation of Single Variable Function**	
2.1	Lagrange Interpolation Polynomial	1
	Tutorial	1
2.2	Newton Gregory Interpolating Polynomial	1
	Tutorial	1
2.3	Cubic Spline Interpolation Polynomial	1
	Tutorial	1
2.4	Curve Fitting with sinusoidal functions.	1
	Tutorial	1
3	**Methods for Numerical Integration and Differentiation**	
3.1	Newton Cote's methods of Integration,Trapezoidal, Simpson rule	1
	Tutorial	1
3.2	Gauss Quadrature method	1
	Tutorial	1
3.3	Simpson's cubature formula for Integration of Two variable Functions	1
	Tutorial	1
3.4	Numerical differentiation by using Newton-Gregory polynomial.	1
	Tutorial	1
4	**Methods for Numerical Solution of Ordinary Differential Equations and Finite Difference Methods for Partial Differential Equations**	
4.1	The Euler, Modified Euler methods	1
	Tutorial	1
4.2	Runge Kutta Method order 4	1
	Tutorial	1
4.3	Runge Kutta Method order 45	1
	Tutorial	1
4.4	Milne's Method.	1
	Tutorial	1
4.5	Adam - Bashforth Method	1
	Tutorial	1
4.6	Solution Elliptic equation for Laplace and Poisson equation	2
	Tutorial	1
4.7	Parabolic equation by Bender Schmidt Method, Crank-Nicolson Scheme	2
	Tutorial	1
	Total	**48**

* Tutorials problems are to be solved using MatLab/Maple Software.

Course Designers:

1. Dr. V.Gnanaraj vignanaraj@gmail.com
2. Dr. R.Rammohan rr_maths@tce.edu

14ME420	**ENGINEERING DESIGN**	Category	L	T	P	Credit
		PC	1	0	2	3

Common for B.E./B.Tech Degree Programmes
(Course Codes: 14CE450, 14ME420, 14EE450, 14EC450, 14IT450, 14CS340,14MT420)

Preamble

Engineering design is normally taught, not as a unified course in India. The courses like Product design, Machine design, Electrical machine design and transformer design, Control system design and Communication system design are tailored to specific topics There were many new approaches developed over a period of time. There is a need to discuss a unified approach of design in a course.

Prerequisite

- None

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO1.	**Explain the steps involved in Engineering Design**	**Understand**
CO2.	**Explain the Engineering Design process and review designs with societal considerations.**	**Understand**
CO3.	Provide specification for customer needs/requirements, considering engineering Characteristics and quality Function Deployment.	**Apply**
CO4.	**Prepare conceptual design document.**	**Apply**

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1.	M	L	L	_	_	_	_	_	_	_	_	_	L	_	L
CO2.	M	L	L	_	_	M	_	_	_	_	_	_	L	_	L
CO3.	S	L	L	L	_	_	_	_	_	_	_	_	M	_	L
CO4.	S	L	L	_	_	_	_	_	_	_	_	_	S	_	L
	S	L	L	_	_	L	_	_	_	_	_	_	M	_	L

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		
	CAT 1	Review 1	Review 2
Remember	20	0	0
Understand	40	0	0
Apply	40	100	50
Analyse	0	0	50
Evaluate	0	0	0
Create	0	0	0

Milestones:

1. Problem description (3 weeks)
2. Framework (4 weeks)
   i. Functional requirements
   ii. User requirements
   iii. Performance requirements
   iv. Specifications
3. Preliminary design (conceptual) (3 weeks)
   i. Cost estimates
4. Final design (conceptual document) (2 weeks)

Review 1 for milestones1 & 2 and Review 2 for milestones 3 & 4

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define Engineering Design
2. State different activities involved in Product Engineering Life Cycle
3. List different design considerations that are required for a good design
4. Explain different types of design
5. List the characteristics of environmentally responsible design

Course Outcome 2 (CO2):

1. List different modes to collect user requirements.
2. Briefly explain the classification of different types of User requirement
3. Define Benchmarking or Reverse Engineering or Product Dissection
4. List two categories of Redesign
5. Explain different activities involved in Design process
6. Explain different steps involved in Conceptual Design process

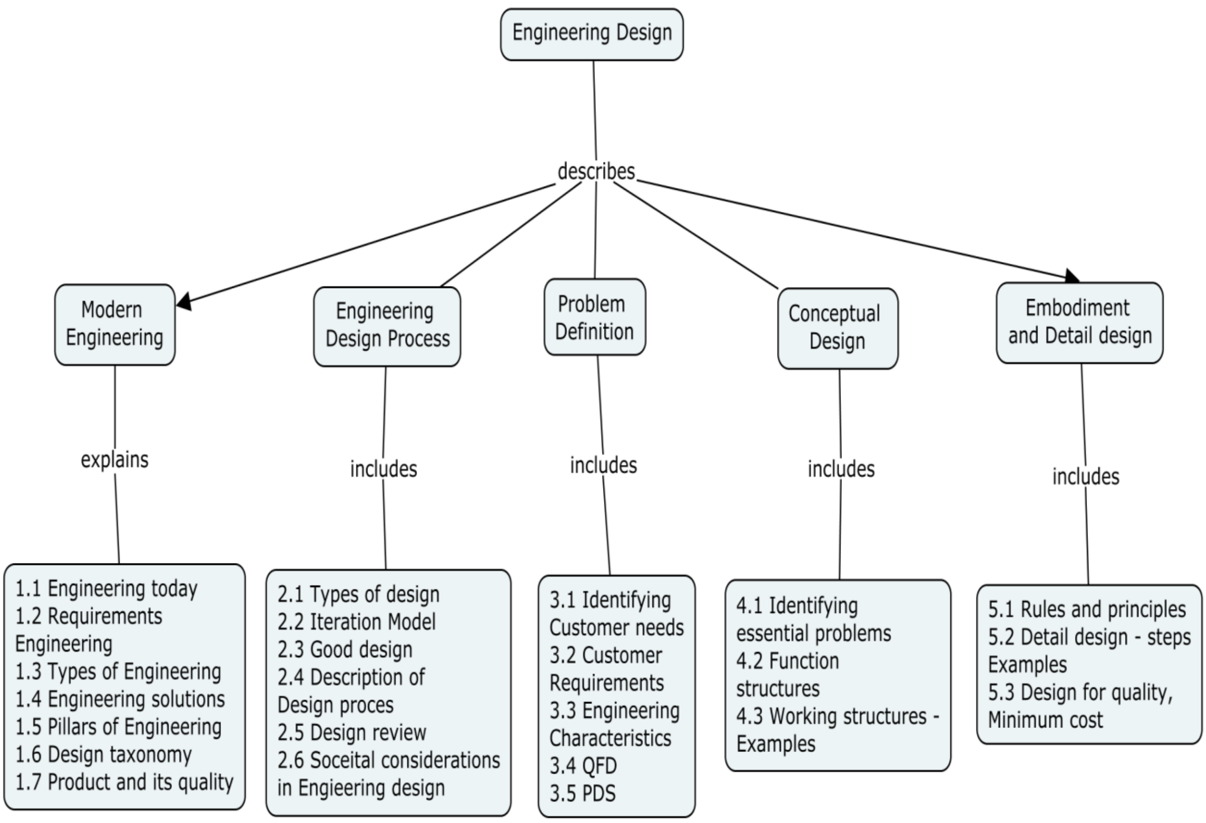
Course Outcome 3 (CO3)

1. Write product design specifications for any of the following product - Desktop Computer or Bicycle or Pencil or Computer Table or mobile.
2. Translate customer requirements into **Engineering characteristics** of any product like mobile or computer or bicycle.

Course Outcome 4 (CO4)

1. Prepare conceptual design document for any complex engineering problem related to societal engineering under specific domain.

Concept Map



Syllabus

Modern Engineering: Introduction, Engineering today, Requirements of engineering, Types of engineering, Engineering Solutions, Pillars of Engineering, Design Taxonomy, Product, Quality of product.

Engineering Design Process: Types of Designs, A Simplified Iteration Model, Considerations of a Good Design, Description of Design Process, Design Review, Societal Considerations in Engineering Design,

Problem Definition and Need Identification: Identifying Customer Needs, Customer Requirements, Establishing the Engineering Characteristics, Quality Function Deployment, product Design Specification

Conceptual Design: Steps, Abstracting to Identify the Essential Problems, Establishing Function Structures, Developing Working Structures and concepts. Examples

Embodiment and Detail Designs: Steps, Basic Rules and Principles of Embodiment Design, Detail Design, Design for Quality and minimum Cost. Examples

Reference Books

1. G.Pahl and W.Beitz (Translated by Ken Wallace et al.,) "**Engineering Design: A Systematic Approach**", Second Edition, Springer, 2005.
2. George E. Dieter and Linda C. Schmidt, "**Engineering Design**", Fourth Edition, McGraw Hill Higher Education, 2009.
3. Power Point Presentation material by Prof.D.K.Subramanian in the Workshop on Engineering Design at TCE, Madurai.
4. Foundation Skills in Integrated Product Development, NASSCOM, Edition 2015.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	Modern Engineering	
1.1	Introduction - Engineering today	1
1.2	Requirements of engineering	
1.3	Types of engineering	1
1.4	Engineering Solutions	
1.5	Pillars of Engineering	
1.6	Design Taxonomy	1
1.7	Product and Quality of product	
2	Engineering Design Process	
2.1	Types of Designs	1
2.2	A Simplified Iteration Model	
2.3	Considerations of a Good Design	
2.4	Description of Design Process	1
2.5	Design Review	
2.6	Societal Considerations in Engineering Design	1
3	Problem Definition and Need Identification	
3.1	Identifying Customer Needs	1
3.2	Customer Requirements	
3.3	Establishing the Engineering Characteristics	
3.4	Quality Function Deployment	1
3.5	Product Design Specification	
4	Conceptual Design	2
4.1	Steps, Abstracting to Identify the Essential Problems	
4.2	Establishing Function Structures	
4.3	Developing Working Structures and concepts - *Examples*	
5	Embodiment and Detail Design	2
5.1	Steps, Basic Rules and Principles of Embodiment Design	
5.2	Detail Design – *Examples*	
5.3	Design for Quality and minimum Cost	
	Total Lectures	12

Course Designers:

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14ME430	MACHINING PROCESSES	Category	L	T	P	Credit
		PC	3	0	0	3

Preamble

Machining is one among the manufacturing processes for converting raw materials into end products. The end product is obtained by machining the unwanted material from a metal block / stock in the form of chips. Machine tools are power driven machine for making products of a given shape, size and accuracy by removing metal from the metal block. Most of the products get their final shape and size by metal removal. Products may be piston, engine blocks, cams, gear, shafts, hubs, flange etc.
This course aims to provide knowledge on the working, advantages, limitations and applications of various machining processes.

Prerequisite

- 14ES150 Basics of Civil and Mechanical Engineering

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Calculate the cutting forces and cutting tool life.	**Apply**
CO 2.	Explain the working principle of machine tools and work and tool holding devices.	**Understand**
CO 3.	Develop process sheet for machining operation of a given part.	**Apply**

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	S	L	L	_	_	_	_	L	_	M	M	M	_	L
CO2.	S	_	_	_	_	_	_	_	L	_	_	M	L	_	L
CO3.	S	S	S	M	_	_	_	_	L	_	L	M	M	_	M
	S	M	M	L	_	_	_	_	L	_	L	M	M	_	M

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	30	20	20	20
Understand	40	40	40	40
Apply	30	40	40	40
Analyse	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. In an orthogonal cutting on a M.S tube of size 150mm diameter and 2.1mm thickness, conducted at 90 m/min and 0.21mm/rev feed, the following data are recorded: Cutting force = 1250N. Feed force = 300N, Chip thickness =0.3mm,

contact length = 0.75mm and power = 2 KW, rake angle 10°. Compute shear strain, shear energy per unit volume.

2. A 50 mm outside diameter mild steel tubing is turned on a lathe with cutting speed of 20 m/min with a tool having rake angle of 35°. The tool is given a feed of 0.1 mm/rev and it is found by dynamometer that the cutting forces is 2500 N and feed force is 1000 N. Length of the continuous chip in one revolution is 80 mm. Calculate the coefficient of friction, shear plane angle, velocity of chip along tool face and chip thickness. Define chip thickness ratio.
3. A Carbide tool with mild steel work piece was found to give life of 2 hrs while cutting 50 m/min. If Taylor's exponent n = 0.27, Determine: (i) The tool life if the same tool is used at a speed of 25% higher than the previous one. (ii) The value of cutting speed if the tool is required to have tool life 3 hours.

Course Outcome 2 (CO2):

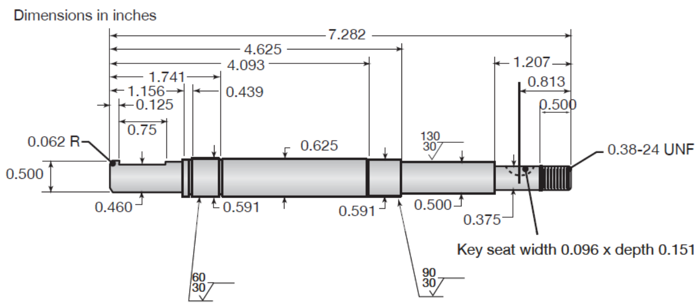
1. Explain any four work holding devices used in planning machine.
2. Describe the drill nomenclature with neat sketches.
3. Sketch and describe the details of a broach used to machine an internal hole.

Course Outcome 3 (CO3):

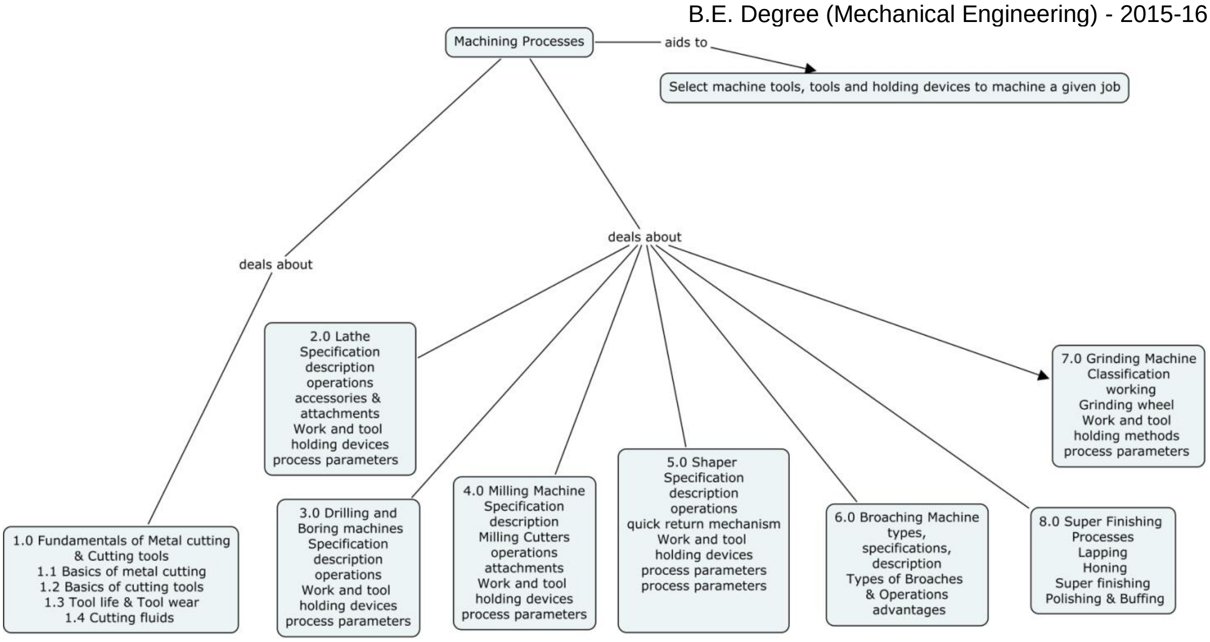
1. A 160 mm long 15 mm diameter rod is reduced to 14 mm diameter in a single pass straight turning. If the spindle speed is 450 r.p.m. and feed rate is 225 mm/min. Determine:

   (i) Material removal rate. (ii) Cutting time.
2. Find the correct number of strokes per minute to use on a shaper cutting a mild steel piece of 250 mm long and 150 mm wide. The cutting speed is 20 m/min for HSS tool. If a feed of

   1 mm is used then how much time will be taken for machining one surface of job.
3. The part shown in the accompanying figure is a power-transmitting shaft; it is to be produced on a lathe. List the operations that are appropriate to make this part.



Concept Map



Syllabus

Fundamentals of Metal cutting & Cutting tools: Basics of metal cutting: Mechanism of chip formation (orthogonal and oblique cutting) , Chip thickness ratio, Velocity ratio, Merchant circle diagram, Cutting forces in orthogonal and oblique cutting , measurement of cutting forces, Types of chips - continuous, discontinuous & continuous with built up edge, Chip breakers. Basics of cutting tools: Characteristics, Cutting tool materials, properties and applications. Tool life: Taylor's equation, Variables affecting tool life and Tool wear**:** Causes, Mechanisms and types, Machinability- Definition. Cutting fluids: Function, and types.
Lathe: Centre lathe and Capstan & Turret Lathe, specifications, description, Nomenclature of single point cutting tool, operations performed on lathe, lathe accessories & attachments, Work & tool holding methods/devices, Process parameters **-** Definition of process parameters - cutting speed, feed, Depth of cut (DOC) & machining time.
Drilling and Boring machines: Introduction to Radial drilling machine and Horizontal boring machine, specifications, description, Nomenclature of drill, operations performed on drilling machine, Work & tool holding methods/devices, Process parameters **-** Definition of process parameters - cutting speed, feed, DOC & machining time.
Milling Machine: Column and Knee type milling machine, specifications, description, attachments, milling cutters, Nomenclature of plain milling cutter & operations performed, Work & tool holding methods/devices, Process parameters **-** Definition of process parameters - cutting speed, feed, DOC & machining time.
Shaper: Introduction, types, specifications, description, quick return mechanism, Process parameters **-** Definition of process parameters - cutting speed, feed, DOC & machining time.
Broaching Machine: Introduction, types, specifications, description, Types of Broaches & Operations, advantages.
Grinding Machines: Introduction, Classification, working of grinding machines, Grinding wheel (Abrasives & Bond), Selection of Grinding wheel, mounting, glazing & loading, dressing, balancing, Work & tool holding methods/devices, Process parameters **-** Definition of process parameters - cutting speed, feed, DOC & machining time.
Super finishing processes: Lapping, Honing, Super finishing, Polishing & Buffing.

Text Book

1. S. K. Hajra Choudhury, Nirjhar Roy, A. K. Hajra Choudhury, **“Elements of Work shop Technology, Vol – II Machine Tools**”, Media Promoters and Publishers Pvt. Ltd, 2009.

Reference Books

1. Serope Kalpakjian and Steven R.Schmid, "**Manufacturing Engineering and Technology**", Sixth Edition, PHI, 2010.
2. Mikell P.Groover, "**Fundamental of Modern Manufacturing**", Wiley India Edition, Third Edition, Reprint, 2012.
3. E. Paul DeGarmo, J.T. Black and Ronald A. Kohser, "**Degarmo's Materials and Processes in Manufacturing** ", John Wiley & Sons, 11th Edition 2011.
4. Philip F. Oswald, and Jairo Munoz, "**Manufacturing Process and Systems**", John Wiley India Edition, 9^{th} Edition, Reprint 2008.
5. P.N.Rao, "**Manufacturing Technology**", Volume-2, Tata McGraw Hill, New Delhi, Third Edition, 2011.
6. P.C. Sharma, "**A Text Book of Production Technology (Manufacturing Processes)**", S. Chand & Company Ltd., New Delhi, Seventh Reprint, 2012.
7. NPTEL Lecture Material for Machining Processes - http://nptel.ac.in/courses/112105126/
8. MIT Lecture Material for Machining Processes- http://ocw.mit.edu/courses/mechanical-engineering/2-854-introduction-to-manufacturing-systems-fall-2010/

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	Fundamentals of Metal cutting and Cutting tools	
1.1	Basics of metal cutting: Mechanism of chip formation (orthogonal and oblique cutting) , Chip thickness ratio, Velocity ratio	2
1.1.1	Merchant circle diagram, Cutting forces in orthogonal and oblique cutting, measurement of cutting forces	1
1.1.2	Types of chips - continuous, discontinuous & continuous with built up edge, Chip breakers.	1
1.2	Basics of cutting tools: Characteristics, Cutting tool materials, properties and applications.	1
1.3	Tool life: Taylor's equation, Variables affecting tool life and Tool wear**:** Causes, Mechanisms and types	1
1.4	Machinability-Definition. Cutting fluids - Function, and types	1
2.	Lathe	
2.1	Centre lathe, Capstan & Turret Lathe -specifications, description	1
2.2	Nomenclature of single point cutting tool, Operations performed on lathe.	1
2.3	Lathe accessories & attachments.	1
2.4	Work and tool holding methods / devices	1
2.5	Definition of process parameters – cutting speed, feed, DOC & machining time	1
3.	Drilling and Boring machines	
3.1	Introduction, Radial drilling machine and Horizontal boring machine, specifications, description,	2
3.2	Nomenclature of drill, Operations performed on drilling machine.	1
3.3	Work and tool holding methods / devices	1
3.4	Definition of process parameters – cutting speed, feed, DOC & machining time	1
4	Milling Machine	
4.1	Introduction, Column and Knee type milling machine, specifications	1
4.2	Description, attachments	1
4.3	Milling cutters, Nomenclature of plain milling cutter & operations performed	1
4.4	Work and tool holding methods / devices	1
4.5	Definition of process parameters – cutting speed, feed, DOC &	1

Module No.	Topic	No. of Lectures
	machining time	
5	Shaper	
5.1	Introduction, specifications, description	1
5.2	Quick return mechanism	1
5.3	Definition of process parameters - cutting speed, feed, DOC & machining time	2
6	Broaching Machine	
6.1	Introduction, types, specifications, description	1
6.2	Types of Broaches & Operations, advantages	1
7.0	Grinding Machine	
7.1	Introduction, Classification, working of grinding machines.	1
7.2	Grinding wheel (Abrasives & Bond), Selection of Grinding wheel, mounting, glazing & loading, dressing, balancing.	2
7.3	Work and tool holding methods / devices	1
7.3	Definition of process parameters – cutting speed, feed, DOC & machining time	2
8	Super Finishing Processes	
8.1	Lapping, Honing	1
8.2	Super finishing, Polishing & Buffing	1
	Total	**36**

Course Designers:

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		Category	L	T	P	Credit
14ME440	**THERMAL ENGINEERING**	PC	2	2	0	3

Preamble

Thermal Engineering is the branch of mechanical engineering which deals with the applications of engineering thermodynamics in engineering devices such as boilers, engines, turbines, compressors, nozzles, refrigerators and air conditioners. A mechanical engineer needs to know the basic construction, working principle and performance analysis of these devices.

Prerequisite

- 14ME240: Engineering Thermodynamics

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	**Analyze the effect of various gas power cycles.**	**Analyze**
CO 2.	**Analyze the effect of various thermodynamic processes of vapour power cycles.**	**Analyze**
CO 3.	**Calculate the performance characteristics of refrigeration systems.**	**Apply**
CO 4.	**Apply thermodynamic principles in steam nozzles and steam turbines of steam power plants.**	**Apply**
CO 5.	**Determine performance characteristics of reciprocating air compressors.**	**Apply**
CO 6.	**Determine the psychrometric properties and their effect in various psychrometric processes.**	**Apply**

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	S	S	S	_	_	_	_	_	_	_	_	_	S	_
CO2.	S	S	S	S	_	_	_	_	_	_	_	_	_	S	_
CO3.	S	M	S	M	_	_	_	_	_	_	_	_	_	M	_
CO4.	S	M	S	M	_	_	_	_	_	_	_	_	_	M	_
CO5.	S	M	S	M	_	_	_	_	_	_	_	_	_	M	_
CO6.	S	M	S	M	_	_	_	_	_	_	_	_	_	M	_
	S	S	S	S	_	_	_	_	_	_	_	_	_	S	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	10
Understand	20	20	20	30
Apply	30	60	60	40
Analyse	30	0	0	20
Evaluate	0	0	0	0
Create	0	0	0	0

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	10	10
Understand	20	20	30	30
Apply	30	60	40	40
Analyse	30		20	20
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Compare the air standard efficiency of Otto and Diesel cycles for the following conditions with the illustrations in p-v and T-s diagrams.
   i) same compression ratio and same heat input
   ii) same maximum pressure and same net work output
2. An Internal combustion engine has to operate between atmospheric temperature of 300 K and peak temperature of 1500 K with the exhaust temperature of 800 K. Among Otto and Diesel cycle, which thermodynamic cycle will you prefer? Justify your answer.
3. A gas turbine works on an air standard Brayton cycle. The initial condition of the air is 25°C and 1 bar. The maximum pressure and temperature are limited to 3 bar and 650°C. Determine the following.
   i) cycle efficiency ii) specific heat supplied and specific heat rejected
   iii) specific work output iv) exhaust temperature

Course Outcome 2 (CO2):

1. Steam at 20 bar, 360°C is expanded in a steam turbine to 0.08 bar. It then enters a condenser, where it is condensed to saturated liquid water. The pump feeds back the water into the boiler. Assuming ideal processes, find per kg of steam the net work and cycle efficiency.
2. In a reheat cycle, the steam inlet is at 6 MN/m^2 and 450°C. The first reheat is done at 1 MN/m^2 to 370°C. The second reheat is done at 0.2 MN/m^2 to 320°C. The exhaust pressure is 0.02 MN/m^2. Determine the thermal efficiency of this cycle and compare it with that of the simple cycle. Determine also the power per kg of steam flow per second.
3. A regenerative cycle with three stages of bleed heating works between 30 bar, 450°C and 0.04 bar. The bleed temperatures are chosen for optimum efficiency i.e., at equal temperature ranges. Determine the efficiency of the cycle.

Course Outcome 3 (CO3):

1. A refrigerator using R134a works between -15°C and 30°C. The vapour is dry saturated at entry to the compressor. Determine the C.O.P, power/ton and displacement per ton.
2. A refrigeration system of 10.5 tonnes capacity at an evaporator temperature of -12°C and a condenser temperature of 27°C is needed in a food storage locker. The refrigerant Ammonia is sub cooled by 6°C before entering the expansion valve. The compression in the compressor is of adiabatic type. Find i) Condition of vapour at outlet of the compressor. ii) Condition of vapour at the entrance of the Evaporator iii) COP & power required.
3. A refrigeration machine using R-12 as refrigerant operates between the pressures 2.5 bar and 9 bar. The compression is isentropic and there is no under cooling in the condenser. The vapour is in dry saturated condition at the beginning of the compression. Estimate the theoretical coefficient of performance. If the actual coefficient of performance is 0.65 of theoretical value, calculate the net cooling

produced per hour. The refrigerant flow is 5 kg per minute. Take c_p for super heated vapour at 9 bar as 0.67 kJ/kg K.

Course Outcome 4 (CO4):

1. Dry saturated steam at 6.5 bar with negligible velocity expands isentropically in a convergent divergent nozzle to 1.4 bar and dryness fraction 0.956. Determine the final velocity of steam from the nozzle if 13% heat is loss in friction. Find the % reduction in the final velocity.

2. An impulse turbine having a set of 16 nozzles receives steam at 20 bar, 400° C. The pressure of steam at exist is 12 bar. if the total discharge Is 260 kg/min and nozzle efficiency is 90% . Find the cross sectional area of each nozzle, if the steam has velocity of 80m/s at entry to the nozzle. Also find the percentage increase In discharge.
3. At a stage of 50% reaction turbine, the mean diameter of the rotor is 1.4 m. The speed ratio is 0.7. Determine the blade inlet angle if the blade outlet angle is 20°. The rotor speed is 3000 rpm. Also find the diagram efficiency. Find the percentage increase in diagram efficiency and rotor speed if the rotor is designed to run at the best theoretical speed, the exit angle being 20°.

Course Outcome 5 (CO5):

1. A three stage reciprocating compressor compresses air from 1 bar and 27°C to 40 bar. The law of compression is $PV^{1.35}$=constant and is same for all the three stages of compression. Assuming perfect inter cooling and neglecting clearance, find the minimum power required to compress $0.35m^3/s$ of free air. Also find the intermediate pressures.
2. A single stage single acting air compressor is used to compress air from 1.013 bar and 25° C to 7 bar according to law $PV^{1.3}$ = C. The bore and stroke of a cylinder are 120mm and 150mm respectively. The compressor runs at 250 rpm .If clearance volume of the cylinder is 5% of stroke volume and the mechanical efficiency of the compressor is 85%, determine volumetric efficiency, power, and mass of air delivered per minute.
3. A two stage singe acting air compressor compresses 2 m^3 of air from 1 bar and 20°C to 15 bar. The air from the low pressure compressor is cooled to 25°C in the intercooler. Calculate the minimum power required to run the compressor if the compression follows $Pv^{1.25}$=C and the compressor runs at 400 rpm. Compare it with the power required when intercooling is perfect. Discuss the effect of perfect intercooling with P-v diagrams.

Course Outcome 6 (CO6):

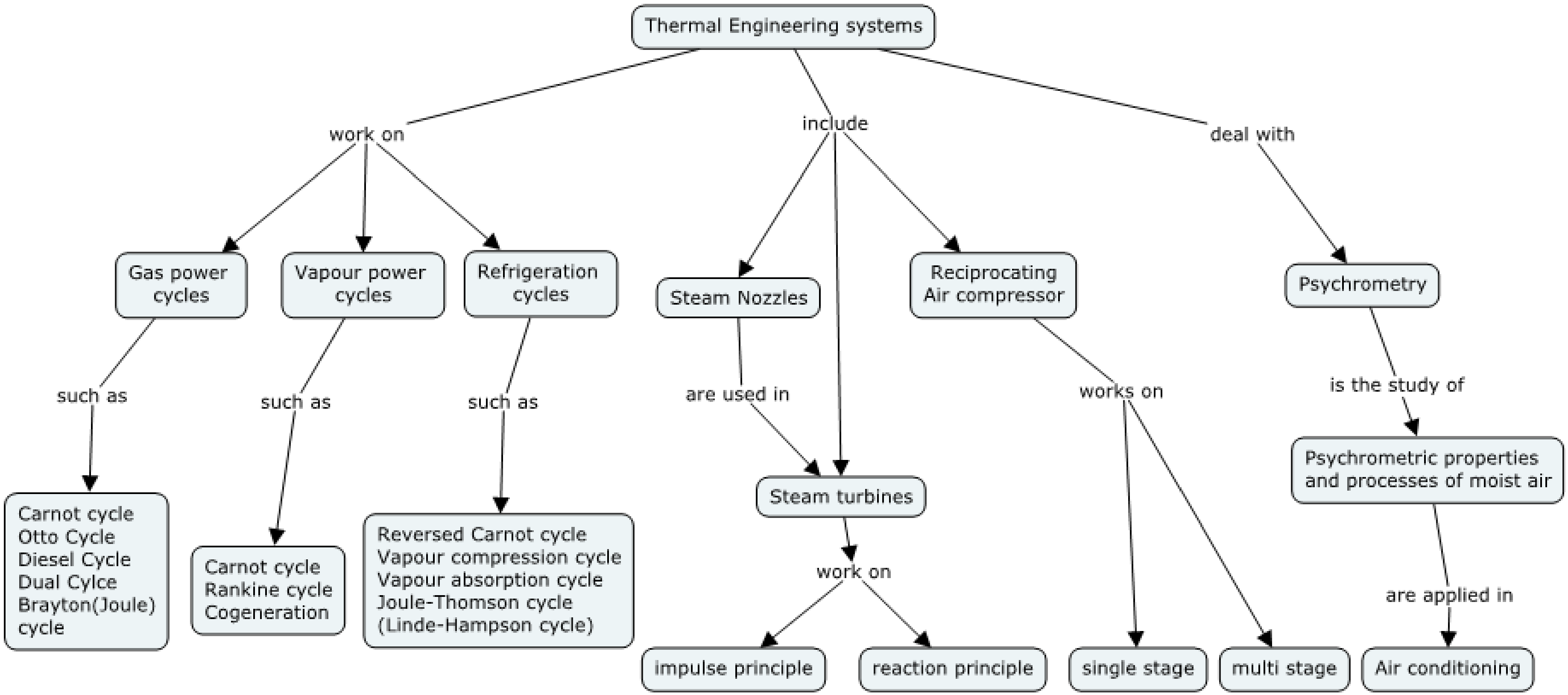
1. A sling psychrometer in a lab test recorded the following readings DBT=35°C, WBT=25°C Calculate the following 1. Specific humidity 2. Relative humidity 3. Vapour density in air 4. Dew point temperature 5. Enthalpy of mixing per kg of air take atmospheric pressure=1.0132 bar.

2. Air at 20°C, 40% RH is mixed adiabatically with air at 40°C, 20% RH in the ratio of 1 kg of the former with 3 kg of the latter on dry basis. Find the following of mixture.
   i. Dry bulb temperature
   ii. Wet bulb temperature
   iii. Dew point temperature
   iv. Relative humidity
   v. Enthalpy

3. 40 m^3 air per minute at 31°C DBT and 18.5°C WBT is passed over the cooling coil whose surface temperature is 4.4°C. The coil cooling capacity is 3.56 tons of

refrigeration under the given condition of air. Determine the DBT and WBT of the air leaving the cooling coil.

Concept Map


Thermal Engineering systems
work on
include
deal with
Gas power cycles
Vapour power cycles
Refrigeration cycles
Steam Nozzles
Reciprocating Air compressor
Psychrometry
such as
such as
such as
are used in
works on
is the study of
Carnot cycle
Otto Cycle
Diesel Cycle
Dual Cylce
Brayton(Joule) cycle
Carnot cycle
Rankine cycle
Cogeneration
Reversed Carnot cycle
Vapour compression cycle
Vapour absorption cycle
Joule-Thomson cycle
(Linde-Hampson cycle)
Steam turbines
work on
Psychrometric properties and processes of moist air
are applied in
impulse principle
reaction principle
single stage
multi stage
Air conditioning

Syllabus

Introduction to Power plants: Steam, Diesel and Gas turbine power plants.
Gas power cycles: Carnot cycle, Otto cycle, Diesel cycle, Air standard efficiency and mean effective pressure calculations, Comparison of Otto and Diesel cycles, Dual cycle- Air standard efficiency and mean effective pressure calculations, Applications in I.C.Engines. Brayton(Joule)cycle- Air standard efficiency and mean effective pressure calculations, Applications in gas turbines.
Vapour power cycles: Carnot cycle, Rankine cycle, Reheat Rankine cycle, Regenerative Rankine Cycle – Performance calculations, Super critical boilers, Cogeneration, Applications in thermal power plants.
Refrigeration cycles: Reversed Carnot cycle, Vapour Compression Refrigeration cycle with super heating and sub-cooling, performance calculations and applications. Working principle of Vapour Absorption Refrigeration System, Joule-Thomson cycle (Linde-Hampson cycle).
Steam Nozzles and turbines: Shapes of nozzles flow through nozzles, effect of friction, critical pressure ratio, and maximum discharge. **Steam turbines:** Impulse and reaction principles, Compounding, velocity diagrams and performance calculations for single stage turbine, governors.
Reciprocating air compressors: Working principle, Work of compression in single stage with and without clearance volume, free air delivery, isothermal efficiency, volumetric efficiency, Multi stage compression, Intercooling, condition for minimum work, power calculations.
Psychrometry and air-conditioning: Psychrometric properties, psychrometric processes, Applications in air-conditioning.

Text Books

1. Yunus A.Cengel and Michael A.Boles, "**Thermodynamics: An Engineering Approach**", Eighth edition, McGraw-Hill, 2014.
2. P.K. Nag, "**Basic and Applied Thermodynamics**", McGraw Hill Education (India) Private Limited; 2nd edition, 2009.
3. A. Valan Arasu, "**Thermal Engineering**", McGraw Hill Education (India) Private Limited, 2009.

Tables

1. R.S. Khurmi, "**Steam Tables with Mollier Diagram**", S.Chand Publishers, 2008.
2. C.P. Kothandaraman, "**Refrigerant tables and charts including air conditioning data**", 4th edition, New Age International Publishers, 2014.

Reference Books

1. T.D.Eastop and McConkey, "**Applied Thermodynamics for Engineering Technologists**" Fifth Edition, Pearson Education Ltd, 2009.
2. Gordon Rogers and Yon Mayhew "**Engineering Thermodynamics: Work and Heat Transfer**", 4th edition, Pearson Education Ltd, 2009.
3. V. Ganesan, "**Internal Combustion Engines**", 4rd edition, Tata McGraw-Hill, New Delhi, 2012.
4. Michael J. Moran, Howard N. Shapiro, Daisie D. Boettner P, Margaret B. Bailey, "**Fundamentals of Engineering Thermodynamics**", Seventh Edition, John Wiley & Sons Inc., 2011.
5. R.K. Rajput, "**Thermal Engineering**", Laxmi Publications, Ninth Edition, 2013.

Web Resources

1. http://nptel.ac.in/courses/IIT-MADRAS/Applied_Thermodynamics/
2. http://ocw.mit.edu/courses/aeronautics-and-astronautics/16-050-thermal-energy-fall-2002/lecture-notes/

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Introduction to Power plants-**Steam, Diesel and Gas turbine power plants.	1
1.1	**Gas power cycles**	
1.1.1	Carnot cycle - Air standard efficiency and mean effective pressure calculations	1
1.1.2	Otto cycle - Air standard efficiency and mean effective pressure calculations	1
1.1.3	Diesel cycle- Air standard efficiency and mean effective pressure calculations	1
1.1.4	Comparison of Otto and Diesel cycles	1
	Tutorial	**1**
1.1.5	Dual cycle- Air standard efficiency and mean effective pressure calculations, Applications in I.C.Engines	1
1.1.6	Brayton(Joule)cycle- Air standard efficiency and mean effective pressure calculations, Applications in gas turbines	1
	Tutorial	**1**
1.2	**Vapour power cycles**	
1.2.1	Carnot cycle	1
1.2.2	Rankine cycle- Performance calculations	1
	Tutorial	**1**
1.2.3	Reheat Rankine cycle - Performance calculations	1
1.2.4	Regenerative Rankine cycle- Performance calculations	2
1.2.5	Cogeneration , Applications in thermal power plants	1
	Tutorial	**1**
2	**Refrigeration cycles**	
2.1	Reversed Carnot cycle	1
2.2	Vapour Compression Refrigeration cycle with super heating and sub-cooling, performance calculations and applications.	2
	Tutorial	**1**
2.3	Working principle of Vapour Absorption Refrigeration System	0.5
2.4	Joule-Thomson cycle (Linde-Hampson cycle).	0.5
3	**Steam Nozzles and Steam turbines**	
3.1	**Steam Nozzles**	
3.1.1	Shape of nozzles ,flow through nozzles	1
3.1.2	Effect of friction	1
3.1.3	Critical pressure ratio	1
3.1.4	Maximum discharge	1
	Tutorial	**1**
3.2	**Steam turbines**	
3.2.1	Impulse and reaction principles	1

Module No.	Topic	No. of Lectures
3.2.2	Compounding	1
3.2.3	Velocity diagrams	1
	Tutorial	**1**
3.2.4	Performance calculations for single stage turbine	1
3.2.5	Governors	1
	Tutorial	**1**
4	**Reciprocating air compressors**	
4.1	Working principle, Work of compression in single stage with and without clearance volume, free air delivery	2
4.2	Isothermal efficiency, volumetric efficiency	1
4.3	Multi stage compression, intercooling	1
4.4	Condition for minimum work, power calculations	2
	Tutorial	**2**
5	**Psychrometry and air-conditioning**	
5.1	Psychrometric properties	1
5.2	Psychrometric processes	2
	Tutorial	**2**
5.3	Applications in air-conditioning	1
	Total	**48**

Course Designers:

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14ME450	**PRODUCTION DRAWING**	Category	L	T	P	Credit
		PC	1	0	4	3

Production Drawing is an indispensable communicating medium employed in industries, to furnish all the information required for the manufacture and assembly of the components of a machine. It deals with the preparation of orthographic projections of various machine parts and assemblies and all details of product, regarding size, shape, material, processes, surface finish, tool and equipment as per Indian Standards on drawing practices and standard components.

Prerequisite

- 14ME170 : Engineering Graphics

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO1	Interpret the drawing and represent any matter or object with the help of diagrams.	Understand
CO2	Draw the assembled view of the mechanical products from the part drawing.	Apply
CO3	Draw the part drawing of the mechanical products from the assembled drawing.	Apply
CO4	Draw the production drawing of machine component	Apply
CO5	Draw the orthographic views of machine element using drafting package.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	M	L	L	L	_	_	_	_	_	_	_	_	M	_	_
CO2.	M	L	L	L	L	_	_	_	_	_	_	_	S	_	L
CO3.	M	L	L	L	L	_	_	_	_	_	_	_	S	_	L
CO4.	M	L	L	L	L	_	_	_	_	_	_	_	S	_	L
CO5.	M	L	L	L	L	_	_	_	_	_	_	_	_	_	L
	M	L	L	L	_	_	_	_	_	_	_	_	L	_	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Continuous Assessment: 50 marks

(Manual drawing plate: 20 marks, Computer Aided Drafting: 15 marks and Manual Drawing test: 15 marks)

Bloom's Category	Manual Drawing Test (15)	Terminal Examination (Manual Drawing only) (100)
Remember	0	0
Understand	10	10
Apply	90	90
Analyse	0	0
Evaluate	0	0
Create	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):
1. Sketch the following types of line: (a) centre line, (b)cutting plane line (c) long break
2. With a sketch explain revolved and removed sections.
3. Describe the various types of fits with necessary diagram.

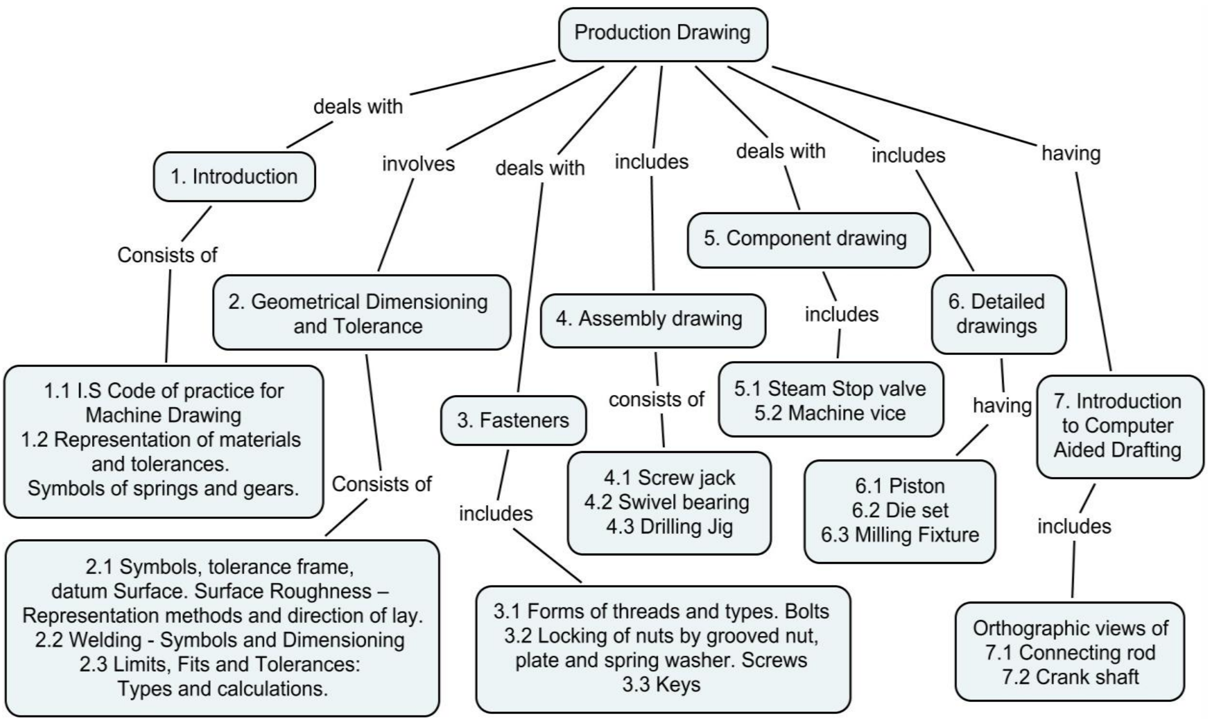
Course Outcome 2 (CO2):
1. The component drawing of the drill jig is given in the figure 1. Assemble them and draw the sectional elevation and left side view.
2. The component drawing of the screw jack is given in the figure 2. Assemble them and draw the sectional elevation and left side view.

Course Outcome 3 (CO3):
1. The assembled view of machine vice is given in the figure 3. Draw the component drawing of base, guide screw and serrated plate with all dimensions.
2. The assembled view of steam stop valve is given in the figure 4. Draw the component drawing of body, valve, hand wheel with all dimensions.

Course Outcome 4 (CO4):
1. Draw the detailed drawing including the dimensional tolerance, geometrical tolerance and surface finish for the piston, piston pin given in the figure 5.
2. Draw the detailed drawing including the dimensional tolerance, geometrical tolerance and surface finish for blanking die and punch, piercing die and punch, pillars for the die set given in the figure 6.

Course Outcome 5 (CO5):
1. Draw the orthographic projection of the connecting rod given in the figure 7 using the modelling software and mention the dimensions
2. Draw the orthographic projection of the crank shaft given in the figure 8 using the modelling software and mention the dimensions

Concept Map



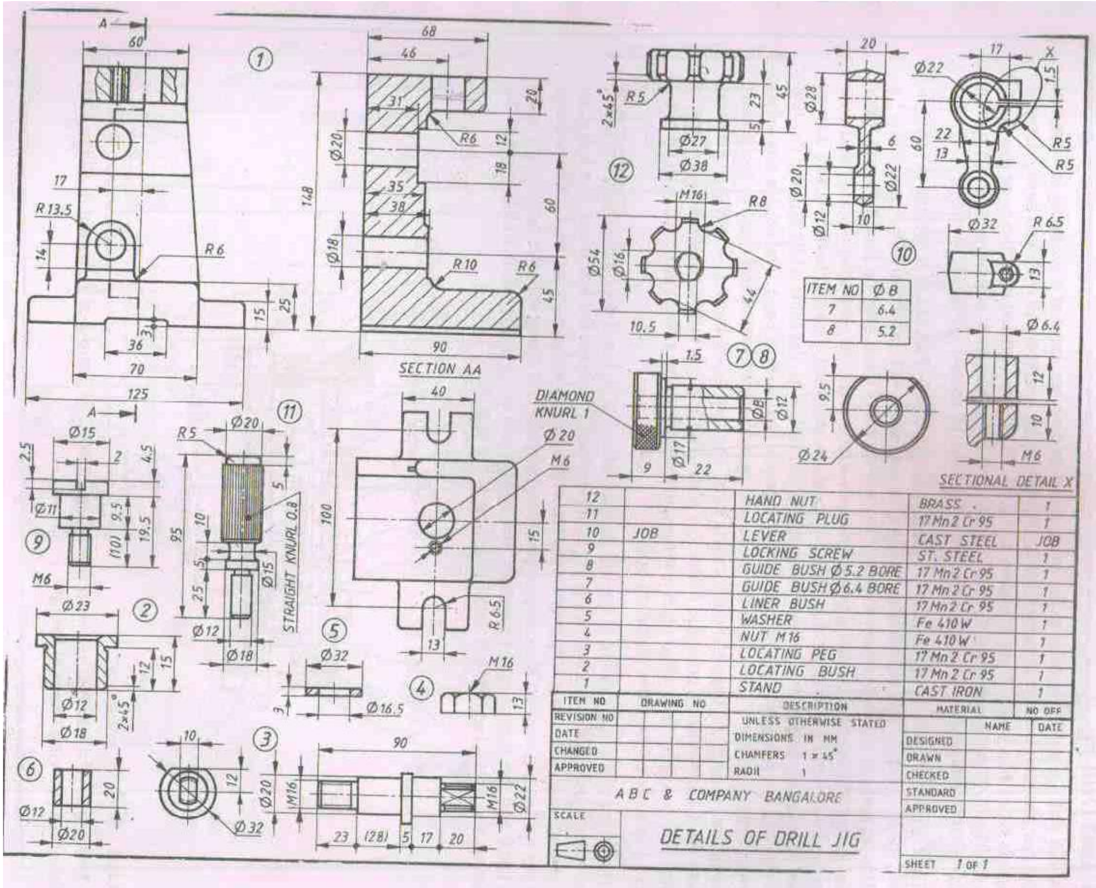


Figure 1 Component details of a drill jig

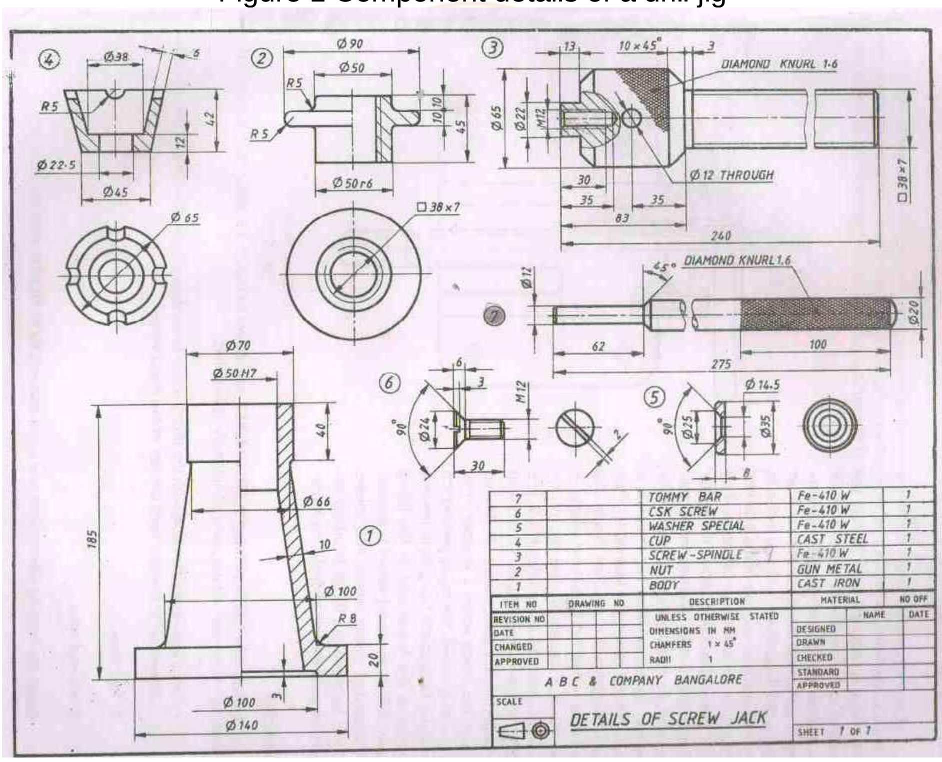
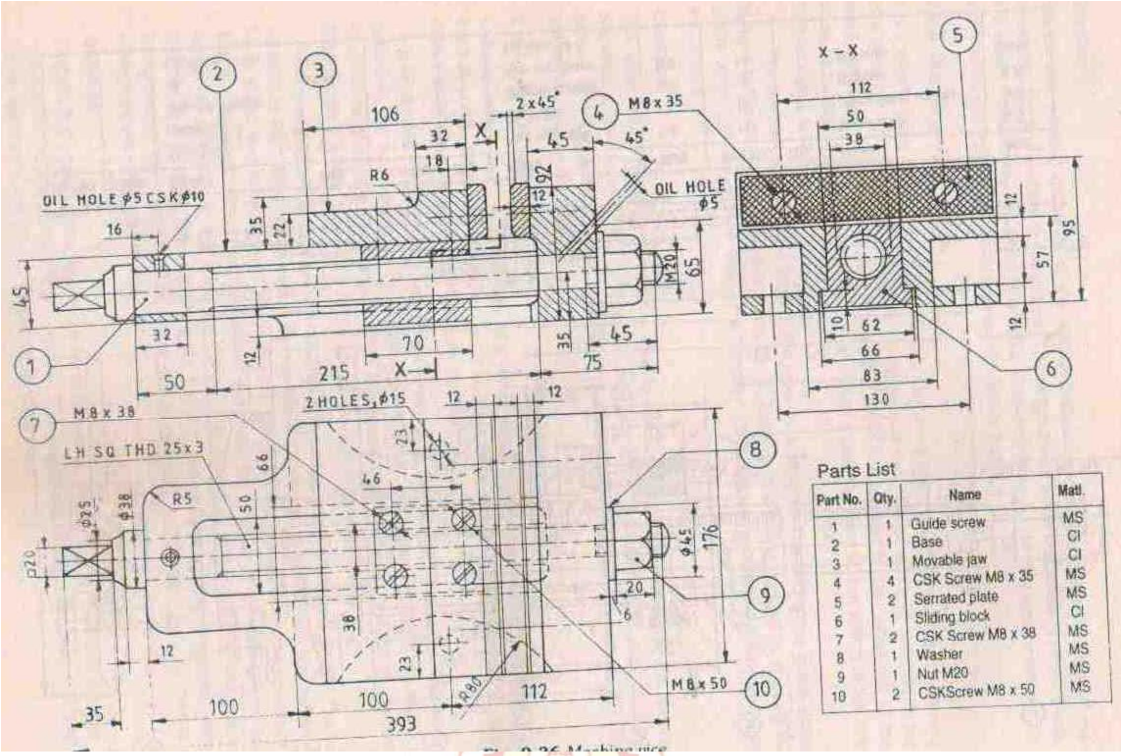
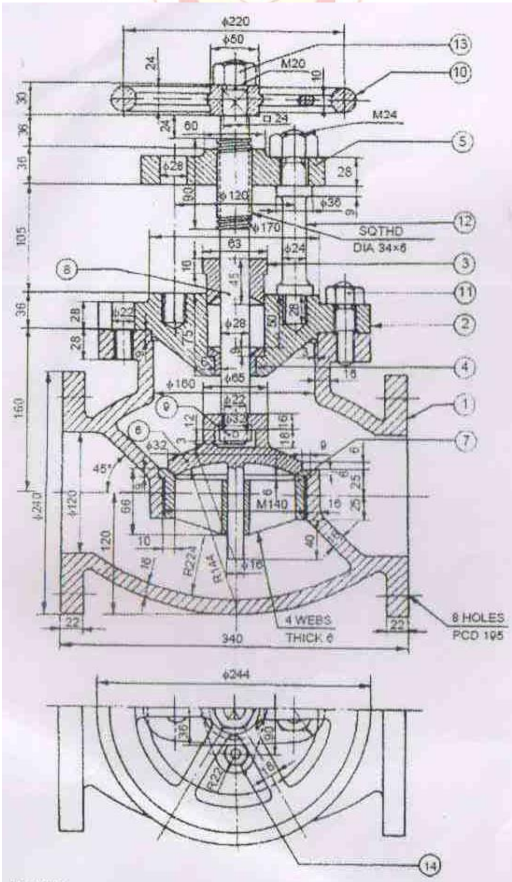


Figure 2 Component details of screw jack



Part No.	Qty.	Name	Matl.
1	1	Guide screw	MS
2	1	Base	CI
3	1	Movable jaw	CI
4	4	CSK Screw M8 x 35	MS
5	2	Serrated plate	MS
6	1	Sliding block	CI
7	2	CSK Screw M8 x 38	MS
8	1	Washer	MS
9	1	Nut M20	MS
10	2	CSKScrew M8 x 50	MS

Figure 3 Assembly details of machine vice



Part No.	Name	Matl.	Qty.	Part No.	Name	Matl.
1	Body	CI	1	8	Spindle	GM
2	Cover	CI	1	9	Collar	GM
3	Gland	GM	1	10	Hand wheel	CI
4	Neck bush	GM	1	11	Stud with nut	MS
5	Bridge	MS	1	12	Stud with collar	MS
6	Valve	GM	1	13	Nut	MS
7	Valve seat	GM	1	14	Stud with nut	MS

Figure 4 Assembly details of stop valve

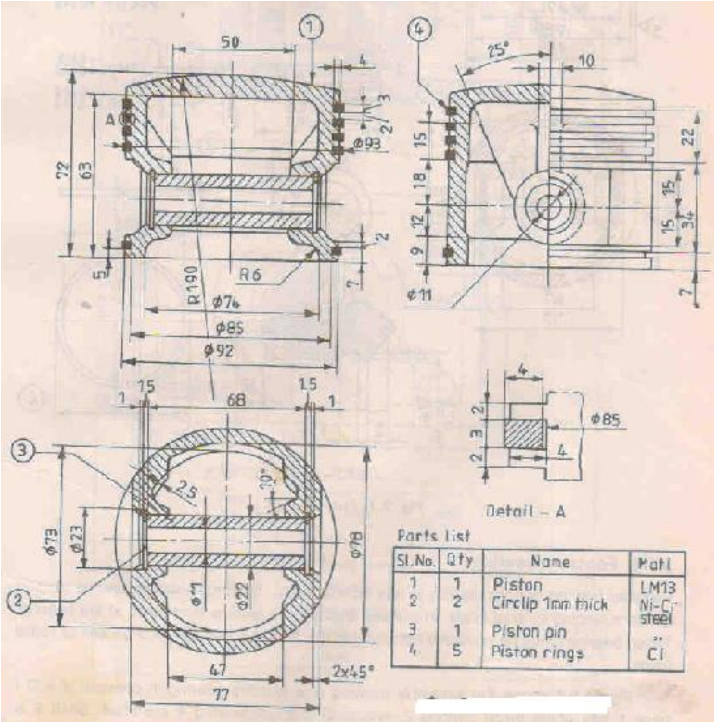
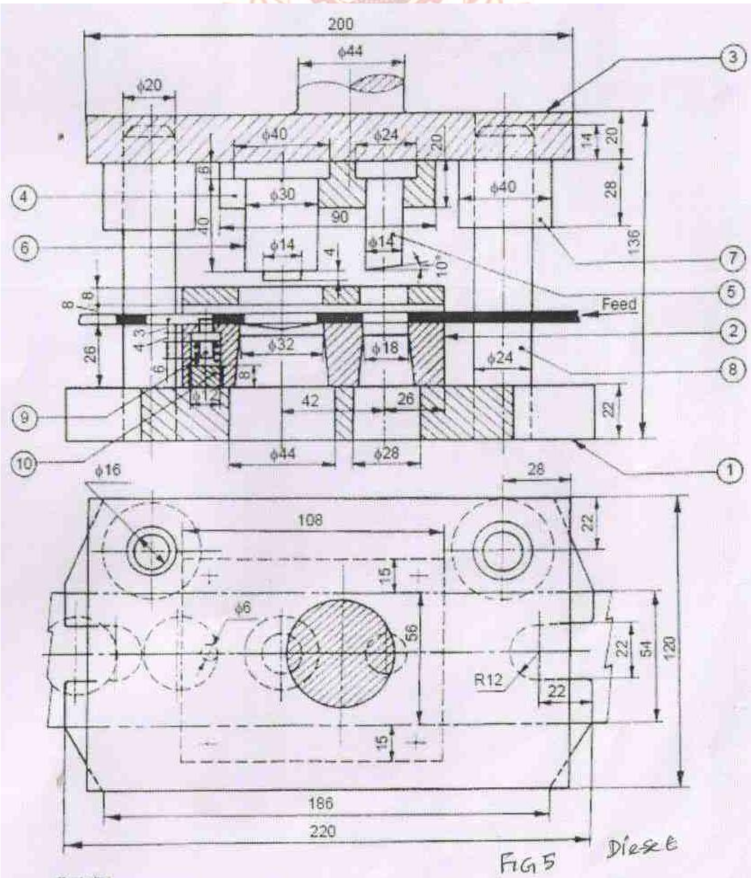


Figure 5 Component details of a piston



Parts list

Part No.	Name	Matl.	Qty.	Part No.	Name	Matl.	Qty.
1	Base	MS	1	6	Blanking tool	Tool steel	1
2	Die block	Tool steel	1	7	Guide block	MS	2
3	Cover plate	MS	1	8	Guide pin	MS	2
4	Tool holder	MS	1	9	Stop	HCS	1
5	Punch	Tool steel	1	10	Spring retainer	MS	1

Figure 6 Component details of die set

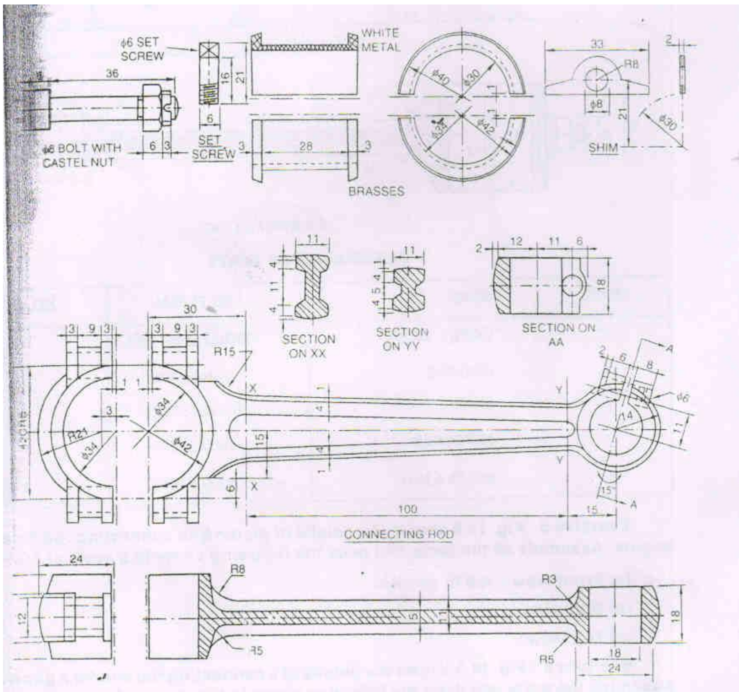


Figure 7 Component details of connecting rod

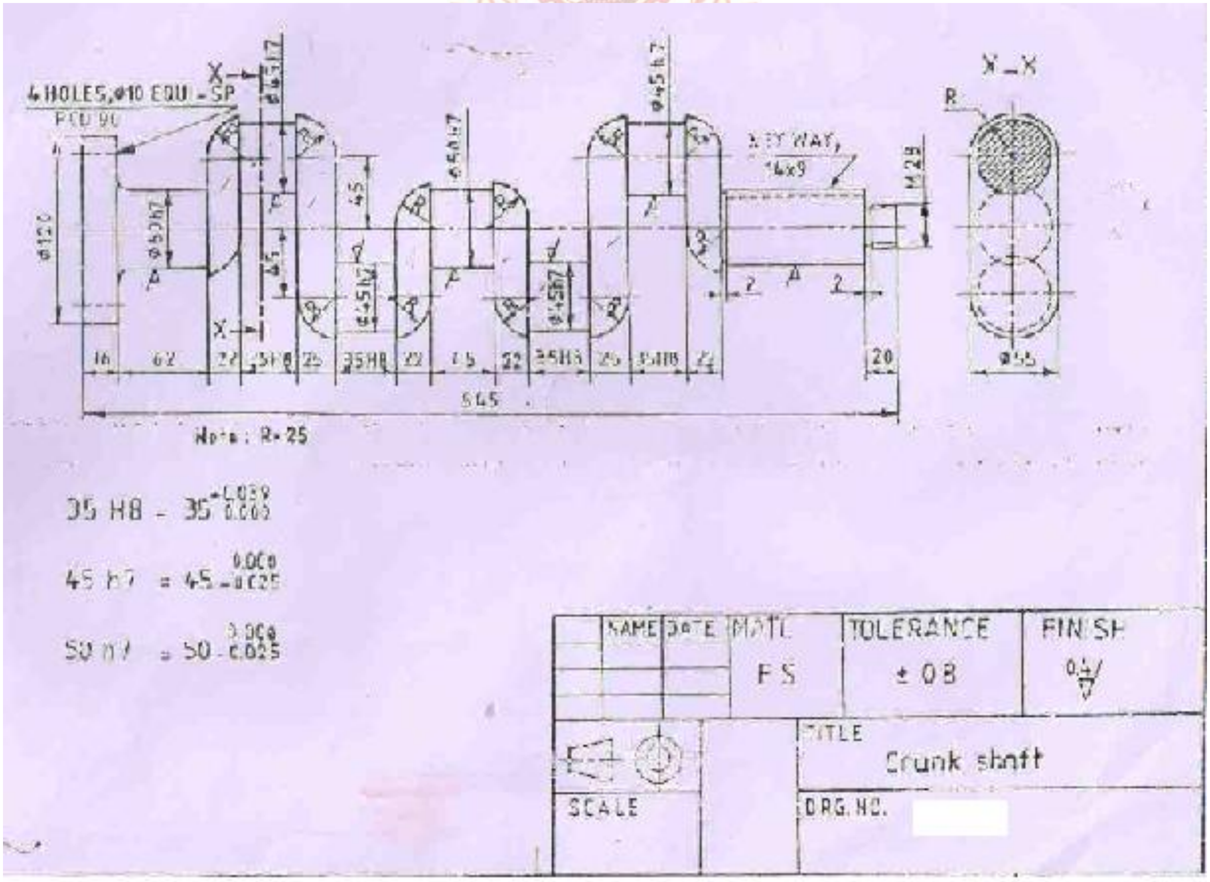


Figure 8 Component details of crank shaft

Syllabus

Introduction: I.S Code of practice for machine drawing - Use of scales, types of lines. Sectional views – full section, half section, revolved, removed section and hatching of sections. Representation of materials and tolerances. Symbols of springs and gears. Machining capabilities - dimensional accuracy and surface roughness values produced by common production processes. **Geometrical Dimensioning and Tolerance:** Symbols, tolerance frame, datum surface. **Surface roughness** – Representation methods and direction of lay. **Welding:** Symbolic representation, symbols and dimensioning. **Limits, Fits and Tolerances** - Types and calculations. **Fasteners** - Forms of threads and types. **Bolts** – Hexagonal and square headed bolt. **Nuts** – Hexagonal, square and locknuts. Locking of nuts by grooved nut and spring washer. **Screws** - Grub screws, set screws and studs. **Keys** - Hollow, saddle, taper sunk and wood ruff. **Assembly drawing (Part to assembly) -** Screw jack, Swivel bearing and Drilling Jig. **Component drawing (Assembly to part) -** Steam Stop valve, Machine vice. **Detailed drawings -** Piston, Die set, milling fixture.
Introduction to Computer Aided Drafting (Orthographic views From Pictorial view) **-** Connecting rod and Crank shaft. **(** Sketch and part modelling, for internal assessment only).

Text Books

1. K.R.Gopalakrishna, "**Machine Drawing**", Eighteenth Edition, Subhas Stores, Bangalore, 2004.
2. K.L. Narayana, P.Kannaiah and K. Venkata Reddy, "**Production Drawing**", Third Edition, New Age International Ltd., New Delhi, 2014.

Reference Books

1. Warren Hammer, "**Blueprint Reading Basics**", Third edition, Industrial Press Inc, New York, 2003.
2. P.S. Gill, "**A Text Book of Machine Drawing**", Seventh edition Reprint, S. K. Kataria & Sons. New Delhi. 2004.
3. R.K. Dhawan, "**A Text book of Machine Drawing**", First Edition, Sultan Chand and Sons, New Delhi, 1996.
4. IS 919 (Part 1 & 2):1993.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Introduction**	
1.1	I.S Code of practice for Machine Drawing- Use of scales, types of lines. Sectional views – full section, half section, revolved, removed section and hatching of sections.	3
1.2	Representation of materials and tolerances. Symbols of springs and gears. Machining capabilities - dimensional accuracy and surface roughness values produced by common production processes.	3
2	**Geometrical Dimensioning and Tolerance**	
2.1	Symbols, tolerance frame, datum Surface. Surface Roughness – Representation methods and direction of lay.	2
2.2	Welding: Symbolic representation, symbols and dimensioning	2
2.3	Limits, Fits and Tolerances: Types and calculations.	3
3.0	**Fasteners**	
3.1	Forms of threads and types. Bolts – Hexagonal and square headed bolt. Nuts – Hexagonal, square and locknuts.	3
3.2	Locking of nuts by grooved nut and spring washer. Screws - grub screws, set screws and studs.	2
3.3	Keys - hollow, saddle taper sunk and wood ruff.	2
4	**Assembly drawing (Part to assembly)**	

Module No.	Topic	No. of Lectures
4.1	Screw jack	4
4.2	Swivel bearing	4
4.3	Drilling Jig	4
5	**Component drawing (Assembly to part)**	
5.1	Steam Stop valve	3
5.2	Machine vice	3
6	**Detailed drawings**	
6.1	Piston	4
6.2	Die set	4
6.3	Milling Fixture	4
7	**Introduction to Computer Aided Drafting -** Sketch and Part modelling only.	
7.1	Connecting rod	5
7.2	Crank shaft	5
		60

Course Designers:

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		Category	L	T	P	Credit
14ME470	**PROFESSIONAL COMMUNICATION**	HSS	1	0	2	2

Preamble

This course provides opportunities to students to develop and demonstrate basic communication skills in technical, professional and social contexts effectively.

Prerequisite

- 14EG140: English

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Plan, organise, write, and present project reports, and technical papers in the frame of the scientific method	Apply
CO 2.	Establish themselves through communication skills in corporate environment.	
CO 3.	Solve verbal aptitude questions related to placement and higher studies.	Apply
CO 4.	Apply their interpersonal skills in technical, professional and social contexts.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	_	L	_	_	_	_	_	_	M	S	_	M	_	_	L
CO2.	_	_	_	_	_	_	_	_	M	S	_	M	_	_	L
CO3.	_	_	_	_	_	_	_	_	M	S	_	M	_	_	_
CO4.	_	_	_	_	_	_	_	_	S	S	_	M	_	_	L
	_	_	_	_	_	_	_	_	S	S	_	M	_	_	L

S- Strong; M-Medium; L-Low

Assessment Pattern

Internal

- **No Continuous Assessment Test (CAT) will be conducted.**

Project Report Preparation and
Technical Presentation through PPT - 15
Listening Test - 10
Spoken Task – Group Discussion / Mock Job Interview - 10
Writing – Verbal Aptitude for Placement and Higher studies - 15
(The test will be conducted for 50 marks and reduced to 15)

External (Practical)

Listening Test - 20
Group Discussion - 25
Personal Interview / Situational Conversation - 25
Technical Presentation - 20
Resume - 10

Course Contents and Lecture Schedule

Sl. No.	Topic	No. of Hours	
		Theory	Practical
1	Literature Survey / Project Title Selection	1	
2	Characteristics of Technical Paper and Project Report	1	
3	Abstract / Data Presentation	1	
4	Common Errors in Technical Writing	1	
5	Bibliography and References	1	
6	Vocabulary Development	1	
7	Sentence Completion	1	
8	Error Spotting	1	
9	Interpretation of Verbal Analogy	1	
10	Interpretation of Reading (Comprehension - Conception)	1	
11	Interpretation of Reading (Comprehension - Reasoning)	1	
12	Practice for writing E-mails	1	
13	PPT Preparation /Demonstration of Technical Presentation		4
14	Preparation of Resume		2
15	Preparation for Job Interviews		4
16	Demonstration of Group Discussion Skills		4
17	Developing Listening Skill (Comprehension)		3
18	Practice for Short Speeches / Situational Conversation		4
19	Development of Employability Skills		2
20	Non-Verbal Communication		1
	Total	**12**	**24**

Reference Books:

1. Courseware on "**Technical Communication for Scientists and Engineers**", IIT Bombay, 2015.
2. Cappel, Annette and Sharp, Wendy, "**Cambridge English: Objective First**", 4th edition., CUP, New Delhi, 2013
3. Sue Prince, Emma, "**The Advantage: The 7 soft skills you need to stay one step ahead**", 1st edition, Pearson; 2013.

4. Cusack, Barry, "**Improve Your IELTS Listening and Speaking Skills (With CD)**" Paperback, Macmillan, 2007.
5. Bates, Susan, "**TOEFL iBT Exam Paperback**", Oxford, 2012.
6. Hart, Guy Brook, "**Cambridge English Business Benchmark**", 2nd edition, CUP 2014.

Course Designers:

1.	Dr. T.Sadasivan	sadasivan@tce.edu
2.	Dr. S.Rajaram	sreng@tce.edu
3.	Dr. A.Tamilselvi	tamilselvi@tce.edu
4.	Mr. R.Vinoth	vino@tce.edu
5.	Dr.R.K.Jaishree Karthiga	jai@tce.edu

14ME480	**MACHINING PRACTICES LAB**	Category	L	T	P	Credit
		PC	0	0	2	1

Preamble

To impart knowledge and skill in the field of machine tools used in the industries. To increase the level of confidence of students by working individually in various machine tools. This would supplement the understanding of the theory course on 14ME430 Machining Processes.

Prerequisite

14ME290 Workshop

Course Outcomes

On the successful completion of the course, students will be able to:

Sl. No	Course Outcomes	Blooms level
CO1.	**Experiment with various operations in lathe**	**Apply**
CO 2.	**Experiment with various operations in milling, machines.**	**Apply**
CO 3.	**Experiment with various operations in drilling**	**Apply**
CO 4.	**Experiment with various operations in grinding machines.**	**Apply**

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	M	_	_	_	_	_	L	M	_	_	M	S	_	_
CO2.	S	M	_	_	_	_	_	L	M	_	_	M	S	_	_
CO3.	S	M	_	_	_	_	_	L	M	_	_	M	S	_	_
CO4.	S	M	_	_	_	_	_	L	M	_	_	M	S	_	_
	S	M	_	_	_	_	_	L	M	_	_	M	S	_	_

S- Strong; M-Medium; L-Low

Syllabus

List of Exercises

S.No	Exercises / Experiments	No of Hrs
	Cycle-I	
1.	Plain, Step and Taper Turning in Lathe	2
2.	Spur Gear Cutting in Horizontal Milling	2
3.	Key Way Milling in Vertical Milling	2
4.	Plain Grinding in Grinding Machine	2
5.	Drilling and Counter Boring in Drilling Machine	2
6.	Grooving (UCD)and Left Hand Thread operation in Lathe	2
	Cycle-II	
7.	Grooving (UCD) and Right Hand Thread operation in Lathe	2
8.	Helical Gear Generation in Horizontal Milling	2
9.	Flat Milling in Vertical / Horizontal Milling Machine	2
10.	Morse Taper Grinding in Grinding Machine	2

11.	Drilling and Tapping in Drilling Machine	2
12.	Gear Hobbing in Grinding Machine	2
	Total	**24**

A work/tool holding device shown in Figure 1 is made by a set of above mentioned 12 machining operations.

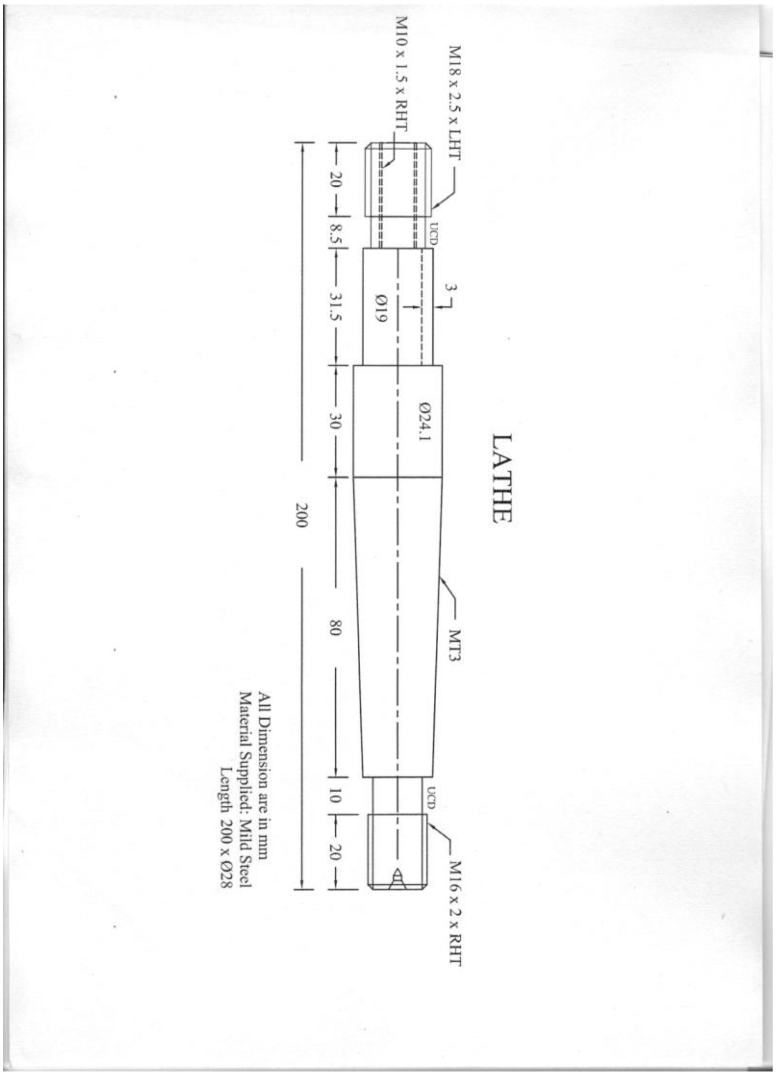

Figure 1

Assessment Pattern

- Students should be tested in any two exercises in Terminal Practical Examination.
- Students should be tested in any one Exercise in I Cycle Exercises and one Exercise in II Cycle Exercises with 90 Minutes each.

Course Designers:

1. Mr. M. Balamurali balacim@tce.edu
2. Mr. J. Umar Mohamed umar_tce_mech@tce.edu

		Category	L	T	P	Credit
14ME490	**THERMAL ENGINEERING LAB**	PC	0	0	2	1

Preamble

It is essential for students of Mechanical engineering to know construction, working and performance evaluation of thermal systems such as I.C.Engines, steam boiler, air compressor, refrigerator and air conditioners. This course caters to this need and also to determine physical properties of fuels.

Prerequisite

- 14ME240: Engineering Thermodynamics

Course Outcomes

On the successful completion of the course, students will be able to:

Sl. No	Course Outcomes	Blooms level
CO1.	**Determine various performance characteristics of I.C.Engines and air compressor**	**Apply**
CO2.	**Determine COP of Refrigerator and Air-conditioning units**	**Apply**
CO3.	**Determine dryness fraction of steam and thermal efficiency of steam generator**	**Apply**
CO4.	**Determine physical properties of fuels**	**Understand**
CO5.	**Find valve timing of 4-stroke engine and port timing of 2-stroke engine**	**Understand**

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1.	S	M	S	M	_	_	_	_	_	_	_	_	M	_	_
CO2.	S	M	S	M	_	_	_	_	_	_	_	_	M	_	_
CO3.	S	M	S	M	_	_	_	_	_	_	_	_	M	_	_
CO4.	M	L	M	L	_	_	_	_	_	_	_	_	L	_	_
CO5.	M	L	M	L	_	_	_	_	_	_	_	_	L	_	_
	S	L	L	L	_	_	_	_	_	_	_	_	L	_	_

S- Strong; M-Medium; L-Low

List of Experiments

1. Performance test on constant speed 4-stroke Diesel engine
2. Performance test on variable speed 4-stroke petrol engine
3. Energy balance test on constant speed 4-stroke Diesel engine by calorimeter method
4. Energy balance test on constant speed 4-stroke Diesel engine by air flow measurement.
5. Retardation test on twin cylinder Diesel engine.
6. Volumetric efficiency test on constant speed 4-stroke Diesel engine.
7. Finding valve timing of 4-stroke and port timing of 2-stroke engine.
8. Determination of economic load and optimum coolant flow rate of a Diesel engine.
9. Volumetric efficiency test on reciprocating air compressor.
10. Determination of COP of refrigeration test rig.
11. Determination of equivalent evaporation and boiler efficiency.
12. Determination of dryness fraction of steam using throttling calorimeter.
13. Evaluation of physical properties such as flash point, fire point and viscosity of fuel.
14. Determination of calorific value of fuel using digital bomb calorimeter.

15. Determination of cooling load and COP of air conditioning unit.

***Note:** Any twelve experiments are to be conducted in two cycles.

Course Designers:

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2.	Dr. A.Samuel Raja	samuel1973@tce.edu

14ME4C1	CAPSTONE COURSE - I	Category	L	T	P	Credit
		PC	0	0	2	2

Preamble

The purpose of this course is to apply the concept of mathematics, science and engineering fundamentals and an engineering specialization to solve complex engineering problems.

Syllabus

1. PHYSICS

First and second law of thermodynamics- Carnot's engine-Temperature-Entropy diagram-Change in entropy in reversible and irreversible process- entropy of a perfect gas-application: Heat engine-refrigerator Scanning Electron Microscope-Transmission Electron Microscope, Laser and Fibre optics, Properties of Bulk Material-Thermal properties, Expansion, Heat capacity and conductivity, Dielectric constant, Dielectric strength, Dielectric loss, Dielectric breakdown - Magnetic properties-permeability, Hysteresis, Mechanical properties-Concept of stress and strain, Elastic and plastic deformation, Creep, Hardness and tensile strength.

2. CHEMISTRY

Fuels and combustion: Classification of fuels Calorific Values- Theoretical calculation by using Dulong's formula Coal – classification- Analysis of coal Proximate and Ultimate analysis Refining of petroleum- Knocking Refining of petroleum- Knocking Refining of petroleum- Knocking gas-bio gas- alternate fuels- power alcohol- bio diesel Combustion-calorific intensity- SIT Calculation of minimum quantity of air required for combustion Flue gas analysis Gaseous fuels Bio fuels. **Environmental pollution** : Environmental pollution, Environmental pollution due to automobiles and industries ,Alternate fuels – bio-fuel Nuclear hazardous safety and protection Solid, liquid and e-waste management Climatic change - Global warming and its effects Euro and bharath norms for pollution

3. ENGINEERING GROUP- 1

a. Free Body Mechanics

System of forces: Representation of Force, Moment and Couples-Reduction of system of forces to one force and couple. **Distributed forces:** Centroid of lines and areas-Centre of gravity of mass-Moment of inertia of areas-Mass moment of inertia. **Objects with friction**: Ladder, Wedge and Screw friction, Applications.

b. Metal Casting and Forming Processes

Permanent mould casting processes: Applications of Permanent mould casting processes - Centrifugal casting and Pressure die casting. **Plastic forming Processes: Types -** Extrusion, Injection Molding and Blow Molding operations. **Metal forming Processes:** Concept of strain hardening. Hot and cold working processes. **Rolling**

Process: Hot and cold rolling process, Type of rolling mills and process parameters. Production of seamless pipe and tubes. **Forging:** Types of Forging Processes - open die, closed die forging - Heading, Piercing and coining. **Drawing Process:** Wire and tube drawing and process parameters. **Extrusion Process**: hot, cold, impact and hydro static extrusion. **Sheet metal forming Process**: Formability of Sheet metal, Shearing mechanism, process parameters, Shearing operations- Blanking, Piercing, fine Blanking, Slitting, trimming, lancing, cut off, coining, Nibbling, bending, shaving, Forming, Beading, bulging Flanging, Dimpling, Hemming, Tube bending, Deep Drawing.

4. MATHEMATICS

Matrices - Characteristic Equation – Eigen values and eigen vectors of a real matrix-Properties of eigen values-Cayley Hamilton Theorem-Orthogonal reduction of a symmetric matrix to diagonal form-Orthogonal matrices Reduction of quadratic form by orthogonal transformation. **Ordinary Differential Equation-**Linear Differential Equations of second and higher order with constant coefficients-Cauchy's homogeneous linear equation-Legendre's linear equation-Method of variation of parameters-Simultaneous linear equations with constant coefficients. **Vector Calculus-**Introduction to vector algebra and its applications to Mechanics-Gradient of scalar point functions, Divergent and Curl of vector point functions-Vector Integrals ,Line, Surface and Volume Integrals-Theorems and their applications to fluid flow. **Partial Differential equation-**Solution to standard types of equations-Solution to Lagrange's equations-Solution to Higher order PDEs with Constant Coefficients -Solution to Partial Differential equations using variable separable method. **Probability Distributions** - The Binomial probability distribution - hyper geometric - negative Binomial distribution - the Poisson probability distribution - the normal distribution - the exponential distribution gamma distribution.

5. ENGINEERING GROUP- 2

a. Engineering Thermodynamics

Thermodynamic Systems: Definition - Open, closed and isolated systems. **First law of Thermodynamics:** Energy Transfer (Work and Heat) –pdv work for closed system using air and water/steam in thermodynamic processes, Steady flow energy equation (SFEE) for nozzle, compressor, turbine and heat exchanger. **Second Law of Thermodynamics:** Second law statements and its equivalence - Heat engine, refrigerator and heat pump. **Entropy: C**hange in entropy for reversible and irreversible processes, principle of increase of entropy. **Third law of thermodynamics** – Change of entropy for solids, liquids and gases. **Exergy and Anergy:** Available (Exergy) and Unavailable energy (Anergy) - Irreversibility. **Ideal gas mixture:** Avagdro's law, Dalton's law of partial pressure, property equations and change of properties of gas mixture – **Combustion:** Basic combustion equations.

b. Metal joining processes and manufacturing practices

Metal joining Process - Solidification of the weld metal, base metal, heat affected zone, weld metal, shielding gases, filler metal, fluxes. **Fusion welding:** Oxy-fuel gas Welding, Arc welding, MIG welding, Thermit welding, Plasma arc welding and Laser Beam welding. **Solid State welding:** Resistance Welding-spot, seam, projection welding, friction welding, diffusion bonding and ultra sonic welding.

6. ENGINEERING GROUP - 3

a. Fluid Mechanics

Fluid Statics: Pressure at a Point: Pascal's Law - Pressure force on a fluid element: Hydrostatic law and aerostatic law – Manometry. **Fluid Kinematics:** Lagrangian and Eulerian Descriptions – Velocity and Acceleration of a fluid particle-Stream line, stream tubes and path line- Continuity Equation in Cartesian Co-ordinates – Vorticity and irrotationality- Velocity Potential and Stream Function. **Fluid Dynamics:** Different types of fluid forces- non-dimensional number: Reynolds number, Froude number, Euler number, Weber number and Mach number- Euler's Equation for Motion - Bernoulli's Equation - Applications of Bernoulli's Equation, Venturimeter and orifice meter – Momentum equation - Navier Stokes Equation – Boundary layer separation. **Pipe Flow:** Laminar and turbulent flow - Reynolds Experiment - Significance of Reynolds Number - Laminar Flow in Pipes: Hagen Poiseuille's flow, Darcy-Weisbach equation, losses due sudden enlargement and contraction. **Fanno Flow:** Fanno curve - Fanno flow governing equations - Maximum duct length. **Rayleigh Flow:** Rayleigh curve - Rayleigh flow governing equations - Maximum heat transfer.

b. Geometric Modeling

Mathematical modeling of Curves and surfaces: Synthetic modeling - Hermite Cubic Spline, Bezier and B-spline Curves and surfaces. **Mathematical modeling of Solids:** Properties of solid model, Solid modeling Techniques - Boundary representation, Constructive Solid Geometry, Analytical Solid Modeling and Sweep representation schemes. **Transformation and Projection techniques:** 2D and 3D transformation techniques - Translation, Rotation, Scaling and Reflection principles. Orthographic and perspective projections. **Graphic Standards:** Direct and indirect data transfer. Neutral file formats - Data Exchange Format (DXF) and Initial Graphics Exchange Specification (IGES).

Reference Books

1. B.S.Grewal ,"**Higher Engineering Mathematics"**, 43rd Edition., Khanna Publishers, Newdelhi, 2014

2. Beer F.P. and Johnston Jr. E.R., "**Vector Mechanics for Engineers: Statics and Dynamics"**, Eighth Edition, Tata McGraw Hill, 2008.
3. Serope Kalpakjian and Steven R.Schmid, **"Manufacturing Engineering and Technology"**, Sixth Edition, PHI, 2010.
4. Yunus A. Cengel and Michael A. Boles, **"Thermodynamics: An Engineering Approach"**, Seventh Edition, McGraw Hill, 2011.
5. Bruce R. Munson, Theodore H. Okiishi, Wade W. Huebsch, Rothmayer, **"Fluid Mechanics**", Seventh Edition, Wiley India Pvt. Ltd, 2015.
6. Ibrahim Zeid, "**Mastering CAD/CAM**", Tata McGraw Hill Education (P) Ltd., Special Indian Edition, 2008.

Assessment Pattern

(Common to B.E./B.Tech Programmes)

TEST - 1: Physics, Chemistry, Engineering Group – 1

Duration: 90 Minutes **(Total: 60 Marks)**

Objective Type Questions : 30 (10 Questions from each group)

Fill-in the blanks Type Questions : 30 (10 Questions from each group)

TEST - 2: Mathematics, Engineering Group - 2, Engineering Group - 3

Duration: 90 Minutes **(Total: 60 Marks)**

Objective Type Questions : 30 (10 Questions from each group)

Fill-in the blanks Type Questions : 30 (10 Questions from each group)

TEST - 3: Comprehensive (Physics, Chemistry, Mathematics Engineering Group - 1, 2 and 3)

Duration: 90 Minutes **(Total: 60 Marks)**

Objective Type Questions : 30 (5 Questions from each Group)

Fill-in the blanks Type Questions : 30 (5 Questions from each Group)

Final Mark consolidation:

Test No.	Max. Marks to be Obtained	Converted to
Test - 1	60 Marks	20 Marks
Test - 2	60 Marks	20 Marks
Test - 3	60 Marks	60 Marks
	Total	**100 Marks**

Note:

1. NO re-test will be conducted at any circumstances
2. All the tests are to be conducted along with the respective scheduled CAT period

Course Designers

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BE Mechanical Engineering 2016-17 onwards

14ME4C2	CAPSTONE – I	Category	L	T	P	Credit
		PC	0	0	2	2

Preamble

The objective of this course is to refresh the previous semester courses and to enable the students to perform well in the placement activities and technical interviews.

Syllabus

1. ENGINEERING GROUP - I

a. Free Body Mechanics

System of forces: Representation of Force, Moment and Couples-Reduction of system of forces to one force and couple. Distributed forces: Centroid of lines and areas-Centre of gravity of mass-Moment of inertia of areas-Mass moment of inertia. Objects with friction: Ladder, Wedge and Screw friction, Applications.

b. Metal Casting and Forming Processes

Permanent mould casting processes: Applications of Permanent mould casting processes - Centrifugal casting and Pressure die casting. Plastic forming Processes: Types - Extrusion, Injection Molding and Blow Molding operations. Metal forming Processes: Concept of strain hardening. Hot and cold working processes. Rolling Process: Hot and cold rolling process, Type of rolling mills and process parameters. Production of seamless pipe and tubes. Forging: Types of Forging Processes - open die, closed die forging - Heading, Piercing and coining. Drawing Process: Wire and tube drawing and process parameters. Extrusion Process: hot, cold, impact and hydro static extrusion. Sheet metal forming Process: Formability of Sheet metal, Shearing mechanism, process parameters, Shearing operations-Blanking, Piercing, fine Blanking, Slitting, trimming, lancing, cut off, coining, Nibbling, bending, shaving, Forming, Beading, bulging Flanging, Dimpling, Hemming, Tube bending, Deep Drawing.

c. Engineering Thermodynamics

Thermodynamic Systems: Definition - Open, closed and isolated systems. First law of Thermodynamics: Energy Transfer (Work and Heat) –pdv work for closed system using air and water/steam in thermodynamic processes, Steady flow energy equation (SFEE) for nozzle, compressor, turbine and heat exchanger. Second Law of Thermodynamics: Second law statements and its equivalence - Heat engine, refrigerator and heat pump. Entropy: Change in entropy for reversible and irreversible processes, principle of increase of entropy. Third law of thermodynamics – Change of entropy for solids, liquids and gases. Exergy and Anergy: Available (Exergy) and Unavailable energy (Anergy) - Irreversibility. Ideal gas mixture: Avagdro's law, Dalton's law of partial pressure, property equations and change of properties of gas mixture – Combustion: Basic combustion equations.

2. ENGINEERING GROUP- II

a. Fluid Mechanics

Fluid Statics: Pressure at a Point: Pascal's Law - Pressure force on a fluid element: Hydrostatic law and aerostatic law – Manometry. Fluid Kinematics: Lagrangian and Eulerian Descriptions – Velocity and Acceleration of a fluid particle-Stream line, stream tubes and path line- Continuity Equation in Cartesian Co-ordinates – Vorticity and irrotationality-Velocity Potential and Stream Function. Fluid Dynamics: Different types of fluid forces- non-dimensional number: Reynolds number, Froude number, Euler number, Weber number and Mach number- Euler's Equation for Motion - Bernoulli's Equation - Applications of Bernoulli's Equation, Venturimeter and orifice meter – Momentum equation - Navier Stokes Equation – Boundary layer separation. Pipe Flow: Laminar and turbulent flow - Reynolds Experiment - Significance of Reynolds Number - Laminar Flow in Pipes: Hagen Poiseuille's flow, Darcy-Weisbach equation, losses due sudden enlargement and contraction. Fanno Flow: Fanno curve - Fanno flow governing equations - Maximum duct length. Rayleigh Flow: Rayleigh curve - Rayleigh flow governing equations - Maximum heat transfer.

b. Metal joining processes and manufacturing practices

Metal joining Process - Solidification of the weld metal, base metal, heat affected zone, weld metal, shielding gases, filler metal and fluxes. Fusion welding: Oxy-fuel gas Welding, Arc welding, MIG welding, Thermit welding, Plasma arc welding and Laser Beam welding. Solid State welding: Resistance Welding-spot, seam, projection welding, friction welding, diffusion bonding and ultra-sonic welding.

c. Geometric Modeling

Mathematical modeling of Curves and surfaces: Synthetic modeling - Hermite Cubic Spline, Bezier and B-spline Curves and surfaces. **Mathematical modeling of Solids:** Properties of solid model, Solid modeling Techniques - Boundary representation, Constructive Solid Geometry, Analytical Solid Modeling and Sweep representation schemes. **Transformation and Projection techniques:** 2D and 3D transformation techniques - Translation, Rotation, Scaling and Reflection principles. Orthographic and perspective projections**. Graphic Standards:** Direct and indirect data transfer. Neutral file formats - Data Exchange Format (DXF) and Initial Graphics Exchange Specification (IGES).

Reference Books

7. Beer F.P. and Johnston Jr. E.R., '**Vector Mechanics for Engineers: Statics and Dynamics**', Eighth Edition, Tata McGraw Hill, 2008.
8. Serope Kalpakjian and Steven R.Schmid, **"Manufacturing Engineering and Technology"**, Sixth Edition, PHI, 2010.

9. Yunus A. Cengel and Michael A. Boles, **“Thermodynamics: An Engineering Approach”**, Seventh Edition, McGraw Hill, 2011.
10. Bruce R. Munson, Theodore H. Okiishi, Wade W. Huebsch, Rothmayer, **“Fluid Mechanics**”, Seventh Edition, Wiley India Pvt. Ltd, 2015.
11. Mikell P.Groover, ”**Fundamental of Modern Manufacturing**”, Wiley India Edition, Third Edition, Reprint, 2012.
12. Ibrahim Zeid, "**Mastering CAD/CAM**", Tata McGraw Hill Education (P) Ltd., Special Indian Edition, 2008.

Assessment Pattern

(Common to B.E./B.Tech Programmes)

TEST - 1: Engineering Group – I

Duration: 90 Minutes (Total: 60 Marks)

Objective Type Questions : 30 (10 Questions from each course)

Fill-in the blanks Type Questions : 30 (10 Questions from each course)

TEST - 2: Engineering Group - II

Duration: 90 Minutes (Total: 60 Marks)

Objective Type Questions : 30 (10 Questions from each course)

Fill-in the blanks Type Questions : 30 (10 Questions from each course)

TEST - 3: Comprehensive Test (Engineering Group – I & II)

Duration: 90 Minutes (Total: 60 Marks)

Objective Type Questions : 30 (5 Questions from each course)

Fill-in the blanks Type Questions : 30 (5 Questions from each course)

Final Mark consolidation:

Test No.	Max. Marks	Converted in to
Test - 1	60 Marks	20 Marks
Test - 2	60 Marks	20 Marks
Test - 3	60 Marks	60 Marks
Total		**100 Marks**

Note:

3. NO re-test will be conducted at any circumstances.
4. NO final examination for this course.

Course Designers

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		Category	L	T	P	Credit
14 ME510	**ACCOUNTING AND FINANCE**	BS	3	0	0	3

Preamble

Engineering profession involves lots of decision making. The decisions may range from operation to non-operation. For taking decisions of these kinds an engineer needs among other things data about the organization's routine operations and non-routine operations. Accounting is a science which provides all the data by recording, classifying, summarizing and interpreting the various transactions taking place in an organization and thereby helps an engineer in taking vital decisions in an effective manner. Finance is an allied but a separate field relying on accounting, and enables engineers in taking useful financial and cost related decisions by providing well defined concepts, tools and techniques.

Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Prepare financial statements and analyze them with common size statements, comparative statements and trend percentage methods	Apply
CO 2.	Prepare cost sheet.	Apply
CO 3.	Prepare various functional budgets and cash budget	Apply
CO 4.	Calculate material, labour and overhead cost variance and and identify the reasons for the variances.	Apply
CO 5.	Evaluate the probability of capital budgeting decisions by using pay back, accounting rate of return, net present value and internal rate of return methods.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	_	M	_	_	_	_	L	M	M	M	S	M	_	_	_
CO2.	_	L	_	L	L	L	_	M	M	M	S	M	_	_	_
CO3.	_	L	_	L	L	L	_	M	M	M	S	M	_	_	L
CO4.	_	_	_	_	_	_	_	_	L	M	S	M	_	_	M
CO5.	_	M	_	M	M	_	_	_	_	M	S	M	_	_	M

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	30	30	30	30
Apply	50	50	50	50
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. What is Accounting?
2. What are financing functions?
3. What is a ledger?
4. What is trial balance?
5. What is single entity concept?
6. What are the various principles of accounting?
7. Give an example nominal account
8. How is adjustment done for depreciation in final account?
9. Write down the various assets and liabilities.
10. What is a bad debt?
11. From the following Trial balance of Excellent & co on 31st March 2005 you are required to prepare the trading and profit and loss account and a balance sheet as on that date.

Ledger Balances	Amount in Rs.	Ledger balances	Amount in Rs.
Opening stock	500	Commission received	200
Bills receivable	2250	Purchases returns	250
Purchases	19500	Trade expenses	100
Wages	1400	Office fixtures	500
Insurance	550	Cash in hand	250
Sundry debtors	15000	Cash at bank	2375
Carriage inward	400	Rent and taxes	550
Commission paid	400	Carriage outward	725
Interest on capital	350	Sales	25000
Stationery	225	Bills payable	1500
Sales return	650	Sundry creditors	9825
Capital	8950		

The closing stock was valued at Rs.12,500.

Course Outcome 2 (CO2):

1. Explain the various elements of cost.
2. Discuss the significance of cost accounting in a manufacturing industry?
3. Compare balance sheet and cost sheet.
4. Explain the procedure for preparing the cost sheet for an organization.
5. From the following details prepare a cost sheet for the production of 5000 units for the month of Jan 2005.
6.

Cost particulars	**Amount in Rs**
Stock of raw-materials on 1.01.2005	10,000
Stock of finished goods on 31.01.2005	12,000
Materials purchased	25,000
Carriage inwards	1500
Direct expenses	700
Factory Rent	1000
Office rent	2000
Depreciation : factory	900
Office	600
Repairs and maintenance: factory	900

Office	600
Lighting : Factory	450
Office	750
Manager's salary	3500
Printing and stationery	1000
Telephone charges	1250
General expenses	800
Salesmen commission	650
Advertising	1250
Opening stock of work-in-process (1.01.2005)	2000
Opening stock of finished goods (1.01.2005)	3000
Closing stock of work-in-process (31.01.2005)	4000
Closing stock of finished goods (31.01.2005)	5000

Course Outcome 3 (CO3):

1. Explain the various types of budgets
2. Explain the procedure for preparing cash budget
3. Write the advantages of Zero Base Budgeting
4. Prepare cash budget for the months of March, April, May and June for the following information with the opening balance on March 1st being Rs.25, 000

Months	Sales	Purchases	Wages	Office Exp.	Selling Exp.	R & D exp.
Jan	120000	80000	1200	2500	1800	1600
Feb	125000	82000	1300	2600	2000	1720
March	120000	78000	1400	2750	2100	1640
April	130000	85000	1400	2750	1900	1680
May	140000	90000	1300	2600	2000	1760
June	135000	86000	1350	2700	2000	1800

Second Call money on shares to be received in May Rs.20000
Expected income from investments Rs.5000 in March
Dividends of Rs.3000 to be received in April
Machinery expected to sell for Rs. 10000 for cash in April
Dividend to be paid in May for Rs.6000
Delay in paying….. wages, office expenses one month
Selling expenses 1 / 4 month
R &d expenses 1/8 month
Credit allowed by suppliers one month
Credit allowed for customers 20% on sales immediately and remaining in two equal instalments in subsequent months
Machinery purchased in May for Rs.2, 00,000.

Course Outcome 4(CO4):

1. Explain the features of standard costing
2. Explain the procedure for preparing cash budget.

Course Outcome 5(CO5):

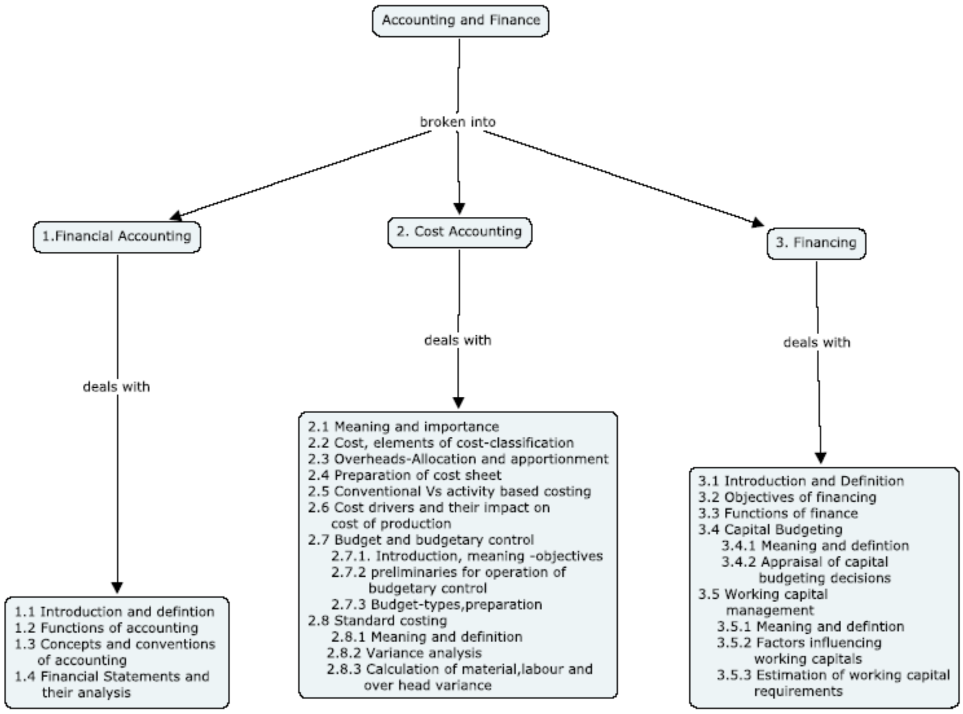
1. Identify the various sources of finance
2. Distinguish owners capital from borrowed capital.
3. Compare preference shares and equity shares.
4. What is the meaning of capital budgeting.

5. Explain the advantages and disadvantages of both conventional and non-conventional methods of evaluating capital budgeting.
6. Compare IRR and ARR.
7. Calculate IRR if the project cost is Rs.10000 with life period of 3 years generating an even annual cash inflow of Rs.4000 every year.
8. PSG mills Ltd., is considering two mutually exclusive proposals A and B.

Particulars	Year	Proposal A (in Rs.)	Proposal B (in Rs.)
Expected cash outlay	0	2,25,000	3,75,000
Expected cash flows	1	1,50,000	2,50,000
	2	1,00,000	2,00,000
	3	75,000	1,25,000

Assuming a discount rate of 10% suggest which proposal can be accepted?

Concept map



Syllabus

Financial Accounting - Introduction and Definition -Functions of accounting -Concepts and conventions of accounting -Financial statements and their analysis
Cost Accounting - Meaning and importance -Cost-Elements of cost-Cost classification -Overheads –Allocation and apportionment of overheads - Preparation of Cost sheet-Conventional Vs activity based costing -Cost drivers and their impact on costs of production
Budget and Budgetary control- Introduction-Meaning -objectives of budgetary control -Preliminaries for operation of budgetary control-Budget-Types of budgets and their preparation -Standard costing-Meaning and definition-Importance -Variance analysis-calculation of material, labour and overhead variances.
Finance -Introduction and Definition-Objectives of financing-Profit maximization vs wealth maximization -Functions of finance-Capital Budgeting - Introduction-Meaning and Definition-Importance –process of capital budgeting - Appraisal of capital budgeting decisions
Working capital - Meaning and definition-Importance-Factors influencing working capital-components of working capital -Estimation of working capital requirements

Text Books

1. M.C.Shukla, T.S.Grewal, S.C.Gupta, "**Advanced Accounts-volume-I**", Reprint, S.Chand& Company Ltd., 2007.
2. S.N.Maheswari, "**Financial Management, Principles and Practices**", Sultan Chand & Company Ltd., 2013.
3. P.S.BoopathiManickam, "**Financial and Management Accounting**" PSG Publications, 2009.

Reference Books

1. Prasanna Chandra, "**Financial Management-Theory and Practice**". Sixth Reprint, Tata McGraw-Hill Publishing company Limited, 2015.
2. RamachandraAryasri, A, RamanaMoorthy, V.V, "**Engineering Economics and financial Accounting**", Tata McGraw hill, 2007.
3. S.N.Maheswari, "**Advanced accountancy**", Vikas publishing, 2007.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.0	**Financial Accounting**	
1.1	Introduction and Definition	1
1.2	Functions of accounting	1
1.3	Concepts and conventions of accounting	1
1.4	Financial statements	
1.4.1	Comparative statement	2
1.4.2	Common size statement	1
1.4.3	Trend percentage	1
2.0	**Cost Accounting**	
2.1	Meaning and importance	1
2.2	Cost-Elements of cost-Cost classification	1
2.3	Overheads – Allocation and apportionment of overheads	1
2.4	Preparation of Cost sheet	2
2.5	Conventional Vs Activity based costing	1
2.6	Cost drivers and their impact on costs of production	1
2.7	Budget and Budgetary control	
2.7.1	Introduction-Meaning -objectives of budgetary control	1
2.7.2	Preliminaries for operation of budgetary control	1
2.7.3	Budget-Types of budgets and their preparation	2
2.8	Standard costing	
2.8.1	Meaning and definition-Importance	1
2.8.2	Variance analysis-calculation of material, labour and overhead variances.	1
2.8.3	Calculation of material, labour and overhead variances.	1
3.0	**Finance**	
3.1	Introduction and Definition	1
3.2	Objectives of financial management	1
3.3	Functions of finance	1
3.4	Capital Budgeting	
3.4.1	Introduction-Meaning and Definition-Importance –process of capital budgeting	1
3.4.2	Appraisal of capital budgeting decisions	1
3.4.3	Payback Period, ARR	2
3.4.4	NPV, IRR and PI methods	2

Module No.	Topic	No. of Lectures
3.5	Working capital Management	
3.5.1	Meaning and definition-Importance	1
3.5.2	Factors influencing working capital-components of working capital	2
3.5.3	Estimation of working capital requirements	2
	Total	**35**

Course Designers:

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		Category	L	T	P	Credit
14ME520	**DESIGN OF MACHINE ELEMENTS**	PC	2	0	0	2

Preamble

Design of machine elements is the process of deriving a system, component or process to meet desired needs. It is a decision-making process, in which the basic sciences and mathematics and engineering sciences are applied to convert resources optimally to meet a stated objective. Among the fundamental elements of the design process are the establishment or objectives and criterion, synthesis, analysis, construction, testing and evaluation.. Machine Elements Design deals with the creation of machine element that goes into the making of a machine as a product.

Prerequisites

- 14ME220 – Free Body Mechanics
- 14ME320 - Mechanics of Materials
- 14ME420 - Engineering Design

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the design concepts of static and fatigue strength of mechanical components	Understand
CO 2	Determine the strength of the welded, threaded and knuckle joints.	Apply
CO 3.	Design the shafts, rigid and flexible couplings parametrically for different loading conditions.	Apply
CO 4.	Design the energy absorbing mechanical components such as springs and flywheels for the specified loading conditions.	Apply
CO 5.	Design the primary components of internal combustion engines such as piston, connecting rod and crank shaft	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1.	M	M	M	L	_	_	_	_	_	_	_	_	S	_	S
CO2.	S	S	S	M	_	_	_	_	_	_	_	_	S	_	S
CO3.	S	S	S	M	_	_	_	_	_	_	_	_	S	_	S
CO4.	S	S	S	M	_	_	_	_	_	_	_	_	S	_	S
CO5.	S	S	S	M	_	_	_	_	_	_	_	_	S	_	S

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	10	10	10	10
Understand	10	10	10	10
Apply	80	80	80	80

Design Project: Students are grouped as 3 per batch. One topic for each batch will be given in the course contents and they will be submitted a detailed report for their work. The total marks for project evaluation is 100 marks and it is converted into 20 marks.

Evaluation pattern for Design project

S. No	Description	Marks
1	Selection of Design Concept	20
2	Design Procedure and Selection of best design concept	50
3	Final report	30
	Total Marks	**100**

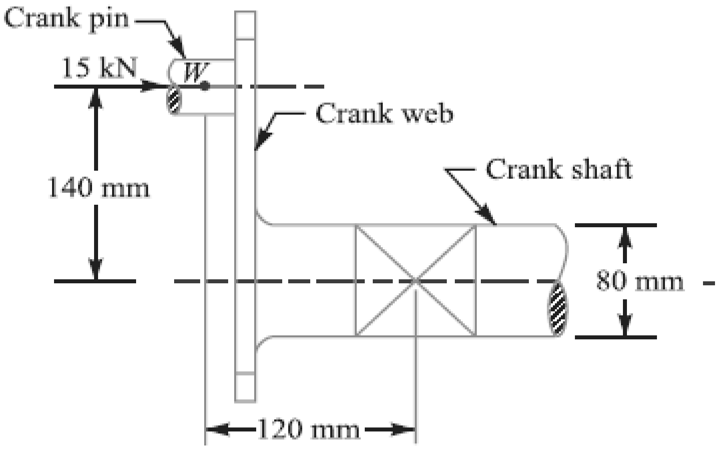
Marks allocation

S. No	Description	Marks
1	Terminal Theory Examinations	50
2	Continuous assessment marks	30
3	Design Project	20
	Total Marks	**100**

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. An overhang crank with pin and shaft is shown in figure. A tangential load of 15 kN acts on the crank pin. Determine the maximum principal stress and the maximum shear stress at the centre of the crankshaft bearing.



2. The load on a bolt consists of an axial pull of 10 kN together with a transverseshear force of 5 kN. Find the diameter of bolt required according to
   1. Maximum principal stress theory.
   2. Maximum shear stress theory.
   3. Maximum principal strain theory.
   4. Maximum strain energy theory.
   5. Maximum distortion energy theory.

3. Determine the diameter of a circular rod made of ductile material with a fatigue strength (complete stress reversal), σ_{-1} = 265 MPa and a tensile yield strength of 350 MPa. The member is subjected to a varying axial load from Wmin = – 300 × 10^3 N to Wmax = 700 × 10^3 N and has a stress concentration factor = 1.8. Use factor of safety as 2.0.

Course Outcome 2 (CO2):

1. A 125 × 95 × 10 mm angle is joined to a frame by two parallel fillet welds along the edges of 150 mm leg. The angle is subjected to a tensile load of 180 kN. Find the lengths of weld if the permissible static load per mm weld length is 430 N.

2. The pull in the tie rod of an iron roof truss is 50 kN. Design a suitable adjustable screwed joint. The permissible stresses are 75 MPa in tension, 37.5MPa in shear and 90 MPa in crushing.
3. Design a knuckle joint to connect two mild steel bars under a tensile load of 25 kN. The allowable stresses are 65 MPa in tension, 50 MPa in shear and 83 MPa in crushing.

Course Outcome 3 (CO3):

1) A solid circular shaft is subjected to a bending moment of 3000 N-m and a torque of 10 000 N-m. The shaft is made of 45 C 8 steel having ultimate tensile stress of 700 MPa and a ultimate shear stress of 500 MPa. Assuming a factor of safety as 6, determine the diameter of the shaft.

2)A hollow shaft is subjected to a maximum torque of 1.5 kN-m and a maximum bending moment of 3 kN-m. It is subjected, at the same time, to an axial load of 10 kN. Assume that the load is applied gradually and the ratio of the inner diameter to the outer diameter is 0.5. If the outer diameter of the shaft is 80 mm, find the shear stress induced in the shaft.

3)Design a bushed-pin type flexible coupling for connecting a motor shaft to a pump shaft for the following service conditions :Power to be transmitted = 40 kW ; speed of the motor shaft = 1000 r.p.m.; diameter of the motor shaft = 50 mm ; diameter of the pump shaft = 45 mm. The bearing pressure in the rubber bush and allowable stress in the pins are to be limited to 0.45 N/mm^2 and 25 MPa respectively.

Course Outcome 4 (CO4):

1) Design a close coiled helical compression spring for a service load ranging from 2250 N to 2750 N. The axial deflection of the spring for the load range is 6 mm. Assume a spring index of 5. The permissible shear stress intensity is 420 MPa and modulus of rigidity,G = 84 kN/mm^2.Neglect the effect of stress concentration.

2) A truck spring has 12 number of leaves, two of which are full length leaves. The spring supports are 1.05 m apart and the central band is 85 mm wide. The central load is to be 5.4 kN with a permissible stress of 280 MPa. Determine the thickness and width of the steel spring leaves. The ratio of the total depth to the width of the spring is 3. Also determine the deflection of the spring.

3) A multi-cylinder engine is to run at a speed of 500 r.p.m. On drawing the crank effort diagram to scale 1 mm = 2500 N-m and 1 mm = 3º, the areas above and below the mean torque line are in mm^2 as below:

+ 160, – 172, + 168, – 191, + 197, – 162.The speed is to be kept within ± 1% of the mean speed of the engine. Design a suitable rim type C.I. flywheel for the above engine. Assume rim width as twice the thickness and the overhang of the flywheel from the centre of the nearest bearing as 1.2 metres. The permissible stresses for the rim in tension are 6 MPa and those for shaft and key in shear are 42 MPa. The allowable stress for the arm is 14 MPa.

Course Outcome 5 (CO5):

1) Determine the dimensions of an *I*-section connecting rod for a petrol engine from the following data: Diameter of the piston = 110 mm; Mass of the reciprocating parts = 2 kg; Length of the connecting rod from centre to centre = 325 mm; Stroke length = 150 mm; R.P.M. = 1500 with possible over speed of 2500; Compression ratio = 4: 1; Maximum explosion pressure = 2.5 N/mm^2.

2) Design a side crankshaft for a 500 mm × 600 mm gas engine. The weight of the flywheel is 80 kN and the explosion pressure is 2.5 N/mm^2. The gas pressure at maximum torque is 0.9 N/mm^2 when the crank angle is 30º. The connecting rod is 4.5 times the crank radius.

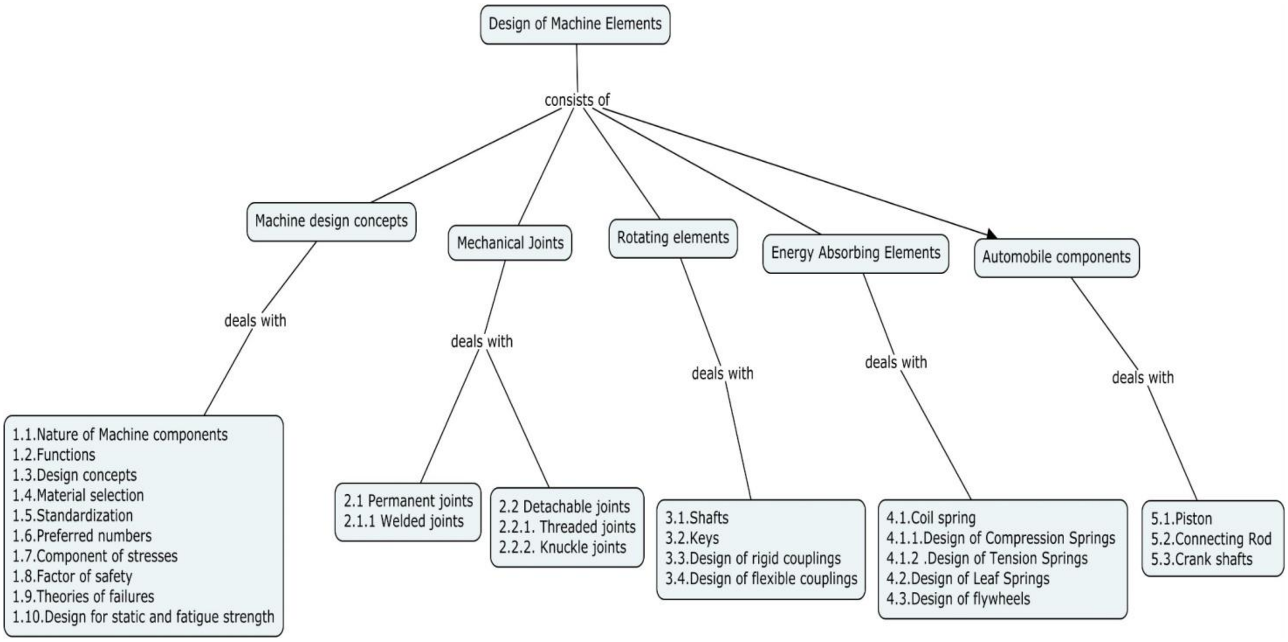
3) Design a Connecting Rod for a Steam Engine to the following specifications

Steam Pressure: 0.6N/mm^2

Bore of the Cylinder:	300 mm
Stroke of the Piston:	600 mm
Length of Connecting Rod	1500 mm
Speed of the Engine:	450 rpm

Select suitable Material.

Concept Map



Machine Design Concepts: Nature of Machine Elements- Design concepts- Factors influencing Design -Selection of materials - Standardization – Preferred Numbers - Component of stresses, ultimate and allowable stress, Factor of safety Theories of failure - Design for static and fatigue strength. **Joints:** Welded Joints – Lap and Butt Joints – Design of Welded Joints with all types loading – Design of Detachable joints: Threaded Joints and Knuckle joint. **Rotating Elements and Couplings:** Shafts subjected to Twisting moment, Combined Bending and twisting moment with axial loads - Design of Keys for shafts - Design of couplings – Rigid couplings and Flexible couplings. **Energy Absorbing Elements:** Coil Springs: Tension Springs -Compression Springs –Leaf Springs - Flywheels. **Automobile Components**: Piston - Connecting rod with I section and Circular section - Crank shafts: Side crank and Centre crank.

Text Book

1. Joseph Edward Shigley and Charles R. Misucke, "**Mechanical Engineering Design**", Tenth Edition, Tata McGraw Hill, 2015.
2. Robert L. Norton, "**Machine Design: An Integrated Approach**", Third Edition", Prentice Hall, 2005.
3. V.B. Bhandari, **"Design of Machine Elements", Third Edition,** Tata McGraw Hill, 2010.

Reference Books

1. Sundarajamoorthy T.V. and Shanmugam. N, "**Machine Design**", Anuradha Publications, 2000.
2. K. Ganesh Babu, K. Srithar, "**Design of Machine Elements"**, Mc Graw Hill Education, 2009.

3. Hall, Holowenko and Laughin, “**Theory and Problems of Machine Design**”, Tata McGraw Hill Company, 2002.
4. Sharma P. C, and Agarwal D.K, “**Machine design**”, S.K. Kataria and Sons, New Delhi, 2000.
5. M. F. Spotts, T. E. Shoup, “**Design of Machine Elements”**, Eighth Edition” Pearson Education Asia, 2006.
6. PSG, “**Design Data Book**”, 2012

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Machine design concepts**	
1.1	Nature of machine elements	
1.2	Functions of machine elements	
1.3	Machine design concepts	1
1.4	Selection of materials	
1.5	Standardization – Preferred Numbers ,Components of stresses- Ultimate and allowable stress- Factor of safety	1
1.6	Principal Stresses	1
1.7	Theories of failure	
1.8	Design for static strength	1
1.9	Design for fatigue strength	1
	Tutorial	1
2.	**Mechanical Joints**	
2.1	Permanent joints	
2.1.1	Design of welded Joints Lap and Butt Joints – Design of Welded Joints with all types of loading	1
2.2	Detachable joints	
2.2.1	Design of threaded Joints - Foundation Bolts	1
2.2.2	Design of knuckle joint	1
	Tutorial	1
3	**Rotating Elements and Couplings**	
3.1	Design of Shafts	1
3.1.1	Shafts subjected to Twisting moment and Combined Bending and Twisting moment	1
3.1.2	Shafts subjected to Combined Bending and Twisting moment with axial loads	1
3.2	Design of Keys	1
3.3	Design of rigid couplings	1
3.4	Design of flexible couplings	
	Tutorial	1
4	**Energy Absorbing Elements**	
4.1	Coil spring	
4.1.1	Design of Compression Springs	1
4.1.2	Design of Tension Springs	
4.2	Design of Leaf Springs	1
4.3	Design of flywheels	1
	Tutorial	1

5.	**Automobile Components**	
5.1	Design of Piston	1
5.2	Design of Connecting Rod - I section and Circular section -	1
5.3	Design of Crank shafts- Side crank -Centre crank-	1
	Tutorial	1
	Total	**24**

Course Designers

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14ME530	MANUFACTURING SYSTEMS AND AUTOMATION	Category	L	T	P	Credit
		PC	3	0	0	3

Preamble

Manufacturing Systems and Automation deals with different manufacturing systems and its programming methods. It also includes fundamentals of assembly system, automated material handling system, inspection system along with its system of controls. Further, it deals with the working principles of manufacturing support systems and the simulation technique to build manufacturing environment.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1	Identify the different manufacturing systems, programming techniques and interfacing methods	Apply
CO 2	Construct assembly line using line balancing algorithms	Apply
CO 3	Explain the transportation and storage system for material handling	Understand
CO 4.	Explain the principles of part identification and inspection system	Understand
CO 5.	Construct ladder logic program for given manufacturing process	Apply
CO 6.	Model given manufacturing system using GPSS coding.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	M	L	L	L	_	_	L	_	_	_	_	M	_	_
CO2.	S	M	L	L	L	_	_	L	_	_	_	_	M	_	_
CO3.	M	L	_	_	_	_	_	L	_	_	_	_	_	_	_
CO4.	M	L	_	_	_	_	_	L	_	_	_	_	L	_	_
CO5.	S	M	L	L	L	_	_	L	_	_	_	_	M	_	_
CO6.	S	M	L	L	L	_	_	L	_	_	_	_	_	_	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	**10**	**20**	**10**	**10**
Understand	**20**	**60**	**40**	**40**
Apply	**70**	**20**	**50**	**50**
Analyse	**-**	**-**	**-**	**-**
Evaluate	**-**	**-**	**-**	**-**

Course Level Assessment Questions

Course Outcome 1 (CO1):
1. Write a CNC program for turning the part made up of aluminum material which has step and curvature features with all necessary calculations.
2. Discuss about the planning and implementation issues.
3. Explain the data framing technique with an example of 8 bit data along with different possible data communication errors.

Course Outcome 2 (CO2):
1. Define the term minimum rational work element.
2. Illustrate the principle of line balancing using Kilbridge and Wester method with at least 8 minimum rational work elements.
3. Mention the advantages and limitations of computerized line balancing technique.

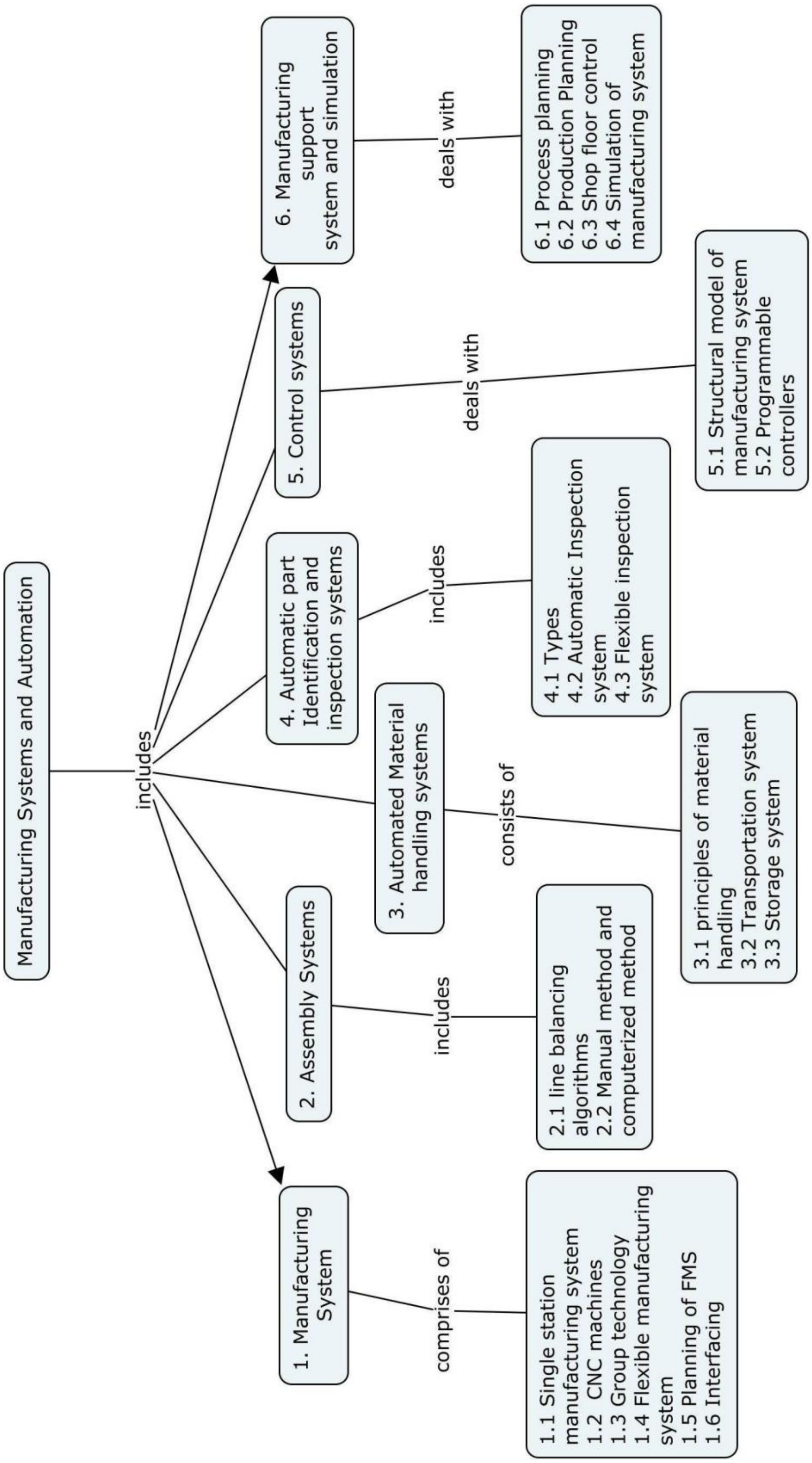
Course Outcome 3 (CO3):
1. Discuss the important factor that influences the design or selection of material handling system.
2. Summarize the different features of material handling systems.
3. Classify the different categories of AS/RS with its brief description.

Course Outcome 4 (CO4):
1. Describe the working principle of linear bar-coding system with simple example.
2. Classify the different techniques used to identify the parts in the assembly system.
3. Write short note on flexible inspection system.

Course Outcome 5 (CO5):
1. Explain in detail about the Structural model of manufacturing system?
2. Explain in detail about Sequence and programmable controllers?
3. Write a ladder logic program for a given manufacturing situation.

Course Outcome 6 (CO6):
1. Illustrate the working principle of MRP with suitable example.
2. Write a GPSS code to simulate a manufacturing environment of your choice.
3. Explain the retrieval type CAPP and compare it with generative type CAPP. Also, give your comment.

Concept Map


Manufacturing Systems and Automation
includes
1. Manufacturing System
comprises of
1.1 Single station manufacturing system
1.2 CNC machines
1.3 Group technology
1.4 Flexible manufacturing system
1.5 Planning of FMS
1.6 Interfacing
2. Assembly Systems
includes
2.1 line balancing algorithms
2.2 Manual method and computerized method
3. Automated Material handling systems
consists of
3.1 principles of material handling
3.2 Transportation system
3.3 Storage system
4. Automatic part Identification and inspection systems
includes
4.1 Types
4.2 Automatic Inspection system
4.3 Flexible inspection system
5. Control systems
deals with
5.1 Structural model of manufacturing system
5.2 Programmable controllers
6. Manufacturing support system and simulation
deals with
6.1 Process planning
6.2 Production Planning
6.3 Shop floor control
6.4 Simulation of manufacturing system

Syllabus

Manufacturing systems: Single station manufacturing system - Single Station Manned cell, Single station automated cell, CNC machines - classification, programming, Group technology– Part classification and coding, cellular manufacturing, production flow analysis. Flexible manufacturing system – Types, Functions, FMS layout, computer control and planning of FMS, Interfacing: Data framing, Serial and parallel data communication. **Assembly systems:** Classification, line balancing algorithms – manual method and computerized method. **Automated Material handling system:** Consideration of material handling, principles of material handling. Transportation system - Automated guided vehicle, conveyor system and analysis of transportation system. Storage system - Automated Storage and Retrieval system and Carousel storage system. **Automatic part Identification and inspection system:** Types - Bar code technique, RF identification system, Magnetic stripes and Optical character recognition. Automatic Inspection system - Contact versus Noncontact Inspection Techniques, Coordinate Measuring Machine – operation, Flexible inspection system and Machine vision. **Control systems:** Structural model of manufacturing system, steady state optimal control and adaptive control. Programmable controllers: logic control and sequencing, logic control elements, sequencing elements, ladder logic diagrams. **Manufacturing support system and simulation:** Process planning–Computer Aided Process planning, types. Production Planning- Master production schedule, bill of material, inventory record, working of Material Requirements Planning and its outputs. Shop floor control – phases of shop floor control, factory data collection system. Simulation - classification of simulation language, Building of simulation models using General Purpose Simulation System (GPSS)–simulation of manufacturing shop and super market using GPSS.

Text Book

1. Mikell P.Groover, "**Automation, Production systems and Computer Integrated Manufacturing**" PHI Learning Pvt. Ltd., 3rd Edition, 2009.

Reference Books

1. Vajpayee S. Kant, "**Principles of Computer Integrated Manufacturing**", Prentice Hall of India Learning, 2009.
2. P.M. Agarwal and V.J.Patel, "**CNC Fundamentals and Programming**", Charotar Publishing House Pvt. Ltd., Second Edition, 2014.
3. Hindustan Machine Tool Ltd., "**Mechatronics**", Tata McGraw Hill, 2000.
4. Jerry Banks and Barry L. Nelson, "**Discrete Event System Stimulation**", Pearson Education, 2006.
5. H.K. Shivanand and M.M. Benal, "**Flexible Manufacturing System**", New Age International Pvt Ltd Publishers, 2006.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.	Manufacturing systems	
1.1	Single station manufacturing system - Single Station Manned cell, Single station automated cell	1
1.2	CNC machines - classification, programming, safety aspects of CNC machines	3
1.3	Group technology– Part classification and coding, Cellular manufacturing, production flow analysis	3
1.4	Flexible manufacturing system – Types, Functions, FMS layout, computer control	2
1.5	planning of FMS	1
1.6	Interfacing: Data framing, Serial and parallel data communication	1

Module No.	Topic	No. of Lectures
2.	Assembly systems	
2.1	Classification, line balancing algorithms	1
2.2	Manual method and computerized method	2
3.	Automated Material handling system	
3.1	Consideration of material handling, principles of material handling.	1
3.2	Transportation system - Automated guided vehicle, conveyor system and analysis of transportation system.	2
3.3	Storage system - Automated Storage and Retrieval system and Carousel storage system.	2
4.	Automatic part Identification and inspection system	
4.1	Types - Bar code technique, RF identification system, Magnetic stripes and Optical character recognition.	2
4.2	Automatic Inspection system - Contact versus Noncontact Inspection Techniques, Coordinate Measuring Machine	2
4.3	Flexible inspection system and Machine vision	2
5.	Control systems	
5.1	Structural model of manufacturing system, steady state optimal control and adaptive control.	1
5.2	Programmable controllers: logic control and sequencing, logic control elements, sequencing elements, ladder logic diagrams.	2
6.	Manufacturing support system and simulation	
6.1	Process planning–Computer Aided Process planning, types.	1
6.2	Production Planning- Master production schedule, bill of material, inventory record, working of Material Requirements Planning and its outputs.	3
6.3	Shop floor control – phases of shop floor control, factory data collection system.	2
6.4	Simulation - classification of simulation language, Building of simulation models using General Purpose Simulation System – simulation of manufacturing shop and super market using GPSS	3
	Total	**37**

Course Designers:

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14ME540 HEAT AND MASS TRANSFER

Category	L	T	P	Credit
PC	2	2	0	3

Preamble

Heat and mass are two different forms of energy. Heat is the form of energy that can be transferred from one system to another as a result of temperature difference. The science that deals with the determination of the rates of heat energy transfers is **Heat transfer**. In engineering practice, an understanding of the mechanisms of heat transfer is becoming increasingly important since heat transfer plays a crucial role in the design of vehicles, power plants, refrigerators, electronic devices, buildings, and bridges, among other things. **Mass transfer** refers to the movement of a chemical species from a high concentration region toward a lower concentration one relative to the other chemical species present in the medium. Mechanisms of heat and mass transfer are analogous to each other. The objectives of this course are to understand the basic principles of heat transfer, to develop an intuitive understanding of the heat transfer mechanisms and apply the knowledge to analyse heat transfer systems in real world engineering applications and to understand the principle and mechanisms of mass transfer with little effort by using the knowledge of heat transfer.

Prerequisite

- 14PH120 - Engineering Physics
- 14ME210 - Engineering Calculus
- 14ME240 - Thermodynamics
- 14ME340 - Fluid Mechanics

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Determine the temperature variations and rate of heat flow in conduction heat transfer problems	Apply
CO 2.	Determine the temperature variations and rate of heat flow in convection heat transfer problems	Apply
CO 3.	Determine the temperature variations and rate of heat flow in radiation heat transfer problems	Apply
CO 4.	Determine the size and heat transfer rate of heat exchangers using LMTD and NTU method	Apply
CO 5.	Explain the principles of heat transfer with phase change and Determine the rate of diffusion and mass transfer coefficient in mass transfer problems	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	M	_	S	_	_	_	_	_	_	_	_	L	M	L
CO2.	S	M	_	S	_	_	_	_	_	_	_	_	L	M	L
CO3.	S	M	_	S	_	_	_	_	_	_	_	_	L	M	L
CO4.	S	M	_	S	_	_	_	_	_	_	_	_	L	M	L
CO5.	S	M	_	S	_	_	_	_	_	_	_	_	L	M	L

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	10	10	10	10
Understand	40	40	40	40
Apply	50	50	50	50
Analyse	--	--	--	--
Evaluate	--	--	--	--
Create	--	--	--	--

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. A pipe is insulated to reduce the heat loss from it. However, measurements indicate that the rate of heat loss has increased instead of having decreased. Can the measurement be right?
2. Starting with energy balance equation derive the three dimensional, steady state heat conduction equation with heat generation.
3. A laboratory furnace wall is constructed of 0.2 m thick fire clay bricks (k= 1 W/m K). The wall is covered on the outer surface with a thick layer of insulating material (k = 0.07 W/m K). The furnace inner brick surface is at 1250 K and the outer surface of the insulating material is at 32^0C. If the maximum allowable heat transfer rate through the wall of the furnace is 900 W/m^2, how thick must the insulating layer be?
4. A long cylinder of radius 150 mm and at an initial uniform temperature of 530^0 C is suddenly exposed to an environment at 30^0 C. The convection heat transfer coefficient between the surface of the cylinder and the environment is 380 W/m^2 K. The thermal conductivity and thermal diffusivity of the cylinder material are 200 W/ m K and 8.5 x 10^{-5} m^2/s respectively. Determine the temperature at a radius of 120 mm after the time duration of 265 seconds.
5. One end of long rod of diameter 10 mm is inserted into a furnace. The temperatures measured at two points **A** and **B**, 40 mm apart gave 265^0 C and 150^0 C respectively. If the convection coefficient is 35 W/m^2 K, when exposed to air at 25^0 C, determine the conductivity of the material.

Course Outcome 2 (CO2):

1. Give the physical significance of Prandtl number.
2. Explain the development of velocity and thermal boundary layer for flow over a flat plate.
3. A flat plate 1 m wide and 1.5 m long is to be maintained at 90^oC to air with a free stream temperature of 10^oC. Analyze the velocity at which air must flow over the flat plate so that the rate of heat loss from the plate is 3.75 kW.
4. A person tries to keep cool on a hot summer day by turning a fan on and exposing his entire body to air flow. The air temperature is 25^0 C and the fan is blowing air at a velocity of 5 m/s. If the person does light work and generates heat at a rate of 100 W. By suitable heat transfer analysis, determine the temperature of the outer surface of the person. The average human body can be treated as a 0.3 m diameter cylinder with an exposed surface area of 1.6 m^2. Take the property values at free stream temperature of 25^0 C.
5. Air at 2 atm and 200^0 C is heated as it flows through a tube with a diameter of 2.54 cm at a velocity of 10 m/s. Calculate the heat transfer per unit length of tube if a constant heat flux condition is maintained at the wall and the wall temperature is 20^0 C above air

temperature all along the length of the tube. How much would the bulk temperature increase over a 3 m length of the tube? Take ρ = 1.493 kg/m^3; Pr = 0.681; μ =2.57 x 10^{-5} kg/ ms and k = 0.0386 W/m K.

Course Outcome 3 (CO3):

1. What is a black body?
2. Show that, the heat exchange between two parallel non black bodies is given by,

$$Q_{1-2} = \frac{E_{b,1} - E_{b,2}}{\frac{1-\varepsilon_1}{A_1\varepsilon_1} + \frac{1}{A_1F_{12}} + \frac{1-\varepsilon_2}{A_2\varepsilon_2}}$$

3. Two very large parallel plates are maintained at uniform temperature of T_1 = 600 K and T_2 = 400 K both having area of 1 m^2. Which case of following emissivity pair is better to give better heat transfer rate? Comment on the results.
   (i) $\varepsilon_1 = 0.5$ and $\varepsilon_2 = 0.9$ and (ii) $\varepsilon_1 = 0.9$ and $\varepsilon_2 = 0.5$
4. Two parallel plates 0.5 by 1 m spared 1 m apart. One plate is maintained at 1000^0 C and the other at 600^0 C. The emissivities of the plates are 0.2 and 0.5 respectively. The plates are located in a very large room, the walls of which are maintained at 30^0 C. The plates exchange heat with each other and with the room, but only the plate surface facing each other are to be considered in the analysis. Find the net transfer to each plate and to the room.
5. Two square plates, each 1 m by 2 m are perpendicular to each other. The hot plate is at T_1 = 800 K and has an emissivity ε_1 = 0.8. The colder plate is at T_2 = 600 K and also an emissivity, ε_2 = 0.5. (i) What is the heat transfer rate by radiation if the common side is 2 m?; (ii) Compare result with (i), by changing the common side as 1 m; and (iii) What could be the change of result of (i), if both the emissivities are mutually exchanged as ε_1 = 0.5 and ε_2 = 0.8.

Course Outcome 4 (CO4):

1. Obtain an expression for LMTD of a parallel flow heat exchanger.
2. Derive effectiveness, ε, for a parallel flow heat exchanger by assuming cold fluid is minimum.
3. Water at 68^0 C is cooled using air in a cross flow heat exchanger, the air entering at 30^0 C. The flow rate of water is 10 kg/s and that of air is 60 kg/s. The overall heat transfer coefficient is 2050 W/m^2 K. The area is 45 m^2. Determine the exit temperatures of the fluid.
4. A counter flow heat exchanger is employed to cool 0.55 kg/s (C_p = 2.45 kJ/kg K) of oil from 115^0 C to 40^0 C by the use of water. The inlet and outlet temperatures of cooling water are 15^0 C and 75^0 C respectively. The overall heat transfer coefficient is expected to be 1450 W/ m^2 K. Using the NTU method, calculate the following: (i) the mass flow rate of water; (ii) the effectiveness of the heat exchanger and (iii) the surface area required.
5. It is desired to heat 230 kg/h of water (C = 4.18 kJ/kg K) from 35^0 C to 95^0 C with oil (C = 2.1 kJ/kg K) having an initial temperature of 180^0 C. The mass flow of oil is also 230 kg/h. Two double pipe counter flow heat exchangers are available:
   Exchanger 1: U = 600 W/m^2 K, A = 0.47 m^2
   Exchanger 2: U = 300 W/m^2 K, A = 0.94 m^2
   Which exchanger should be used? Justify your answer.

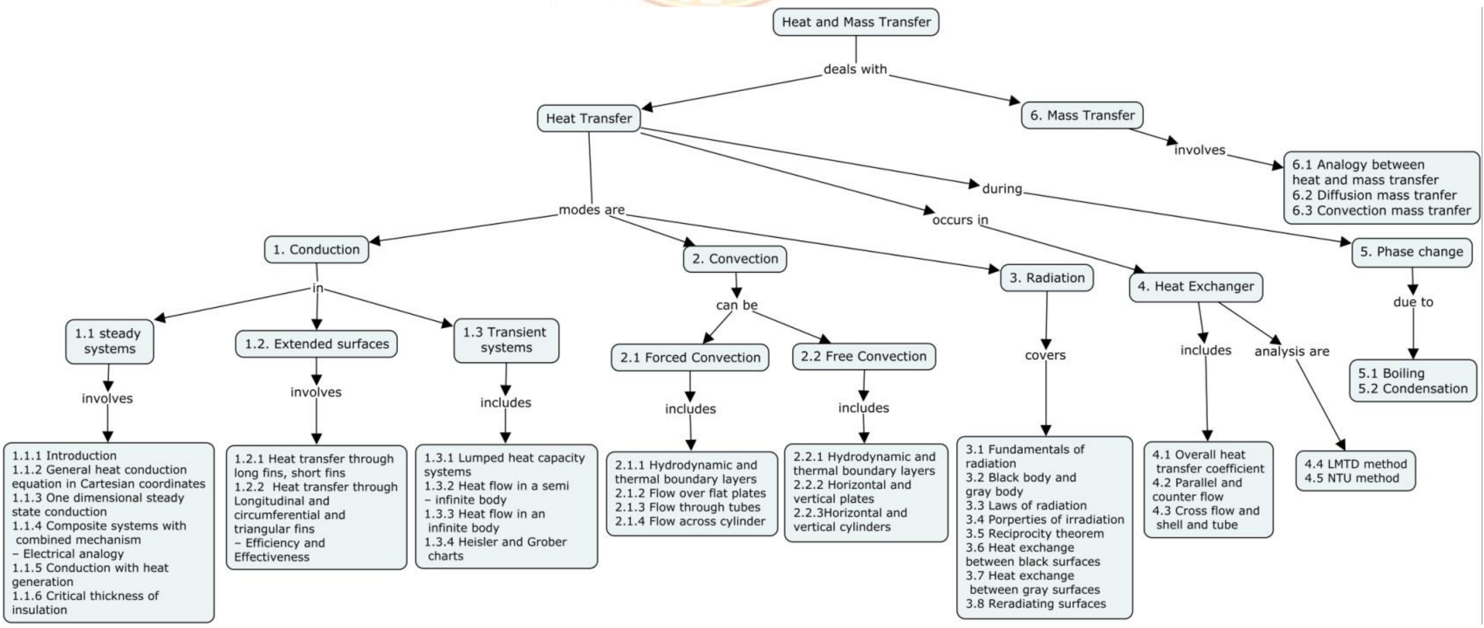
Course Outcome 5 (CO5):

1. What is the difference between boiling and evaporation?
2. What is pool boiling?
3. Draw the boiling curve for water and explain the different regimes.
4. Draw the typical velocity and temperature profiles of the condensate.
5. Dropwise condensation is the preferred mode of condensation in heat transfer applications. Why?

Course Outcome 6 (CO6):

1. State Fick's law of mass diffusion.
2. Discuss the analogy between heat and mass transfer.
3. Pressurized hydrogen gas is stored at 358 K in a 4.8 m outer-diameter spherical container made of nickel. The shell of the container is 6 cm thick. The molar concentration of hydrogen in the nickel at the inner surface is determined to be 0.087 kmol/m3. The concentration of hydrogen in the nickel at the outer surface is negligible. Determine the mass flow rate of hydrogen by diffusion through the nickel container.
4. Estimate the diffusion rate of water from the bottom of a test tube 10 mm in diameter and 150 mm long into dry atmospheric air at 25^{o}C.
5. Consider a circular pipe of inner diameter D = 0.015 m whose inner surface is covered with a layer of liquid water as a result of condensation (Fig.). In order to dry the pipe, air at 300 K and 1 atm is forced to flow through it with an average velocity of 1.2 m/s. Using the analogy between heat and mass transfer, determine the mass transfer coefficient inside the pipe for fully developed flow.

Concept Map



Syllabus

Conduction

Steady systems

Introduction, Modes of heat transfer, Fourier law of conduction, General heat conduction equation in Cartesian co-ordinates. One dimensional steady state heat conduction -plane wall, hollow cylinder and sphere, numerical problems. Composite systems with combined mechanism, electrical analogy, critical thickness of insulation, numerical problems. Conduction with inner heat sources - plane wall and solid cylinders, numerical problems.

Extended surfaces
Introduction, Heat transfer through long fins, short fins with negligible heat loss from the fin tip (insulated fin tip) and convection from fin tip- longitudinal and circumferential and triangular fins - efficiency and effectiveness, numerical problems.
Transient systems
Introduction, Lumped heat capacity systems, numerical problems. Heat flow in a semi - infinite body- initial temperature with suddenly immersed in liquid and convection boundary conditions, numerical problems.- Heat flow in an infinite body - Heisler and Grober charts, numerical problems.
Convection
Introduction, Forced convection- Hydrodynamic and thermal boundary layers - Flow over flat plates- laminar boundary layer thickness in terms of Reynolds number - Flow through tubes, Flow across cylinder- Nusselt equations, numerical problems.
Free convection - Hydrodynamic and thermal boundary layers, Horizontal and vertical plates, Horizontal and vertical cylinders - Nusselt equation, numerical problems.
Radiation
Introduction, Wave theory and quantum theory- concepts of black body and gray body - Stefan - Boltzman law - emissive power – monochromatic emissive power - Weins law - Kirchoff's law- numerical problems. Radiative properties, Emissivity, absorptivity, reflectivity, transmissivity, radiosity - Radiation shape factor - Reciprocity theorem. Heat exchange between black and gray surfaces, numerical problems - Reradiating surfaces, numerical problems.
Heat exchangers
Classification- overall heat transfer co-efficient- fouling factor-parallel and counter flow heat exchangers – cross flow and shell tube heat exchangers - LMTD method, numerical problems -NTU method, numerical problems.
Phase change heat transfer
Boiling -Pool boiling and flow boiling- Condensation-drop wise and film wise.
Mass transfer
Introduction to mass transfer - Fick's law of diffusion, Analogy between heat, mass and momentum transfer, numerical problems, Diffusion mass transfer- diffusion coefficient, numerical problems, Mass transfer in convection- mass transfer coefficient, numerical problems

Text Books

1. Yunus A.Cengel, "**Heat and Mass Transfer: fundamentals and applications**", Mc Graw Hill, 2010.

Reference Books

1. Holman, J.P., **"Heat Transfer"**, Fourth Edition, McGraw Hill., 2010.
2. Frank P. Incropera, David P. DeWitt, Theodore L. Bergman, and Adrienne S. Lavine, "**Introduction to Heat Transfer**", John Wiley and Sons, 2010.
3. Mahesh M. Rathore, "**Engineering Heat and Mass Transfer**", University Science Press, 2006.
4. Necati Ozisik, "**Heat Transfer – a Basic Approach**", McGraw Hill, 1994.
5. Rajput, R.K., "**Heat and Mass Transfer**", S.Chand & Company Ltd, 2010.
6. Mills, A.F and Ganesan, V., "**Heat Transfer**", Pearson Education, 2009.
7. Som, S.K. "**Introduction to Heat Transfer**", PHI Learing Private Ltd, 2008.
8. Frank Kreith, Mark S. Bohn, "**Principles of Heat Transfer"**, Sixth Edition, Brooks/cole, Thomson Asia Private Ltd., Singapore, 2001.
9. Sachdeva, R.C., **"Fundamentals of Engineering Heat and Mass Transfer"**, New Age International Publishers, 2010.
10. Kothandaraman, C.P., **"Fundamentals of Heat and Mass Transfer",** Second Edition, New Age International, 2010.

Heat Transfer Data Book

Kothandaraman, C. P., "Heat and Mass Transfer Data Book", New Age International Publisher, 2014.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Conduction**	
1.1	**Steady systems**	
1.1.1	Introduction, Modes of heat transfer	1
1.1.2	Fourier law of conduction, general heat conduction equation in Cartesian co-ordinates	1
1.1.3	One dimensional steady state conduction- plane wall, hollow cylinder and sphere, numerical problems.	2
1.1.4	Composite systems with combined mechanism – electrical analogy, numerical problems.	1
1.1.5	Conduction with inner heat sources – plane wall and solid cylinders, numerical problems.	2
1.1.6	Critical thickness of insulation, numerical problems.	1
1.2	**Extended surfaces**	
1.2.1	Introduction, Heat transfer through long fins, short fins with negligible heat loss from the fin tip (insulated fin tip).	2
1.2.2	Heat transfer through extended surfaces – short fins with convection from fin tip Longitudinal and circumferential and triangular fins – efficiency and effectiveness, numerical problems.	2
1.3	**Transient systems**	
1.3.1	Introduction, Lumped heat capacity systems, numerical problems.	2
1.3.2	Heat flow in a semi – infinite body: initial temperature with suddenly immersed in liquid and convection boundary conditions, numerical problems.	1
1.3.3	Heat flow in an infinite body	1
1.3.4	Heisler and Grober charts, numerical problems.	1
2	**Convection**	
2.1	**Forced convection**	
2.1.1	Introduction, Hydrodynamic and thermal boundary layers	1
2.1.2	Flow over flat plates: Laminar boundary layer thickness in terms of Reynolds number, Nusselt equation numerical problems.	1
2.1.3	Flow through tubes - Nusselt equation, numerical problems.	1
2.1.4	Flow across cylinder- Nusselt equation, numerical problems.	1
2.2	**Free convection**	
2.2.1	Introduction, Hydrodynamic and thermal boundary layers	1
2.2.2	Horizontal and vertical plates – horizontal and vertical cylinders – Nusselt equation, numerical problems.	1
2.2.3	Horizontal and vertical cylinders – Nusselt equation, numerical problems.	1
3	**Radiation**	
3.1	Introduction, Wave theory and quantum theory	1
3.2	Concepts of black body and gray body	1

Module No.	Topic	No. of Lectures
3.3	Stefan – Boltzman law – emissive power – monochromatic emissive power – Weins law –Kirchoff's law, numerical problems.	1
3.4	Radiative properties, Emissivity, absorptivity, reflectivity, transmissivity, radiosity	2
3.5	Radiation shape factor – Reciprocity theorem	1
3.6	Heat exchange between black surfaces, numerical problems.	2
3.7	Heat exchange between gray surfaces, numerical problems.	1
3.8	Reradiating surfaces, numerical problems.	1
4	**Heat exchangers**	
4.1	Classification- overall heat transfer co-efficient- fouling factor	1
4.2	Parallel and counter flow heat exchangers	2
4.3	Cross flow and shell tube heat exchangers	1
4.4	LMTD method, numerical problems	2
4.5	NTU method, numerical problems	2
5	**Phase change heat transfer**	
5.1	Boiling –Pool boiling and flow boiling	2
5.2	Condensation-drop wise and film wise	1
6	**Mass transfer**	
6.1	Introduction to mass transfer - Fick's law of diffusion, Analogy between heat, mass and momentum transfer, numerical problems.	1
6.2	Diffusion mass transfer - diffusion coefficient, numerical problems	1
6.3	Mass transfer in convection- mass transfer coefficient, numerical problems	1
	Total	**48**

Course Designers:

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14ME550 **MECHANICAL MEASUREMENTS AND METROLOGY**

Category	L	T	P	Credit
PC	3	0	0	3

Preamble

In science and engineering, objects of interest have to be characterized by measurement and testing. Measurement is an essential activity in every branch of technology and science and it is the process of experimentally obtaining quantity values that can reasonably be attributed to a property of a body or substance. Metrology is the science of measurement. Globalization of research, development and manufacture has produced greatly increased attention to international standards of measurement. It is no longer sufficient to achieve internal consistency in measurements within a local manufacturing facility; measurements must now be able to be reproduced accurately anywhere in the world. In a time of constant and rapid technological development, it would be quite ambitious to develop and present a course that claimed to cover each and every industrial measuring type of equipment.

Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the static characteristics, standards and errors of measuring instruments	Understand
CO 2.	Design of various transducers for the measurement of motion/ strain/ force/ torque/ temperature/ pressure/ flow and level and virtual instrumentation.	Apply
CO 3.	Design of measurement methodology for linear/ angular/ surface finish/ form/roundness/ inspecting gauges / coordinated measuring machines.	Apply
CO 4.	Choose appropriate instruments for the measurement/ inspection of the specified applications	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	M	M	M	L	M	_	_	_	_	_	_	_	_	_	_
CO2.	S	M	S	M	S	_	_	_	_	_	_	_	_	_	_
CO3.	S	M	S	M	S	_	_	_	_	_	_	_	_	_	M
CO4.	S	M	S	M	S	_	_	_	_	_	_	_	_	_	M

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	40	40	40	40
Apply	40	40	40	40

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define international standard for length.
2. What are the elements of generalized measurement system?
3. Define ‘precision and ‘accuracy’.
4. Define Resolution.
5. Explain the static characteristics of a measurement system.

Course Outcome 2 (CO2):

1. Explain construction, working, merits and demerits of ultrasonic type flow meters.
2. Explain Hall Effect displacement sensor with neat diagram.
3. Discuss the semiconductor’s gauge factor.
4. Explain the temperature compensation in strain gauges.
5. Define Seebeck and Peltier effect.
6. Write the advantages of data acquisition using virtual instrumentation software.
7. A Rotameter has an effective height of 200mm, effective base diameter of 10 mm and top diameter 20mm.it has a float of diameter 10 mm, thickness 3 mm and density 2500kgm^{-3}.its discharge coefficient is .95, if water is flowing through it and the float is at 1000.00 mm height what is the rate of flow?
8. A thermometer is initially at room temperature of 23˚ C. it is immersed in an oil bath at 151˚ C. After 3 seconds it shows a reading of 95˚ c. find its time constant. After what time from the start will be thermometer read 150˚ C.

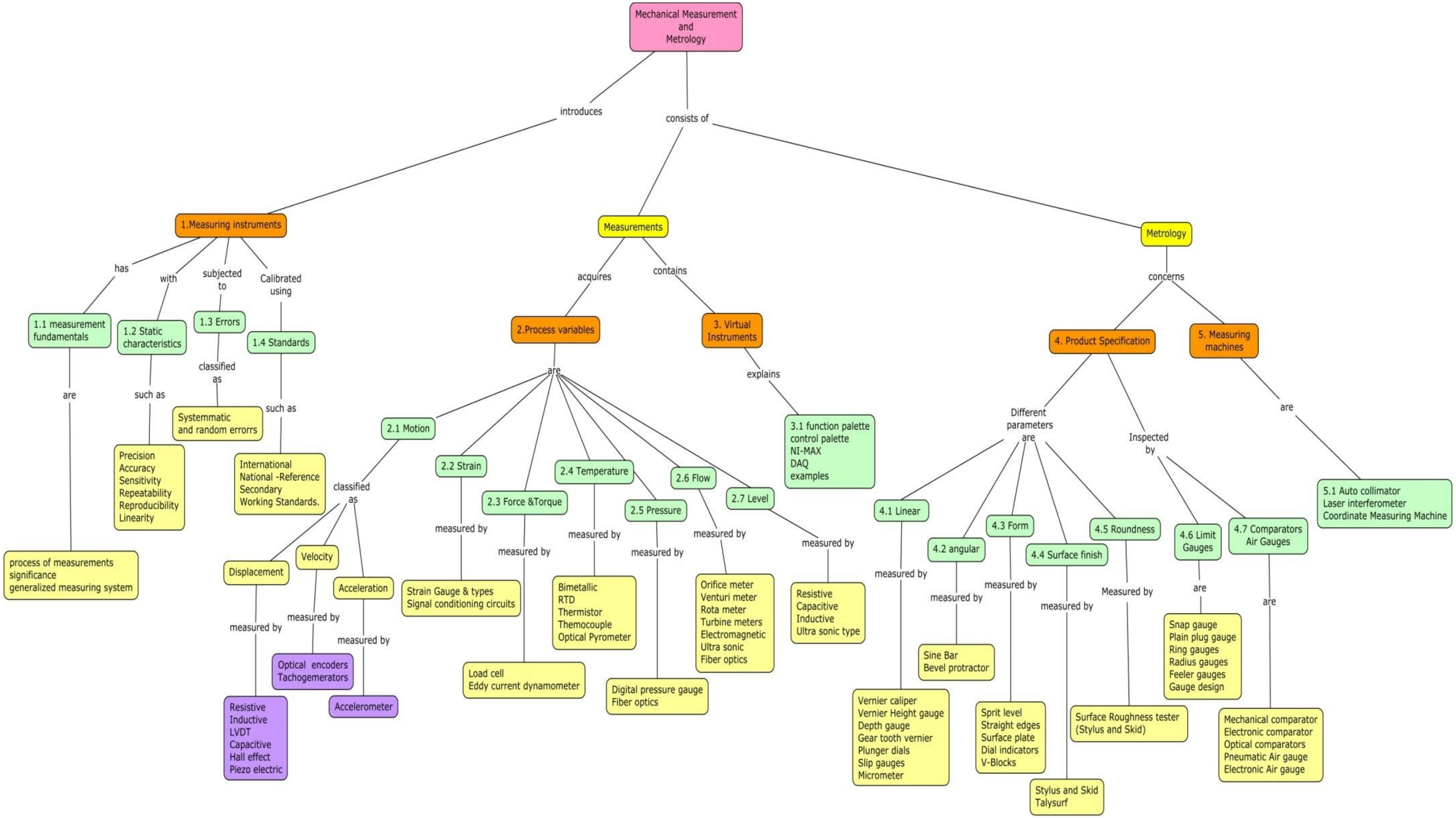
Course Outcome 3 (CO3):

1. Explain the basic principles of interferometer.
2. Write the principle of Mikrokator.
3. Explain how a pneumatic comparator works and briefly enumerate the merits of differential pneumatic comparator.
4. Describe with a sketch the principle of working of an auto-collimator.
5. Explain the working principle of pneumatic comparator with a neat sketch.
6. How are the major and minor diameters of thread measured?
7. Prepare a stack of slip – gauges for Height 34.468 mm by using a normal set of M45.
8. Design and sketch a working gauge with a GO and NO-GO ends for spindle $\frac{80.009}{80.000}$ mm and a hole of $\frac{79.866}{79.786}$ mm.

Course Outcome 4 (CO4):

1. Select the suitable measuring technique for high speed turbine. The process parameters such as angular velocity and acceleration should be recorded.
2. Select the proper measuring technique to analyze the vibration of cantilever beam. Justify your selection.
3. Select suitable instruments for measuring i) diameter of a hole up to 50 mm and ii) diameter of hole less than 5 mm.
4. Using a linear reading adjustable sprit level, suggest the suitable method of determining the parallelism of two square bearing surfaces.

Concept Map


Mechanical Measurement and Metrology
introduces
consists of
1.Measuring instruments
Measurements
Metrology
has
with
subjected to
Calibrated using
1.1 measurement fundamentals
1.2 Static characteristics
1.3 Errors
1.4 Standards
are
such as
classified as
such as
Systemmatic and random errorrs
Precision
Accuracy
Sensitivity
Repeatability
Reproducibility
Linearity
International
National -Reference
Secondary
Working Standards.
process of measurements
significance
generalized measuring system
acquires
contains
2.Process variables
3. Virtual Instruments
are
explains
3.1 function palette
control palette
NI-MAX
DAQ
examples
2.1 Motion
2.2 Strain
2.3 Force &Torque
2.4 Temperature
2.5 Pressure
2.6 Flow
2.7 Level
classified as
Displacement
Velocity
Acceleration
measured by
Resistive
Inductive
LVDT
Capacitive
Hall effect
Piezo electric
Optical encoders
Tachogemerators
Accelerometer
Strain Gauge & types
Signal conditioning circuits
Load cell
Eddy current dynamometer
Bimetallic
RTD
Thermistor
Themocouple
Optical Pyrometer
Digital pressure gauge
Fiber optics
Orifice meter
Venturi meter
Rota meter
Turbine meters
Electromagnetic
Ultra sonic
Fiber optics
Resistive
Capacitive
Inductive
Ultra sonic type
concerns
4. Product Specification
5. Measuring machines
Different parameters are
Inspected by
are
5.1 Auto collimator
Laser interferometer
Coordinate Measuring Machine
4.1 Linear
4.2 angular
4.3 Form
4.4 Surface finish
4.5 Roundness
4.6 Limit Gauges
4.7 Comparators Air Gauges
Vernier caliper
Vernier Height gauge
Depth gauge
Gear tooth vernier
Plunger dials
Slip gauges
Micrometer
Sine Bar
Bevel protractor
Sprit level
Straight edges
Surface plate
Dial indicators
V-Blocks
Stylus and Skid
Talysurf
Surface Roughness tester
(Stylus and Skid)
Snap gauge
Plain plug gauges
Ring gauges
Radius gauges
Feeler gauges
Gauge design
Mechanical comparator
Electronic comparator
Optical comparators
Pneumatic Air gauge
Electronic Air gauge

Syllabus

Measurement Fundamentals: The process of measurement- significance, generalized measuring system **Characteristics of measuring instruments:** Static characteristics - Precision, Accuracy, Sensitivity, Repeatability, Reproducibility, Linearity , **Errors**- Systematic and Random, Uncertainty of Measurement, **Standards** - National, Reference, Secondary, and Working Standards, interchangeability, Bias, Calibration, calibration of machine tools Traceability, Confidence level.

Measurement of motion: Displacement measurement- Resistive, inductive-LVDT, capacitive, piezo electric, hall effect sensor, **Speed/ Velocity measurement:** optical encoders, tacho generators. **Acceleration measurement**: Seismic type, Piezo electric type Accelerometers. **Measurement of strain:** Types of strain gauges – Gauge factor - Signal conditioning circuits for strain gauges. **Measurement of Force and Torque:** Load cells, Dynamometers: Eddy current dynamometer. **Measurement of Temperature:** Thermal Expansion: Bimetallic, Thermo Electric Methods: RTD, Thermistor, Thermo couples, Optical Pyrometers. **Measurement of Pressure:** Digital pressure gauges, fiber optic based pressure measurement. **Measurement of Flow:** Orifice meter, Venturi meter, Rota meter_ (elementary treatment only) , Turbine meters, Electromagnetic flow meters, ultra sonic flow meters, fiber optic based flow meter. **Measurement of Level:** Resistive, capacitive, inductive and ultra sonic type. **Virtual instrumentation:** introduction, function palette, control palette, NI-MAX, DAQ, examples. **Linear Measurement:** Usage, Internal/ External calipers, Vernier caliper, Vernier Height gauge, Depth gauge, Gear tooth vernier, plunger dials, Slip gauges, Inside / Outside Micrometer.

Angular Measurement: Sine Bar, Bevel protractor. Form Measurement: Sprit level, Straight edges, Surface plate, Dial indicators for squareness, V-Blocks, Measurement of major diameter, minor diameter, flank angle, pitch and effective diameter of screw thread.

Surface finish Measurement: Surface Roughness, Symbols, sample length, cut off cutoff length, Roughness comparison as per specimen, R_a, R_z, R_q, R_t, R_p, R_v - Principle and operation of stylus probe instruments. **Inspection using gauges:** Types- limit gauges, Snap gauge, Plain plug gauge, ring gauges, Radius gauges, Feeler gauges - Gauge design. **Comparator** - Mechanical comparator, Electronic comparator, Optical comparators, Pneumatic Air gauge, Electronic Air gauge. **Roundness tester**- Surface Roughness tester (Stylus and Skid). **Measuring Machines:** Auto collimator, Laser interferometer, Coordinate measuring machine (CMM).

Text Book

1. Anand K Bewoor and Vinay A Kulkarni, “**Metrology and Measurement**”, Tata McGraw Hill, 2009.

Reference Books

1. Ernest O Doeblin, “**Measurement Systems Application and Design**”, Tata McGraw Hill Fifth Edition, 2008.
2. Sabrie Solomon, “**Sensors and control systems in manufacturing**”, McGraw Hill International Editions, 2009.
3. Galyer.J.F.W. Shotbolt, C.R., “**Metrology for Engineers**”, ELBS with Casell Ltd., UK, Fifth Edition, 1990.
4. Sanjay Gupta and Joseph John**, “Virtual Instrumentation Using LabVIEW”**, Tata McGraw-Hill Publishing Company Limited, 2005.
5. Rajput R.K., “**Mechanical Measurements and Instrumentation**”, Kataris & sons Publishers, 2009.
6. Singh S.K., “**Industrial Instrumentation and Control**”, Tata McGraw Hill Edition, 2003.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Measuring instruments**	
1.1	Measurement fundamentals: process of measurements- significance, generalized measuring system	1
1.2	Static characteristics –Precision, Accuracy, Sensitivity, Repeatability, Reproducibility, Linearity	2
1.3	Errors- Systematic and Random, Uncertainty of Measurement	1
1.4	Standards – National, Reference, Secondary, and Working Standards, interchangeability, Bias, Calibration, calibration of machine tools, Traceability, Confidence level	1
2	**Measurement of Process Variables**	
2.1	Measurement of motion	1
2.1.1	Displacement Measurement: Resistive, inductive-LVDT, capacitive, piezo electric, hall effect sensor	2
2.1.2	Speed/velocity measurement: optical encoders, tacho generators	1
2.1.3	Acceleration measurement: Seismic type, piezo electric type accelerometers.	1
2.2	Measurement of strain: Types of strain gauges - Gauge factor - Signal conditioning circuits for strain gauges	1
2.3	Measurement of Force and Torque: Load cells, Dynamometers: Eddy current dynamometer.	1
2.4	Measurement of temperature: Thermal expansion- Bimetallic, Thermo electric methods- RTD, Thermistor	2
2.4.1	Thermo couples, Optical Pyrometers	1
2.5, 2.6	Measurement of Pressure: Digital pressure gauges, fiber optic based pressure measurement. Measurement of Flow: Orifice meter, venturi meter, rota meter	1
2.6.1	Turbine meters, Electromagnetic flow meters	1
2.6.2	Ultra sonic flow meters, fiber optic based flow meter	1
2.7	Measurement of Level: Resistive, capacitive, inductive and ultra sonic type	2
3	**Virtual instrumentation**: introduction, function palette, control palette, NI-MAX, DAQ, examples	2
4	**Measurement of Product Specifications**	
4.1	Linear Measurements: Usage, Internal/ External calipers, Vernier caliper, Vernier Height gauge, Depth gauge, Gear tooth vernier, plunger dials, Slip gauges, Inside/Outside Micrometer	2
4.2	Angular Measurement: Sine Bar, Bevel protractor	1
4.3	Form Measurement: Sprit level, Straight edges, Surface plate	1
4.3.1	Dial indicators for squareness, V-Blocks	1
4.3.2	Measurement of major diameter, minor diameter, flank angle, pitch and effective diameter of screw thread	1
4.4	Surface finish Measurement: Surface Roughness, Symbols, sample length, cut off, cut-off length	1
4.5	Roughness comparison as per specimen, R_a, R_z, R_q, R_t, R_p, R_v	1
4.5.1	Principle and operation of stylus probe instruments	1
4.6	Inspection using gauges: Types- limit gauges	1
4.6.1	Snap gauge, Plain plug gauge, Ring gauges, Radius gauges, Feeler gauges - Gauge design	1
4.7	Comparator - Mechanical comparator, Electronic comparator, Optical	1

Module No.	Topic	No. of Lectures
	comparators	
4.7.1	Pneumatic Air gauge, Electronic Air gauge, roundness tester-Surface Roughness tester (Stylus and Skid).	1
5	**Measuring Machines**	
5.1	Auto collimator, laser interferometer, Co-ordinating measuring machine (CMM)	2
	TOTAL	**37**

Course Designers:

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2. Mr.T. Vivek — vivekcontrols@gmail.com
3. Ms. S. Sivapriya — siva2692@hotmail.com

14ME560	DRIVES AND CONTROL	Category	L	T	P	Credit
		PC	2	0	0	2

Preamble

Today, Industries are increasingly demanding process automation in all sectors. Automation results into better quality, increased production and reduced costs. The controlling parameters like motion , Speed, Position and torque are paramount in raising productivity and quality and reducing energy and equipment costs in all industries. Electric drives share most of industrial machine control applications. The variable speed drives which controls speed of a.c/d.c motors are indispensable controlling elements in automation systems. Such drives contains various high performance motors, power electronic converters and digital control systems. With wide options which are open to engineers for selecting proper drive system ,one can look forward for a highly efficient and reliable drive for every application in industry.

Prerequisite

14ES160 – Basics of Electrical and Electronics Engineering.

Course Outcomes

On the successful completion of the course, students will be able to,

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the selection and application range of different drives.	Understand
CO 2.	Develop a fluid power circuit for a given application	Apply
CO 3.	Discuss different power electronics converters used in electrical drives	Understand
CO 4.	Explain the characteristics and control of AC and DC drives	Understand
CO 5.	Choose appropriate drives for controlling machines in industrial applications.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	M	M	S	M	M	M	_	_	_	_	_	_	L	_	L
CO2.	M	M	M	S	S	M	_	_	_	_	_	_	S	M	S
CO3.	M	M	M	M	M	M	_	_	_	_	_	_	M	_	M
CO4.	M	M	M	S	S	M	_	_	_	_	_	_	M	_	M
CO5.	M	L	S	S	M	M	_	_	_	_	_	_	M	_	S

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	60	50	60	60
Apply	20	30	20	20
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. List out the advantages of Electric drive over mechanical drive.
2. Define Electric Drive.
3. Explain the advantages of Electric Drives in terms of Energy saving and Motion/Time profile match.
4. List out the applications of Electric Drives.

Course Outcome 2 (CO2):

1. A hydraulic motor has an 82-cm^3 volumetric displacement. If it has a pressure rating of 70 bars and it receives a oil from a 0.0006 M3/s Pump. Find the motor speed, Torque capacity, Power capacity.
2. Explain the function of Vane motor and pump.
3. Develop a sequential circuit with 2 cylinders for a delay of 5 seconds change over.

Course Outcome 3 (CO3):

1. Explain the effect of source inductance in the operation of three phase fully controlled converter, indicating clearly the conduction of various thyristors during one cycle with relevant waveforms.
2. Explain the effect of source inductance in the operation of single phase fully controlled converter, indicating clearly the conduction of various thyristors during one cycle.
3. Explain the operation of three phase half wave controlled converter with inductive load. Sketch the associated waveforms.
4. With necessary circuit and waveforms, explain the principle of operation of three phase controlled bridge rectifier feeding R-L load and derive the expression for the average output dc voltage.

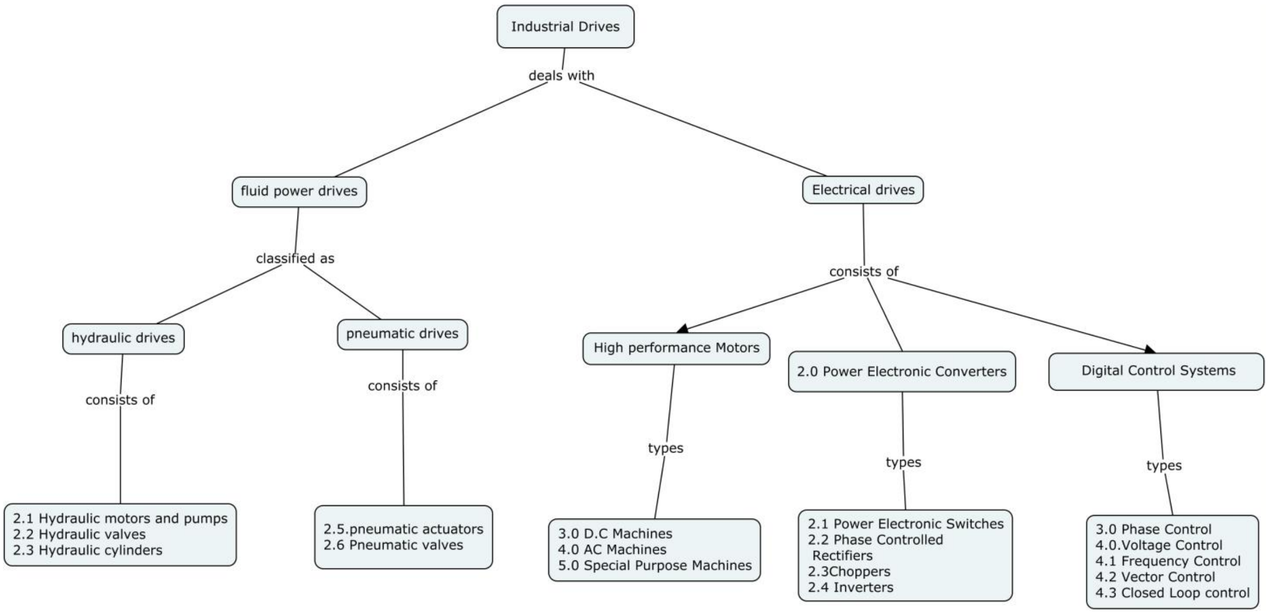
Course Outcome 4 (CO4):

1. Draw the circuit diagram and explain the operation of 3-phase full wave converter drives.
2. Explain various schemes of DC motor Speed Control.
3. State and explain the various schemes for Induction Motor Speed Control by voltage Source Inverters.
4. Describe the VSI fed induction motor and drives with relevant diagram.

Course Outcome 5 (CO5):

1. Select a suitable converter for separately excited dc motor drive.
2. Select a suitable inverter for operating BLDC motor in industrial application.
3. Choose an appropriate Electric drive for Motion Control Applications.
4. Design an Axis and Spindle drive for CNC turning and milling machine based on Speed and Load requirements.

Concept Map



Syllabus

Introduction:
Industrial drives-Definition-Typical configuration- Selection & Application range of Industrial drives-Comparison of fluid power and electric drives-advantages of electrical drives- Energy saving-motor/mechanical load match-Motion/time profile match.

Fluid Power Drives: Hydraulic Motors and Pumps-Hydraulic valves-Hydraulic cylinders and cushioning- Pneumatic actuators-pneumatic valves and control circuits-Multiple actuator circuits-Hydraulic and Pneumatic circuit Design.

Power Electronic Converter (PEC) for Electrical Drives:
Power electronic switches (PECs) - Single phase and 3-phase diode rectifiers-phase controlled rectifiers - D.C-D.C converters – D.C-A.C converters-Direct A.C-A.C converters

Control of Electrical Drives: DC-Drives- basic machine equations-Schemes for DC motor speed control –Controlled rectifier DC drives-Chopper controlled DC drives-AC Drives: Basic principle of operation-Induction motor drives-characteristics, voltage, current, frequency control, vector control, Case Study: Design a Spindle Drive using VFD for CNC milling and Turning Machine.

Special Machine Drives: Stepper motor control-Variable reluctance, Permanent magnet stepper motors-BLDC drives-AC and DC Servo drives, Case Study: Design a Axis drive using AC servo Motor for axis control of CNC machines.

Text Books

1.Ion Boldea, S.A Naser, “**Electric Drives**”, CRC Taylor & Francis Group Edition,2009
2. Anthony Esposito, “**Fluid power with Applications**”, Pearson 7th Edition,2014.
3.MD Singh, K B Khanchandani, “**Power Electronics**”, Tata McGraw-Hill, 2008

Reference Books

1. Bimal Bose, “**Power Electronics and Driver Circuits**” Elseveir, 2006.
2. Bogdan M. Wilamowski, J. David Irwin, **Power Electronics and Motor Drives**” CRC Press, 2011.
3. Mohammed H Rashid, “**Power Electronics**” Pearson Education India, 2009.
4. Vedam Subramanian, “**Electric drives (Concept & Applications)**”, Tata McGraw-Hills

2001
5. Joji. P, "**Pneumatic Controls**", Wiley India Edition, 2008.

Course contents and Lecture schedule

Module No.	Topic	No. of Lectures
1.0	**Introduction**	
1.1	Industrial drives-Definition-Typical configuration- Selection & Application range of Industrial drives	1
1.2	Comparison of Fluid power and electric drives.	1
1.3	Advantages of Electric drives-- Energy saving-motor/mechanical load match-Motion/time profile match.	1
2.0	**Fluid Power Drives**	
2.1	Hydraulic Motors and Pumps	1
2.2	Hydraulic valves-Hydraulic cylinders & cushioning	1
2.3	Pneumatic actuators	1
2.4	Pneumatic valves and control circuits	1
2.5	Hydraulic and Pneumatic circuit design	2
3.0	**Power Electronic Converter (PEC) for Drives:**	
3.1	Power electronic switches (PECs)	1
3.2	Single phase & 3-phase diode rectifiers	1
3.3	Phase controlled rectifiers	1
3.4	D.C-D.C Converters, D.C-A.C Converters, A.C-A.C Converters	2
4.0	**Control of Electric Drives**	
4.1	Basic machine equations	1
4.2	Schemes for DC motor speed control	1
4.3	Controlled rectifier DC drives, Chopper controlled DC drives	1
4.4	3-phase Induction motor-Construction, characteristics, speed control	1
4.2	Induction motor drives- voltage, current, frequency control, vector control	1
4.4	Case Study: Design a Spindle Drive using VFD for CNC milling and Turning Machine.	1
5.0	**Control of Special Machine drives**	
5.1	Stepper motor control-Variable reluctance, Permanent magnet	1
5.2	BLDC drives	1
5.3	Servo drives	1
5.4	Case Study: Design a Axis drive using AC servo Motor for axis control of CNC machines.	1
	TOTAL	**24**

Course Designers:

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14ME580	COMPUTER AIDED MODELING LABORATORY	Category	L	T	P	Credit
		PC	0	0	2	1

Preamble

Computer-aided Modelling is the use of computer systems to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing.

Course Outcomes

On the successful completion of the course, students will be able to,

Sl. No	Course Outcomes	Blooms level
CO1.	Develop and assemble the given model	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	L	M	_	S	L	_	_	_	_	_	M	S	_	_
CO2.	S	L	M	_	S	L	_	_	_	_	_	M	S	_	_
CO3.	S	L	M	_	S	L	_	_	_	_	_	M	S	_	_

Syllabus

List of Exercises (Any twelve will be given)

1. Draw the 2D sketch of given part (2 exercises)
    a. Without constraints.
    b. With constraints.
2. Develop 3D model of given object (4 exercises)
3. Develop a detailed drawing of given model such as (any 6 exercises)
    a. Universal joint
    b. Screw jack.
    c. Machine vice.
    d. Tail stock.
    e. Milling Fixture.
    f. Four pillar Die set
    g. Piston head
    h. Swivel bearing
    i. Drill Jig
    j. Steam stop valve
    k. Ramson bottom safety valve

l. Spring loaded safety valve
m. Plumber block

(2D sketch and 3D solid modelling exercises will be practised in Creo-Parametric modelling package

Course Designers:

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14ME590	HEAT TRANSFER LAB	Category	L	T	P	Credit
		PC	0	0	2	1

Preamble

The purpose of this course is to *To gain practical knowledge of various heat transfer principles*.

Course Outcomes

Sl. No	Course Outcomes	Blooms level
CO1.	Analyse and interpret heat transfer parameters by conducting experiments on conduction experimental setups.	Evaluate
CO2.	Analyse and interpret heat transfer parameters by conducting experiments on natural and forced convection apparatus.	Evaluate
CO3.	Analyse and interpret heat transfer parameters by conducting experiments on radiation and heat exchanger test setups.	Evaluate

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	S	M	S	M	_	_	_	_	_	_	_	M	S	S
CO2.	S	S	M	S	M	_	_	_	_	_	_	_	M	S	S
CO3.	S	S	M	S	M	_	_	_	_	_	_	_	M	S	S

List of Experiments

1. Determination of specific heat capacity of air.
2. Conduction heat transfer test on metal bar apparatus.
3. Heat transfer performance of pin-fin in natural convection.
4. Heat transfer performance of pin-fin in forced convection.
5. Determination of heat transfer co-efficient in natural convection
6. Determination of heat transfer co-efficient in forced convection
7. Determination of Stefan - Boltzman constant and verification of Stefan's Boltzman law.
8. Emissivity test of the given surface.
9. LMTD and effectiveness comparison between parallel flow and counter flow heat exchangers.
10. Determination of COP in thermo electric heat pump.
11. Heat transfer analysis in a lagged pipe.
12. Transient heat transfer effect on different solid shapes of same materials.
13. Determination of dimensionless temperature distribution and Fourier number in Lumped system.

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2. Dr. K. Srithar ksrithar@tce.edu
3. Dr. G. Kumaraguruparan gkptce@tce.edu

14MEPA0	PRODUCT DESIGN AND DEVELOPMENT	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

The course aims at giving adequate exposure to product design and development process and the various methods and techniques that are used in real-life to realize successful products. The course is designed to give a flavour of the design process in a structured way.

Prerequisite

- 14ME420 : Engineering Design

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the concept of product design and its applications.	Understand
CO 2.	Classify the product planning process based on the customer need.	Understand
CO 3.	Identify the best concept based on concept evaluation process	Evaluate
CO 4.	Communicate the final specification (product concept) of the product with cost, aesthetic and ergonomics aspects.	Apply
CO 5.	Implement the suitable product architecture.	Analyse

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1.	M	L	L	L	L	_	_	_	_	_	_	_	M	_	M
CO2.	M	L	L	L	L	_	_	_	_	_	_	_	M	_	M
CO3.	S	S	S	S	S	_	_	_	_	_	_	_	S	_	S
CO4.	S	M	M	M	M	_	_	_	_	_	_	_	M	_	M
CO5.	S	S	S	S	S	_	_	_	_	_	_	_	M	_	S

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	10	10	10	10
Understand	20	20	20	20
Apply	30	30	30	30
Analyse	20	20	20	20
Evaluate	20	20	20	20
Create				

Course Level Assessment Questions

Course Outcome 1,2 (CO1, CO2):

1. Define product design.
2. Distinguish between functional design and production design, with suitable examples.
3. What is pre project planning?
4. What is Intellectual Property?
5. Define proto type product.

6. What is industrial design?

Course Outcome 3 (CO3):

1. Evaluate concept selection methods for five automobiles you might consider for purchasing.
2. Develop five pencil holder concepts. Assume the pencil holders are for the member of product development team who is continually moving from site to site. Evaluate the best concept.
3. As a customer Identify the basic needs while selection a new car

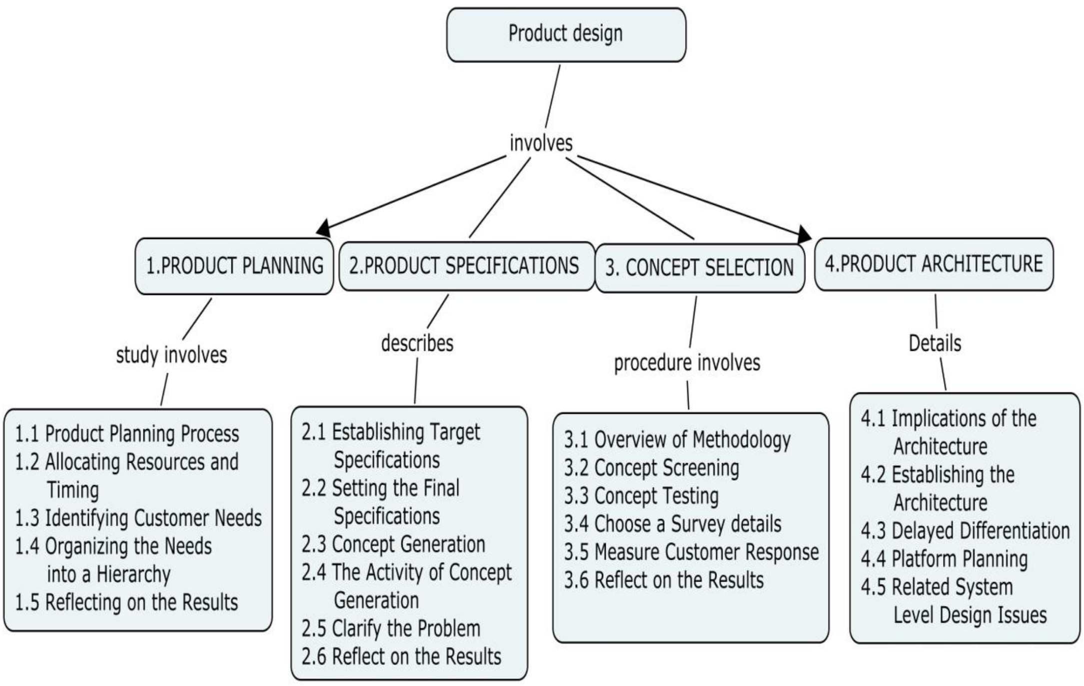
Course Outcome 4 (CO4):

1. What is metrics?
2. List your needs with respect to two wheeler motorcycle suspension and convert to a product specification.
3. How concept selection methods can is used to benchmark or evaluate the existing product?

Course Outcome 5 (CO5):

1. Draw a schematic for a wrist watch using only functional element and analyse its incidental interaction and fundamental interaction
2. Analyse the various product architecture for a laser printer in terms paper tray and feed system
3. Draw proposed product architecture for a digital camera with chunks details. and analyse the various interaction

Concept Map



Syllabus

PRODUCT PLANNING- Product Planning Process- Identify Opportunities- Evaluating and Prioritizing Projects- Allocating Resources and Timing- Pre-Project Planning-Reflect on the Results and the Process-Identifying Customer Needs- Raw Data from Customers-Interpreting Raw Data in Terms of Customer Needs-Organizing the Needs into a Hierarchy-Establishing the Relative Importance of the Needs-Case study for motor driven nailer-Reflecting on the Results and the Process -**PRODUCT SPECIFICATIONS** – Specifications -

Specifications Established-Establishing Target Specifications–QFD-Setting the Final Specifications-Concept Generation-The Activity of Concept Generation- Clarify the Problem-Search Externally-Search Internally-Explore Systematically- Case study for motor driven nailer -Reflect on the Results and the Process **CONCEPT SELECTION**-Concept Selection-Overview of Methodology- The Decision matrix – Pugh's method - Concept Screening-Concept Testing-Define the Purpose of the Concept Test- Choose a Survey Population-Choose a Survey Format- Communicate the Concept- Measure Customer Response-Interpret the Results- Case study for motor driven nailer -Reflect on the Results and the Process – COSTING – Material – manufacturing –assembly – structure - Ergonomics and aesthetic aspects. **PRODUCT ARCHITECTURE**- Implications of the Architecture-Establishing the Architecture-Delayed Differentiation-Platform Planning-Related System-Level Design Issues - Case study.

Text Book

1. Ulrich, Karl T. and Steven D. Eppinger, '"**Product Design and Development**", Irwin/McGraw-Hill, 6th Edition, 2015.

Reference Books

1. David G.Ullman, "**The Mechanical Design Process**", Tata McGraw Hill , 2011
2. Orwin, Homewood, "**Effective Product Design and Development**", Stephen Rosenthal, Business One 1992,ISBN, 1-55623-603-4
3. Stuart Pugh, "**Tool Design – Integrated Methods for successful Product Engineering**", Addison Wesley Publishing,Neyourk,NY,1991, ISBN 0-202-41639-5
4. Kevin Otto, and Kristin Wood, "**Product Design – Techniques in Reverse Engineering and New Product Development**", Pearson Education, First edition,2000, ISBN 81-7758-821-4'

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.0	PRODUCT PLANNING	
1.1	Product Planning Process- Identify Opportunities	2
1.2	Evaluating and Prioritizing Projects- Allocating Resources and Timing	2
1.3	Pre-Project Planning-Reflect on the Results and the Process-Identifying Customer Needs, Raw Data from Customers.	2
1.4	Interpreting Raw Data in Terms of Customer Needs, Organizing the Needs into a Hierarchy-Establishing the Relative Importance of the Needs	2
1.5	Case study for motor driven nailer- Reflecting on the Results and the Process	2
2.0	PRODUCT SPECIFICATIONS	
2.1	Specifications - Specifications Established-Establishing Target Specifications	2
2.2	QFD-Setting the Final Specifications-Concept Generation.	2
2.3	The Activity of Concept Generation	1
2.4	Clarify the Problem- Search Externally-Search Internally	2
2.5	Explore Systematically- Case study for motor driven nailer.	2
2.6	Reflect on the Results and the Process	1
3.0	CONCEPT SELECTION	
3.1	Concept Selection- Overview of Methodology.	1
3.2	The Decision matrix – Pugh's method	1
3.3	Concept Screening-Concept Testing-Define the Purpose of the Concept Test	2
3.4	Choose a Survey Population- Choose a Survey Format-Communicate the Concept.	2

Module No.	Topic	No. of Lectures
3.5	Measure Customer Response-Interpret the Results.	1
3.6	Case study for motor driven nailer -Reflect on the Results and the Process.	1
3.7	COSTING: Material – manufacturing –assembly – structure.	2
3.8	Ergonomics and aesthetic aspects	2
4.0	PRODUCT ARCHITECTURE	
4.1	Implications of the Architecture-Establishing the Architecture	2
4.2	Delayed Differentiation, Platform Planning-Related System-Level Design Issues. Case study.	2
	TOTAL	**36**

Course Designers:

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2. Dr. M.Elango memech@tce.edu

		Category	L	T	P	Credit
14MEPB0	**ENERGY CONVERSION SYSTEMS**	PE	3	0	0	3

Preamble

The development of energy conversion systems is constrained by the depletion of fossil fuel, local environmental impacts, the problem of global warming and associated climate change and search for alternative fuels to reduce the dependence on imported oil. The energy sector is in transition and needs engineering, design, research and development inputs in building efficient conventional energy systems, cost effective renewable sources and conversion devices.

This course is designed to enable the students to understand, demonstrate, and calculate the performance of various energy conversion systems and their applications. The course also focuses on combined use of fossil fuels and renewable energy for power generation.

Prerequisite

- 14ME240: Engineering Thermodynamics
- 14ME440 Thermal Engineering

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Describe with a layout, the working of steam power plant with fuel handling and ash handling systems.	Understand
CO 2.	Determine the performance of Diesel engine and gas turbine power plants.	Apply
CO 3.	Describe the working of power plants using non-conventional energy sources such as nuclear, wind, biofuel.	Understand
CO 4.	Determine the performance of solar energy conversion in collectors and photovoltaic cell.	Apply
CO 5.	Calculate load factor, capacity and utilization factor and cost of power generated by power plants.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1.	M	L	L	_	_	L	L	_	_	_	_	L	_	L	_
CO2.	S	M	L	_	_	L	_	_	_	_	_	L	_	M	_
CO3.	M	L	L	_	_	L	L	_	_	_	_	L	_	L	_
CO4.	S	M	L	_	_	L	L	_	_	_	_	L	_	M	_
CO5.	S	M	L	_	_	L	_	_	_	_	_	L	_	M	_

S- Strong; M-Medium; L-Low.

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	10	10
Understand	60	60	60	60
Apply	20	20	30	30

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define conventional energy source
2. Give example for non-conventional energy soruces.
3. Discuss the potential of conventional energy sources in India.
4. Describe the availability and consumption trend of non-conventional energy sources in the world.

Course Outcome 2 (CO2):

1. Define High pressure boiler
2. What is the advantage of using fluidized bed in boilers?
3. Explain different methods of starting of Diesel Engine Plant.
4. Describe the different methods to improve efficiency of gas turbine.
5. Explain the ash handling plant of thermal power station.
6. Describe the hydraulic ash handling system.
7. Define High pressure boiler
8. What is the advantage of using fluidized bed in boilers?
9. Name any two combined power cycles.

Course Outcome 3 (CO3):

1. A gas turbine power plant consists of one turbine as compressor drive and the other to drive a generator. Each turbine has its own combustion chamber getting air directly from the compressor. Air enters the compressor at 1 bar and 15^o C and compressed with isentropic efficiency of 76 %. The gas inlet pressure and temperature in both the turbines are 5 bar and 680^o C respectively. Take isentropic efficiency of both the turbines as 86%. The mass flow rate of air entering compressor is 23 kg/s. The calorific value of the fuel is 42,000 kJ/kg. Determine the power output and thermal efficiency of the plant.

2. In a test on a single cylinder oil engine with 30 cm bore and 45 cm stoke and working on four stroke cycle, the following observations were made:

Duration of trial = 1 hour, TFC = 7.6 kg, Calorific value of the fuel = 45000 kJ/kg, Total revolution made = 12000, Room temperature = 20^0 C, IMEP = 6 bar, Net brake load = 150 kg, Brake drum diameter = 180 cm, Rope diameter = 3 cm, Mass of the jacket cooling water = 550 kg, Inlet temperature of the jacket cooling water = 15^0 C, Outlet temperature of the jacket cooling water = 60^0 C, Temperature of exhaust gases = 300^0 C, Total air consumption = 365 kg, Specific heat of exhaust gases = 1 kJ/kg K.

Calculate the Indicated power, brake power, mechanical efficiency, and indicated thermal efficiency.

3. In an open cycle regenerative gas turbine plant, the air enters the compressor at 1 bar abs 32°C and leaves at 6.9 bar abs. The temperature at the end of combustion chamber is 816°C. The isentropic efficiencies of compressor and turbine are espectively 0.84 and 0.85. Combustion efficiency is 90% and the regenerator effectiveness is 60 percent, determine: (a) Thermal efficiency, (b) Air rate, (c) Work ratio.

4. A gas turbine power plant is operated between 1 bar and 9 bar pressures and minimum and maximum cycle temperatures are 25°C and 1250°C. Compression is carried out in two stages with perfect intercooling. The gases coming out from HP. turbine are heated to 1250°C before entering into L.P. turbine. The expansions in both turbines are arranged in such a way that each stage develops same power. Assuming compressors and turbines isentropic efficiencies as 83%, (1) determine the cycle efficiency assuming ideal regenerator. Neglect the mass of fuel. (2) Find the power developed by the cycle in kW if the airflow through the power plant is 16.5 kg/sec.

Course Outcome 4 (CO4):

1. Explain applications of solar energy.
2. Describe the fast breeder reactor.
3. Name the types of reactors.
4. What are the advantages of wind power generation?
5. Name the different biofuels available for power generation.

Course Outcome 5 (CO5):

1. When a photovoltaic cell is exposed to solar insolation of 950 W/m^2, the short circuit current is 220 A/m^2 both based on a unit area of the exposed junction. The open circuit voltage is 0.60 V and the temperature is 300 K. Calculate
   (a) reversed saturation current
   (b) the voltage that maximizes the power
   (c) the load current that maximizes the power
   (d) the maximum power
   (e) the maximum conversion efficiency
   (f) the cell area for an output of 1 kW at the condition of maximum power.

Course Outcome 6 (CO6):

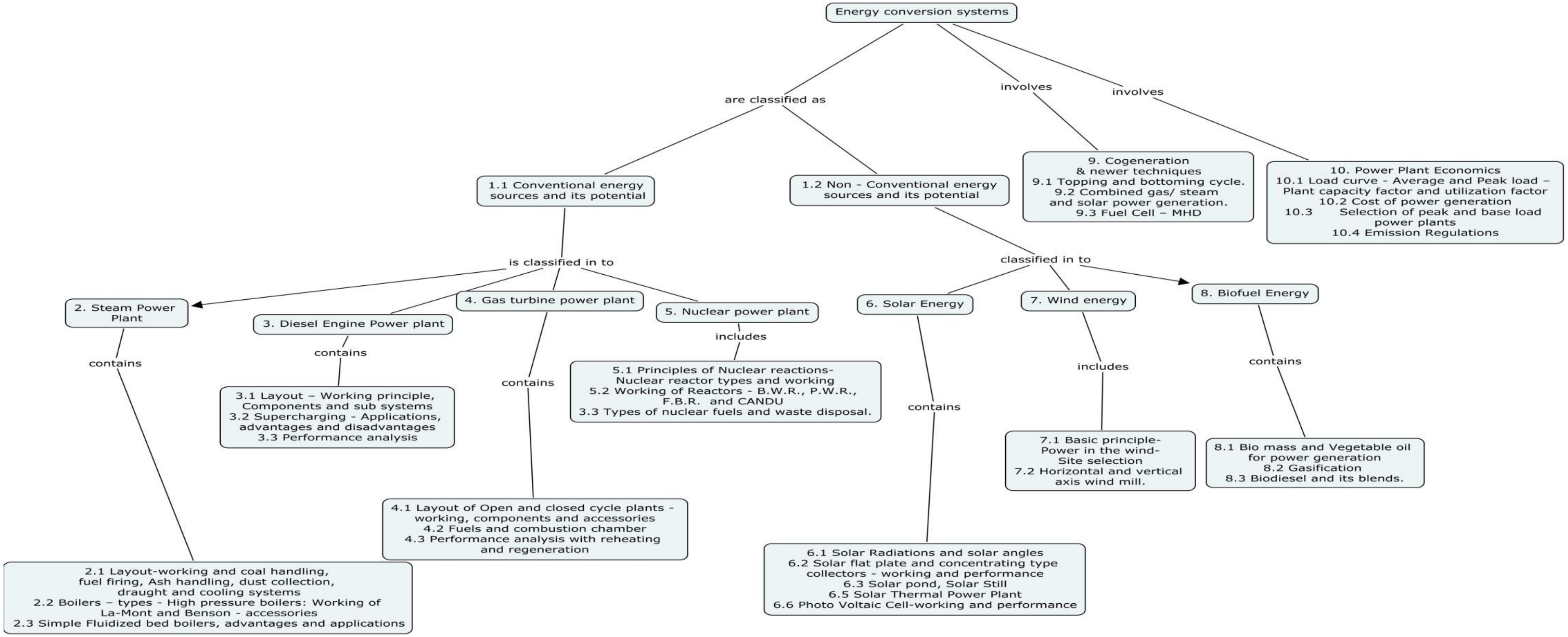
1. A base load power station having a capacity of 18 MW and a standby station having a capacity of 20 MW share a common load. Find i) annual load factor ii) use factor and iii) capacity factor of the two stations from the following data: Annual standby station output = 7.35 x 10^6 kWh
   Annual base load station output = 101.35 x 10^6 kWh
   Peak load on the stand by station = 12 MW
   Hours of use of stand by station during the year = 2190 hours

2. A generating station has a maximum demand of 30 MW, a load factor of 0.6, a plant capacity factor of 0.48 and a plant use factor of 0.82. Find, i) the daily energy produce, ii) the reserve capacity of the plant iii) the maximum energy that could be produced if the plant were running all the time and iv) the maximum energy that could be produced daily, if the plant when running according to the operating schedule were fully loaded.

3. The maximum (peak) load on a thermal power plant of 60 mW capacity is 50 MW at an annual load factor of 50%. The loads having maximum demands of 25 MW, 20 MW, 8 MW and, 5 MW are connected to the power station. Determine: (a) Average load on power station (b) Energy generated per year (c) Demand factor
   (d) Diversity factor.

4. A steam power station has an installed capacity of 120 MW and a maximum demand of 100 MW. The coal consumption is 0.4 kg per kWh and cost of coal is Rs. 80 per tonne. The annual expenses on salary bill of staff and other overhead charges excluding cost of coal are Rs.50 × 105. The power station works at a load factor of 0.5 and the capital cost of the power station is Rs. 4 × 105. If the rate of interest and depreciation is 10% determine the cost of generating per kWh.

Concept Map


Energy conversion systems
are classified as
involves
involves
1.1 Conventional energy sources and its potential
1.2 Non - Conventional energy sources and its potential
9. Cogeneration & newer techniques
9.1 Topping and bottoming cycle.
9.2 Combined gas/ steam and solar power generation.
9.3 Fuel Cell – MHD
10. Power Plant Economics
10.1 Load curve - Average and Peak load – Plant capacity factor and utilization factor
10.2 Cost of power generation
10.3 Selection of peak and base load power plants
10.4 Emission Regulations
is classified in to
classified in to
2. Steam Power Plant
3. Diesel Engine Power plant
4. Gas turbine power plant
5. Nuclear power plant
6. Solar Energy
7. Wind energy
8. Biofuel Energy
contains
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3.1 Layout – Working principle, Components and sub systems
3.2 Supercharging - Applications, advantages and disadvantages
3.3 Performance analysis
5.1 Principles of Nuclear reactions- Nuclear reactor types and working
5.2 Working of Reactors - B.W.R., P.W.R., F.B.R. and CANDU
3.3 Types of nuclear fuels and waste disposal.
7.1 Basic principle- Power in the wind- Site selection
7.2 Horizontal and vertical axis wind mill.
8.1 Bio mass and Vegetable oil for power generation
8.2 Gasification
8.3 Biodiesel and its blends.
4.1 Layout of Open and closed cycle plants - working, components and accessories
4.2 Fuels and combustion chamber
4.3 Performance analysis with reheating and regeneration
6.1 Solar Radiations and solar angles
6.2 Solar flat plate and concentrating type collectors - working and performance
6.3 Solar pond, Solar Still
6.5 Solar Thermal Power Plant
6.6 Photo Voltaic Cell-working and performance
2.1 Layout-working and coal handling, fuel firing, Ash handling, dust collection, draught and cooling systems
2.2 Boilers – types - High pressure boilers: Working of La-Mont and Benson - accessories
2.3 Simple Fluidized bed boilers, advantages and applications

Syllabus

Energy source: Conventional energy sources- types - Non-conventional energy sources- types – wind, solar, biomass, geothermal, tidal, OTEC - global and national potential.
Steam power plant: Layout – Working, coal handling, fuel firing – grate firing and pulverised fuel firing, Ash handling, dust collection draught and cooling systems – Boilers – types - High pressure boilers: Working of La-Mont and Benson - accessories - Simple Fluidized bed boiler - advantages and Applications.
Diesel engine power plant: Layout – Working principle, Components and sub systems- Supercharging - Applications, advantages and disadvantages, Performance analysis.
Gas turbine power plant: Layout of open and closed cycle plants- working, components and accessories – Fuels and combustion chamber– Performance analysis with reheating and regeneration.
Nuclear power plant: Principles of Nuclear reactions- Nuclear reactor types and working of reactors - Boiling water reactor (B.W.R.), Pressurised water reactor (P.W.R.) and Fast Breeder Reactor (FBR), CANDU type reactor- types of nuclear fuels and waste disposal.
Solar Energy: Solar Radiations and solar angles - latitude angle, declination angle, hour angle, zenith angle - Solar flat plate and concentrating type collectors - performance. Solar pond, Solar Still. Solar Thermal Power Plant, Photo Voltaic Cell-performance.
Wind energy: Basic principle - Power in the wind- site selection- working of Horizontal and vertical axis wind mill.
Bio fuel Energy: Bio mass and vegetable oil for power generation – Gasification- Biodiesel and its blends.
Cogeneration and Newer Techniques: Topping and bottoming cycle – working of combined gas turbine and steam power plants – Fuel Cell – Working of Hydrogen cell - MHD.
Power Plant Economics: Load curve - Average and Peak load – Plant capacity factor and utilization factor - Cost of power generation - Selection of peak and base load power plant - Emission Regulations.

Text Books

1. M.M. El-Wakil, **“Power Plant Technology”**, McGraw Hill, 2002.
2. A.K. Raja, Amit Prakash Srivastava, Manish Dwivedi, **“Power Plant Engineering**”, New Age International Publishers, 2006.
3. Aldo V. Da Rosa **“Fundamentals of Renewable Energy Process”**, Elsevier Academic Press, 2005.

Reference Books

1. Volker Quaschning, “**Understanding Renewable Energy Systems**”, Earth scan, 2005.
2. Rajput R.K., **“A Text Book of Power Plant Engineering”,** Laxmi Publications (P) Ltd., 2001.
3. Nag P.K., “**Power Plant Engineering**”- second edition, Tata McGraw Hill, New Delhi, 2001.
4. Rai G.D., **Non- Conventional Energy Sources**, Khanna Publishers, New Delhi, 1995.
5. John R Fanchi, **“Energy in the 21st Century”**, World Scientific Publishing Co. Pvt Ltd, 2005.
6. John R Fanchi, **“Energy – Technology and directions for future”**, Elsevier Academic Press, 2004.
7. David Pimentel, “**Bio Fuels, Solar and Wind as Renewable Energy Systems**”, Springer, 2008.
8. Bent Sorensen, “**Renewable Energy**”, Elsevier Academic Press, 2004.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.	**Energy source:**	
1.1	Conventional energy sources- types, global and national potential	1
1.2	Non-conventional energy sources-types– wind, solar, biomass, geothermal, tidal, OTEC, global and national potential	1
2	**Steam power plant:**	
2.1	Layout – Working, coal handling, fuel firing – grate firing and pulverised fuel firing, Ash handling, dust collection, draught and cooling systems	3
2.2	Boilers – types - High pressure boilers: Working of La-Mont and Benson - accessories	2
2.3	Simple Fluidized bed boilers, advantages and Applications	1
3.	**Diesel engine power plant:**	
3.1	Layout – Working principle, Components and sub systems	1
3.2	Supercharging - Applications, advantages and disadvantages	1
3.3	Performance analysis	2
4.	**Gas turbine power plant:**	
4.1	Layout of Open and closed cycle plants- working, components and accessories	1
4.2	Fuels and combustion chamber	1
4.3	Performance analysis with reheating and regeneration	2
5.	**Nuclear power plant**:	
5.1	Principles of Nuclear reactions- Nuclear reactor types	1
5.2	Working of Reactors - Boiling water reactor (B.W.R.), Pressurised water reactor (P.W.R.) Fast Breeder Reactor (FBR) and CANDU type reactor	2
5.3	Types of nuclear fuels and waste disposal.	1
6.0	**Solar Energy:**	
6.1	Solar Radiations and solar angles - latitude angle, declination angle, hour angle, zenith angle	1
6.3	Solar Collectors - working and performance of flat plate and concentrating type	2
6.4	Solar pond, Solar Still	1
6.5	Solar Thermal Power Plant	1
6.6	Photo Voltaic Cell-working and performance	2
7.0	**Wind energy:**	
7.1	Basic principle- Power in the wind- Site selection	1
7.2	Horizontal and vertical axis wind mill.	2
8.0	**Biofuel Energy:**	
8.1	Bio mass and Vegetable oil for power generation	1
8.2	Gasification	1
8.3	Biodiesel and its blends.	1
9.0	**Cogeneration and Newer Techniques:**	
9.1	Topping and bottoming cycle.	1
9.2	Combined gas turbine and steam power plants	1
9.3	Fuel Cell – Working of Hydrogen cell - MHD	1
10.0	**Power Plant Economics:**	
10.1	Load curve - Average and Peak load – Plant capacity factor and utilization factor	1

Module No.	Topic	No. of Lectures
10.2	Cost of power generation	2
10.3	Selection of peak and base load power plant	1
10.4	Emission Regulations	
	Total	**40**

Course Designers:

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14MEPC0	REFRIGERATION AND AIR CONDITIONING	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

The subject of refrigeration and air conditioning has evolved out of human need for food and comfort. Refrigeration deals with cooling of bodies or fluids to temperatures lower than surroundings temperature. Air conditioning is one of the major applications of refrigeration.. Air conditioning involves control of temperature, humidity, cleanliness of air and its distribution to meet the comfort requirements of human beings and/or some industrial requirements. Air conditioning has made the living conditions more comfortable, hygienic and healthy in offices, work places and homes. The objectives of this course are to understand the functioning of various components of refrigeration and air-conditioning systems, to analyse the performance of air and vapour compression refrigeration cycles and various psychrometric processes and to estimate the cooling load of air conditioned space.

Prerequisite

- 14ME240-Thermodynamics
- 14ME340-Fluid Mechanics
- 14ME440-Thermal Engineering

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the functioning of various refrigeration and air conditioning systems	Understand
CO 2.	Determine the performance of components of air and vapour compression refrigeration cycles.	Apply
CO 3.	Explain the working of components of vapour compression refrigeration system and select environmentally besignrefrigerants.	Understand
CO 4.	Determine the mass and energy transfer of various psychrometric processes	Apply
CO 5.	Calculate the cooling load of an air conditioned space	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	M	L	_	M	_	_	_	_	_	_	_	_	_	L	_
CO2.	S	M	_	S	_	_	_	_	_	_	_	_	L	M	L
CO3.	M	_	_	M	_	M	S	_	_	_	_	_	_	L	_
CO4.	S	M	_	S	_	_	_	_	_	_	_	_	L	M	L
CO5.	S	M	_	S	_	_	_	_	_	_	_	_	L	M	L

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	10	10
Understand	40	40	40	40
Apply	40	40	50	50

Analyse	-	-	-	-
Evaluate	-	-	-	-
Create	-	-	-	-

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define the term ton of refrigeration.
2. Explain the working of vapour absorption refrigeration system.
3. Describe the operation of steam jet refrigeration system,
4. Explain the working of summer air conditioning system with a neat sketch.
5. With the neat diagram, explain the working of a window air conditioner.

Course Outcome 2 (CO2):

1. Draw the p-h diagram of vapour compression refrigeration cycle.
2. Derive an expression for COP of a reversed Brayton cycle
3. A refrigeration unit working on Bell-Coleman cycle takes air from cold chamber at -10°C and compresses it from 1 bar with index of compression being 1.2. The compressed air is cooled to a temperature 10°C above the ambient temperature of 25°C before it is expanded in the expander where the index of expansion is 1.35. Determine the following: (i) COP, (ii) Quantity of air circulated per minute for the production of 2000 kg of ice per day at 0°C from water at 20°C (iii) Capacity of the plant in ton of refrigeration.
4. A refrigeration uses R12 as refrigerant. The condenser temperature is 50°C and the evaporator temperature is 0°C. The refrigeration capacity is 7 tons. Assume the simple vapour saturation cycle and determine with the help of p-h diagram. (i) The refrigerant flow rate, (ii) COP, (iii) The heat rejected in the condenser.
5. A refrigerator works on VCR cycle between the temperature limits 253 K and 298 K. If the liquid refrigerant enters the throttle valve at 293 K and the entry to the compressor is dry and saturated, find the tonnage of refrigeration, work required to drive the compressor and COP. The mass flow rate of refrigerant is 1 kg/s.

T (K)	h_f (kJ/kg)	h_g (kJ/kg)	s_f (kJ/kgK)	s_g (kJ/kgK)	Specific Heat (kJ/kgK)	
					Liquid	Vapour
253	327.4	1655.9	3.8416	9.09	-	-
298	536.3	1703.3	4.5956	8.50	1.15	0.888

Course Outcome 3 (CO3):

1. What are eco-friendly refrigerants?
2. Discuss in detail about the points to be considered while selecting a refrigerant.
3. Explain the advantages and disadvantages of hermetic compressor over open type compressor.
4. Explain the working of shell and tube condenser using a diagram.
5. Discuss the merits and demerits of thermostatic expansion valve over other expansion devices.

Course Outcome 4 (CO4):

1. Define: SHF.
2. Calculate the following properties of air at 450C DBT and 300C WBT (i) Specific humidity, (ii) Degree of saturation, (iii) Relative Humidity, (iv) Absolute humidity, (v) Enthalpy, (vi) DPT

3. Find the wet-bulb temperature, dew point temperature, specific humidity, specific enthalpy, and specific volume of humid air, if the dry-bulb temperature is 29°C and relative humidity is 45 %. Verify the results using psychrometric chart.
4. Atmospheric air at 38°C and 40 per cent RH is to be cooled and dehumidified to a state of saturated air at 10°C. The mass rate of flow of atmospheric air entering the dehumidifier is 45.5 kg/h. neglecting any pressure drop, determine: (i) the mass of water removed, (ii) the quantity of heat removed.
5. A class room of 60 seating capacity is air conditioned. The out-door conditions are 32°C DBT and 22°C WBT and the required conditions are 22°C and 55% RH . The quantity of outdoor air supplied is 0.5 m3/min/student. The comfort conditions are achieved first by chemical dehumidifying the air and then cooling by the cooling coil. Find the followings: (i) DBT of the air leaving the humidifier, (ii) Capacity of the humidifier, (iii) Capacity of the cooling coil in tons of refrigeration, (iv) If the bypass factor of the cooling coil 0.3. Then find the surface temperature of the cooling coil required.

Course Outcome 5 (CO5):

1. Draw and discuss various features of Comfort chart.
2. Define RSHF
3. The following data relate to a conference room for seating 100 persons.

Inside design conditions	22°C DBT, 60 % RH
Outside design conditions	40°C DBT, 27^{0} C WBT
Sensible and latent heat loads per person	80 W and 50 W respectively
Lights and fans loads	15000 W
Air infiltration	20 m^3/min
Sensible heat gain through glass, walls, ceiling etc	15000 W
Fresh air supply	100 m^3/min
By-pass factor of the coils	0.1

If two-third of recirculated room air and one-third of fresh air are mixed before entering the cooling coils. Determine: Apparatus dew point; (ii) Grand total heat load; and (iii) effective room sensible heat factor.

4. An office for seating 25 occupants is to be maintained at 24°C DBT, 50 % RH. The outdoor conditions are 34°C DBT, 28°C WBT. The various loads in the office are:

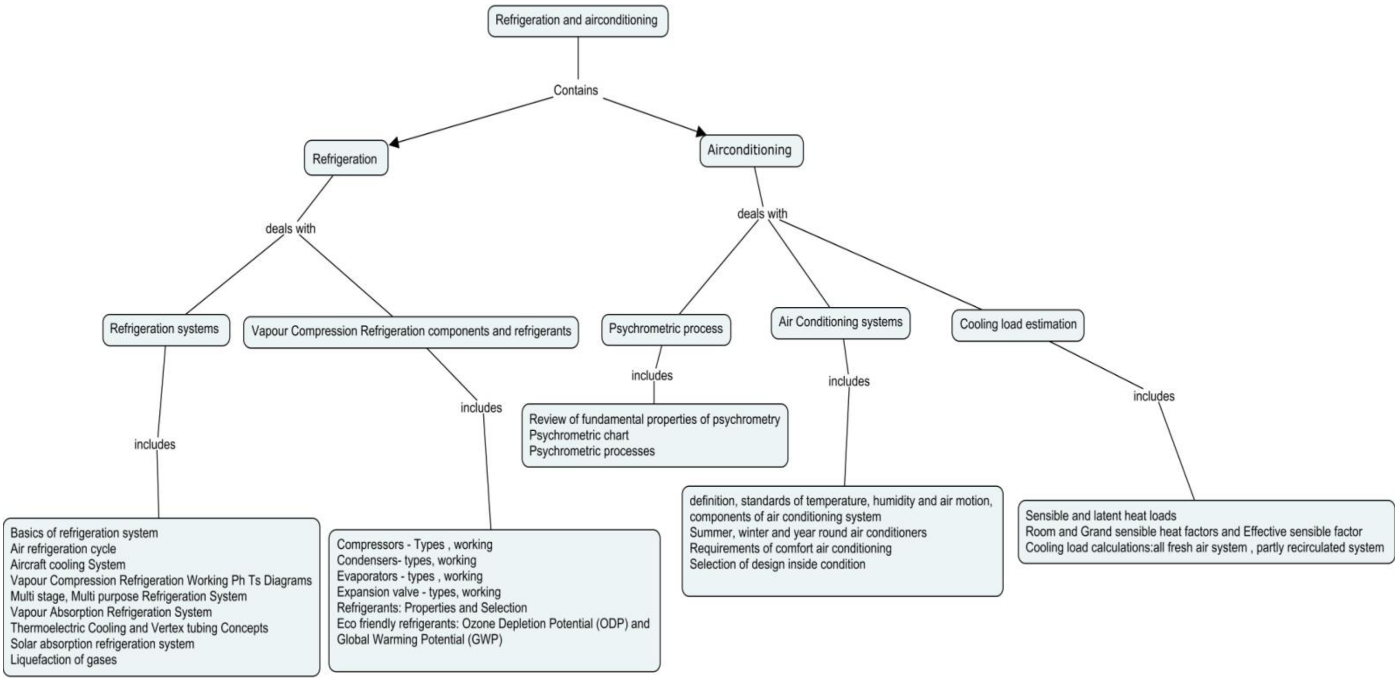
Solar heat gain	9.12 kW
Sensible heat gain per occupant	0.09 kW
Latent heat gain per occupant	0.105 kW
Lighting load	2.3 kW
Sensible heat load from other sources	11.63 kW
Infiltration load	14 m^3/min

Assuming 40% fresh air and 60 percent of recirculated air passing through the evaporator and the bypass factor of 0.15, determine: (i) Dew point temperature of the coil; and (ii) Capacity of the plant.

5. The following data is avialable for designing an air conditioning system for a restaurant: Inside design conditions = 27°C DBT, 55 % RH; Outdoor conditions = 35°C DBT, 26°C WBT; Minimum temperature of air supplied to room = 17°C DBT; Total amount of fresh air supplied = 1600 m^3/h; Total infilteration air = 400 m^3/h; seating chairs for dining = 50; Employees serving the meals = 5; Sensible heat gain per person =58 W: Latent heat gain per seating person = 44 W; Latent heat gain per employee = 76 W; Sensible heat added from meals = 0.17 kW; Latent heat added

from meals = 0.3 kW; Total heat flow through the walls, roof and floor = 6.2 kW; Solar heat gain through glass = 2 kW; Equipment sensible heat gain = 2.9 kW; Equipment latent heat gain = 0.7 kW; Motor power connected to the fan = 7.5 kW. If the fan is installed before the conditioner, determine: (i) Amount of air delivered to the room in m^3/h; (ii) percentage of recirculated air; (iii) refrigeration load on the coil in tonnes of refrigeration; and (iv) Dew point temperature of the cooling coil and by pass factor.

Concept Map



Syllabus

Refrigeration systems – Review of thermodynamic principles of refrigeration. Air cycle refrigeration- Bell-Coleman cycle – ideal and actual, numerical problems. Aircraft cooling system – simple and bootstrap systems. Vapour compression refrigeration- working, p-h and T-s diagrams, Innovative VCR systems- cascade, Multistage compression, Multipurpose refrigeration systems, Vapour compression refrigeration cycle – ideal and actual, numerical problems. Vapour absorption refrigeration – Ammonia Water system, Lithium Bromide Water system, Electrolux system, Solar vapour absorption refrigeration system. Thermoelectric and Vortex tube refrigeration. Liquefaction of gases- Linde and Claude system. **Vapour compression Refrigeration components and refrigerants -** Compressors: Types – based on operation and based on arrangement. Condensers: Types- air cooled, water cooled and evaporative condensers. Evaporators: Flooded and dry expansion types. Expansion valves: Capillary type, Automatic expansion valve, Thermostatic expansion valve. Refrigerants: Properties and Selection. Eco friendly refrigerants: Ozone Depletion Potential (ODP) and Global Warming Potential (GWP). **Psychrometric process -** Review of fundamental properties of psychrometry, Psychrometric chart, Psychrometry properties calculation, Psychrometric processes, Bypass factor, Apparatus Dew Point (ADP) temperature, numerical problems. **Air Conditioning systems -** Air conditioning – definition, standards of temperature, humidity and air motion, components of air conditioning system. Summer, winter and year round air conditioners, Window, Split air conditioners, Central air conditioner systems. Requirements of comfort air conditioning: oxygen supply, body heat and body moisture removal, sufficient air movement, purity of air. Selection of design inside condition – thermal comfort, factors affecting thermal comfort, indices for thermal comfort, comfort chart. Selection of design outside condition. **Cooling load estimation -** Sensible and latent heat loads: Internal heat sources, heat transmission through building, load from occupants, Equipment load, load due to food storage, load due to solar radiation, infiltration, fresh air load, estimation of total load. Room and Grand sensible heat factors and Effective sensible factor. Cooling load calculations: without and with fresh air system (mixing before conditioner and mixing after conditioner).

Text Books

1. Arora C.P, “**Refrigeration and Air Conditioning**”, Tata McGraw Hill, 2008.
2. Stoecker W.F. and Jones J.W., “**Refrigeration and Air Conditioning**”, McGraw Hill, 1984.

Reference Books

1. Ibrahim Dincer and Mehmet Kanoglu, “**Refrigeration Systems and Applications**”, John Wiley and Sons, 2010.
2. Domkundwar, Arrora and Domkundwar, “**Refrigeration and Air Conditioning**”, Dhanpat Rai and Co, 2009.
3. Manohar Prasad, “**Refrigeration and Air Conditioning**”, New Age Publishing Ltd, 2010.
4. Jones, W.P., “**Air Conditioning Engineering**”,5th Edition, Butterworth Heinemann, 2005.
5. Rex Miller and Mark R. Miller, “**Modern Refrigeration and Air Conditioning**”, McGraw-Hill, 2006.
6. Jordan and Priester, “**Air Conditioning and Refrigeration**”, Prentice Hall of India, 1985.

Tables:

1. Khurmi,R.S, “**Steam Tables with Mollier Diagrams**”, S.Chand and Co., 2010.
2. Maskara, P.N and Sathish Chand, “**Tables and Charts on Refrigerant and Psychrometric properties**”, Technical Publishers of India, 2003.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Refrigeration systems**	
1.1	Review of thermodynamic principles of refrigeration	1
1.2	Air cycle refrigeration: Bell-Coleman cycle – ideal and actual, numerical problems.	2
1.3	Aircraft cooling system – simple and bootstrap	1
1.4	Vapour compression refrigeration- working, p-h and T-s diagrams	2
1.5	Innovative VCR systems- cascade, Multistage compression, Multipurpose refrigeration systems	1
1.5	Vapour compression refrigeration cycle – ideal and actual, numerical problems.	2
1.6	Vapour absorption refrigeration – Ammonia Water system, Lithium Bromide Water system, Electrolux system, Solar vapour adsorption refrigeration system	2
1.7	Thermoelectric Cooling, Vortex tube refrigeration.	1
1.8	Liquefaction of gases- Linde and Claude system.	1
2	**Vapour Compression Refrigeration components and refrigerants**	
2.1	Compressors: Types – based on operation and based on arrangement.	2
2.2	Condensers: Types- air cooled, water cooled and evaporative condensers.	1

Module No.	Topic	No. of Lectures
2.3	Evaporators: Flooded and dry expansion types. Expansion valves: Capillary type, automatic expansion valve, Thermostatic expansion valve.	2
2.4	Refrigerants: Properties and Selection	1
2.5	Eco friendly refrigerants: Ozone Depletion Potential (ODP) and Global Warming Potential (GWP)	1
3	**Psychrometric process**	
3.1	Review of fundamental properties of psychrometry	1
3.2	Psychrometric chart, psychrometry property calculation.	2
3.3	Psychrometric processes- Bypass factor, Apparatus Dew Point (ADP) temperature	2
3.4	Numerical problems	2
4	**Air Conditioning systems**	
4.1	Air conditioning – definition, standards of temperature, humidity and air motion, components of air conditioning system	1
4.2	Summer, winter and year round air conditioners	1
4.3	Window, Split air conditioners, Central air conditioner systems.	1
4.4	Requirements of comfort air conditioning: oxygen supply, body heat and body moisture removal, sufficient air movement, purity of air	1
4.5	Selection of design inside condition – thermal comfort, factors affecting thermal comfort, indices for thermal comfort, comfort chart, Selection of design outside condition	2
5	**Cooling load estimation**	
5.1	Sensible and latent heat loads: Internal heat sources, heat transmission through building	1
	load from occupants, Equipment load, load due to food storage, load due to solar radiation, infiltration, fresh air load, estimation of total load	1
5.2	Room and Grand sensible heat factors and Effective sensible factor	1
5.3	Cooling load calculations: without fresh air system	2
	Cooling load calculations: with fresh air system (mixing before conditioner and mixing after conditioner)	2
	Total	**40**

Course Designers:

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		Category	L	T	P	Credit
14MEPD0	**ADDITIVE MANUFACTURING**	PE	3	0	0	3

Preamble

Additive Manufacturing is a group of techniques used to quickly fabricate a scale model of a physical part or assembly using three-dimensional computer aided design (CAD) data. Construction of the part or assembly is usually done using 3D printing or "additive layer manufacturing" technology. Additive manufacturing improves product development by enabling better communication in a concurrent engineering environment and also reduces product development cycle time. This course aims to provide knowledge on the additive manufacturing and its application, advantages, limitations.

Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO1.	Explain the concepts of prototypes and AM process chain	Understand
CO2.	Select the suitable AM process for a given product/part drawing.	Apply
CO3.	Select rapid tooling methods for additive manufacturing	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	M	L	L	L	L	_	_	_	_	_	_	_	L	_	L
CO2.	S	M	M	M	M	_	_	_	_	_	_	_	M	_	M
CO3.	S	M	M	M	M	_	_	_	_	_	_	_	M	_	M

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3*#	
Remember	20	20	--	20
Understand	60	60	--	50
Apply	20	20	--	30

* - Fabrication of FDM product. Students are grouped as 3 or more per batch. Each batch will be given 90 minutes with 35cc material to fabricate the given component drawing.

- Evaluation pattern:

S. No	Description	Marks
1	CAD Model	45
2	Process chain	45
3	Finished Products	10
	Total Marks	**100**

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define Prototyping
2. Explain the process chain of additive manufacturing process
3. Explain the classification of additive manufacturing process

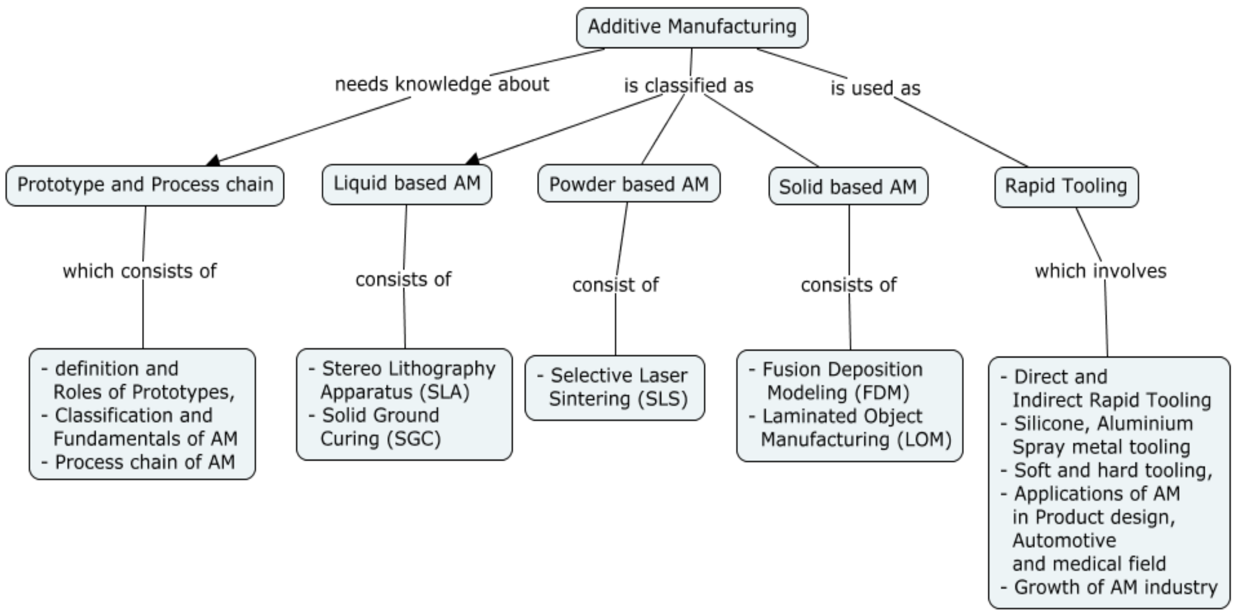
Course Outcome 2 (CO2):

1. Define polymerization Process
2. Explain the process parameters of Solid Ground Curing (SGC).
3. Explain the principle of Stereo lithography (SLA) processes.
4. Discuss the solid ground process steps in details with suitable diagrams.
5. Select the suitable AM process for the development of Pattern for jewellery application
6. Discuss the process parameters to be considered in selective laser sintering
7. Explain the process parameters considered for laminated object manufacturing.
8. Discuss the working principle of Fusion Deposition Modelling (FDM).
9. Select the suitable AM process for the development of Fixture for measurement purpose

Course Outcome 3 (CO3):

1. Differentiate direct and indirect tooling process.
2. Explain silicon rubber tooling processes in detail.
3. Differentiate soft tooling and hard tooling.
4. Select the suitable AM process for fabrication of injection moulding too.

Concept Map



Syllabus

Introduction: Definition of Prototypes, Roles of Prototypes, Need for time compression in product development, History of AM Process, classification of AM Process - Fundamentals of AM Process – Process chain of AM Process – Data format – STL files. Benefits of AM.

Liquid Based AM: Stereo Lithography Apparatus (SLA) – Principle – Photo polymerization – Post processes – process parameters – Machine details – Advantages, Solid Ground Curing (SGC) – Principle – processes parameters – Process details - Machine details – Limitations.

Solid Based AM: Fusion Deposition Modeling (FDM) – Principle – Raw materials – BASS – Water soluble support system – Process parameters – Machine details – Advantages and limitations, Laminated Object Manufacturing – Principle – Processes parameters = Process details – Advantages and limitations.

Powder based AM: Selective Laser Sintering (SLS) – Principle – process parameters – Process details –Machine details.

Rapid Tooling and Applications of AM: Classification of Rapid Tooling - Indirect rapid tooling - Silicone rubber tooling, Aluminium filled epoxy tooling, Spray metal tooling, Direct rapid tooling - Direct ACES Injection Moulding. Soft tooling vs hard tooling, Applications of AM in product design, automotive industry, medical field – Case studies, Role of AM Process parameter on Part Quality, Growth of AM industry.

Text Books

1. C.K. Chua, K.F. Leong, and C.S Lim, "**Rapid Prototyping: Principles and Applications**", World Scientific, New Jersey, 201.
2. D.T. Pham, and S.S. Dimov, "**Rapid Manufacturing**", Springer-Verlag,2011.

Reference Books

1. P.F. Jacobs, "**Rapid Prototyping and Manufacturing: Fundamentals of Stereolithography**", McGraw-Hill, New York, 2011.
2. P.D.Hilton, "**Rapid Tooling**", Marcel Dekker, New York, 2000.
3. Rapid Prototyping Journal, Emerald Group Publishing Limited.
4. www.utah.edu/~asn8200/rapid.html
5. http://www.cheshirehenbury,com/rapid/index.html

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Introduction:**	
1.1	Definition of Prototypes, Roles of Prototypes	1
1.2	History of AM Process, classification of AM Process, benefits of AM.	1
1.3	Need for time compression in product development	1
1.4	Fundamentals of AM Process – Process chain of AM Process – Data format – STL files	2
2	**Liquid Based AM:**	
2.1	Stereo Lithography Apparatus(SLA) – Principle	1

Module No.	Topic	No. of Lectures
2.2	Photo polymerization – Post processes - process parameters	2
2.3	Machine details – Advantages,	2
2.4	Solid Ground Curing (SGC) – Principle	2
2.5	Processes parameters	1
2.6	Process details - Machine details – Limitations	2
3	**Solid Based AM:**	
3.1	Fusion Deposition Modeling (FDM) – Principle – Raw materials – BASS	2
3.2	Water soluble support system – Process parameters	2
3.3	Machine details – Advantages and limitations	1
3.4	Laminated Object Manufacturing – Principle – Processes parameters - Process details – Advantages and limitations	2
4	**Powder based AM:**	
4.1	Selective Laser Sintering (SLS) – Principle – process parameters	2
4.2	Process details –Machine details	1
5	**Rapid Tooling and Applications of AM:**	
5.1	Classification of Rapid Tooling - Indirect Rapid Tooling – Silicone rubber tooling, Aluminium filled epoxy tooling, Spray metal tooling	2
5.2	Direct Rapid Tooling – Direct ACES Injection Moulding - soft tooling Vs hard tooling	2
5.3	Applications of AM in product design, automotive industry, medical field	2
5.4	Case studies	2
5.5	Role of AM Process parameter on Part Quality	2
5.6	Growth of AM industry	2
	Total	36

Course Designers:

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2. Mr. T. Prakash tpmech@tce.edu

		Category	L	T	P	Credit
14MEPE0	**ROBOTICS**	PE	3	0	0	3

Preamble

Robotics is the applied science of motion control for multi-axis manipulators and is a large subset of the field of "mechatronics" (Mechanical, Electronic and Software engineering for product or systems development, particularly for motion control applications). Robotics, sensors, actuators and controller technologies are continuously improving and evolving synergistically. In the 20^{th} century, engineers have mastered almost all forms of motion control and have proven that robots and machines can perform almost any job that is considered too heavy, too tiring, too boring or too dangerous and harmful for human beings. This course supports the students to design and develop multi-DOF manipulator and wheeled mobile robot.

Prerequisite

- Matrix manipulations.

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the working of the subsystems of robotic manipulator and wheeled mobile robot	Understand
CO 2.	Develop the forward kinematic model of multi-degree of freedom (DOF) manipulator and *inverse kinematic model* of two and three degrees of freedom planar robot arm and wheeled robot	Apply
CO 3.	Develop the static force and dynamic model of two degrees of freedom planar robot arm	Apply
CO 4.	Generate a trajectory in joint space using polynomial and trigonometric functions with given kinematic constraints of multi-degree of freedom (DOF) manipulator	Apply
CO 5.	Develop a offline robot program for point-to-point applications such as pick and place, palletizing, sorting and inspection of work-parts	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	M	L	L	L	L	_	_	L	_	_	_	_	_	_	_
CO2.	S	M	L	L	L	_	_	L	_	_	_	_	L	_	_
CO3.	S	M	L	L	L	_	_	L	_	_	_	_	L	_	_
CO4.	S	M	L	L	L	_	_	L	_	_	_	_	L	_	_
CO5.	S	M	L	L	L	_	_	L	_	_	_	_	L	_	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	10	10
Understand	20	20	30	30
Apply	60	60	60	60

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define industrial robot.

2. Explain the classification of actuators used in robotic manipulators and indicate their advantages and limitations.
3. Describe the constructional features of an industrial robot.
4. With use of simple sketches, explain the working of castor wheel for steering a mobile robot.

Course Outcome 2 (CO2):

1. Write the coordinate transformation matrices for all PUMA joints as shown in figure 1 using DH parameters.

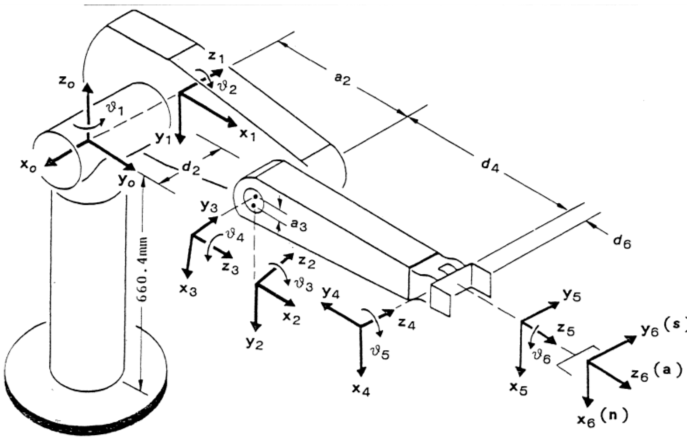


Figure 1

2. Consider the two-link planar arm of Figure 2. The joint axes z_0 and z_1 are normal to the page. The established base frame $x_0y_0z_0$ is as shown. The origin is chosen at the point of intersection of the z_0 axis with the page and the direction of the x_0 axis is completely arbitrary. Once the base frame is established, the $x_1y_1z_1$ frame is fixed as shown by the DH convention, where the origin, o_1 has been located at the intersection of z_1 and the page. The final frame $x_2y_2z_2$ is fixed by choosing the origin, o_2 at the end of link 2 as shown. Write the DH parameters and its corresponding transformation matrices.

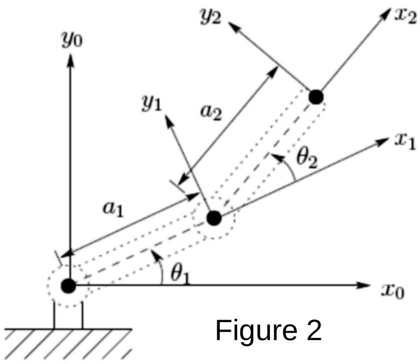
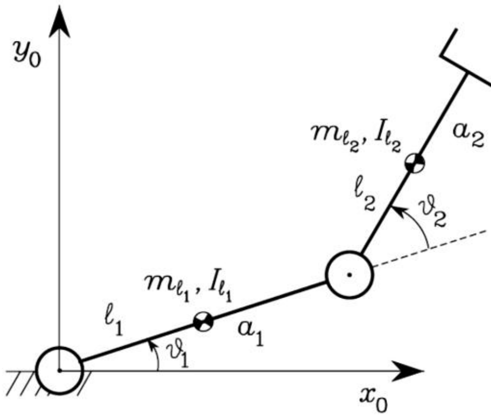


Figure 2

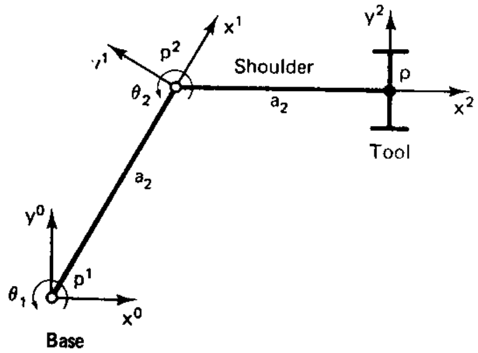
3. A differential drive robot has wheels of differing diameters. The left wheel has diameter of 2 units and the right wheel has diameter of 3 units. The length between the wheels is 5 units. The robot is positioned at $\theta = \frac{\pi}{4}$. The robot spins both wheels at a speed of 6 units/sec. Compute the robot's instantaneous velocity in the global reference frame.

Course Outcome 3 (CO3):

1. Develop a dynamic model for two degree of freedom manipulator as shown in figure .



2. Find the manipulator Jacobian matrix of the two axis planar articulated robot shown in the following figure.



3. A two link planar manipulator is applying a force (newtons) of $\begin{bmatrix} 1.25 \\ 2 \\ 0 \end{bmatrix}^T$ in the end-effector frame on the environment. Find the required joint torques when $\theta_1 = \pi/4$ and $\theta_2 = \pi/2$, link lengths $l_1 = 1$ and $l_2 = 1$ assuming that gravity does not play any role.

4. Find the joint torques for a two DOF manipulator considering the acceleration due to gravity, when $\theta_1 = 0$, $\theta_2 = \pi/4$, $\dot{\theta}_1 = 0$ rad/s $\dot{\theta}_2 = 2$ rad/s link lengths $l_1 = 1$m and $l_2 = 1$m with mass m_1 and m_2 = 0.5 kg.

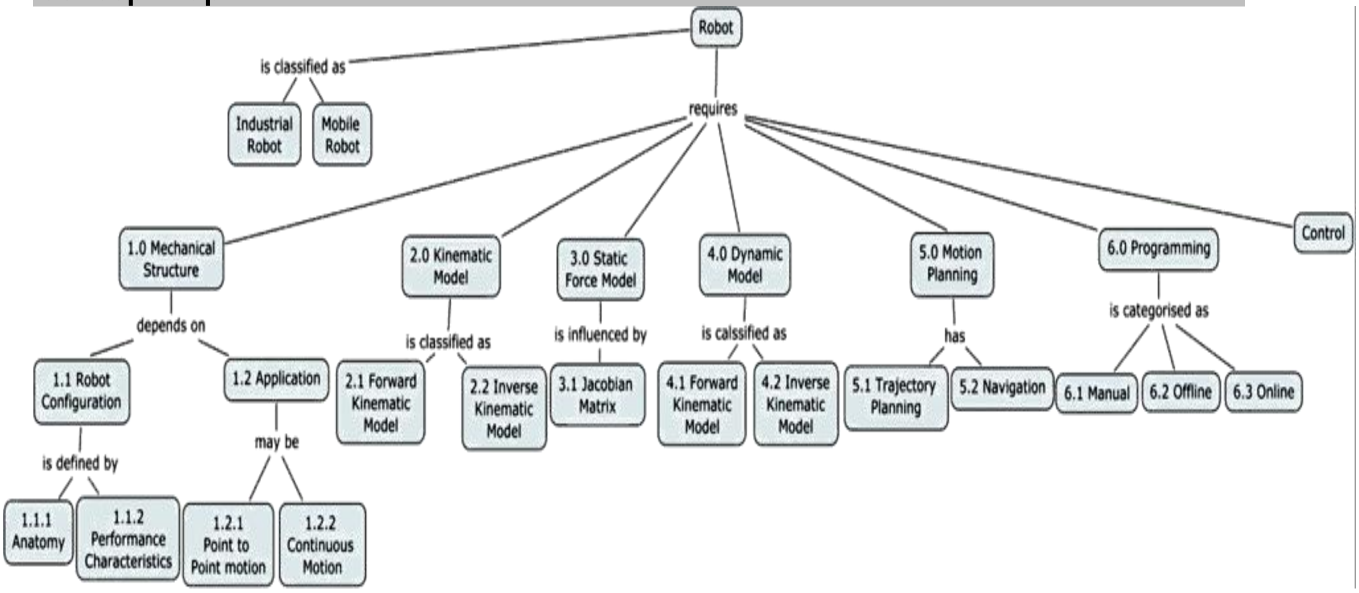
Course Outcome 4 (CO4):

1. Explain step by step procedure for the generation a cubic polynomial trajectory for a joint with specified kinematic constraints.
2. The initial and final joint positions of a robot joint are $\theta_i = 15^\circ$ and $\theta_f = 75^\circ$ with time period of 3 sec. The following expressions are governing equations for position, velocity and acceleration. Develop a trajectory for the above conditions.
   $\theta(t) = 15 + 20t^2 - 4.44t^3$
   $\theta^{'}(t) = 40t - 13.32t^2$
   $\theta^{''}(t) = 40 - 26.64t$
3. Develop a trajectory for a robot whose initial and final position are given as $\theta_i = -45^\circ$ and $\theta_f = 15^\circ$ and governing equation is $\theta(t) = -45 + 24t + 4t^2$. Determine the time period for this trajectory.

Course Outcome 5 (CO5):

1. Write a robot programming for a palletizing operation. The robot must pick up the parts from an incoming chute and deposit them onto a pallet. The pallet has four rows that are 50 mm apart and six columns that are 40 mm apart. The plane of the pallet is assumed to be parallel to XY plane. The rows of the pallet are parallel to the x-axis and the columns of the pallet are parallel to the Y-axis. The objects are to be picked up are about 25 mm tall.
2. Write a VAL statements for defining coordinate frame *'Grasp – Point 1'* which can be obtained by rotating coordinate frame '*Block – Point 2'* through an angle 65° about Y-axis and then translate it by 100 and 150 mm in X and Y axes respectively.
3. Write a program in VAL II to instruct the robot to pick up bottles from a fixed location on a conveyor and insert them into a cardboard carton. A mechanical stop along the conveyor is used to locate the parts in known position. The bottles are to be loaded into the carton about 12 in. away from the pickup point. Each carton holds two parts. Open cartons are presented to the robot and then subsequently closed and sealed at a different location. The open cartons are 4.0 in. tall and measure 5.0 by 10.0 in. The bottles to be loaded are 4.5 in. in diameter. Make a sketch of the workstation before programming and identify the various points used in the program.

Concept Map



Syllabus

Introduction to Robotics. Mechanical structure: Robot Configuration - Robot Anatomy, Sub-systems/Elements of Industrial Robot - Performance characteristics of industrial Robots. Mobile robot locomotion: Introduction, key issues for locomotion, wheeled locomotion-wheel design, geometry, stability, manoeuvrability and controllability. Applications - Progressive advancement in Robots – Point to point and continuous motion applications - Mobile manipulators and its applications.

Kinematic model - Forward Kinematics for two DOF manipulator – Algebraic method, Mechanical structure and notations, Coordinate frames, Description of objects in space, Transformation of vectors, Fundamental rotation matrices (principal axes and fixed angle rotation) Description of links and joints, Denavit-Hartenberg (DH) notation, Forward Kinematics for multi-Degrees of Freedom (DOF) manipulator. Inverse kinematics of two DOF planar manipulator - Manipulator workspace. Mobile Robot kinematics: kinematic model and constraints, Mobile robot workspace-motion control.

Static model: Differential relationship - Velocity analysis – Jacobian matrix – Determination of forces and equivalent torques for joints of two link planar robot arm.

Dynamic model: Euler – Lagrangian formulation - Forward and inverse dynamic model for two DOF planar manipulator.

Trajectory planning: Definitions and planning tasks, Joint space techniques – Motion profiles – Cubic polynomial, Linear Segmented Parabolic Blends and cycloidal motion - Cartesian space techniques. Navigation: Graph search and potential field path planning - navigation architecture - offline and online planning.

Robot Programming - Manual Programming – Teach Pendant, Offline programming - VAL programming, Online Programming. Case Studies.

Text Books

1. S.K.Saha, "**Introduction to Robotics**", Second Edition, McGraw Hill Education (India) Private Limited, 2014.
2. Roland Siegwart and Illah R.Nourbakhsh, "**Introduction to Autonomous Mobile Robots**", Prentice Hall of India (P) Ltd., 2005.

Reference Books/Learning Resources

1. B. Siciliano, L. Sciavicco, L. Villani, G. Oriolo, "**Robotics: Modelling, Planning and Control**", First Edition, Springer-Verlag London,2009
2. K.S. Fu, R.C Gonzalez and C.S. Lee, "**Robotics- Control, Sensing, Vision and Intelligence**", Tata McGraw-Hill Editions, 2008.
3. John J.Craig, "**Introduction to Robotics, Mechanics and Control**", Third Edition, Pearson Education, 2005.
4. Mark W.Spong, M.Vidyasagar, "**Robot Dynamics and Control**", Wiley India, 2009.
5. George A. Bekey, "**Autonomous Robots – From Biological Inspiration to Implementation and Control**", MIT Press, 2005.
6. Howie Choset, Kevin M. Lynch, Seth Hutchinson, George A. Kantor, Wolfram Burgard, Lydia E. Kavraki and Sebastian Thrun, "**Principles of Robot Motion – Theory, Algorithms and Implementation**", MIT Press, 2005.
7. Mikell P. Groover, Mitchell Weiss, Roger N.Nagel and Nicholas G. Odrey, "**Industrial Robotics – Technology, Programming and Applications**" Tata McGraw-Hill, 2008.
8. Yoram Koren, "**Robotics for Engineers**", McGraw-Hill Book Co., 1992.
9. P.A. Janakiraman, "**Robotics and Image Processing**", Tata McGraw-Hill, 1995.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.0	**Mechanical Structure:**	
1.1	Robot Configuration - Robot Anatomy	1
1.1.1	Sub- systems of Industrial Robot	1
1.1.2	Mobile robot locomotion: Introduction, key issues for locomotion	1
1.1.3	Wheeled locomotion - wheel design, geometry	1
1.1.4	Stability, manoeuvrability and controllability	1
1.1.2	Performance characteristics of industrial Robots	1
1.2	Applications - Progressive advancement in Robots – Point to point and continuous motion applications - Mobile manipulators and its applications.	1
2.0	**Kinematic Model**	
2.1	Forward Kinematics for two DOF manipulator – Algebraic method,	1
2.1.1	Mechanical structure and notations, Coordinate frames,	1

Module No.	Topic	No. of Lectures
	Description of objects in space	
2.1.2	Transformation of vectors, Fundamental rotation matrices (principal axes and fixed angle rotation)	1
2.1.3	Description of links and joints, Denavit-Hartenberg (DH) notation,	1
2.1.4	Forward Kinematics for multi-Degrees of Freedom (DOF) manipulator.	1
2.2	Inverse kinematics of two DOF manipulator - Manipulator workspace.	1
2.3	Mobile Robot kinematics: kinematic model and constraints, Mobile robot workspace-motion control.	1
3.0	**Static Force Model**	
3.1	Differential relationship - Velocity analysis – Jacobian matrix	2
3.2	Determination of forces and equivalent torques for joints of two link planar robot arm	2
4.0	**Dynamic model**	
4.1	Euler-Lagrangian formulation	1
4.2	Forward dynamic model for two DOF manipulator	2
4.3	Inverse dynamic model for two DOF manipulator.	1
5.0	**Motion planning**	
5.1	Trajectory Planning: Definitions and planning tasks, Joint space techniques	1
5.1.1	Motion profiles – Cubic polynomial motion	2
5.1.2	Linear Segmented Parabolic Blends	1
5.1.3	Cycloidal motion - Cartesian space techniques	1
5.2	Navigation: Graph search path planning	2
5.2.1	Potential field path planning	2
5.2.2	Navigation architecture	1
5.2.3	Offline and online planning	
6.0	**Robot Programming**	
6.1	Manual Programming – Teach Pendant	1
6.2	Offline programming - VAL programming	2
6.3	Online Programming	1
	Total	**36**

Course Designers:

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		Category	L	T	P	Credit
14MEPF0	**TOTAL QUALITY MANAGEMENT**	PE	3	0	0	3

Preamble:

Quality is the mantra for success or even for the survival of any organization in this competitive global market. Total Quality Management (TQM) is an enhancement to the traditional way of doing business. It is a proven technique to guarantee survival in world-class competition. It integrates fundamental management techniques, existing improvement efforts, and technical tools under a disciplined approach. At the end of the course the students are expected to recognize the quality issues in an organization and analyze the ways to solve those using TQM techniques, and demonstrate skills in using modern TQM tools and software to analyze problems.

Prerequisite

- NIL

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the principles of TQM.	Understand
CO 2.	Explain the concepts of Statistical process control	Understand
CO 3.	Implement the tools and techniques of TQM in an organization.	Apply
CO 4.	Explain the need for Quality systems of international standards.	Apply
CO 5.	Implement the Quality Management Systems in a different organization environment.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	M	_	_	_	L	_	_	L	_	_	_	_	_	_	_
CO2.	M	_	_	L	L	_	_	L	_	_	_	_	_	_	_
CO3.	S	L	L	S	M	_	_	L	M	L	_	_	_	_	M
CO4.	L	_	L	_	M	_	L	L	_	_	L	_	_	_	L
CO5.	L	L	L	_	M	_	L	L	_	_	_	_	_	_	M

S- Strong; M-Medium; L-Lo

Assessment Pattern

	Bloom's Category	Test 1	Test 2	Test 3	End Semester examination
1	Remember	20	20	20	20
2	Understand	30	30	30	30
3	Apply	50	50	50	50
4	Analyze	0	0	0	0
5	Evaluate	0	0	0	0
6	Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define TQM.

2. What is the need for quality planning?
3. What is a customer?
4. What are 5S?
5. List any four concepts under KAIZEN umbrella.
6. What is a ‘defect’ and ‘defective’?

Course Outcome 2 (CO2):

1. Discuss in detail the role of senior management.
2. How can you retail your customer in the organization’s business?
3. Explain about Juran’s Trilogy.
4. Differentiate between specification limit and control limit.
5. How will you calculate process capability ratio?
6. Explain the six basic steps in bench marking process.

Course Outcome 3 (CO3):

1. In plastic moulding process, the results of the inspection of 10 lots of 125 items each are given in the following table.

Lot No.	1	2	3	4	5	6	7	8	9	10
No. of defectives	4	8	9	2	12	6	7	5	4	7

(i) Compute trial control limits
(ii) Plot the appropriate chart
(iii) Draw the conclusion

2. The following observations are made in a crankshaft machining process.

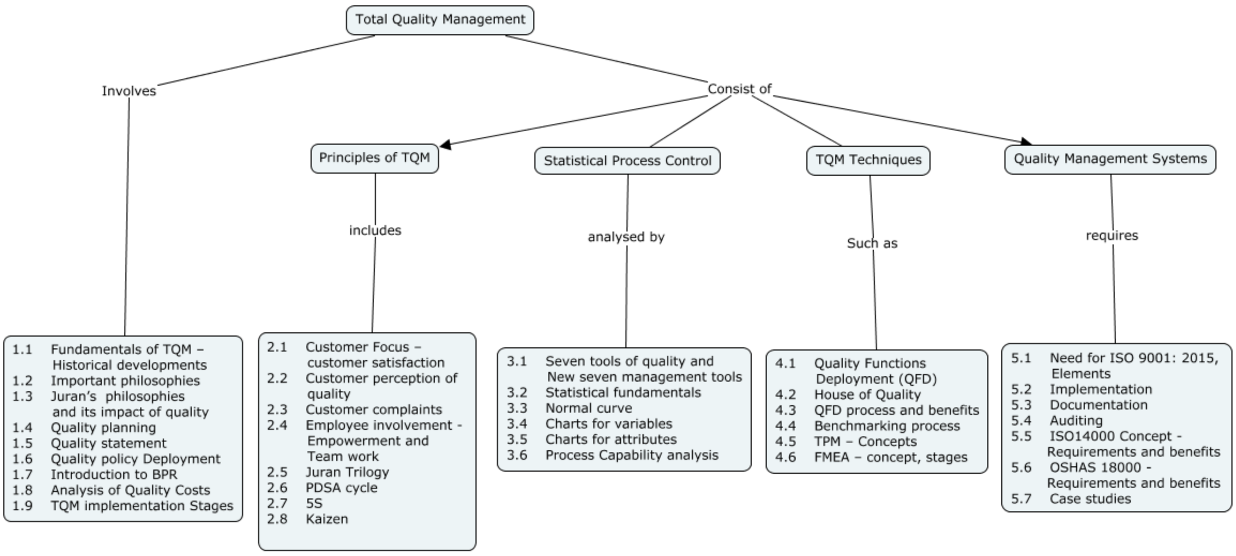
Sample No.	Observations			
	1	2	3	4
1	20.21	20.19	20.25	20.15
2	20.24	20.19	20.23	20.17
3	20.17	20.16	20.20	20.18
4	20.10	20.14	20.18	20.09
5	20.04	20.03	20.05	19.97
6	20.04	19.97	19.99	20.01
7	20.09	20.05	20.00	20.03
8	19.99	19.98	20.01	19.97

(i) Compute the trial control limits for X and R charts.
(ii) Construct and R chart
(iii) Comment of the process.
(iv) Calculate the process capability
(v) Compute percent defective if any.

Course Outcome 4 and 5 (CO4, CO5):

1. The piston for a petrol engine is made in lots of 150 each. The lots are subjected to 100% inspection. 25 such lots are inspected and the number of defectives found was 125.
   (a) Compute the control limits for a *p* charts.
   (b) Compute the control limits for the *np* chart
2. Build the house of quality matrix to show the inter relationship between the customer requirements and technical descriptors for a manufacturing system.
3. Discuss the mandatory items of ISO 14000.
4. Explain the steps to be followed in implementing quality system ISO 9000:2000.

Concept Map



Syllabus

Introduction: Fundamentals of TQM – Historical developments – important philosophies- (Deming, Juran, Crossby, Ishikawa) and their impact of quality – Quality planning, Quality statement – Quality policy Deployment, introduction to BPR and analysis of Quality Costs- TQM implementation stages **Principles of TQM:** Customer focus - Customer satisfaction – customer perception of quality, customer complaints, Employee involvement – Empowerment and Team work- Supplier Quality Management Juran Trilogy, PDSA cycle, 5S, Kaizen. **Process Monitoring:** Seven tools of quality, New Seven management tools, statistical fundamentals – Normal curve charts for variables and attributes, Process Capability analysis. **TQM Techniques:** - Quality Functions Deployment (QFD) – house of Quality, QFD process and benefits, Benchmarking process, TPM – Concepts, FMEA – concept, stages. **Quality Management Systems:** Need for ISO 9001: 2015 – Elements, Implementation, Documentation and Auditing. ISO14000 and OSHAS 18000 – Concept requirements and benefits – Case studies.

Text Book

1. Dale H.Besterfiled, Carol Besterfiled-Michna. Glen H. Beseterfiled and Mary Besterfield-Sacre., "**Total Quality Management**", Pearson Education Asia, 2004.

Reference Books

1. Shridhara Bhat, "**TQM – Text and Cases**", Himalaya Publishing House, 2002.
2. Berk, Joseph and Berk, S., "**The Essence of TQM**", Prentice Hall of India, 1998.
3. Narayana and Sreenivasan, "**Quality Management – Concepts and Tasks**", New Age International, 1996.
4. Sharma, D.D, "**Total Quality Management**", Sultan Chand & Sons, 2005.

Course contents and Lecture schedule

Module No.	Topic	No. of Lectures
1	**Introduction**	
1.1	Fundamentals of TQM – Historical developments	1
1.2	Important philosophies - (Deming, Crossby, Ishikawa) & their impact of quality	2

Module No.	Topic	No. of Lectures
1.3	Juran's philosophies and its impact of quality	1
1.4	Quality planning,	1
1.5	Quality statement	1
1.6	Quality policy Deployment	
1.7	Introduction to BPR	1
1.8	Analysis of Quality Costs	1
1.9	TQM implementation Stages	1
2	**Principles of TQM**	
2.1	Customer Focus – customer satisfaction	1
2.2	Customer perception of quality	1
2.3	Customer complaints	1
2.4	Employee involvement - Empowerment and Team work	1
2.5	Juran Trilogy	1
2.6	PDSA cycle	1
2.7	5S	1
2.8	Kaizen	1
3	**Process Monitoring**	
3.1	Seven tools of quality and New seven management tools	1
3.2	Statistical fundamentals	1
3.3	Normal curve	1
3.4	Charts for variables	1
3.5	Charts for attributes	1
3.6	Process Capability analysis	1
4	**TQM Techniques**	
4.1	Quality Functions Deployment (QFD)	1
4.2	House of Quality	1
4.3	QFD process and benefits	1
4.4	Benchmarking process	1
4.5	TPM – Concepts	1
4.6	FMEA – concept, stages	1
5	**Quality Management Systems**	
5.1	Need for ISO 9001: 2008, Elements	1
5.2	Implementation	1
5.3	Documentation	1
5.4	Auditing	1
5.5	ISO14000 Concept - Requirements and benefits	1
5.6	OSHAS 18000 - Requirements and benefits	1
5.7	Case studies	1
	Total	**36**

Course Designers

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2. Dr. ML.Mahadevan mlmmech@tce.edu.

		Category	L	T	P	Credit
14MEPG0	**MARKETING MANAGEMENT**	PE	3	0	0	3

Preamble

Marketing management is a business discipline which is focused on the practical application of marketing techniques and the management of a firm's marketing resources and activities. Rapidly emerging forces of globalization have compelled firms to market beyond the borders of their home country making International Marketing highly significant and an integral part of a firm's marketing strategy. Marketing managers are often responsible for influencing the level, timing, and composition of customer demand.

Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Illustrate the concepts of marketing and to identify the factors influencing customer satisfaction	Apply
CO 2.	Develop the marketing research plan for all types of products.	Apply
CO 3.	Identify the various pricing strategies	Apply
CO 4.	Classify the distribution channels and outline the significant features of supply chain distribution	Understand
CO 5.	Select suitable models for sales promotion, advertisement andMarketing techniques for various types of products.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	L	L	L	L	_	_	_	L	_	L	_	_	_	_	_
CO2.	M	M	M	M	_	_	_	L	M	M	L	_	_	_	_
CO3.	L	M	L	M	_	_	_	L	_	_	S	L	_	_	_
CO4.	L	L	L	M	_	_	_	L	_	_	L	_	_	_	_
CO5.	M	M	M	M	_	_	_	L	_	M	M	_	_	_	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	20	20	20	20
Apply	60	60	60	60
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Write the meaning of Marketing.
2. What is Industrial Marketing?

3. What is Services Marketing?
4. Present all the factors influencing customer satisfaction of FMCGs.

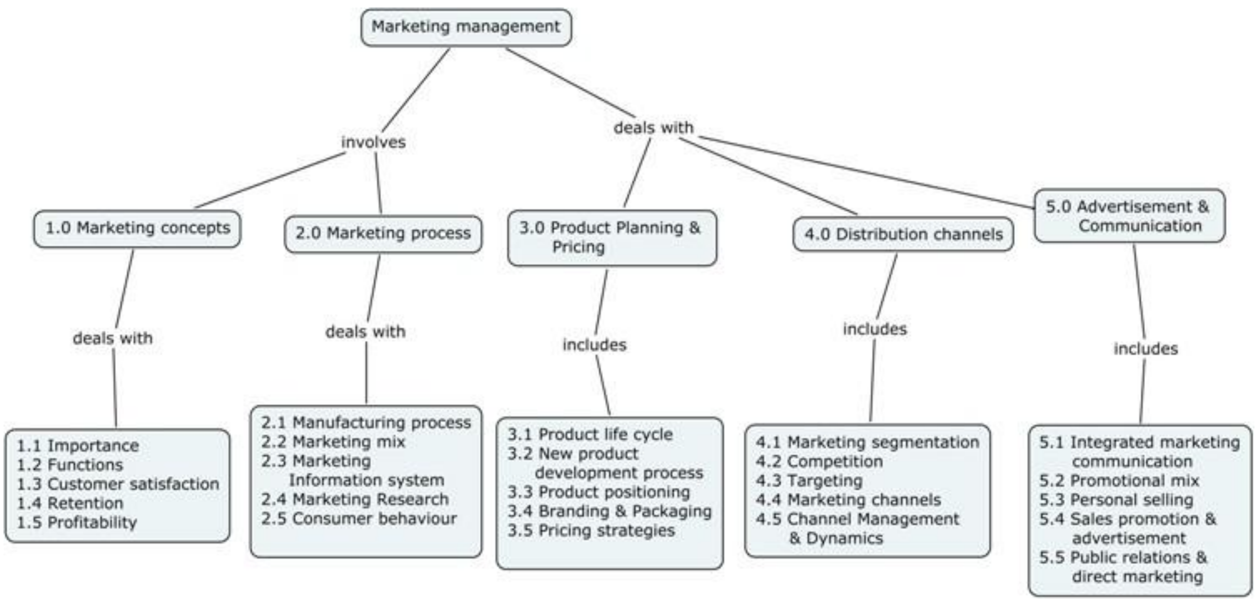
Course Outcome 2 (CO2):
1. Write the meaning of Marketing Mix.
2. What are the features of basic market plan?
3. What is Market Research?
4. Explain the various techniques of Market Research.

Course Outcome 3(CO3):
1. Explain the various factors that are influencing Product Promotion.
2. Write the meaning of Pricing?
3. Explain the various pricing strategies
4. Explain the difficulties in pricing FMCG.

Course Outcome 4(CO4):
1. Explain the various costs associated with supply chain distribution.
2. Write down the distribution related issues faced by dealers.
3. What is the meaning of buffer stock?
4. Classify the various distribution channels.

Course Outcome 5(CO5):
1. Explain the various advertisement techniques.
2. What are the limitations of media promotion and how will you overcome them?
3. Explain how you will prepare sales budget
4. Select the suitable advertisement techniques for services marketing.
5. Discuss the challenges in promoting the sales of machinery spare parts.

Concept Map



Syllabus

MARKETING CONCEPTS : Scope and Process of marketing- Marketing concepts – Importance - Function customer satisfaction and value - customer retention - consumer profitability **MARKETING PROCESS :** marketing plan - marketing mix - Marketing Information system - marketing research - Consumer behaviour. **PRODUCT PLANNING AND PRICING :**Product Life Cycle - New Product development process - Product

Positioning - Branding & Packaging - Pricing Strategies **DISTRIBUTION CHANNELS :**Marketing Segmentation – Competition – Targeting - Marketing Channels – Channel - Management & Dynamics. **ADVERTISEMENT AND COMMUNICATION:**Integrated marketing communication - Promotional mix - Personal selling - Sales promotion & advertisement - Public relations & direct marketing.

Text Book

1. Philip Kotler, "**Marketing management**", Millennium Edition, Prentice Hall of India P (ltd), 2015.

Reference Books

1.Kumar.V., "Marketing Research: a Global outlook", SAGE Texts, 2015.
2.L.Natarajan, " Retail Management", Margham Publications,2016.
3.Micheal R. Czinkota& Masaaki Kotabe, "**Marketing management**", Vikas Thomson learning, 2010.
4. Douglas, J. Darymple "**Marketing Management**" John Wiley & Sons, 2008.
5. Aakar, Day, Kumar, "**Essential of Marketing Research** "**,**8th Edition**,** Wiley Eastern , 2011.
6. Keith Flether, "**Marketing Management and Information Technology**", Prentice Hall of India, 2000.

Course contents and Lecture schedule

Module No.	Topic	No. of Lectures
1.	**Marketing concepts**	
1.1	Importance	2
1.2	Functions	2
1.3	Customer Satisfaction	2
1.4	Retention	1
1.5	Profitability	1
2	**Marketing process**	
2.1	Marketing plan	2
2.2	Marketing Mix	2
2.3	Marketing Information System	2
2.4	Marketing Research	2
2.5	Consumer Behaviour	2
3	**Product Planning & Pricing**	
3.1	Product Life Cycle	2
3.2	New Product development process	2
3.3	Product Positioning	2
3.4	Branding & Packaging	2
3.5	Pricing Strategy	1
4.0	**Distribution Channels**	
4.1	Marketing Segmentation	2
4.2	Competition	2
4.3	Targeting	1
4.4	Marketing Channels	2
4.5	Channel Management & Dynamics	2
5	**Advertisement & Communication**	
5.1	Integrating Marketing Communication	2
5.2	Promotional Mix	1
5.3	Personal Selling	2
5.4	Sales Promotion & Advertisement	2
5.5	Public Relations & Direct Marketing	2

Module No.	Topic	No. of Lectures
	Total	**45**

Course Designers:

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2. Dr. R.Muruganandham rmmech@tce.edu

14MEPH0	AUTOMOTIVE ENGINEERING	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

Knowledge on fundamentals of automotive engineering is generally expected from a mechanical engineering graduate. Automotive engineering is the branch of mechanical engineering dealing with design, production and maintenance of automotive subsystems. This course covers vehicle performance calculations, vehicle dynamics and design of various subsystems such as transmission, suspension and braking.

Prerequisite

14ME220 - Free body mechanics

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Determine centre of gravity, vehicle performance parameters such as acceleration &gradability, vehicle stability in slope, cornering in level and banked track.	Apply
CO 2.	Design chassis frame, steeringand suspension system of an automobile.	Apply
CO 3.	Design of and transmission and braking system of an automobile.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	M	S	M	L	_	_	_	_	_	_	_	M	_	_
CO2.	S	M	S	M	L	_	_	_	_	_	_	_	M	_	_
CO3.	S	M	S	M	L	_	_	_	_	_	_	_	M	_	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	10	10	10	10
Understand	30	30	30	30
Apply	60	60	60	60
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. A motor car with wheel base 2.75 m with a centre of gravity 0.85 m above the ground 1.15 m behind the front axle has a coefficient of adhesion 0.6 between the tyre and the ground. Calculate the maximum possible acceleration when the vehicle is
   (a) Driven on four wheels
   (b) Driven on the front wheels only
   (c) Driven on rear wheels only

2. A motor cycle with a rider weight 1962 N, the centre of the gravity of the machine and the rider combined being 0.6 m above the ground level when the machine is standing upright. Each road wheel has a moment of inertia of 9.8 Nm^2 and a rolling diameter 0.6 m. The engine rotates at six times the speed of the road wheels and in the same sense. The moment of inertia of the rotating part of the engine is 1.57 Nm^2. Determine the angle of wheel necessary if the unit is travelling at the speed of 64 km/h in a curve of radius of 30m.
3. A car weighing 21336.75 N, has a static weight distribution on the axles 50:50. The wheel base is 3 m and the height of the centre of gravity above ground is 0.55 m. If the coefficient of friction on the highway is 0.6, prove that rear wheel drive offers higher gradability than front wheel drive, if engine power is not a limitation.

Course Outcome 2 (CO2):

1. A bus chassis 5.2 m long, consists of two longitudinal members and many cross members. The distance between front and rear axle is 3.6 m. Front axle is at 0.9 m from the front of the chassis frame. The details of the load and distances are given below.

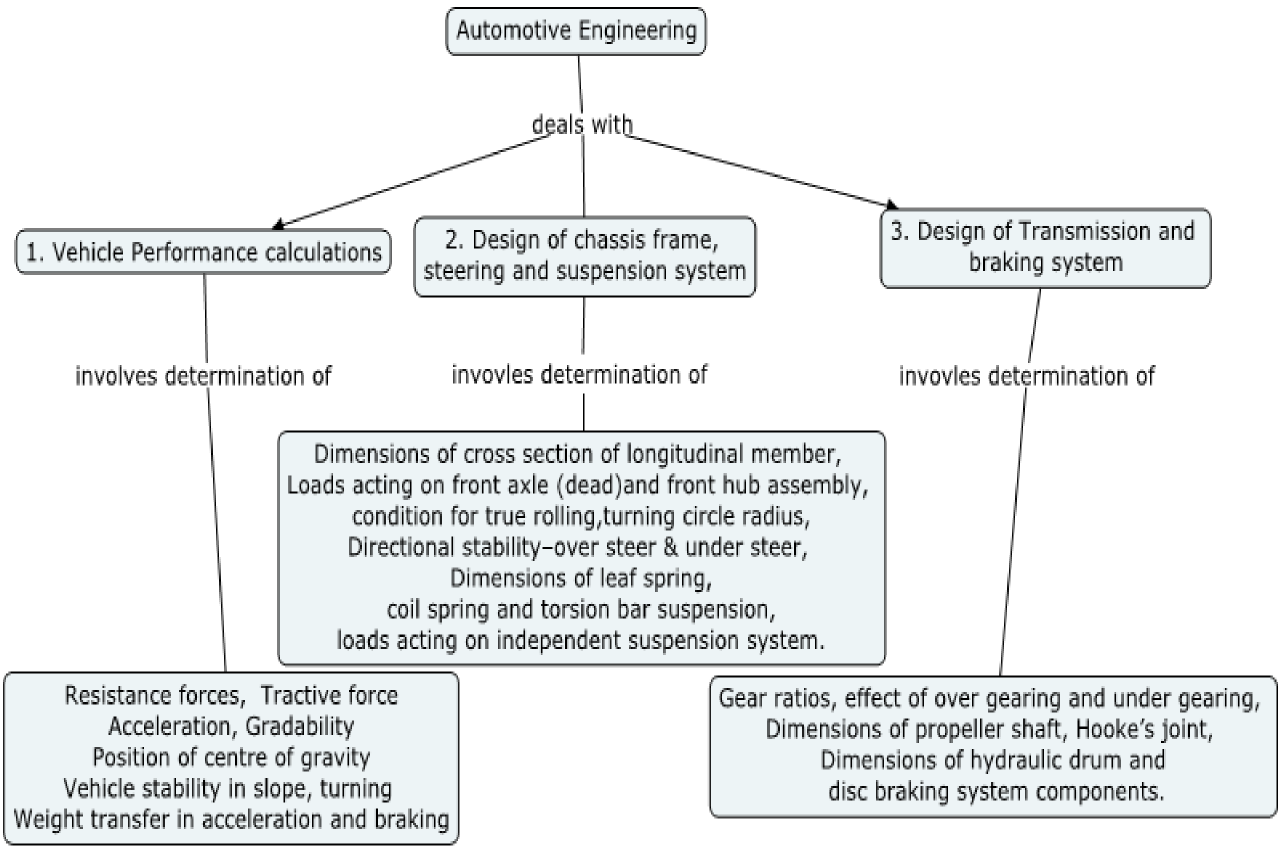
Load	Magnitude (kN)	Distance from the front of the frame (m)
Engine weight (at front)	2	0.6
Engine weight (at rear)	25	1.8
Gear box weight	0.5	2.4
Vehicle body weight	W	3

   If the reaction by front axle is 8.5 kN, determine the magnitude of vehicle body weight W, and the support reaction at B. Suggest suitable cross section to the chassis frame to account for maximum bending moment.
2. A truck has pivot points 1.4 m apart, the length of each track arm is 0.17 m and the track rod is behind front axle and 1.2 m long. Determine the wheel base which will give true rolling for all wheels when the car is turning so that the inner wheel stub axle is 60° to the centre line of the car. Find the turning circle radius of each of the four wheels.
3. A torsion bar suspension is to be designed to support a maximum static load of 3400 N at the end of a lever arm 250 mm long. The deflection of a lever above the horizontal is to be 30° with a total angle deflection of 90°. Assuming a safe allowable stress of 784000 kPa, calculate (a) the diameter of the torsion bar (b) the effective length and (c) the load rate.

Course Outcome 3 (CO3):

1. A motor car engine develops maximum torque at 1900 rpm and maximum power at 3200 rpm. If the bottom gear ratio is 3:1, find the approximate ratios of speed for a gear box having 4 forward speeds when the ratios are in geometrical progression.
   If the same car at top gear has speeds of near about 48 km/h and 80 km/h at the corresponding engine speeds at maximum torque and maximum power respectively and the effective diameter of the driving wheels is 0.61 m, find a suitable back axle ratio.
2. Explain the effect of over gearing and under gearing on vehicle performance.
3. A Hooke's joint connects two shafts whose axes intersect at 150°. The driving shaft rotates uniformly at 120 rpm. The driven shaft operates against a steady torque of 150 Nm and carries q flywheel whose mass is 45 kg and radius of gyration 150 mm. Find the maximum torque which will be exerted by the driving shaft.

Concept Map



Syllabus

Vehicle performance – Various Resistance forces, tractive force, engine power, acceleration, gradability and draw bar pull, Selection of gear ratios. Determination of centre of gravity of a four-wheeler, Vehicle stability in slope, turning in level and banked track, gyroscopic effects, Weight transfer in acceleration and braking.
Design chassis frame: Construction of chassis frame of four wheeler and two wheeler, operating conditions of chassis frame, design of longitudinal member of four wheeler chassis frame. **Vehicle body – components, types and construction.**
Design of front axle and steering system: Loads acting on front axle (dead) and front hub assembly, Front wheel alignment, condition for true rolling, turning circle radius, Directional stability – over steer & under steer, steering linkages, working of power steering.
Design of suspension system: Functions, types of automotive suspension, choice of suspension, design of leaf spring, coil spring and torsion bar suspension, effect of pre-load, Mechanics of independent suspension system.
Design of transmission system: Function and types of automotive clutches, working of diaphragm clutch, Need for gears, working of synchromesh gearbox, over gearing and under gearing, construction and working of torque converter, CVT, Design of propeller shaft, Hooke's joint, types of drives, Need for limited slip differential and centre differential, types of rear axles (live), types of joints in live front axle, **types of wheels and tyres, construction, tyre dynamics.**
Design of braking system: Types, working and design of drum and disc brakes, Hydraulic brake system, Power brake system, Anti-lock braking system (ABS).

Text Books

1. N.K.Giri, "**Automobile Mechanics**", 8th Edition, Khanna Publishers, 2008.
2. Kirpal Singh, "**Automobile Engineering**", Volume-1&2, 13th Edition, Standard Publishers Distributers, 2013.

Reference Books

1. William Crouse, "**Automobile Engineering Series** ", McGraw-Hill, 1988.
2. Newton and Steeds, "**Motor Vehicles** ", ELBS, 1985.
3. Richard Stone and Jeffrey K. Ball, "**Automotive Engineering Fundamentals**" SAE International, 2011.
4. Joseph Heitner, "**Automotive Mechanics, Principle and practices**", East West Press, (Second Edition), 2001.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Vehicle Performance**	
1.1	Various Resistance forces – factors affecting	1
1.2	Tractive force, engine power, acceleration, gradability and draw bar pull, Selection of gear ratios – Theory.	1
1.3	Tractive force, engine power, acceleration, gradability and draw bar pull, Selection of gear ratios - Problems	2
1.4	Determination of centre of gravity of a four-wheeler – Theory and Problems	1
1.5	Vehicle stability in slope, turning in level and banked track, gyroscopic effects – Theory.	1
1.6	Vehicle stability in slope, turning in level and banked track, gyroscopic effects – Problems.	1
1.7	Weight transfer in acceleration and braking – Theory & problems.	1
2	**Design chassis frame, steering and suspension system of an automobile.**	
2.1	Construction of chassis frame of four wheeler and two wheeler, operating conditions of chassis frame.	1
2.2	Design of longitudinal member of four wheeler chassis frame, SF BM diagrams, choice of various cross sections.	2
2.3	Vehicle body – components, types and construction.	1
2.4	Loads acting on front axle (dead) and front hub assembly and their design.	2
2.5	Front wheel alignment	1
2.6	condition for true rolling, turning circle radius	1
2.7	Directional stability – over steer & under steer.	1
2.8	Steering linkages, working of power steering.	1
2.9	Functions, types of automotive suspension, choice of suspension.	1
2.10	Design of leaf spring, coil spring and torsion bar suspension, effect of pre-load.	2
2.11	Mechanics of independent suspension system and its design.	1
3	**Design of Transmission system and braking system**	
3.1	Function and types of automotive clutches, working of diaphragm clutch.	1
3.2	Need for gears, working of synchromesh gearbox.	1
3.3	Effect of over gearing and under gearing on vehicle performance.	1
3.4	Construction and working of torque converter	0.5
3.5	Construction and working CVT	1
3.6	Design of propeller shaft and Hooke's joint.	2
3.7	Construction of Hotchkiss drive and Torque tube drive	1
3.8	Need for limited slip differential and centre differential.	0.5
3.9	Types of rear axles (live), types of joints in live front axle.	1
3.10	Types of wheels and tyres, construction, tyre dynamics	1
3.11	Types of braking system, construction and working of drum and disc brakes.	1

Module No.	Topic	No. of Lectures
3.12	Design of hydraulic drum and disc brakes.	2
3.13	Power brake system, Anti-lock braking system (ABS).	1
	Total	**36**

Course Designers:

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2. Dr. M.Balamurali balacim82@tce.edu

		Category	L	T	P	Credit
14ME610	**OPERATIONS RESEARCH**	BS	2	2	0	3

Preamble

Operations Research is a scientific approach to decision making that leads to best design and operate a system, usually under the conditions requiring the allocation of limited resources.

The term Operations research was coined during world war II when the British military leaders asked scientists and engineers to analyze several military problems such as the management of convoy, bombing, anti submarine and mining operations.

A model is an abstraction or Mathematical representation of a problem of interest and is an essential part of the process of solving that problem optimally. However, it is difficult and sometimes impossible ,to develop a mathematical model that reveals all the aspects of the problem and its planning environment, since most real world problems are too complex.

As the modelling approach provides solutions to the simplified or approximated problem , it is possible to have a significant error between those solutions and the subjectively obtained realistic solution to the original problem.

Prerequisite

- Nil

Course Outcomes

On the successful completion of the course, students will be able to\

Sl. No	Course Outcomes	Blooms level
CO 1.	Apply the concepts of linear Programming Techniques	Apply
CO 2.	Apply the concepts of integer programming problems in the	Apply
CO 3.	Analyse the concepts of dynamic programming	Analyse
CO 4.	Analyse the concepts of transportation and assignment problems	Analyse
CO 5.	Apply the concept of inventory for the purchasing and production models	Analyse
CO 6.	Determine the solutions to Single and Multi channel Queuing problems	Apply
CO 7.	Determine the solutions to non linear programming problems.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	M	M	M	S	_	_	_	_	_	_	M	_	_	_
CO2.	S	M	M	M	S	_	_	_	_	_	_	M	_	_	_
CO3.	S	M	S	S	S	_	_	_	_	_	_	M	_	_	_
CO4.	S	M	S	S	S	_	_	_	_	_	_	M	_	_	_
CO5.	S	M	S	S	S	_	_	_	_	_	_	M	_	_	_
CO6.	S	M	M	M	S	_	_	_	_	_	_	M	_	_	_
CO7.	S	M	M	M	S	_	_	_	_	_	_	M	_	_	_
	S	M	S	S	S	_	_	_	_	_	_	M	_	_	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	10	10	10	00
Understand	20	20	20	20
Apply	50	70	70	60
Analyse	20	00	00	20

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. State the various models of study in OR / Classify OR models.
2. Mention the variants of graphical solution.
3. Compute all the basic feasible solutions to the LPP Max. $Z = 2x_1 + 3x_2 + 4x_3 + 7x_4$ *subject to* $2x_1 + 3x_2 - x_3 + 4x_4 = 8$; $x_1 - 2x_2 + 6x_3 - 7x_4 = -3$; $x_i \geq 0$ *for every* i. Also find the optimal solution.
4. Using Graphical solution solve the following LPP: Max. $Z = 5x_1 + 7x_2$ *subject to* $x_1 + x_2 \leq 4$; $3x_1 + 8x_2 \leq 24$; $10x_1 + 7x_2 \leq 35$; x_1 , $x_2 \geq 0$.
5. Use Simplex Method to solve the LPP: Max. $Z = 5x_1 + 3x_2$ *subject to* $x_1 + x_2 \leq 2$; $5x_1 + 2x_2 \leq 10$; $3x_1 + 8x_2 \leq 12$; x_1 , $x_2 \geq 0$.

Course Outcome 2 (CO2):

1. What is an integer Programming problem (IPP)?
2. What are the different types of IPPs?
3. State the methods available for solving an IPP.
4. Briefly explain / state the different steps in branch and bound technique of solving an IPP.
5. Use Branch and bound Method to solve the IPP: Max. $Z = 7x_1 + 9x_2$ *subject to* $7x_1 + 2x_2 \leq 35$; $-x_1 + 3x_2 \leq 6$; $x_2 \leq 7$; x_1 , $x_2 \geq 0$ are integers.

Course Outcome 3 (CO3):

1. State Bellman's principle of Optimality.
2. Explain the recursive equation approach in solving a dynamic programming problem.
3. What are the characteristics of dynamic programming.
4. State the dynamic programming algorithm.
5. Explain the process of solving Employment smoothing problem using dynamic programming approach.
6. Explain the process of solving Capital Budgeting problem using dynamic programming approach.

7. Determine the positive values value of u1,u2,u3 so as to maximise (u1.u2.u3) subject to u1+u2+u3=10
8. How will you solve a LPP using dynamic programming?
   Solve the following LPP using Dynamic Programming approach: : Max. $Z = 3x_1 + 5x_2$ *subject to* $x_1 + x_2 \le 2$; $5x_1 + 2x_2 \le 10$; $3x_1 + 8x_2 \le 12$; x_1 , $x_2 \ge 0.$

Course Outcome 4 (CO4):

1. State the different methods available for finding an IBFS to a TP.
2. Give the mathematical formulation of an AP
3. Briefly explain the process of solving a maximization type AP.
4. Five workers are available to work with the machines and the respective costs (in Rs.) associated with each worker –machine assignment is given below. A sixth machine is available to replace one of the machines and the associated costs are given below. I) Determine whether the machine can be accepted. II) Determine the optimal assignment and the associated saving cost.

	M1	M2	M3	M4	M5	M6
W1	12	3	6	-	5	8
W2	4	11	-	5	-	3
W3	8	2	10	9	7	5
W4	-	7	8	6	12	10
W5	5	8	9	4	6	--

5. Solve the following travelling Sales man problem

	A	B	C	D	E
A	-	7	6	8	4
B	7	-	8	5	6
C	6	8	-	9	7
D	8	5	9	-	8
E	4	6	7	8	-

Course Outcome 5 (CO5):

1. State the various types of Inventory problems.
2. What are i) Set up Cost ii) Holding cost iii) Shortage cost
3. Briefly explain the News paper boy problem.
4. A manufacturer has to supply his customer with 600 units of his products per year. Shortages are not allowed and storage cost amounts to 60 paise per unit per year. The set up cost is Rs.80. Find i) The economic order quantity ii) The minimum average yearly cost iii) The optimum number of orders per year iv) The optimum period of supply per optimum order.

5. The annual demand for a product is 100000 units The rate of production is 200000 units per year. The set up cost per production run is rs.5000, and the variable production cost of each is Rs.10.The annual holding cost per unit is 20% of the value of the unit. Find the optimum production lot size and the length of the production run.
6. The demand for an item in a company is 18000 units per year, and the company can produce the item at the rate of 3000 per month. The cost of one set up is Rs 500 and the holding cost of one unit per month is 15 paise. The shortage cost of one unit is Rs.20 per month. Determine the optimum manufacturing quantity and the number of shortages .Also determine the manufacturing time and time between set ups.

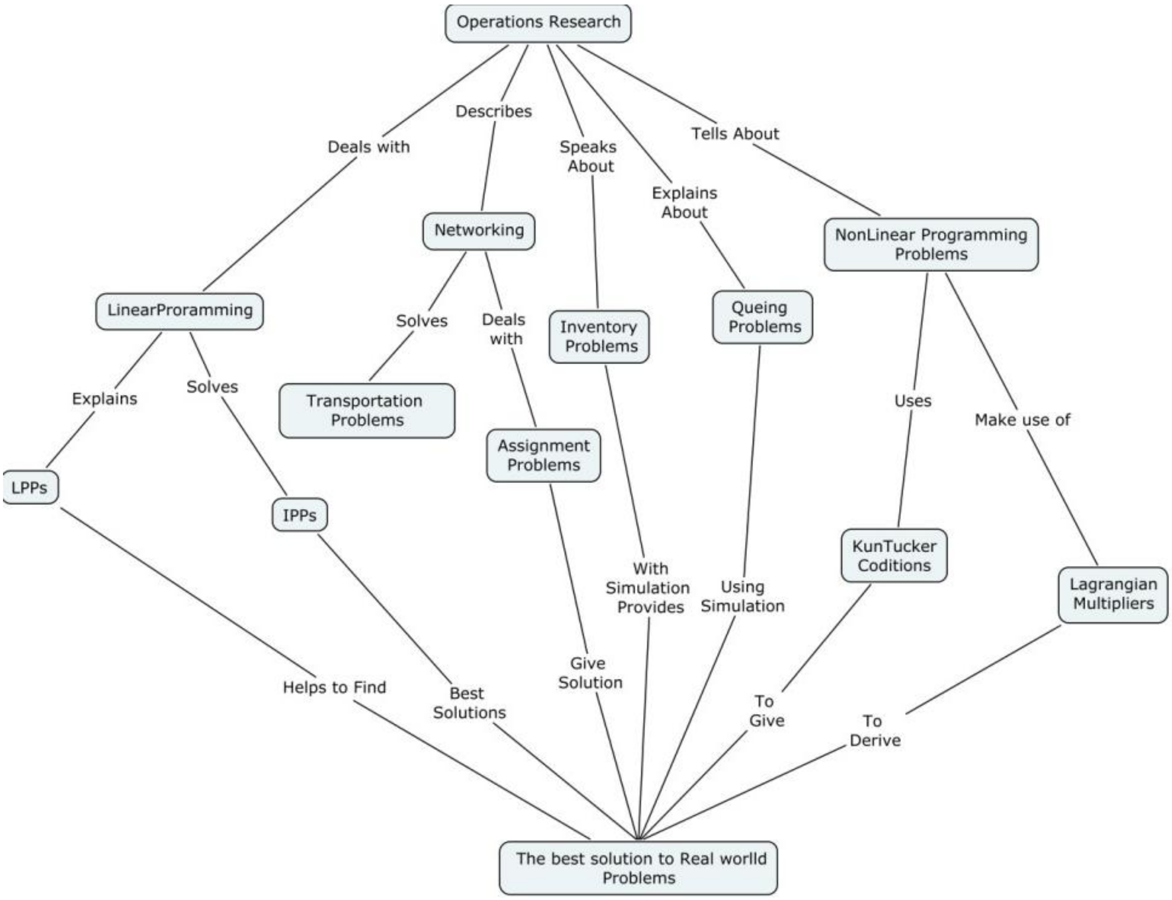
Course Outcome 6 (CO6):

1. Briefly explain a Queuing system.
2. What do you mean by transient and steady state in a Queuing system
3. State the different available service discipline in a queuing system.
4. Explain Kendal's Notation of representing a Queuing system.
5. Specify the basic operating characteristics of a Queuing model.
6. In a railway marshalling yard , goods train arrive at a rate of 30 trains per day Assuming that inter arrival time follows an exponential distribution and the service time distribution is also exponential , with an average of 36 Mins. Calculate the following. I) The mean Queue size ii) The probability that the queue size exceeds 10 iii) If the input of the train increases to an average 33 per day what will be the changes in i) and ii).
7. A T.V repairman finds that the time spent on his job has an exponential distribution with mean 30 Mins. If he repairs sets in the order in which they come in and if the arrival of sets is Poisson with an average rate of 10 per 8 hour day, What is his expected idle time a day? How many jobs are ahead of the average set just brought in?
8. A two channel waiting line with Poisson arrival has a mean rate of 50 per hour and exponential service with mean rate of 75 per hour for each channel. Find i) The probability of an empty system ii) the probability that an arrival in the system will have to wait.

Course Outcome 7 (CO7):

1. What is non linear programming?
2. Define a General NLPP.
3. State the categories of a NLPP.
4. Solve the NLPP $Max.z = 4x_1 - x_1^2 + 8x_2 - x_2^2 \ subject \ to \ x_1 + x_2 = 2 \ and \ x_1 . x_2 \geq 0.$
5. The following NLPP using Lagrangian Multiplier method
   $Optimize.z = 4x_1^2 + 2x_2^2 + x_3^2 - 4x_1x_2 \ subject \ to \ x_1 + x_2 + x_3 = 15 ; 2x_1 - x_2 + 2x_3 = 20 \ and \ x_1 . x_2 \geq 0.$
6. Using Khun Tucker conditions
   $Max.z = 2x_1^2 - 7x_2^2 + 12x \ \ x_2 \ subject \ to \ 2x_1 + 5x_2 \leq 98 \ and \ x_1 . x_2 \geq 0.$

Concept Map



Syllabus

Linear Programming - Phases of **OR** – Linear programming Formulation- Graphical Solution and Simplex Method. **Integer Programming-**IPPs- Definition – types Formulation – Branch and Bound Technique(2 – Variable problems only)(Note: Problems with more than 2 variables and more constraints to be practiced in LINDO / LINGO / Excel / I Log as programming assignments) – **Dynamic Programming** – Principle of optimality-Characteristics of dynamic programming –The recursive equation approach-Dynamic programming Algorithm. **-Transportation problems** – Formulation – Initial solutions using North west Corner Rule, Least Cost Method and Vogel's Approximation Methods-Optimal Solution by Modified Distribution method(MODI)-**Assignment Problems** – Formulation – Optimal Solution by Hungarian Method – Project Management: **Inventory Problems –** Purchase and Production model inventory problems -The Newspaper boy problem- P and Q system of inventories-**Queuing Models-**(Poisson Arrival and Exponential Service pattern)-Basic Terminologies – Single Channel with infinite population queue-Single channel with finite population queue -Multiple channel with infinite population queue. **Simulation-** Stochastic Inventory Models-Waiting line analysis-**Non Linear programming**-Formulation of a NLPP- General NLPP-Constrained optimization with equality constraints, Inequality constraints Solution by Lagrangian Multipler method and verification of Khun Tucker conditions– saddle point problems.

Text Book

1. Sharma J.K **"Operations Research: Theory and Applications"**, Mac Millan India Ltd., Fourth Edition,2009.
2. Hamdy A.Taha "**Operations Research – An Introduction",** MacMillan India Ltd., Seventh Edition ,2003.

Reference Books

1. Panneerselvam.R ‘Operations Research’ Prentice Hall of India -Second Edition 2007.
2. Ravindran.A .Don.T.Phillips and James J.Solbreg ‘Operations Research – Principles and Practce”, John Wiley and Sons second edition – 2000.
3. Hiller / Libermann ,”Introduction to Operations Research” Tata Mc Graw Hill ,Seventh Edition ,2001.
4. Wayne L Winston, “Operations Research : Applications and Algorithms”, Thomson Brooks / Cole Fourth edition,2003.
5. Hira.D Gupta.P.K,”Operations Research”,S.Chand Publications, First Edition, Reprint 2001
6. Sharma S.D ‘Operations Research: Theory, Methods and Applications “, Knrn Publishers, 2015.
7. Kanti swarup Gupta.P.K, Man Muhan” ‘Operations Research: Sultan Chand & Sons India Ltd., Twelth Edition,New Delhi 2004.

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
	Introduction : Phases of Operations Research	1
1	**Linear Programming**	
1.1	LPP formulation	2
	Tutorial	1
1.2	Graphical method for LPPs	1
1.3	Simplex method for LPPs	2
	Tutorial	
2	**Integer Programming**	
2.1	Integer programming Problem Formulation(IPP)	1
2.2	Branch and bound method for IPPs	1
3	**Dynamic Programming**	
3.1	**Dynamic programming Algorithm**	1
	Tutorial	1
3.2	**Solution by dynamic programming approach**	2
	Tutorial	1
4	**Transportation and Assignment problems**	
4.1	Transportation Problems	1
4.2	IBFs by NWCR , LCM and Vogel’s approximation method	1
4.3	Optimal solution for a TP using MODI method	1
	Tutorial	2
4.4	Assignment Problem (AP) Formulation	1

4.5	Hungarian method for AP	1
5	**Inventory Models**	
5.1	Purchase model	1
	Tutorial	1
5.2	Production Model	1
	Tutorial	1
5.3	The news paper boy problem	1
	Tutorial	1
5.4	P and Q system of Inventories	1
	Tutorial	1
6	**Queuing Models** (Poisson arrival and Exponential service pattern)	
5.1	Queuing terminologies and applications	1
5.2	Single Channel – Finite & Infinite population Queue	1
	Tutorial	1
5.4	Multiple channel - Infinite population Queue	1
	Tutorial	1
7	**Simulation**	
7.1	Simulation applied to Queuing problems	1
7.2	Simulation applied to Inventory problems	1
	Tutorial	2
8	**Non Linear Programming**	
8.1	NLPPs with equality constraints	1
	Tutorial	1
8.2	NLPPs with inequality constraints	1
	Tutorial	1
8.3	Solution to NLPPs by Lagrangian Multiplier method and Verification of Khun Tucker conditions	1
	Tutorial	2
	Total	46

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14ME620	KINEMATICS AND DYNAMICS OF MACHINERY	Category	L	T	P	Credit
		PC	2	2	0	3

Preamble

Kinematics and Dynamics of Machines deals with motion and interaction of machine elements. Fundamental concepts of statics, kinematics, and dynamics will be applied to the determination of the motion and interaction of machine elements, as well as forces acting on machines and mechanisms. Specific applications will be made to mechanisms such as rotating machinery, cams, gears, flywheels, and balancing.

Prerequisite

- 14ME220 - Free body Mechanics

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the working principles of various mechanism and its inversions	Understand
CO 2	Determine velocity and acceleration for simple mechanisms	Apply
CO 3.	Develop the cam profile for various type of followers	Apply
CO 4.	Determine the speed and contact ratio of gear pair and gear trains	Apply
CO 5.	Apply the fundamental principles of balancing and gyroscopic effect to various mechanical components.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	M	L	L	L	_	_	_	_	_	_	_	_	M	_	_
CO2.	S	M	M	L	_	_	_	_	_	_	_	_	M	_	M
CO3.	S	M	S	L	_	_	_	_	_	_	_	_	M	_	M
CO4.	S	M	M	L	_	_	_	_	_	_	_	_	M	_	M
CO5.	S	M	M	L	_	_	_	_	_	_	_	_	M	_	M
	S	M	M	L	_	_	_	_	_	_	_	_	M	_	M

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	10
Understand	20	20	20	20
Apply	60	60	60	70
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

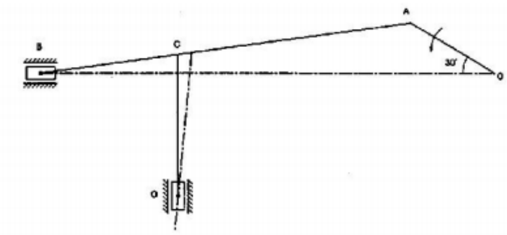
1. Define Kinematic Link. Give examples for Kinematic links.
2. Define kinematic pair
3. Name any four inversions of Single slider Crank Chain Mechanism.

Course Outcome 2 (CO2):

1. The crank of a slider crank mechanism rotates clockwise at a constant speed of 300rpm. the crank is 15 cm and the connecting rod is 600 mm long. Determine (a) linear velocity and acceleration of the midpoint of the connecting rod and (b) angular velocity and angular acceleration of the connecting rod at crank angle of 45º from the inner dead centre position.

2. In a four link mechanism, the dimensions of the links are AB=200 mm, BC=400mm, CD=450 mm and AD=600mm. At the instant when DAB=90°, the link AB has angular velocity of 36 rad/s in the clockwise direction. Determine (i) The velocity of point C, (ii) The velocity of point E on the link BC When BE =200 mm (iii) the angular velocities of links BC and CD, iv) acceleration of link BC.

3. The dimensions of the various links of a mechanism, as shown in fig. are as follows: OA=300 mm; AB=1200; BC=450 mm and CD=450 mm. if the crank OA rotates at 20 r.p.m. in the anticlockwise direction and gives motion to the sliding blocks B and D, find, for given configuration: (1) Velocity of sliding at B and D, (2) Angular velocity of CD (3) Linear acceleration of D and (4) angular acceleration of CD.



Course Outcome 3 (CO3):

1. A cam is used in an IC engine to operate the valves, is required to give a roller follower the motion defined below:

Follower to move outwards through 40 mm during 120^o of cam rotation
Follower to move dwell for next 60^o of cam rotation
Follower to return to its starting position during next 90^o of cam rotation
Follower to dwell for the rest of the cam rotation.

The minimum radius of the cam is 50 mm and the diameter of the roller is 10mm. The line of the stroke of the follower is off-set by 20 mm from the axis of the cam shaft. The displacement of the follower takes place with uniform velocity. Create the cam profile for the given configurations. Also determine the maximum acceleration and velocity during ascent and decent when the cam rotates at 1000 r.p.m.

2. A cam is rotating clockwise at a uniform speed is required to give a roller follower the motion defined below:

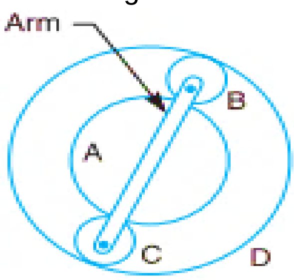
Follower to move outwards through 30 mm during 120^o of cam rotation,
Follower to move dwell for next 60^o of cam rotation,
Follower to return to its starting position during next 90^o of cam rotation
Follower to dwell for the rest of the cam rotation.

The minimum radius of the cam is 45 mm and the diameter of the roller is 20mm. The line of the stroke of the follower is off-set by 10 mm from the axis of the cam shaft. The displacement of the follower is to take place with simple harmonic motion on both the outward and return stroke. Create the cam profile for the given configurations. Also determine the maximum acceleration and velocity during ascent and decent when the cam rotates at 1500 r.p.m.

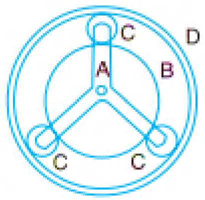
3. Design a cam for operating the exhaust valve of an oil engine. It is required to give equal uniform acceleration and retardation during opening and closing of the valve each of which corresponds to 60° of cam rotation. The valve must remain in the fully open position for 20° of cam rotation.The lift of the valve is 37.5 mm and the least radius of the cam is 40 mm. The follower is provided with a roller of radius 20 mm and its line of stroke passes through the axis of the cam.

Course Outcome 4 (CO4):

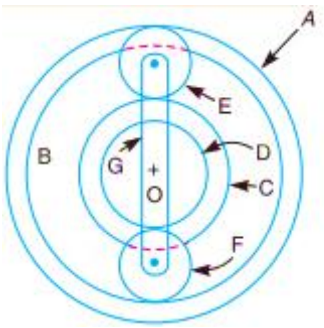
1. An epicyclic train of gears is arranged as shown in Fig. How many revolutions does the arm, to which the pinions B and C are attached, make:
   a) When A makes one revolution clockwise and D makes half a revolution anticlockwise,
   b) When A makes one revolution clockwise and D is stationary? The number of teeth on the gears A and D are 40 and 90 respectively.



2. In an epicyclic gear of the ‘sun and planet’ type shown in Fig. the pitch circle diameter of the internally toothed ring is to be 224 mm and the module 4 mm. When the ring D is stationary, the spider A, which carries three planet wheels C of equal size, is to make one revolution in the same sense as the sunwheel B for every five revolutions of the driving spindle carrying the sunwheel B. Determine suitable numbers of teeth for all the wheels.



3.In an epicyclic gear train, the internal wheels A and B and compound wheels C and D rotate independently about axis O. The wheels E and F rotate on pins fixed to the arm G. E gears with A and C and F gears with B and D. All the wheels have the same module and the number of teeth are: T_C = 28; T_D = 26; TE = T_F = 18.
   1. Sketch the arrangement;
   2. Find the number of teeth on A and B;
   3. If the arm G makes 100 r.p.m. clockwise and A is fixed, find the speed of B
   4. If the arm G makes 100 r.p.m. clockwise and wheel A makes 10 r.p.m. counter clockwise ; find the speed of wheel B.



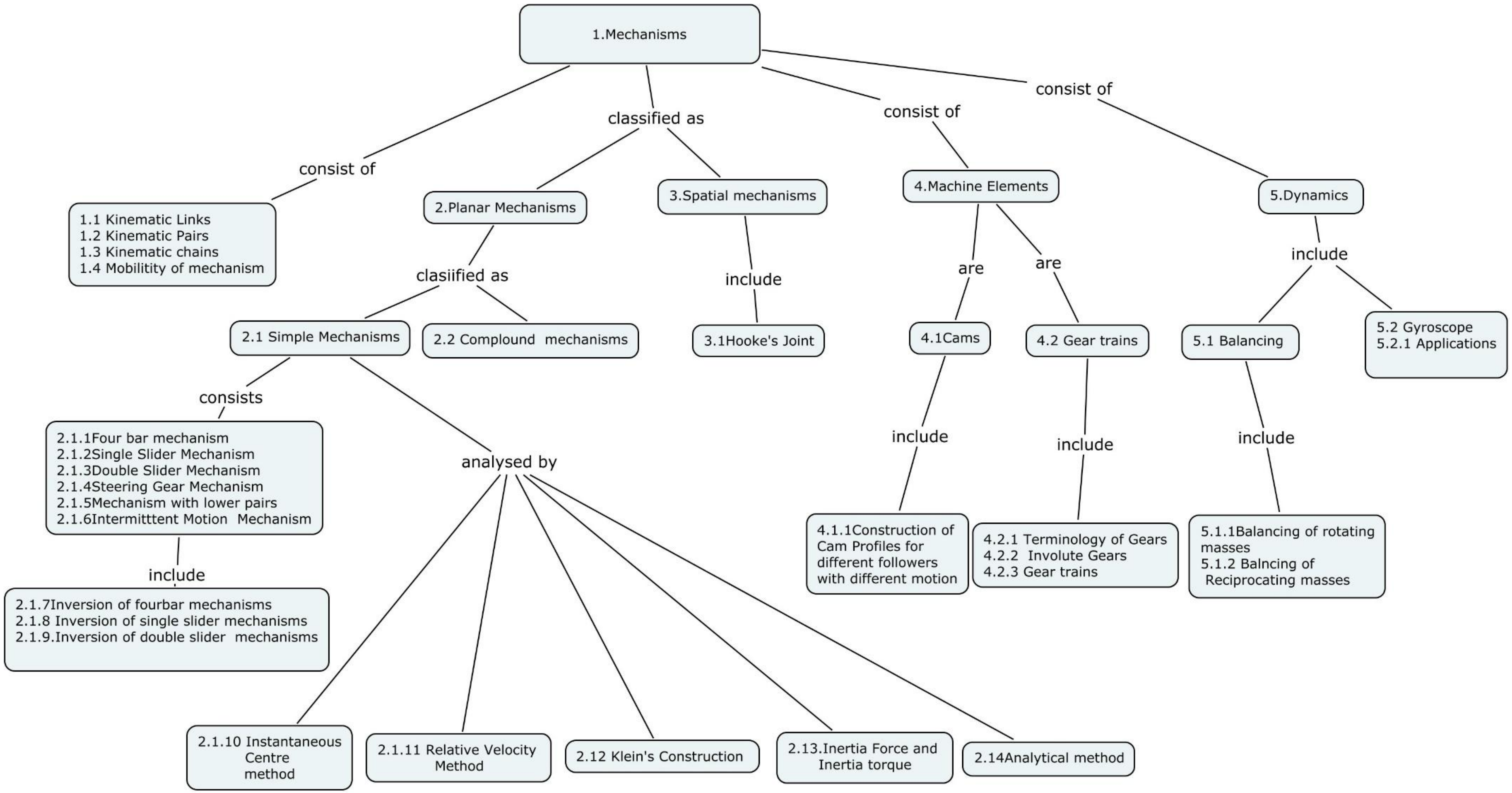
Course Outcome 5 (CO5):

1. The lengths of the crank and connecting rod of a reciprocating engine are 300 mm and 1.5m respectively. The crank is rotating clockwise at a speed of 120 r.p.m. The mass of connecting rod is 250kg and the distance of centre of gravity of the rod from the crank pin centre is 475 mm. The radius of gyration of the rod about centre of gravity is 625 mm. When the crank position is 40° from the inner dead centre then find by graphical method and analytical method (i) Magnitude, position and direction of inertia force due to the mass of the connecting rod (ii) Torque exerted on the crank-shaft in magnitude and direction. Take the mass of reciprocating parts = 290kg.

2. A,B,C and D are four masses carried by a rotating shaft at radii 100. 125, 200 and 150 mm respectively. The planes in which the masses revolve are spaced 600 mm apart and the mass of B, C and D are 10 kg, 5kg, and 4kg respectively. Find the required mass A and the relative angular settings of the four masses so that the shaft shall be in complete balance.

3. A uniform disc of diameter 300 mm and of mass 5 kg is mounted on one end of an arm of length 600 mm. The other end of the arm is free to rotate in a universal bearing. If the disc rotates about the arm with a speed of 300 r.p.m. clockwise, looking from the front, with what speed will it precess about the vertical axis.

Concept Map


1.Mechanisms
consist of
classified as
consist of
consist of
1.1 Kinematic Links
1.2 Kinematic Pairs
1.3 Kinematic chains
1.4 Mobilitity of mechanism
2.Planar Mechanisms
3.Spatial mechanisms
4.Machine Elements
5.Dynamics
clasiified as
include
are
are
include
2.1 Simple Mechanisms
2.2 Complound mechanisms
3.1Hooke's Joint
4.1Cams
4.2 Gear trains
5.1 Balancing
5.2 Gyroscope
5.2.1 Applications
consists
analysed by
2.1.1Four bar mechanism
2.1.2Single Slider Mechanism
2.1.3Double Slider Mechanism
2.1.4Steering Gear Mechanism
2.1.5Mechanism with lower pairs
2.1.6Intermitttent Motion Mechanism
include
include
include
4.1.1Construction of Cam Profiles for different followers with different motion
4.2.1 Terminology of Gears
4.2.2 Involute Gears
4.2.3 Gear trains
5.1.1Balancing of rotating masses
5.1.2 Balncing of Reciprocating masses
include
2.1.7Inversion of fourbar mechanisms
2.1.8 Inversion of single slider mechanisms
2.1.9.Inversion of double slider mechanisms
2.1.10 Instantaneous Centre method
2.1.11 Relative Velocity Method
2.12 Klein's Construction
2.13.Inertia Force and Inertia torque
2.14Analytical method

Syllabus

Introduction to Kinematics, Mechanisms and machines **–Mechanisms:** Kinematic link, Kinematic pairs, Kinematic chains – Mechanism –Mobility of mechanism. **Planar Mechanisms: Simple mechanisms -** Four bar, Single slider crank chain and Double slider crank chain mechanism and their inversions ,Steering gear mechanism, Mechanism with lower pairs -Intermittent Motion Mechanisms. **Analysis of Simple mechanisms:** Instantaneous centre method - Velocity calculation of four bar and Single slider crank chain Mechanisms. **Relative velocity method:** Vector Position Analysis -Velocity and acceleration of four bar and Single slider crank chain Mechanisms -Coriolis component of acceleration in Quick return motion mechanisms. **Klein's construction:** Velocity and acceleration of Single slider crank chain Mechanisms. Inertia force and Inertia torque calculations in single slider mechanisms – Graphical method and Analytical method. **Analytical Method:** Angular velocity and angular acceleration of connecting rod in Single slider crank chain Mechanisms. Complex Mechanisms. **Spatial Mechanisms:** Hooke's Joint. **Cams:** Types of cams and followers - Cam Nomenclature-Displacement, velocity and acceleration curves for various types of motions of follower -Construction of cam profiles for radial cams with reciprocating followers-Knife edge followers - Roller follower - flat faced follower -Uniform Velocity Motion- Cycloidal Motion- Uniform Acceleration and Retardation Motion- Oscillating Roller follower. **Gear trains**: General profiles of gears- Theory of involute gearing -Contact ratio - Gear trains: Simple, Compound, Reverted and Epicyclic gear trains. **Balancing-** need of balancing, concept of static and dynamic balancing, Balancing of rotating mass by another mass in the same plane, Forces due to revolving masses. Concept of reference plane, balancing of several rotating masses in same plane and different planes. Balancing of reciprocating masses. **Gyroscope** – Introduction –gyroscope couple – applications – airplane, ship, two wheelers.

Text Book

1. John Joseph Uicker, Gordon Pennock, Joselph E.Shigley, "**Theory of Machines and Mechanisms**", Third Edition, Oxford University Press, 2010.
2. Rao and Dukkipati, R.V, **"Mechanism and Machine Theory",** New Age International (P) Ltd., 2010.
3. Rattan.S.S**, "Theory of Machines",** Tata McGraw–Hill Publishing Co., New Delhi,2014.

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1. Thomas Bevan, **"Theory of Machines",** CBS – Third Edition, 2010.
2. Singh, V.P., **"Theory of Machines",** Dhanpat Rai & Co., (P) Ltd., New Delhi, 2011.
3. Sadhu Singh, "**Theory of Machines**". Pearson Education, New Delhi, 2009.
4. Ashok G.Ambekar," **Mechanism and Machine theory**",Prentice Hall of India , New Delhi,2011.

5. Ballaney, P.L., **"Theory of Machines",** Khanna Publishers, New Delhi, 2002.
6. **http://nptel.ac.in/courses/112104121/**

Course Contents and Lecture Schedule

S.No	Topic	No. of Lectures
1	**Mechanisms - Introduction**	
1.1	Kinematic link	1
1.2	Kinematic pairs	
1.3	Kinematic chains – Mechanism	1
1.4	Mobility of mechanism	1
2	**Planar Mechanisms**	
2.1	Simple Mechanisms	
2.1.1	Four bar Mechanisms	1
2.1.2	Single slider crank chain Mechanism	
2.1.3	Double slider crank chain mechanisms	
2.1.4	Steering gear mechanism	
2.1.4.1	Ackermann's steering gear mechanism	1
2.1.4.2	Davis steering gear mechanism	1
2.1.5.	Mechanism with lower pairs	
2.1.5.1	Pantograph	2
2.1.5.2	Straight Line Motion Mechanisms	
2.1.6	Intermittent Motion Mechanisms	2
2.1.7	Inversions of Four bar chain	
2.1.8	Inversions of Single slider crank chain mechanisms	1
2.1.9	Inversions of double slider crank chain mechanisms	1
	Analysis of Simple mechanisms	
2.1.10	Instantaneous centre method	
2.1.10.1	Properties of Instantaneous Centre and Arnold-Kennedy's theorem	1
2.1.10.2	Velocity calculation of four bar mechanisms and Single slider crank chain Mechanisms	1
2.1.11	Relative velocity method	
2.1.11.1	Vector Position Analysis -Velocity and acceleration of four bar mechanisms and Single slider crank chain Mechanisms	3
2.1.11.2	Coriolis component of acceleration in Quick return motion	2

S.No	Topic	No. of Lectures
	mechanisms.	
2.1.12	Klein's construction	
2.1.12.1	Velocity and acceleration of Single slider crank chain Mechanisms	1
2.1.13.	Inertia force and Inertia torque	
2.1.13.1	Inertia force and Inertia torque calculations in single slider mechanisms – Graphical method	1
2.1.13.2	Inertia force and Inertia torque calculations in single slider mechanisms – Analytical method	1
2.1.14.	Analytical Method- Angular velocity and angular acceleration of connecting rod in Single slider crank chain Mechanisms	1
2.2	Complex Mechanisms – examples	1
3.1	**Spatial Mechanisms - Hooke's Joint**	
4.1	**Cams**	
4.1.1	Construction of cam profiles for radial cams with reciprocating followers	1
4.1.2	Types of cams and followers - Cam Nomenclature- Displacement, velocity and acceleration curves for various types of motions of follower	1
4.1.3	Construction of cam profiles- Knife edge followers - Roller follower - flat faced follower -Uniform Velocity Motion- Cycloidal Motion- Uniform Acceleration And Retardation Motion- Oscillating Roller follower	3
4.2	**Gear trains**	
4.2.1	General profiles of gears-Terminology of gears and types	1
4.2.2	Theory involute gearing	1
4.2.2.1	Construction of Involute profile and its Characteristics	1
4.2.3	Gear trains	1
4.2.3.1	Simple, Compound and Reverted gear trains	2
4.2.3.2	Epicyclic gear trains	2
5	**Dynamics**	
5.1	**Balancing**	
5.1.1	Need of balancing, concept of static and dynamic balancing	1
5.1.2	Balancing of rotating mass by another mass in the same plane	1

S.No	Topic	No. of Lectures
5.1.3	Forces due to revolving masses. Concept of reference plane	1
5.1.4	Balancing of several rotating masses in same plane and different planes	1
5.1.5	Balancing of reciprocating masses.	1
5.2	**Gyroscope**	
5.2.1	Introduction –gyroscope couple	2
5.2.2	Applications airplane, ship, two wheelers	2
	Total	**46**

Course Designers

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14ME630	QUALITY ENGNEERING	Category	L	T	P	Credit
		PC	2	0	0	2

Preamble

Quality engineering used in the manufacturing and service industries to maintains an improvement environment. For any organization, quality is the key for success or even for the survival in this competitive global market. This course covers the foundations of modern methods of Quality control and improvement.

Prerequisite

- 14ME310 - Statistical techniques

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the basic Concepts of Quality and its tools.	Understand
CO 2.	Construct the X bar, R & σ charts from the available data	Apply
CO 3.	Construct the p, np, c & u charts from the available data	Apply
CO 4.	Measure the performance of the sampling plans	Apply
CO 5.	Inspect the product quality related to specified requirement	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1.	M	L	_	L	M	_	_	L	_	_	_	_	_	_	_
CO2.	S	M	M	L	M	_	_	L	_	_	L	L	_	_	S
CO3.	S	M	M	L	M	_	_	L	_	_	L	L	_	_	S
CO4.	M	M	M	L	M	_	_	L	_	_	L	L	_	_	S
CO5.	M	M	S	M	L	_	_	L	_	_	L	L	_	_	S
	S	M	M	M	M	_	_	L	_	_	L	L	_	_	S

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	40	40	40	40
Apply	40	40	40	40
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. What is the purpose of Quality Control tools?
2. List the Causes of variation.
3. What is Quality Engineering?
4. Explain the 7QC tools?
5. What is Quality Cost?

Course Outcome 2 (CO2):

1. The following observations are made in a crankshaft machining process.

Sample No.	Observations			
	1	2	3	4
1	20.21	20.19	20.25	20.15
2	20.21	20.19	20.23	20.17
3	20.17	20.16	20.20	20.18
4	20.10	20.11	20.18	20.09
5	20.01	20.03	20.05	19.97
6	20.01	19.97	19.99	20.01
7	20.09	20.05	20.00	20.03
8	19.99	19.98	20.01	19.97

(i) Compute the trial control limits for X and R charts.

(ii) Construct X bar and R chart

2. An analyst collects 20 samples of size 200 each from the output of a final assembly line. The items in each sample are inspected and the number of defectives in each sample is noted as below. Compute 3σ control limits for a chart for number of defectives which the analyst wants to maintain at the last station of this assembly line.

Sample No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
No. of defectives	8	8	15	18	9	7	9	11	17	12
Sample No.	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
No. of defectives	12	9	13	15	10	10	8	11	26	18

Course Outcome 3 (CO3):

1. Data for the number of dissatisfied customers in a department store observed for 20 samples of size 300 is shown in the table .Construct an np- chart for the number of dissatisfied customers .

Number of dissatisfied customers:

Sample	Number of dissatisfied customers.
1.	10
2.	12
3.	8
4.	9
5.	6
6.	11
7.	13
8.	10
9.	8

10.	9
11	6
12.	19
13.	10
14.	7
15.	8
16.	4
17.	11
18.	10
19.	6
20.	7
TOTAL	184

2. The following table shows the number of point defects on the surface of a bus body on August 2015.

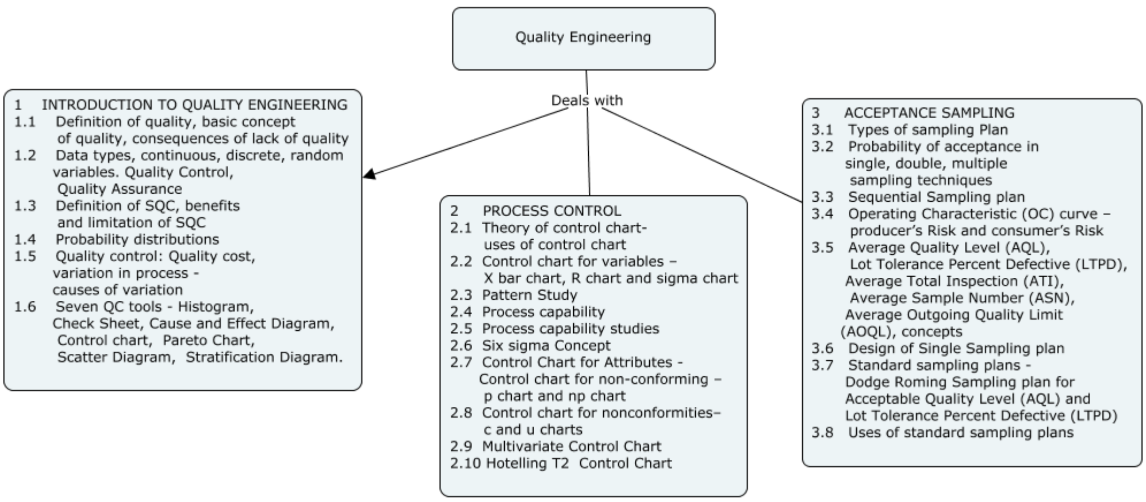
Body No.	1	2	3	4	5	6	7	8	9	10
No. of Defects	2	2	4	7	5	6	7	14	2	9
Body No.	11	12	13	14	15	16	17	18	19	20
No. of Defects	3	0	5	1	3	10	4	3	12	6

(i) Compute the average number of defects
(ii) Compute trial control limits
(iii) Plot the chart
(iv) Draw conclusion.

Course Outcome 4 (CO4):

1. Construct an OC curve for a single sampling plan where the lot size is 2000, the sample size is 50, and the acceptance number is 2
2. Construct the AOQ curve for a sampling plan N=2000, n=50, c=2.
3. Construct the ATI curve for the sampling plan where N=2000, n=50, c=2
4. Find a single sampling plan that satisfies a producers risk of 5% for lots that are 1.8% nonconforming , and a consumers risk of 10% for lots that are 9%
5. nonconforming .

Concept Map



Syllabus

Introduction to Quality Engineering: Definition of quality, basic concept of quality, consequences of lack of quality–Data types, continuous, discrete, random variables. Quality Control, Quality Assurance – Definition of SQC, benefits and limitation of SQC, Probability distributions – Quality control: Quality cost, variation in process - causes of variation – Seven QC tools: Histogram, Check Sheet, Cause and Effect Diagram, Control chart, Pareto Chart, Scatter Diagram, Stratification Diagram.

Process Control : Theory of control chart- uses of control chart – Control chart for variables – X bar chart, R chart and sigma chart – pattern study - process capability – process capability studies – Six Sigma Concept.

Control chart for attributes - Control chart for nonconforming – p chart and np chart – Control chart for nonconformities – c and u charts – Multivariate Control Chart - Hotelling T^2 Control Chart.

Acceptance Sampling: Types of sampling plan – Probability of acceptance in single, double, multiple sampling techniques and Sequential Sampling plan – Operating Characteristic (OC) curve – producer's Risk and consumer's Risk– Average Quality Level (AQL), Lot Tolerance Percent Defective (LTPD), Average Total Inspection (ATI) , Average Sample Number (ASN), Average Outgoing Quality Limit (AOQL), concepts - Design of Single sampling plan - Standard sampling plans - Dodge Roming Sampling Plan for Acceptable Quality Level (AQL) and Lot Tolerance Percent Defective (LTPD) - uses of standard sampling plans.

Introduction about statistical software – (One assignment will be based on statistical software)

Text Book

1. Douglas C. Montgomery, **"Introduction to Statistical Quality control",** John Wiley and Sons Inc, Sixth Edition, 2009.
2. Amitava Mitra, **"Fundamentals of Quality Control and Improvement"**, Pearson Education Asia, Second Edition, 1998.

Reference Books

1. Besterfield D.H., **"Quality Control"**, Prentice Hall, Seventh Edition, 2001.
2. Grant, Eugene .L, **"Statistical Quality Control"**, McGraw-Hill, Tenth reprint, 2008
3. Monohar Mahajan, **"Statistical Quality Control"**, Dhanpat Rai & Sons, 2001.
4. R.C.Gupta, **"Statistical Quality control"**, Khanna Publishers, 1997.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**INTRODUCTION TO QUALITY ENGINEERING**	
1.1	Definition of quality, basic concept of quality, consequences of lack of quality	1
1.2	Data types, continuous, discrete, random variables. Quality Control, Quality Assurance	1
1.3	Definition of SQC, benefits and limitation of SQC	1
1.4	Probability distributions	1
1.5	Quality control: Quality cost, variation in process - causes of variation	1
1.6	Seven QC tools - Histogram, Check Sheet, Cause and Effect Diagram, Control chart, Pareto Chart, Scatter Diagram, Stratification Diagram.	1
2	**PROCESS CONTROL**	
2.1	Theory of control chart- uses of control chart	1
2.2	Control chart for variables – X bar chart, R chart and sigma chart	1
2.3	Pattern Study	1
2.4	Process capability	1
2.5	Process capability studies	1
2.6	Six sigma Concept	1
2.7	Control Chart for Attributes - Control chart for non-conforming – p chart and np chart	1
2.8	Control chart for nonconformities– c and u charts	1
2.9	Multivariate Control Chart	1
2.10	Hotelling T^2 Control Chart	1
3	**ACCEPTANCE SAMPLING**	
3.1	Types of sampling Plan	1
3.2	Probability of acceptance in single, double, multiple sampling techniques	1
3.3	Sequential Sampling plan	1
3.4	Operating Characteristic (OC) curve – producer's Risk and consumer's Risk	1
3.5	Average Quality Level (AQL), Lot Tolerance Percent Defective (LTPD), Average Total Inspection (ATI), Average Sample Number (ASN),	1

	Average Outgoing Quality Limit (AOQL), concepts	
3.6	Design of Single Sampling plan	1
3.7	Standard sampling plans - Dodge Roming Sampling plan for Acceptable Quality Level (AQL) and Lot Tolerance Percent Defective (LTPD)	1
3.8	Uses of standard sampling plans	1
	TOTAL	**24**

Course Designers:

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14ME640	DESIGN OF TRANSMISSION SYSTEMS	Category	L	T	P	Credit
		PC	2	2	0	3

Preamble

A transmission is a machine in a power transmission system, which provides controlled application of the power. A transmission has multiple speed ratios with the ability to switch between them as speed varies. This switching may be done manually or automatically. Single-ratio transmissions also exist, which simply change the speed and torque of output. This course is concerned with design of mechanical transmission systems for engineering applications.

Prerequisites

- 14ME320 - Mechanics of Materials
- 14ME520 - Design of Machine Elements

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level	Expected Proficiency (%)	Expected Attainment Level (%)
CO 1.	Design a suitable flat belt, V-belt and chain drive for specified loading condition.	Apply	70	65
CO 2.	Determine the number of teeth, bending strength and wear strength for given spur gear, bevel gear, worm gear and bevel gear pair.	Apply	70	65
CO 3.	Design the gearbox and gear shaft dimensions for given speed conditions.	Analyze	70	65
CO 4.	Design the single plate clutch, multiple plate clutch for given specified loading conditions.	Apply	70	65
CO 5.	Design a rolling contact bearing and sliding contact bearing for given power transmission application.	Apply	70	70

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	M	S	S	_	_	_	_	_	_	_	_	S	_	S
CO2.	S	M	S	S	_	_	_	_	_	_	_	_	S	_	S
CO3.	M	S	S	S	_	_	_	_	_	_	_	_	S	_	S
CO4.	S	M	S	S	_	_	_	_	_	_	_	_	S	_	S
CO5.	S	M	S	S	_	_	_	_	_	_	_	_	S	_	S
	S	S	S	S	_	_	_	_	_	_	_	_	S	_	S

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	10	10	10	10
Understand	10	10	10	10
Apply	80	80	40	55
Analyse	0	0	40	25
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1) Design a fabric belt to transmit 15kW at 480rpm, from an engine to a line shaft at 1200rpm. The diameter of engine pulley is 600mm and centre distance between the pulley is 2m.
2) Design a V-belt drive and calculate the actual belt tension and average stress for the following data. Driven pulley diameter, D= 500 mm, driver pulley diameter, d=150 mm, center distance c=925 mm, speed n1 = 1000 rpm, n2 = 300 rpm and power, P = 7.5 kW.
3) Designs a chain drive to actuate a compressor from a 12 kW electric motor at 900 rpm, the compressor begin 250 rpm. Minimum centre distance should be 500 mm, the chain tension may be adjusted by shifting the motor on rails. The compressor is to work 8 hour/day.

Course Outcome 2 (CO2):

1) Design a pair of helical gears to transmit 30kW power at a speed reduction ratio of 4:1. The input shaft rotates at 2000 rpm. Take helix and pressure angles equal to 25°and 20°respectively. The number of teeth on the pinion may be taken as 30.
2) A motor shaft rotating at 1500 rpm has to transmit 15kW to a low speed shaft with a speed reduction of 3:1. Assume starting torque to be 25% higher than the running torque. The teeth are 20°involutes with 25 teeth on the pinion. Both the pinion and gear are made of C45 steel. Design a spur gear drive to suit the above conditions and check for compressive and bending stresses and plastic deformations. Also sketch the spur gear drive.
3) Design a worm gear drive to transmit a power of 22.5 kW. The worm speed is 1440 r.p.m. and the speed of the wheel is 60 r.p.m. The drive should have a minimum efficiency of 80% and above. Select suitable materials for worm and wheel and decide upon the dimensions of the drive.

Course Outcome 3 (CO3):

1) Sketch the arrangements of a six speed gear box. The minimum and maximum speeds required are around 460 and 1400 rpm. Drove speed is 1440 rpm. Construct speed diagram of the gear box and obtain various reduction ratios. Use standard output speeds and standard step ratio. Calculate number of teeth in each gear and verify whether the actual output speeds are within + 2% of standard speeds.
2) Design the layout of a 12 speed gear box for a milling machine having an output of speeds ranging from 180 to 2000 rpm. Power is applied to the gear box from a 6 kW induction motor at 1440 rpm. Choose standard step ratio and construct the speed

diagram. Decide upon the various reduction ratios and number of teeth on each gear wheel sketch the arrangement of the gear box.

3) A machine tool gear box is to have 9 speeds. The gear box is driven by an electric motor whose shaft rotational speed is 1400 r.p.m. The gear box is connected to the motor by a belt drive. The maximum and minimum speeds required at the gear box output are 1000 r.p.m. and 200 r.p.m. respectively. Suitable speed reduction can also be provided in the belt drive. What is the step ratio and what are the values of 9 speeds? Sketch the arrangement. Obtain the number of teeth on each gear and also the actual output speeds.

Course Outcome 4 (CO4):

1) Design a single plate automobile clutch to transmit a maximum torque of 250 N-m at 2000 r.p.m. The outside diameter of the clutch is 250 mm and the clutch is engaged at 55 km/h. Find: 1. the number of revolutions of the clutch slip during engagement; and 2. heat to be dissipated by the clutch for each engagement. The following additional data is available: Engine torque during engagement = 100 N-m; Mass of the automobile = 1500 kg; Diameter of the automobile wheel = 0.7 m; Moment of inertia of combined engine rotating parts, flywheel and input side of the clutch = 1 kg-m^2; Gear reduction ratio at differential = 5; Torque at rear wheels available for accelerating automobile = 175 N-m; Coefficient of friction for the clutch material = 0.3; Permissible pressure = 0.13 N/mm^2.
2) A multiple disc clutch, steel on bronze, is to transmit 4.5 kW at 750 r.p.m. The inner radius of the contact is 40 mm and outer radius of the contact is 70 mm. The clutch operates in oil with an expected coefficient of 0.1. The average allowable pressure is 0.35 N/mm^2. Find: 1. the total number of steel and bronze discs; 2. the actual axial force required; 3. the actual average pressure; and 4. the actual maximum pressure.
3) A plate clutch has three discs on the driving shaft and two discs on the driven shaft, providing four pairs of contact surfaces. The outside diameter of the contact surfaces is 240 mm and inside diameter 120 mm. Assuming uniform pressure and μ = 0.3, find the total spring load pressing the plates together to transmit 25 kW at 1575 r.p.m. If there are 6 springs each of stiffness 13 kN/m and each of the contact surfaces has worn away by 1.25 mm, find the maximum power that can be transmitted, assuming uniform wear.

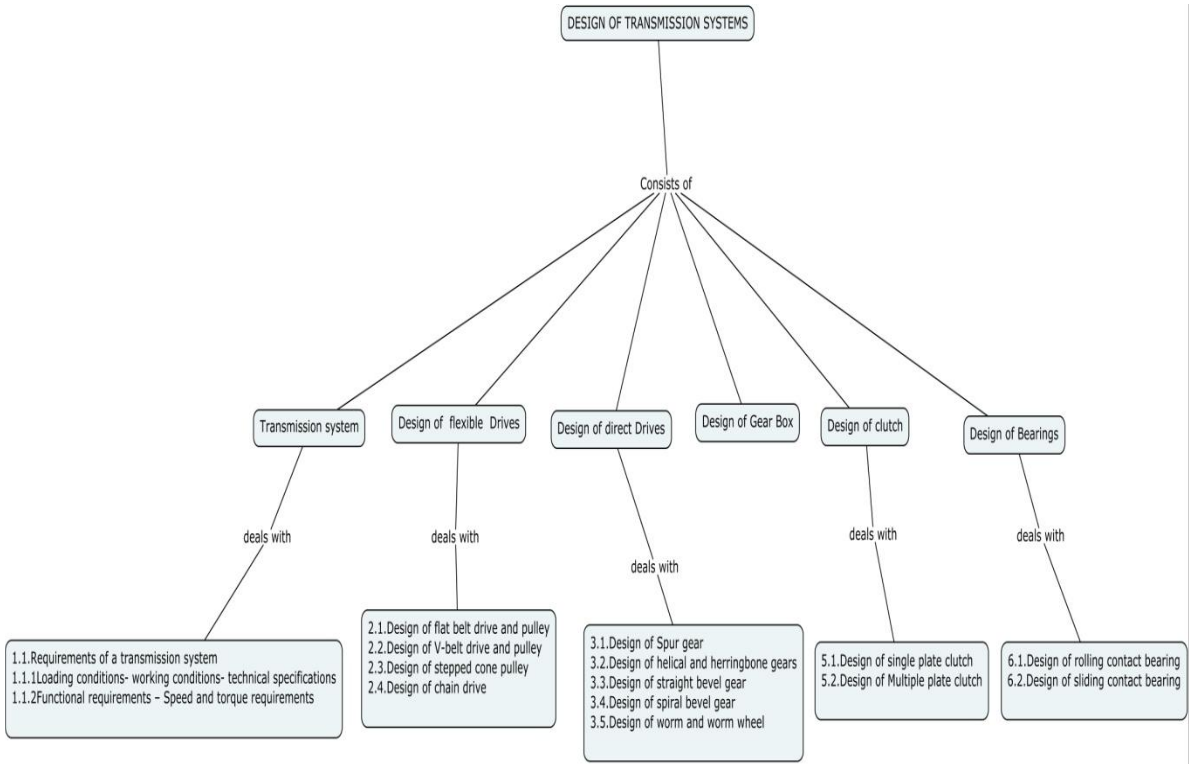
Course Outcome 5 (CO5):

1) Design a journal bearing for a centrifugal pump from the following data: Load on the journal = 20 000 N; Speed of the journal = 900 r.p.m. Type of oil is SAE 10, for which the absolute viscosity at 55°C = 0.017 kg / m-s; Ambient temperature of oil = 15.5°C; Maximum bearing pressure for the pump = 1.5 N / mm^2.Calculate also mass of the

lubricating oil required for artificial cooling, if rise of temperature of oil be limited to 10°C. Heat dissipation coefficient = 1232 W/m^2/°C.

2) A full journal bearing of 50 mm diameter and 100 mm long has a bearing pressure of 1.4 N/mm^2. The speed of the journal is 900 r.p.m. and the ratio of journal diameter to the diametral clearance is 1000. The bearing is lubricated with oil whose absolute viscosity at the operating temperature of 75°C may be taken as 0.011 kg/m-s. The room temperature is 35°C. Find 1. The amount of artificial cooling required, and 2. The mass of the lubricating oil required, if the difference between the outlet and inlet temperature of the oil is 10°C. Take specific heat of the oil as 1850 J / kg / °C.
3) Select a single row deep groove ball bearing for a radial load of 4000 N and an axial load of 5000 N, operating at a speed of 1600 r.p.m. for an average life of 5 years at 10 hours per day. Assume uniform and steady load.

Concept Map



Syllabus

Transmission system- Requirements of a transmission system- Loading conditions- working conditions- technical specifications- Functional requirements – Speed and torque requirements - **Design of flexible Drives-** Design of Flat Belt Drive, Design of V Belt Drive, Design of Stepped cone pulleys- Design of Chain Drive- Strength calculation and checking. **Design of Positive Drives-** Design of Spur gears, Design of helical and herringbone gears, Design of straight bevel gear, Design of spiral bevel gear- Design of worm and worm wheel- Determination of number of teeth, bending strength and wear strength **- Design of Gear Box-** Structural Diagram Kinematic arrangement, Center distance and number of teeth calculation, Strength calculation and checking, Design of gear shafts and shaft Length- **Design of clutch -** Single plate clutch, Multi plate Clutch, **Design of Bearings-** Sliding contact bearing , rolling contact bearing.

Text Books

1. Joseph Edward Shigley and Charles R. Misucke, “**Mechanical Engineering Design**”, Tenth Edition, Tata McGraw Hill, 2015.
2. Robert L. Norton, “**Machine Design: An Integrated Approach**”, Third Edition”, Prentice Hall, 2005.
3. V.B. Bhandari, **“Design of Machine Elements”,** Third Edition, Tata McGraw Hill, 2010
4. T.J.Prabu, "**Design of Transmission Elements”** Fifth Edition, Mani publishers,2008

Reference Books

1. Sundarajamoorthy T.V. and Shanmugam. N, “**Machine Design**”, Anuradha Publications, 2003.
2. Hall, Holowenko and Laughin, “**Theory and Problems of Machine Design**”, Tata McGraw Hill Company, 2002.
3. Sharma P. C, and Agarwal D.K, “**Machine design**”, S.K. Kataria and Sons, New Delhi, 2000.
4. M. F. Spotts, T. E. Shoup, “**Design of Machine Elements”**, Eighth Edition” Pearson Education Asia, 2006.
5. PSG, “**Design Data Book**”, 2015.

Course Contents and Lecture Schedule

S.No.	Topic	No. of Lectures
1	**Power transmission system**	
1.1	Requirements of a transmission system	1
1.1.1	Loading conditions- working conditions- technical specifications	1
1.1.2	Functional requirements – Speed and torque requirements	
2	**Design of flexible drives**	
2.1	Design of flat belt drive and pulley	2
2.2	Design of V-belt drive and pulley	2
2.3	Design of stepped cone pulley	2
2.4	Design of chain drive	2
	Tutorial	1
3	**Design of positive drives**	
3.1	Design of spur gear	2
3.2	Design of helical and herringbone gears	2
	Tutorial	1
3.3	Design of straight bevel gear	2
3.4	Design of spiral bevel gear	2

3.5	Design of worm and worm wheel - Determination of number of teeth, bending strength and wear strength	2
	Tutorial	1
4	**Design of Gear Box**	3
	Tutorial	1
5	**Design of clutch**	
5.1	Design of single plate clutch	2
5.2	Design of multiple plate clutch	2
	Tutorial	1
6	**Design of Bearings**	
6.1	Design of sliding contact bearing	2
6.2	Selection of rolling contact bearing	2
	Tutorial	1
	Total	**37**

Course Designers:

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14ME680	COMPUTER AIDED MANUFACTURING LAB.	Category	L	T	P	Credit
		PC	0	0	2	1

Preamble

Computer Aided Manufacturing (CAM) is the use of different packages to control the computer controlled machine tools and related machineries to produce the work pieces. It uses geometrical design data to control automated machinery. CAM systems are associated with computer numerical control (CNC) or direct numerical control (DNC) systems.

Prerequisite

14ME580 – Computer Aided Modeling Laboratory

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Develop manual CNC Turning Program for the given component and machine the component	Apply
CO 2.	Develop manual CNC Milling Program for the given component and machine the component	Apply
CO 3.	Generate CNC Program for Milling Operation using CAM Package	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	M	M	_	_	S	_	_	_	_	_	_	_	S	_	L
CO2.	M	L	_	_	S	_	_	_	_	_	_	_	S	_	L
CO3.	M	L	_	_	S	_	_	_	_	_	_	_	S	_	L
	M	M	_	_	S	_	_	_	_	_	_	_	S	_	L

S- Strong; M-Medium; L-Low

Syllabus

List of Exercises

1. Develop a manual CNC Program for Step with Tapper turning operation along with its tool simulation.
2. Develop a manual CNC Program for Tapper with curvature operation along with its tool simulation.
3. Prepare a manual CNC program for curvature and threading operation along with its tool simulation.
4. Prepare a manual code for internal step turning operation along with its tool simulation.
5. Perform Step with Tapper turning operation along with its tool simulation using CNC machine.
6. Develop a manual CNC Program for profile milling operation.
7. Develop a manual CNC Program for Profile milling and circular pocket operation with simulation.
8. Develop a manual CNC Program for Profile milling and rectangular pocket with simulation.
9. Prepare a manual CNC Program for Profile milling, pocket and drilling with simulation.
10. Perform profile operation along with its tool simulation using CNC milling machine.

11. Generate CNC Program for profile milling and drilling operations using CAM Package.
12. Generate CNC Program for profile milling and pocketing operations using CAM Package.
13. Generate CNC Program for profile milling, drilling and pocketing operations using CAM Package.
14. Create a given Sheet metal model (Both Unfold and Finish) using sheet metal package.

Note: Minimum of 12 exercises are to be conducted.

Terminal Examination: Students would be tested TWO exercises with 1½ hours duration each.

Course Designers:

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14ME691	MECHANICAL MEASUREMENTS AND METROLOGY LAB.	Category	L	T	P	Credit
		PC	0	0	2	1

Preamble

Students of Mechanical Engineering need to be exposed to the practical knowledge on physical measurement techniques such as force, torque, strain, displacement and dimensional measurement techniques such as linear and angular measurement of part, surface finish measurements and inspection methods using comparators and gauges.

Prerequisite

- 14ME550 - Mechanical Measurements and Metrology.

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO1.	Draw the calibration curve for force, torque, strain, speed and displacement measurements.	Apply
CO2.	Measurement of temperature and level	Apply
CO3.	Determine the linear and angular dimensions of thread, taper plug gauge etc.	Apply
CO4.	Determine the surface finish of the given part.	Apply
CO5.	Calibrate linear measurement devices using slip gauges.	Apply
CO6.	Determine of whirling speed of shaft , Gyroscopic couple, lift of cams	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1.	S	S	S	M	M	_	_	_	_	_	_	_	M	M	L
CO2.	M	M	M	M	M	_	_	_	_	_	_	_	_	_	_
CO3.	S	S	S	M	M	_	_	_	_	_	_	_	M	_	L
CO4.	S	S	S	M	M	_	_	_	_	_	_	_	M	_	L
CO5.	S	S	S	M	M	_	_	_	_	_	_	_	M	_	L
CO6.	S	S	S	M	M	_	_	_	_	_	_	_	M	_	L
	S	S	S	M	M	_	_	_	_	_	_	_	M	L	L

S- Strong; M-Medium; L-Low

Syllabus

MECHANICAL MEASUREMENTS LAB.

List of Experiments:

1. Displacement measurement using LVDT.
2. Force measurement using Load cell.
3. Strain measurement using strain measurement trainer.
4. Torque measurement using torque measurement trainer.
5. Speed measurement using DC servo motor control system.

6. Temperature measurement using temperature trainer.
7. Level measurement using level trainer.
8. Determination of whirling speed of the given shaft
9. Determination of Gyroscopic couple
10. Determination of rising , return, dwell angle and lift of the given cam

METROLOGY LAB.

List of Experiments:

1. Profile measurement of linear, angular and thread elements using Tool Makers Microscope.
2. Profile measurement of linear, angular and thread elements using Profile Projector.
3. Measurement of Surface Roughness using portable surface roughness tester.
4. Straightness / Flatness Testing using Autocollimator.
5. Checking of OD and ID using comparators– Pneumatic, electronic and mechanical.
6. Calibration of micrometer / vernier caliper using Standard slip gauge
7. 2D & 3D measurements using CMM.

Note. Minimum of 12 experiments are to be given. (At least six experiments in each Lab)
Terminal Examination: Students would be tested in both labs each 1 ½ hours duration.

Course Designers:

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		Category	L	T	P	Credit
14ME710	**PROJECT MANAGEMENT**	HS	2	2	0	3

Preamble

This course gives an exposure to the basic concepts involved in the formulation of a project, project management principles, importance and need for network techniques and its applications to a project.

Prerequisite

- Nil

Course Outcomes

On the successful completion of the course, students will be able to:

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain project, project management, life cycle and project formulation	Understand
CO 2.	Analyze and Manage time in projects through Gantt charts, CPM and PERT techniques, update and monitor projects	Apply
CO 3.	Manage resources of project using resource smoothing and levelling techniques	Apply
CO 4.	Optimize resources of projects using scheduling, fast tracking and re-estimation techniques	Apply
CO 5.	Identify the need for communication and risk management in projects with emerging trends in project management	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	_	_	_	_	_	L	L	_	_	_	M	L	_	_	_
CO2.	S	S	M	_	_	M	L	_	M	L	S	L	_	_	_
CO3.	S	S	S	_	_	M	L	_	M	L	S	L	_	_	M
CO4.	S	S	M	_	_	M	L	_	M	L	S	L	_	_	M
CO5.	_	_	_	_	_	M	_	_	_	M	L	_	_	_	_
	M	M	M	_	_	M	L	_	M	L	S	L	_	_	L

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	10	10	10
Understand	20	30	10	10
Apply	60	60	60	60
Analyze	0	0	20	20
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define project and project management. Mention its need
2. Discuss the functions of project management
3. Discuss the life cycle of projects with influencing factors

Course Outcome 2 (CO2):

1. Differentiate between CPM and PERT
2. A project consists of six activities with the following logical relationships. Draw a network for the project and determine the critical path using traditional method

- A and B are initial activities and can be performed concurrently
- C follows A but cannot start until B is over
- D and E succeed B
- C and D precede F
- E and F are terminal activities

Activity	A	B	C	D	E	F
Duration (Days)	7	8	3	2	7	4

Find the status of the project on the 10th day of its commencement.

3. Conduct Event oriented network analysis for the following project and determine:

- Earliest and latest allowable occurrence times for the events
- Expected time and standard deviations for activities
- Project completion time and its degree of variability
- What is the probability of completing the project 2 days ahead of schedule?
- What is the probability of not completing the project 1 day behind schedule?
- Find the due date that has 75% chance of being met?

Activity (i-j)	1-2	1-3	2-4	3-4	3-5	4-5	5-6
t_0 days	2	3	4	0	7	2	4
t_m days	3	3	10	0	12	7	6
$t_p$days	5	3	12	0	15	9	8

Course Outcome 3 (CO3):

1. Prepare the need for balancing of resources in project? Mention its significance
2. For an automobile industry project you as a project manager is vested with the responsibility of balancing manpower requirement, which method would you adopt for this process. Justify your answer with suitable reasons.
3. Balance the resource demand for the following project so as to meet the availability of only 7 men/day

Activity (i-j)	0-1	0-3	0-6	1-2	3-4	3-7	6-7	2-5	4-5	7-8	5-8
Duration (days)	2	2	1	4	5	8	3	1	4	5	3
Manpower	3	6	4	2	2	4	5	4	2	2	5

Course Outcome 4 (CO4):

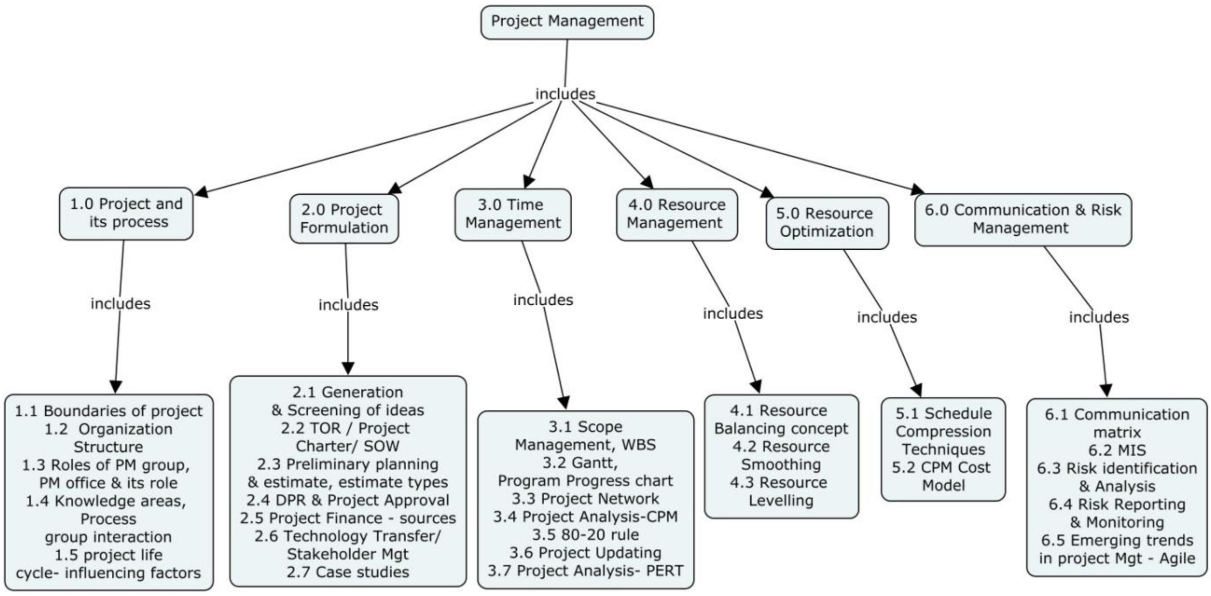
1. Define the term direct cost in projects with examples
2. Prepare the need and meaning of fast tracking and estimation of projects
3. A project consists of 7 activities with costs and times gives as shown in table. Crash the project and determine the optimum time and minimum cost relationship for the project. Assume the indirect cost to vary at Rs.500/- per day.

Activity (i-j)	1-2	1-3	2-4	3-4	3-5	4-5	5-6
Normal time days	5	7	4	2	5	3	4
Crash time days	3	4	2	1	3	2	1
Normal cost Rs.	500	100	200	400	350	380	50
Crash cost Rs.	800	300	500	750	800	900	150

Course Outcome 5(CO5):

1. List the benefits and limitations of latest tools in project management
2. Discuss why effective communication is needed for the success of any projects taking an example
3. Take of project of your choice in a mechanical industry and list and discuss the risks in the project along with possible methods of its mitigation.

Concept Map



Syllabus

Project and its process- Define project and process, boundaries of project, Objectives and functions of Project management, characteristics and types of projects, organization structure / styles, roles of project management group, project management office and its role, project knowledge area, project integration- process group interaction. Project flow, project life cycle- influencing factors. - Case study. **Project Formulation:** Generation and Screening of PM ideas- Triple Constraint – Time, Cost and Scope. TOR/ Project Charter/ SOW (Statement of Work)- Creation of project Charter. Preliminary planning and estimate- Types of estimate- Ball park, Parametric and Bottom up estimates. Project Presentation & Approval – Detailed Project Report & Approval (Technical and Budget Sanction), Project finance- sources of finance. Technology transfer- PPP Concepts, BOT, BOLT, BOOT. Stakeholder Management - Case study. **Time Management:** Project Scope Management - Work break down structure- Activity/ Task- Events- Case study. Project planning tools- Rolling wave planning. Gantt Charts, Milestone chart, Program Progress chart- Creating milestone plan. Project Network- Fulkerson's rules – Activity-On-Arrow and Activity- On - Node networks. Analyze project time- Critical path method (deterministic approach- activity oriented network analysis- 80-20 rule- Case study, type of time estimates & Square network diagram. Introduction to project management software. Project updating and monitoring- Case study**. Estimate time- Program Evaluation & Review Technique (Probabilistic

Approach)- Event oriented network analysis- Optimistic, Pessimistic and Most likely time, Degree of variability in average time, Probabilistic estimate, % utilization of resources. **Resource Management:** Types of resource- Time, Men, Material, Machinery, Money, Space. Balancing of resource- Resource Smoothing technique- Time constraint. Resource leveling technique- Resource constraint- Case study. **Resource optimization:** Types of cost – Direct, Indirect and Total Cost. Variation of Cost with time. Schedule Compression Techniques- Crashing, Fast Tracking & Re-estimation- Crash time and crash cost. Optimize project cost for time and resource. CPM Cost model. **Communication Management:** Communication Management- meaning and process, communication matrix, Management information system, Guidelines of meeting- Case study**. **Risk Management:** Risk management – meaning and process, Risk identification and analysis techniques- FMEA and SWOT analysis- Risk reporting and monitoring- Case study. **Emerging trends in project management :** Introduction to Theory of Constraints, Agile Project management - Case study**

** - Case study discussion through inviting industry experts in the field of project management

Text Book

1. Punmia B. C. and Khandelwal K.K., “Project Planning and Control with PERT/CPM”, Laxmi publications, New Delhi, 1989.

References

1. "A Guide to the Project Management Body of Knowledge (PMBOK Guide)” - Fifth Edition, An American National Standard, ANSI/PMI 990001-2008.
2. Jerome D. Wiest and Ferdinand K. Levy, “A Management Guide to PERT/CPM”, Prentice Hall of India Publishers Ltd., New Delhi, 1994.
3. Srinath L.S., “PERT & CPM- Principles and Applications”, Affiliated East West Press Pvt., Ltd., New Delhi, 2008
4. A Risk Management Standard, AIRMIC Publishers, ALARM, IRM: 2002
5. Gene Dixon, “Service Learning and Integrated Collaborative Project Management”, Project Management Journal, DOI:10.1002/pmi, February 2011, pp.42-58
6. Nptel videos at nptel.ac.in/courses/112102106 by Prof. Arun Kanda, Dept of Mechanical Engineering, IIT, Delhi

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.0 Project and its process		
1.1	Define project and process, boundaries of project	1
1.2	Objectives and functions of Project management, characteristics of projects, Organization structure / styles of project	1
1.3	Roles of project management group, project management office and its role	1
1.4	Project knowledge area, project integration- process group interaction	1
1.5	Project flow, project life cycle- influencing factors, Case study	1
2.0 Project Formulation		
2.1	Generation and Screening of PM ideas, Triple Constraint – Time, Cost and Scope	1
2.2	TOR/ Project Charter/ SOW (Statement of Work)- Creation of project Charter	1
2.3	Preliminary planning and estimate- Types of estimate- Ball park,	1

	Parametric and Bottom up estimates	
2.4	Project Presentation and Approval- Detailed Project Report and Approval (Technical and Budget Sanction)	1
2.5	Project Finance - sources	1
2.6	Technology Transfer – PPP (BOT,BOLT, BOOT), Stakeholder Management	1
2.7	Case study	1
	Tutorials	1
3.0 Time Management		
3.1	Project Scope Management, Work break down structure -Activity/ Task- Events- Case study. Project planning tools- Rolling wave planning	1
3.2	Gantt Charts, Milestone chart, Program Progress chart- Creating milestone plan	2
3.3	Project Network- Fulkerson's rules – A-O-A and A-O-N networks Introduction to software	3
3.4	Analyze project time- Critical path method (deterministic approach- activity oriented network analysis- Square network diagram	1
3.5	80-20 rule, type of time estimates - Case study	1
3.6	Project updating and monitoring- Case study	1
3.7	Estimate time- Program Evaluation & Review Technique (Probabilistic Approach)- Event oriented network analysis- Optimistic, Pessimistic and Most likely time, Degree of variability in average time, Probabilistic estimate, % utilization of resources.	2
	Tutorial	2
4.0 Resource Management		
4.1	Types of resource- Time, Men, Material, Machinery, Money, Space. Balancing of resource- need and purpose- Case study	1
4.2	Resource Smoothing technique- Time constraint	2
4.3	Resource levelling technique- Resource constraint	2
	Tutorial	2
5.0 Resource optimization		
5.1	Types of cost – Direct, Indirect and Total Cost. Variation of Cost with time. Schedule Compression Techniques- Crashing, Fast Tracking & Re-estimation Crash time and crash cost	2
5.2	Optimize project cost for time and resource- CPM Cost model- Case study	2
	Tutorials	2
6.0 Communication & Risk Management		
6.1	Communication Management- meaning and process, communication matrix	2
6.2	Management information system, Guidelines of meeting- Case study	1
6.3	Risk management – meaning and process. Risk identification and analysis techniques- FMEA and SWOT analysis	2
6.4	Risk reporting and monitoring- Case study	1
6.5	Emerging trends in project management: (Brief concept only)- Theory of Constraints, Agile Project Management	1
	Total Periods	48

Course Designers:

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14ME720 INDUSTRIAL ENGINEERING

Category	L	T	P	Credit
PC	3	0	0	3

Preamble

This course deals with productivity measurements, method study techniques, work measurement, production planning and control and industrial Legislation.

Prerequisite

- Nil

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Describe the theory in industrial engineering and their applications.	Understand
CO 2.	Evaluate the work methods through work measurement	Apply
CO 3.	Establish the efficient work system	Apply
CO 4.	Identify the suitable forecasting techniques for given applications	Analyze
CO 5.	Prepare the charts, diagrams and production plan.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	M	M	M	L	M	_	_	_	_	_	_	_	_	_	_
CO2.	S	M	S	M	S	_	_	_	_	_	_	_	_	_	M
CO3.	S	M	S	M	S	_	_	_	_	_	_	_	_	_	_
CO4.	S	S	S	M	S	_	_	_	_	_	M	_	_	_	_
CO5.	S	M	S	M	S	_	_	_	_	_	_	_	_	_	S
	S	S	S	M	S	_	_	_	_	_	L	_	_	_	L

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	40	40	40	40
Apply	40	40	30	30
Analyse	0	0	10	10
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define: Productivity.
2. Explain PMTS.
3. Describe Economic order quantity.
4. Explain the purpose to balance the assembly line.
5. Classify the techniques for aggregate production planning.

Course Outcome 2 (CO2):

1. A work sampling study was conducted to establish the std. Time for a specific operation. The observations of the study: Total no. of observations: 160, manual (hand controlled work) is 14, machine controlled work is 106 and machine idle time is 40, Avg. Performance rating: 80%, study conducted for 3 days and 8 hrs working per day. Calculate the std. time per piece.
2. Differentiate between analytical estimation and PMTS.
3. Demonstrate product flow chart with suitable example.
4. Explain about productivity metric and its functions.
5. Describe about Ranked positional weight method for line balancing.
6. Explain the need of REBA/RULA.

Course Outcome 3 (CO3):

1. In a machine shop work sampling study was conducted for 160 hrs in order to estimate the std. time. Total numbers of observation recorded were 3500. There were 600 no. of working activities. Ratio between manual to machine element was 2:1. Avg. rating factor was 1:2 and total no. of jobs produced during the study was 8000. Rest and personal allowances taken together will be 16% of normal time. Determine the std. time per job.
2. The observed times and the performance ratings for the five elements are given:

Element	1	2	3	4	5
Observed time (min)	0.2	0.06	0.5	0.12	0.1
Performance rating	85	80	90	85	75

Compute the std. time assuming rest and personal allowances as 10% and contingency allowance as 2% of the basic time.

Course Outcome 4(CO4):

1. Explain the need for good forecasting technique?
2. Determine July month forecast if the wt. moving avg. with weights of 0.60,0.30 and 0.10

Month	Jan	Feb	Mar	Apr	May	Jun
Demand	120	110	150	120	160	150

3. M/s. XY corporation has developed a forecast for a group of items that has the following demand pattern.

Quarter	**Demand**	**Cumulative demand**
1	270	270
2	220	490

3	470	960
4	670	1630
5	450	2080
6	270	2350
7	200	2550
8	370	2920

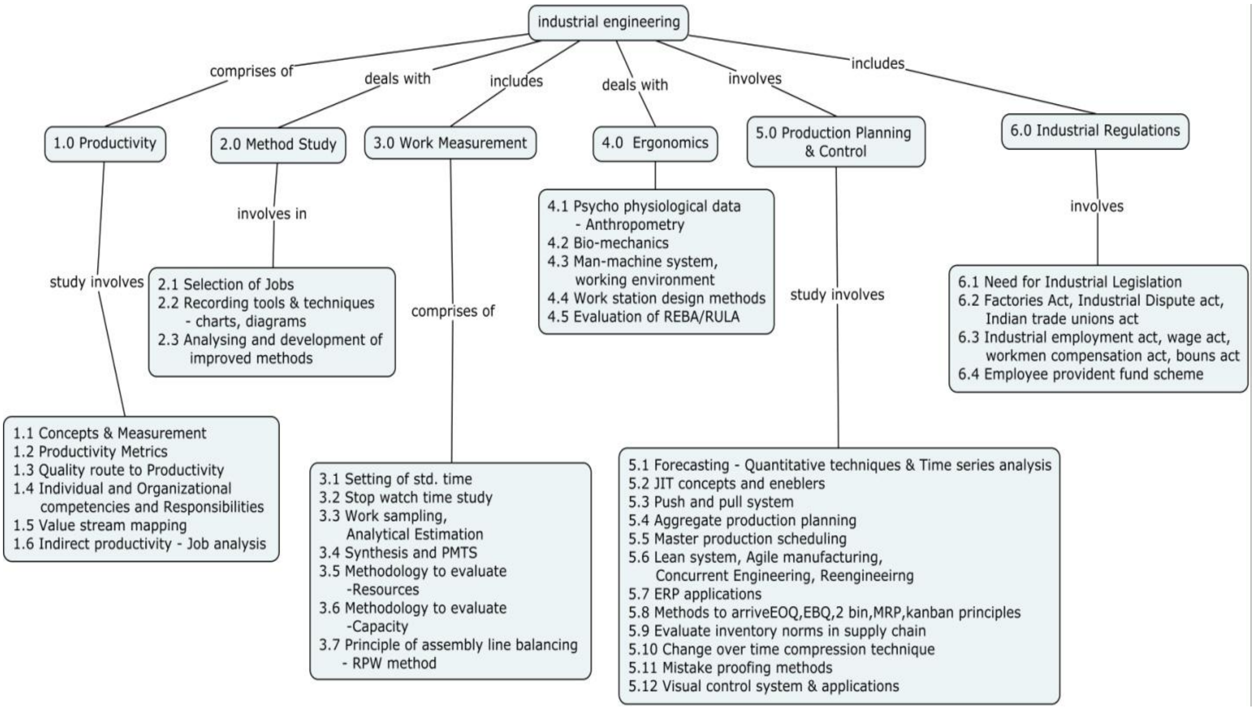
Plot the demand as histogram. Determine the production rate required to meet the avg. demand and plot the avg. demand forecast on the graph.

Course Outcome 5(CO5):

1. Consider the following assembly network relationships of a product. The number of shifts per day is 1 and the no. of working hours is 8. The company aims to produce 40 units of product per shift. Group the activities into optimal no. of stations using RPW method and also compute the balancing efficiency.

Operation No.	**Immediate preceding Tasks**	**Duration (Min)**
1	-	8
2	1	3
3	1	2
4	1	4
5	3,4	7
6	2,7	4
7	2,4,5	5
8	4	6
9	6,8	8

Concept Map



Syllabus

Productivity: concepts and measurements. Productivity metrics – Quality route to productivity - approach to ERCSS, Individual and Organizational competencies and responsibilities, Value Stream mapping, In-direct productivity - Job analysis. **Method study:** Selection of jobs, recording tools and techniques – Flow chart, Process chart, Man-machine chart, two handed process chart, Process flow diagram, Process Flow Analysis, Analyzing, Development of improved methods. **Work Measurement**: Setting of standard time - Stop watch time study, rating, allowances, Work sampling, Analytical estimation, Synthesis and Predetermined Motion Time Standards (PMTS). Methodology to evaluate resources, Methodology to evaluate capacity, Principles of Assembly line balancing- concepts and Rank position weight method problems.

Ergonomics: Psycho physiological data- Anthropometry, Bio mechanics - information displays - Principles of motion economy - Man machine system – Working environment – Work station design methods, Evaluation procedures of REBA, RULA.

Production planning and control: Forecasting - Quantitative techniques and time series analysis, JIT concepts and enablers, Push/ Pull systems. Aggregate production planning, Master production scheduling, Lean Systems, Agile manufacturing, Concurrent Engineering, Reengineering, Introduction about ERP applications in various modules, Methods to arrive EBQ,EOQ values, 2 bin system, MRP, Kanban principles - evaluate inventory norm in the supply chain, Changeover time compression techniques, Various mistake proofing methods & techniques for safety, quality, Visual control systems & applications.

Industrial Legislation: Need for Industrial legislation, Factories act 1948, Industrial dispute act 1947, The Indian trade unions act 1926, Industrial employment act 1946, Payment of wage act 1936, Workmen compensation act 1923, Payment of bonus act 1965, Employees provident fund scheme 1952 – Group Discussion.

Text Books:

1. Chase R.B, Nicholas J. Aquilano, F.and Jacobs R, "**Production and Operations Management: Manufacturing and Services**, Irwin/McGraw-Hill,Vol. 2, 1998.
2. Khan, M.I, "**Industrial Engineering**", New Age International, 2nd Edition, 2009.
3. Kapoor N.D, "**Handbook of Industrial Law**", sultan Chand & sons, 14th revised edition 2013.

Reference Books:

1. Samuel Eilon, "**Elements of Production Planning and Control**", Universal Publishing Corporation, Bombay, 1994.
2. Panneerselvam R, "**Production and Operations Management**", PHI, New Delhi, 2006.
3. Khanna, O.P, "**Industrial Engineering and Management**", Dhanpat Rai and Sons, 2008.
4. Natha Muhi Reddy, "**Industrial Engineering and Management**", New Age International Ltd, New Delhi, 2002.

Course Contents and Lecture schedule

No.	Topics	No.of Lectures
1.0	**Productivity**	
1.1	Concepts and measurements	1
1.2	Productivity metrics	
1.3	Quality route to productivity – approach to ERCSS	1
1.4	Individual and Organizational competencies and responsibilities	1
1.5	Value stream mapping	1
1.6	In-direct productivity – Job analysis	1
2.0	**Method study**	
2.1	Selection of jobs	1
2.2	Recording tools and techniques – Flow chart, Process chart, Man-machine chart, Two handed process chart, Process flow diagram, Process Flow Analysis	2
2.3	Analyzing and Development of improved methods	1
3.0	**Work Measurement**	
3.1	Setting of standard time	1
3.2	Stop watch time study – rating, allowances	1
3.3	Work sampling, Analytical estimation	1
3.4	Synthesis and Predetermined Motion Time Standards (PMTS)	1
3.5	Methodology to evaluate resources	1
3.6	Methodology to evaluate capacity	1

No.	Topics	No.of Lectures
3.7	Principle of Assembly line balancing- concepts and RPW problems	1
4.0	**Ergonomics**	
4.1	Psycho Physiological data - Anthropometry	1
4.2	Bio mechanics	1
4.3	Principles of motion economy	1
4.4	Man machine system – Working environment	1
4.5	Work station design methods	1
4.6	Evaluation procedures of REBA/ RULA	1
5.0	**Production planning and control**	
5.1	Forecasting -Quantitative techniques and Time series analysis	2
5.2	JIT Concepts and enablers	1
5.3	Push/ Pull system	1
5.4	Aggregate production planning	1
5.5	Master production scheduling	1
5.6	Lean Systems, Agile manufacturing	1
5.7	Concurrent Engineering	1
5.8	Reengineering	1
5.9	Introduction about ERP applications in various modules	1
5.10	Methods to arrive Economic Order Quantity, Economic Batch Quantity values, 2 bin system, MRP, Kanban principles	2
5.11	Evaluate inventory norms in supply chain	1
5.12	Change over time compression techniques	1
5.13	Mistake proofing methods and tech. for safety, quality	1
5.14	Visual control system and applications	
6.0	**Industrial Legislation**	
6.1	Need for Industrial legislation, Factories act 1948, Industrial dispute act 1947, The Indian trade unions act 1926, Industrial employment act 1946, Payment of wage act 1936, Workmen compensation act 1923, Payment of bonus act 1965, Employees provident fund scheme 1952 – Group Discussion	2
	Total	**39**

Course Designers:

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14ME770	**FINITE ELEMENT ANALYSIS**	Category	L	T	P	Credit
		PC	2	0	2	3

Preamble

Finite Element Analysis is an advanced computer technique based on numerical methods for solving wide variety of engineering problems. FEA can produce accurate, reliable approximate solutions, at a small fraction of the cost of more rigorous, closed-form analyses. This course provides the basic theoretical knowledge to competently perform finite element analysis for structural and thermal analyses. It also provides an introduction to the finite element analysis from engineering point of view.

Prerequisite

- 14ME220 – Free Body Mechanics
- 14ME320 - Mechanics of Materials
- 14ME410 - Numerical Methods

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Solve the physical problem using functional approximation method.	Apply
CO 2.	Derive the shape functions and stiffness matrix for one dimensional structural and thermal problems	Apply
CO 3.	Derive the shape functions and stiffness matrix for two dimensional structural and thermal problems.	Apply
CO 4.	Derive the shape functions and stiffness matrix for Isoparametric elements.	Apply
CO 5.	Perform structural analysis of mechanical components like beams, trusses, corner bracket and plates	Apply
CO 6.	Perform thermal analysis of composite walss, composite cylinders and fins	Apply
CO 7.	Performm model and harmonic analysis of mechanical components like beams and spring-mass damper system	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1.	S	S	S	M	_	_	_	_	_	_	_	_	S	_	M
CO2.	S	S	S	M	_	_	_	_	_	_	_	_	S	S	S
CO3.	S	S	S	M	_	_	_	_	_	_	_	_	S	S	S
CO4.	S	S	S	M	_	_	_	_	_	_	_	_	S	M	S
CO5.	S	S	S	M	S	_	_	_	_	_	_	_	S	_	S
CO6.	S	S	S	M	S	_	_	_	_	_	_	_	S	S	S
CO7.	S	S	S	M	S	_	_	_	_	_	_	_	S	_	S
	S	S	S	M	M	_	_	_	_	_	_	_	S	M	S

S- Strong; M-Medium; L-Low

Assessment Pattern

Theory (70 marks)					Practical (30 marks)		
Bloom's Category	Continuous Assessment Tests (20)		Terminal Examination (50)		Valuation category	Continuous Assessment (10)	Continuous Assessment Test (20)
	1	2					
Remember	10	10	10		Classwork/Exercise	90	90
Understand	40	40	40		Record / Viva-voce	10	10
Apply	50	50	50				
Analyse	0	0	0				
Evaluate	0	0	0				
Create	0	0	0				

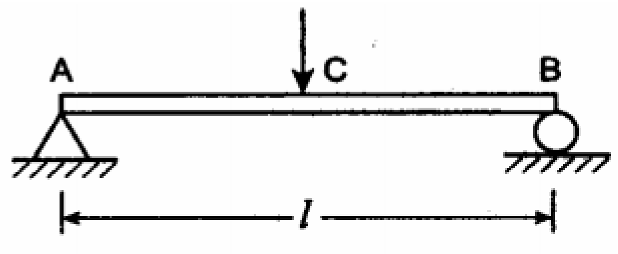
Theory cum Practical Courses:

- There will be three tests: the first two tests (Maximum 50 marks for each test) will be from theory component and the third test (Maximum 50 Marks) will be for practical component.
- The sum of marks of first two tests shall be reduced to 20 Marks and the third test mark shall be reduced to 20 marks.
- Average mark awarded for viva – voce, conduct of experiments, observation & results, record work in regular class works shall be reduced to 10 marks.
- The sum of these 50 Marks would be rounded to the nearest integer.

Course Level Assessment Questions

Course Outcome 1 (CO1):

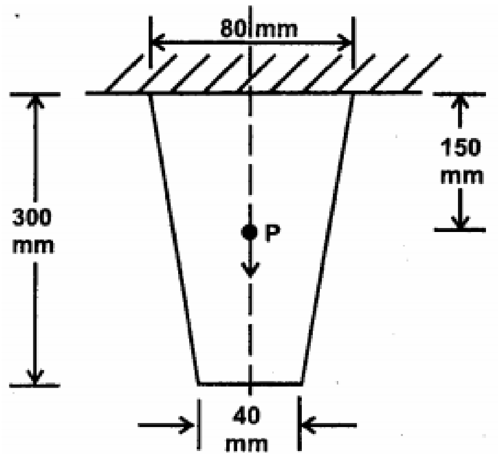
1) A simply supported beam is subjected to uniformly distributed load over entire span. Determine the bending moment and deflection at the mid span using Rayleigh-Ritz method and compare with exact solution. Use a two term trial function $y = a_1 \sin(\pi x/l) + a_2 \sin(3\pi x/l)$.
2) A beam AB of span 'l' simply supported at the ends and carrying a concentrated load 'W' at the centre 'C' as shown in figure. Determine the deflection at the mid span by using Rayleigh-Ritz method and compare with exact solution. Use a suitable one term trigonometric trial function.



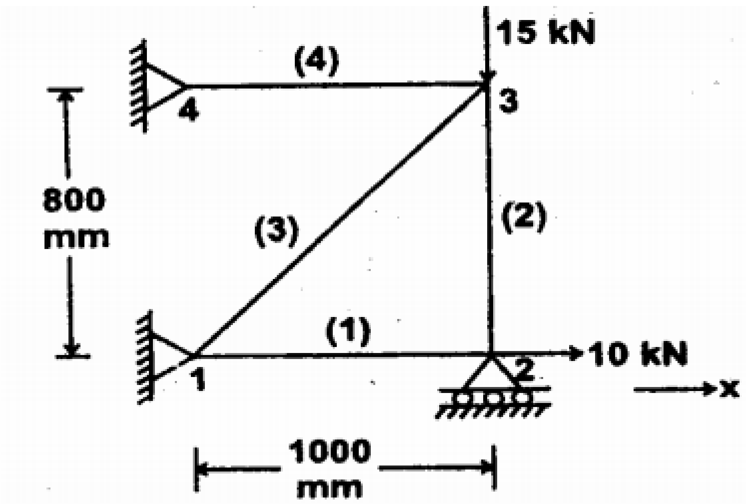
3) The following differential equation is available for a physical phenomenon. $d^2y/dx^2 + 50 = 0$, $0<x<10$.The trial function is, $y=ax(10-x)$The boundary conditions are $y(0)=0$ and $y(10)=0$,Find the value of the parameter 'a' by (i) Point collocation method (ii) Sub-domain collocation method (iii) Least squares method (iv) Galerkin's method

Course Outcome 2 (CO2):

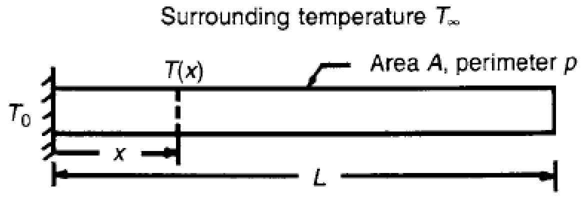
1) Derive the shape functions for a 1-D bar and beam element Derive the stiffness matrix of a 12-D truss element
2) For a tapered bar of uniform thickness t=10mm as shown in figure. Find the displacements at the nodes by forming into two element model. The bar has a mass density ρ = 7800 Kg/m^3, the young's modulus $E = 2x10^5$ MN/m^2. In addition to self-weight, the bar is subjected to a point load P= 1 KN at its centre. Also determine the reaction forces at the support.



3) Consider a 4-bar truss as shown in figure. It is given that E = 200 GPa and A= 500 mm^2 for the elements. Determine (a) Nodal displacements (b) Support reactions (c) Element stresses.

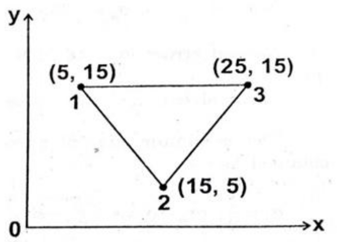


4) Find the distribution of temperature in the one-dimensional fin shown in Figure Assume the following data: h - 10 W/cm2 K, k - 70 W/cm K, T_∞. = 40°C, T_o =140 °C and L = 5 cm, and the cross section of fin is circular with a radius of 1 cm.

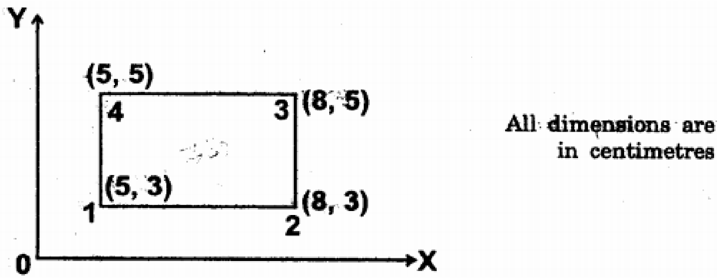


Course Outcome 3 (CO3):

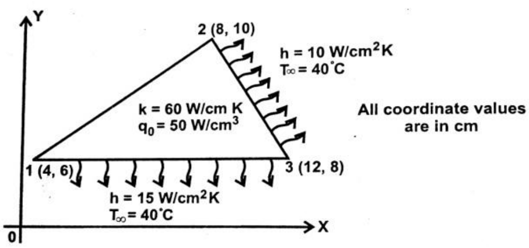
1) Derive the shape function for two dimensional triangular elements using global coordinate System. Derive the shape functions for four noded quadrilateral element using natural coordinates.
2) The plane strain elements as shown in figure. The nodal displacements are u_1=0.005mm, u_2=0.0mm,u_3=0.005mm,v_1=0.002mm,v_2=0.0mm,v_3=0.0mm. Find the element stresses σ_x, σy, Ʈxy. Assume E=70GPa and μ=0.3 use unit thickness for plane strain. All dimensions are in millimeters.



3) For a 4-noded rectangular element shown in figure 3.6. Determine the temperature at the point. The nodal values of the temperatures are T_1= 42°C, T_2= 54°C and T_3= 56°Cand T_4= 46°C. Also determine the three points on the 50°C contour line.



4) Compute the element matrices and vectors for the element shown in figure. When the edges 2-3 and 1-3 experience convection heat loss.



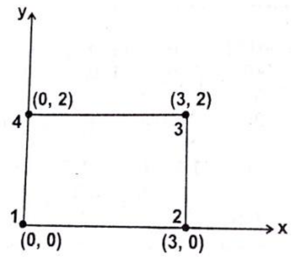
Course Outcome 4 (CO4):

1) For a four noded rectangular element shown in figure. Determine the following

a) Jacobian matrix b) Strain-displacement Matrix c) Element stresses

d)Element strains. Take E=210GPa μ=0.25 ε=0.5,η=0.5,

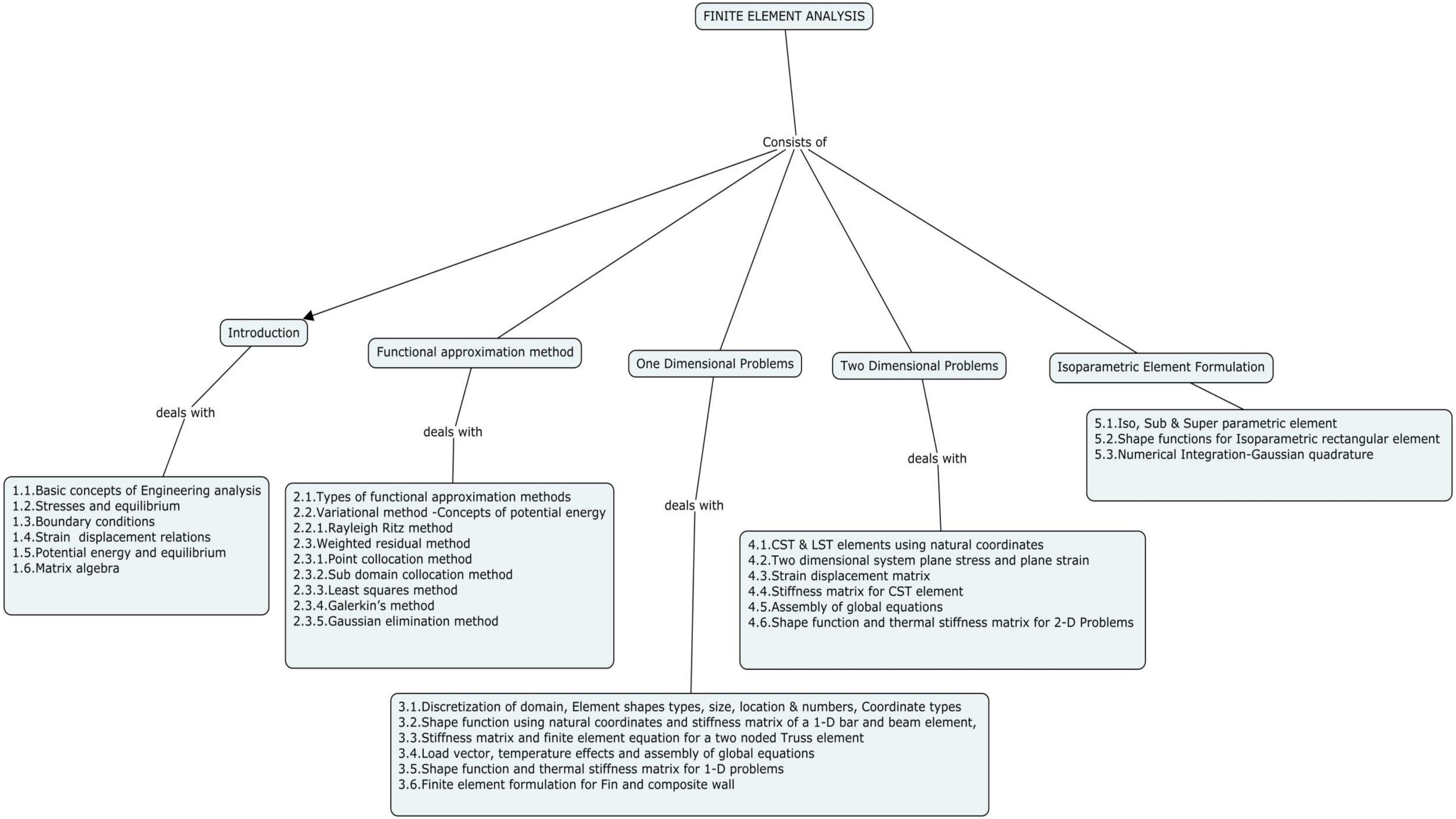
[u] = [0,0,0.002,0.003,0.005,0.004,0,0]T



2) Derive the shape functions for 4 noded rectangular parent element by using natural coordinate system and coordinate transformation.

3) Evaluate the integral, I = $\int$1-1 cos πx/2 dx by applying 3 point Gaussian quadrature and compare with exact solution.

Concept Map


FINITE ELEMENT ANALYSIS
Consists of
Introduction
Functional approximation method
One Dimensional Problems
Two Dimensional Problems
Isoparametric Element Formulation
deals with
deals with
deals with
deals with
1.1.Basic concepts of Engineering analysis
1.2.Stresses and equilibrium
1.3.Boundary conditions
1.4.Strain displacement relations
1.5.Potential energy and equilibrium
1.6.Matrix algebra
2.1.Types of functional approximation methods
2.2.Variational method -Concepts of potential energy
2.2.1.Rayleigh Ritz method
2.3.Weighted residual method
2.3.1.Point collocation method
2.3.2.Sub domain collocation method
2.3.3.Least squares method
2.3.4.Galerkin's method
2.3.5.Gaussian elimination method
3.1.Discretization of domain, Element shapes types, size, location & numbers, Coordinate types
3.2.Shape function using natural coordinates and stiffness matrix of a 1-D bar and beam element,
3.3.Stiffness matrix and finite element equation for a two noded Truss element
3.4.Load vector, temperature effects and assembly of global equations
3.5.Shape function and thermal stiffness matrix for 1-D problems
3.6.Finite element formulation for Fin and composite wall
4.1.CST & LST elements using natural coordinates
4.2.Two dimensional system plane stress and plane strain
4.3.Strain displacement matrix
4.4.Stiffness matrix for CST element
4.5.Assembly of global equations
4.6.Shape function and thermal stiffness matrix for 2-D Problems
5.1.Iso, Sub & Super parametric element
5.2.Shape functions for Isoparametric rectangular element
5.3.Numerical Integration-Gaussian quadrature

Syllabus

Introduction-Basic concepts of engineering analysis - Stresses and equilibrium – boundary conditions. Strain displacement relations – potential energy and equilibrium – Matrix algebra and Gaussian elimination method- **Functional approximation method** –Types of functional approximation methods- Variational method -Concepts of potential energy- Rayleigh Ritz method- weighted residual methods – Point collocation method, Sub domain collocation method, Least squares method, Galerkin's method. **One Dimensional Problems**-Discretization of domain, Element shapes, types, size, location & numbers. Coordinate types, shape function using natural coordinates and generalized coordinates, stiffness matrix of a 1-D bar and beam element, Stiffness matrix and finite element equation for a two noded Truss element, load vector, temperature effects and assembly of global equations. Basic equations of heat transfer - Shape function and thermal stiffness matrix for 1-D heat conduction, with free end convection, with internal heat generation- assembly of global equations and load vector, Finite element formulation for Fin. **Two Dimensional problems** –CST & LST elements - Shape functions for two dimensional CST element using natural coordinates- Stress strain relationship matrix for two dimensional system plane stress and plane strain- strain displacement matrix- stiffness matrix for CST element. load vector, temperature effects and assembly of global equations. Shape function and thermal stiffness matrix for 2-D heat transfer - assembly of global equations and thermal load vector, Finite element formulation. **Isoparametric Elements Formulation** - Iso, Sub & Super parametric element, shape functions for four noded and eight noded rectangular elements, triangular using natural coordinate system – Numerical Integration- Gaussian quadrature

Text Books

1. J.N.Reddy, "**An Introduction to the Finite Element Method"** Third Edition, McGraw-Hill Mechanical Engineering, Reprint, 2015.
2. Singuresu S. Rao, "**Finite Element method in Engineering**", Fourth edition, Elsevier Science & Technology Books, Reprint 2015.

Reference Books

1. Tirupathi R. Chandrupatla, Ashok D. Belagundu, "**Introduction to Finite Elements in Engineering**", Third Edition, Reprint, Prentice Hall, 2012.
2. R. D. Cook, D. S. Malkus, and M. E. Plesha, "**Concepts and Applications of Finite Element Analysis**", Third Edition, John Wiley and Sons, New York, Reprint 2010.

3. O. C. Zienkiewicz and R. L. Taylor, "**The Finite Element Method: Volume 1 The Basis**", 5th Edition, Butterworth-Heinemann, Oxford. Reprint 2011.
4. Daryl L. Logan A, **"First Course in the Finite Element Method**", Fourth Edition, Cengage Learning, 2007.
5. K. J. Bathe, "**Finite Element Procedures**", Second Edition, Prentice-Hall Inc., Englewood Cliffs, New Jersey, Reprint 2012.

Course Contents and Lecture Schedule

S.No.	Topic	No. of Lectures
1	**Introduction**	
1.1	Basic concepts of Engineering analysis	1
1.2	Stresses and equilibrium	
1.3	Boundary conditions	
1.4	Strain displacement relations	1
1.5	Potential energy and equilibrium	
1.6	**Matrix algebra**	
2	Functional approximation method	
2.1	Types of functional approximation methods	1
2.2	Variational method -Concepts of potential energy	
2.2.1	**Rayleigh Ritz method**	
2.3	Weighted residual method	1
2.3.1	Point collocation method	
2.3.2	Sub domain collocation method	
2.3.3	Least squares method	
2.3.4	Galerkin's method	1
2.3.5	Gaussian elimination method	1
	Tutorial	1
3	**One Dimensional Problems**	
3.1	Discretization of domain, Element shapes types, size, location & numbers, Coordinate types	1
3.2	Shape function using natural coordinates and stiffness matrix of a 1-D bar and beam element,	1
3.3	Stiffness matrix and finite element equation for a two noded Truss element	1

3.4	Load vector, temperature effects and assembly of global equations	1
	Tutorial	1
3.5	Shape function and thermal stiffness matrix for 1-D heat conduction, with free end convection, with internal heat generation- assembly of global equations and load vector,	1
3.6	Finite element formulation for Fin and composite wall	1
	Tutorial	1
4	**Two Dimensional Problems**	
4.1	CST & LST elements - Shape functions for two dimensional CST element using natural coordinates	1
4.2	Stress strain relationship matrix for two dimensional system plane stress and plane strain	1
4.3	Strain displacement matrix	1
4.4	Stiffness matrix for CST element	1
4.5	Load vector, temperature effects and assembly of global equations	
4.6	Shape function and thermal stiffness matrix for 2-D heat transfer - assembly of global equations and thermal load vector	1
	Tutorial	1
5	**Isoparametric Element Formulation**	
5.1	Iso, Sub & Super parametric element	1
5.2	Shape functions for a 2-D four noded and eight noded Isoparametric rectangular element using natural coordinate system	
5.3	Numerical Integration-Gaussian quadrature	1
	Tutorial	1
	Total	24

Practical Component:

Ex. No	**List of Exercises**	
1	**Structural Problems**	
1.1	Stress analysis of stepped shaft - one dimensional element	2

1.2	Determination of the nodal deflections, reaction forces, stress and member forces in simple truss system	2
1.3	Determination of deflection, Shear force and bending moment for cantilever beam	2
1.4	Determination of deflection, Shear force and bending moment for cantilever beam	2
1.5	Stress analysis of rectangular plate with hole	2
1.6	Stress analysis of corner bracket.	2
2	**Thermal Problems**	
2.1	Determine the temperature distribution and thermal gradient distribution of Fin	2
2.2	Determine the temperature distribution and hear flux of a composite wall-one dimensional element	2
2.3	Determine the temperature distribution and heat flux of a composite wall-two dimensional element	2
3	**Dynamic analysis**	
3.1	Determine the natural frequency of loaded beams	2
3.2	Harmonic analysis of loaded beams.	2
4	**Coupled analysis**	
4.1	Thermal and Structural analysis of fin	2
	TOTAL HOURS	12

Course Designers:

1. V.Balasubramani vbmech@tce.edu
2. C.Vignesh cvmech@tce.edu

14ME7C0	CAPSTONE II	Category	L	T	P	Credit
		PC	0	0	4	2

Preamble

The purpose of this course is to apply the concept of mathematics, science and engineering fundamentals and an engineering specialization to solve complex engineering problems.

Syllabus

1. ENGINEERING GROUP - 1

a. Thermal Engineering

Gas power cycles: Carnot cycle, Otto cycle, Diesel cycle, Air standard efficiency and mean effective pressure calculations, Comparison of Otto and Diesel cycles, Dual cycle. **Vapour power cycles:** Carnot cycle, Rankine cycle, Reheat Rankine cycle, Regenerative Rankine Cycle – Performance calculations, Applications in thermal power plants. **Refrigeration cycles:** Reversed Carnot cycle, Vapour Compression Refrigeration cycle with super heating and sub-cooling, performance calculations and applications. **Reciprocating air compressors:** Working principle, Work of compression in single stage with and without clearance volume, free air delivery, isothermal efficiency, volumetric efficiency, Multi stage compression, Intercooling and power calculations. **Psychrometry and air-conditioning:** Psychrometric properties, psychrometric processes, Applications in air-conditioning.

b. Production Drawing

Introduction: IS Code of practice for drawings, Sectional views – full section, half section, revolved, removed section and hatching of sections, representation of materials, Symbols of springs and gears. **Geometrical Dimensioning and Tolerance:** Symbols, tolerance frame, datum surface. **Surface roughness** – Representation methods and direction of lay. **Welding:** Symbolic representation, **Limits, Fits and Tolerances** - Types and calculations.

c. Design of Machine Elements

Machine Design: Design concepts- Factors influencing Design -Selection of materials - Standardization – Preferred Numbers - Component of stresses, ultimate and allowable stress, Factor of safety, Theories of failure - Design for static and fatigue strength. **Rotating Elements and Couplings:** Shafts subjected to Twisting moment, Combined Bending and twisting moment with axial loads - Design of Keys for shafts - Design of couplings – Rigid couplings and Flexible couplings. **Energy Absorbing Elements:** Coil Springs: Tension Springs -Compression Springs –Leaf Springs. Design of **Automobile Components**: Piston, Connecting rod and Crank shafts.

2. ENGINEERING GROUP - 2

a. Heat and Mass Transfer

Convection: Forced convection- Hydrodynamic and thermal boundary layers - Flow over flat plates- laminar boundary layer thickness in terms of Reynolds number - Flow through tubes, Flow across cylinder- Nusselt equations, numerical problems. Free convection - Hydrodynamic and thermal boundary layers, Horizontal and vertical plates, Horizontal and vertical cylinders - Nusselt equation, numerical problems. **Radiation:** Wave theory and quantum theory- concepts of black body and gray body - Stefan - Boltzman law - emissive power – monochromatic emissive power - Weins law -Kirchoff's law- numerical problems. Radiative properties, Emissivity, absorptivity, reflectivity, transmissivity, radiosity - Radiation shape factor - Reciprocity theorem. Heat exchange between black and gray surfaces, numerical problems - Reradiating surfaces, numerical problems. **Heat exchangers**: Classification- overall heat transfer co-efficient- fouling factor-parallel and counter flow heat exchangers – cross flow and shell tube heat exchangers - LMTD method, numerical problems. **Mass transfer:** Fick's law of diffusion, Analogy between heat, mass and momentum transfer, numerical problems, Diffusion mass transfer- diffusion coefficient, numerical problems:

b. Mechanical Measurements and Metrology

Measurement of motion: Displacement measurement- Resistive, inductive-LVDT, Piezo electric, hall effect sensor. **Speed/Velocity measurement:** optical encoders, tacho generators. **Acceleration measurement**: Seismic type and Piezo electric type Accelerometers. **Measurement of strain:** Types of strain gauges – Gauge factor. **Measurement of Force and Torque:** Load cells and Dynamometers. **Measurement of Temperature:** RTD, Thermistor, Thermo couples and Optical Pyrometers. **Measurement of Pressure:** Digital pressure gauges, fiber optic based pressure measurement. **Measurement of Flow:** Orifice meter, Venturi meter and Rota meter. **Measurement of Level:** Resistive, capacitive, inductive and ultra sonic type.

c. Kinematics and Dynamics of Machinery

Mechanisms: Kinematic link, Kinematic pairs, Kinematic chains – Mechanism –Mobility of mechanism. **Cams:** Types of cams and followers, Displacement, velocity and acceleration curves for various types of motions of follower and Construction of cam profiles with Knife edge followers and Roller follower. **Gear trains**: Contact ratio - Gear trains: Simple, Compound, Reverted and Epicyclic gear trains. **Balancing: C**oncept of static and dynamic balancing, Balancing of rotating mass by another mass. Concept of reference plane, balancing of several rotating masses in same plane. **Gyroscope:** Gyroscope couple – applications – airplane, ship and two wheelers.

d. Quality Engineering

Process Control: Theory of control chart- uses of control chart – Control chart for variables – X bar chart, R chart and sigma chart. **Acceptance Sampling:** Types of sampling plan – Probability of acceptance in single, double and Sequential Sampling plan – Operating Characteristic (OC) curve.

Reference Books

1. G.Pahl and W.Beitz (Translated by Ken Wallace et al.,) ''Engineering Design: A Systematic Approach", Second Edition, Springer, 2005
2. Yunus A.Cengel and Michael A.Boles, "Thermodynamics: An Engineering Approach", Eighth edition, McGraw-Hill, 2014.
3. K.R.Gopalakrishna, "Machine Drawing", Eighteenth Edition, Subhas Stores, Bangalore, 2004.
4. Joseph Edward Shigley and Charles R. Misucke, "Mechanical Engineering Design", Tenth Edition, Tata McGraw Hill, 2015.
5. Anand K Bewoor and Vinay A Kulkarni, "Metrology and Measurement", Tata McGraw Hill, 2009.
6. John Joseph Uicker, Gordon Pennock, Joselph E.Shigley, "Theory of Machines and Mechanisms", Third Edition, Oxford University Press, 2010.
7. Douglas C. Montgomery, "Introduction to Statistical Quality control", John Wiley and Sons Inc, Sixth Edition, 2009.

Assessment Pattern
(Common to B.E./B.Tech Programmes)

I. Comprehensive Test (30 Marks)

Test 1: Engineering Group 1 (60 Marks) **Duration: 90 Minutes**

Objective Type Questions : 30

Fill-in the blanks type Questions : 30

Test 2: Engineering Group 2 (60 Marks) **Duration: 90 Minutes**

Objective Type Questions : 30

Fill-in the blanks type Questions : 30

II. Complex Engineering Problem Solving (70 Marks):

- Selection of a complex engineering problem (Batch size: 2-4) : 5 Marks
- Literature Survey : 5 Marks

- Problem Formulation : 10 Marks
- Solution Methodology : 15 Marks
- Results and Discussion : 15 Marks
- Technical Report : 10 Marks
- Viva voce : 10 Marks

Final Mark consolidation:

Test	Maximum Marks	Converted to
Test 1	60 Marks	15 Marks
Test 2	60 Marks	15 Marks
Review 1	60 Marks	20 Marks
Review 2	60 Marks	30 Marks
Technical Report	10 Marks	10 Marks
Viva voce	10 Marks	10 Marks
	Total	**100 Marks**

Note: NO re-test will be conducted at any circumstances for Comprehensive Tests.

Rubrics for Review 1

- Selection of a complex engineering problem
- Literature Survey
- Problem Formulation

Rubrics for Review 2

- Solution Methodology
- Results and Discussion

Technical Report

- Each batch of students should submit a technical report before last working day

Course Designers:

1. Dr.C.Paramasivam cpmech@tce.edu
2. Dr.ML. Mahadevan mlmmech@tce.edu

14MEPJ0 MATERIAL HANDLING SYSTEMS ENGINEERING

Category	L	T	P	Credit
PE	3	0	0	3

Preamble

This course deals with material handling by which materials are moved, stored and tracked in any industrial/commercial infrastructure. Applying ergonomic principles in the design of material handling and storage system considering the physical properties, quantities and distance to be moved and type of production facility.

Prerequisite

- Nil

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Map the process and material flow.	Understand
CO 2.	Assess the potential failure modes in material storage and handling between POM/POS to POC.	Apply
CO 3.	Do posture analysis by using REBA/RULA tools and ergonomics in storage and material handling design.	Apply
CO 4.	Measures of material handling systems	Analyze
CO 5.	Develop standardized inventory storage and handling work procedures.	Apply
CO 6.	Choose appropriate material transport system	Analyze

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	M	M	M	L	M	_	_	_	_	_	_	_	_	_	L
CO2.	S	M	S	M	S	_	_	_	_	_	_	_	_	_	_
CO3.	S	M	S	M	S	_	_	_	_	_	_	_	_	_	M
CO4.	S	S	S	M	S	_	_	_	_	_	_	_	_	_	_
CO5.	S	M	S	M	S	_	_	_	_	_	_	_	_	_	M
CO6.	S	S	S	M	S	_	_	_	_	_	_	_	_	_	M

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	40	40	40	40
Apply	40	30	30	30
Analyse	0	10	10	10
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. State process flow mapping.

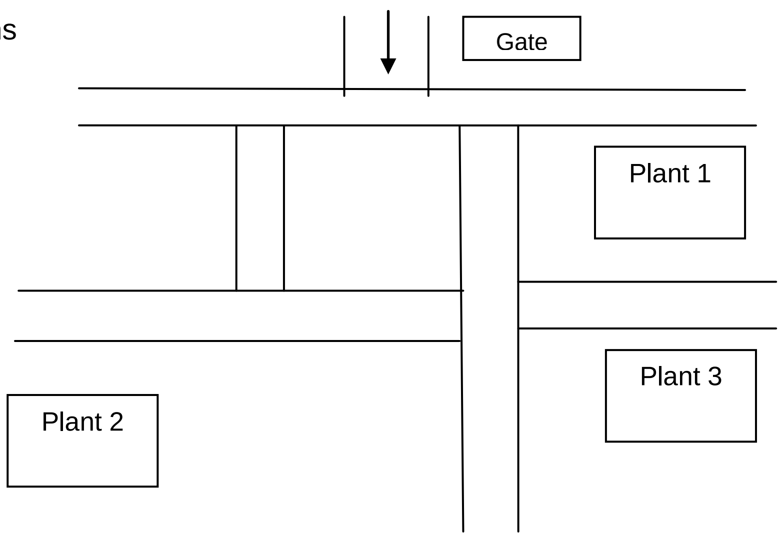
2. Explain about process flow charting technique and its outcomes.
3. To manufacture one 450CC vehicle, 450 parts to be moved from POS to POC with classification of A – 50, B – 100 and C - 300 parts. The tact of vehicle production is 30 seconds. Design a suitable handling and transportation system to meet the product quality and process quality requirements.

Course Outcome 2 (CO2):

1. Describe different types of Material handling equipments and its limitations.
2. Explain about the various selection criteria for Material handling equipment systems.
3. In one of the manufacturing industry, painted fuel tanks to be transported from paint shop to vehicle assembly. Allowable handling system size is 1.2 m x 1m x 2 m (L x B x H). The parts size is 400 mm x 250 mmx 120 mm (L x B XH). Assuming the shape of the fuel tank, design suitable material handling system along with manufacturing BOM and estimated cost. The system should be low cost and should ensure zero quality defects during transportation.

Course Outcome 3(CO3):

1. State the importance of REBA/RULA.
2. To manufacture an engine of 150 cc, it is required metal parts, plastic parts, fabricated parts and machined parts. Design a suitable handling system between feeder shop to assembly line with selection of the material and application of REBA/RULA.
3. Discuss about different types of storage system and its merits.
4. At particular un-loading dock every 15 minutes one truck arrives. The window time for truck servicing is 25 minutes. Make the necessary assumptions and based on that find a) The average que length b) the average waiting time for two shift based operations



Course Outcome 4 (CO4):

1. Define: Maintainability

2. Write down the scope of TPM for MHS.
3. Define the term feasibility analysis.
4. Explain about supportability analysis and functional analysis with illustrations.

Course Outcome 5(CO5):

1. The company has three stores S1, S2 & S3. It is required to deliver a product from these stores to three assembly lines A, B and C. The stock in stores and the assembly line requirement are as follows. Find the optimal transportation route.

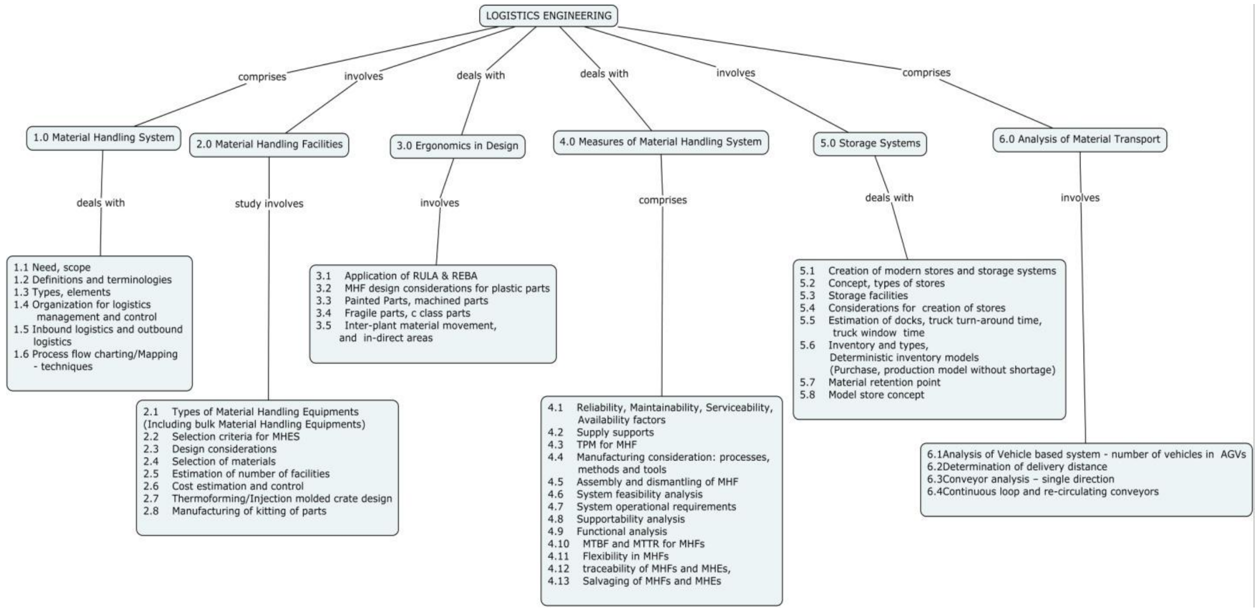
		Stores			
		S1	S2	S3	Requirement
Assembly Line	A	5	7	8	70
	B	4	4	6	30
	C	6	7	7	50
	Stock	65	42	43	150

2. In an automotive company, the total inflow of material supply vehicles is 500 trucks/day. The company has two vehicle assembly plants and one supportive machining plant. 150 trucks will be going for plant 1, 100 for Plant 2 and 250 for plant 3 (machining) and from plant 3, 150 will go to plant 1 and 100 will go to plant 2. Considering the plant layout as below, applying the suitable OR tool, propose the optimized truck path to ease traffic without congestion.

Course Outcome 6(CO6):

1. List the importance of AGVs.
2. Explain about the various analysis of vehicle based material transport system
3. AGV's are proposed for material handling of parts from stores to vehicle assembly line. The distance between POS and POC is 200 m. The quantity per container is 12 and weight of the container is 130 Kg. The AGVs has to feed for the line at 600/shift capacity. The maximum speed of the AGV is 0.4 m /sec and allowable weight is 500 Kg. Calculate the how many AGVs are required considering the return logistics and establish optimised route map.
4. The particular vehicle manufacturing stores works with 45 ITR. The total no. Of pats to be stored is 12,000 out of which 200 are A class parts requiring 1 off, 400 are B class parts requiring 2 off and remaining are C class parts requiring 3 off. The production rate is 5000 /day. Calculate the required inventory and design the suitable storage system with adherence of FIFO.

Concept Map



Syllabus

Material Handling System - Need, scope, definitions and terminologies, types, elements, Organization for logistics management and control. Inbound logistics and outbound logistics, Process flow charting/mapping techniques.

Material Handling Facilities - Types of Material Handling Equipments (AGVs, Fork lift, prime movers, stackers, lifts etc) – including bulk material handling equipment, selection criteria for MHES. Design considerations, selection of materials. Estimation of number of facilities required; cost estimation and control. Introduction to thermoforming/injection molded crate design and manufacturing for kitting of the parts.

Ergonomics in design: Application of RULA & REBA in MHF design, MHF design considerations for plastic parts, painted Parts, machined parts, fragile parts, c class parts, inter-plant material movement, and in-direct areas.

Measures of material handling system: reliability, maintainability, serviceability, availability factors, Supply supports, TPM for MHF, manufacturing consideration: processes, methods and tools, assembly and dismantling of MHF, system feasibility analysis, system operational requirements, Supportability analysis, functional analysis, MTBF and MTTR for MHFs, flexibility in MHFs, traceability of MHFs and MHEs, salvaging of MHFs and MHEs

Storage systems: Creation of modern stores and storage systems: concept of stores, types of stores, storage facilities, considerations for creation of stores, estimation of docks, truck turn-around time, truck window time, inventory and types, Deterministic inventory models, WIP, material retention point, model store concept.

Analysis of Material Transport Systems: Analysis of Vehicle based system- determination of number of vehicles in AGVs and determination of delivery distance. Conveyor analysis – single direction, continuous loop and re-circulating conveyors.

Reference Books:

1. Blanchard and Benjamin S, **"Logistics Engineering and Management"**, 6th International Edition, Prentice Hall Inc, 2004.
2. Christopher M, **"Logistics and Supply Chain Management - Creating Value Adding Networks"**, Prentice Hall, 2005.
3. James M. Apple, **"Plant Layout and Material Handling"** John Wiley, 3rd Edition, 1977.
4. Mikel P.Groover, **"Automation, Production Systems, and Computer-Integrated Manufacturing"**, PHI Publishers, 3rd Edition 2008.
5. Prauss L, **"The Green Multiplier - a Study of Environmental Protection and Supply Chain"**, Antonn Rauss Limited, Palgrave Macmillan, 2005.
6. Taylor G.D, **"Logistics Engineering handbook"**, CRC Press, 2008.
7. TVSM Material Handling Facilities Design Guidelines and Manuals

Course Contents and Lecture schedule

No	Topic	No. of Lectures
1	**Material Handling System**	
1.1	Need, scope	1
1.2	Definitions and terminologies	
1.3	Types, elements	1
1.4	Organization for logistics management and control	
1.5	Inbound logistics and outbound logistics	1
1.6	Process flow charting/Mapping - techniques	2
2	**Material Handling Facilities**	
2.1	Types of Material Handling Equipments (Including bulk Material Handling Equipment	2
2.2	Selection criteria for MHES	1
2.3	Design considerations	1
2.4	Selection of materials	
2.5	Estimation of number of facilities	1
2.6s)	Cost estimation and control	1
2.7	Thermoforming/Injection molded crate design	1
2.8	Manufacturing of kitting of parts	
3	**Ergonomics in design**	
3.1	Application of RULA & REBA	2
3.2	MHF design considerations for plastic parts	1

3.3	Painted Parts, machined parts	1
3.4	Fragile parts, c class parts	1
3.5	Inter-plant material movement, and in-direct areas	1
4	**Measures of material handling system**	
4.1	Reliability, Maintainability, Serviceability, Availability factors	1
4.2	Supply supports	1
4.3	TPM for MHF	1
4.4	Manufacturing consideration: processes, methods and tools	1
4.5	Assembly and dismantling of MHF	1
4.6	System feasibility analysis	1
4.7	System operational requirements	1
4.8	Supportability analysis	1
4.9	Functional analysis	1
4.10	MTBF and MTTR for MHFs	1
4.11	Flexibility in MHFs	
4.12	traceability of MHFs and MHEs,	1
4.13	Salvaging of MHFs and MHEs	1
5	**Storage systems**	
5.1	Creation of modern stores and storage systems	1
5.2	Concept, types of stores	
5.3	Storage facilities	1
5.4	Considerations for creation of stores	1
5.5	Estimation of docks, truck turn-around time, truck window time	1
5.6	Inventory and types, Deterministic inventory models (Purchase, production model without shortage)	1
5.7	Material retention point	1
5.8	Model store concept	
6	**Analysis of Material Transport Systems**	
6.1	Analysis of Vehicle based system - number of vehicles in AGVs	1
6.2	Determination of delivery distance	1
6.3	Conveyor analysis – single direction	1
6.4	Continuous loop and re-circulating conveyors	1
	Total	**40**

Course Designers:

1. Dr.ML.Mahadevan - mlmmech@tce.edu
2. Er.R. Swaminathan - r.swaminathan@tvsmotors.co.in

		Category	L	T	P	Credit
14MEPK0	**AUTOMOTIVE ENGINE SYSTEM**	PE	3	0	0	3

Preamble

This course deals with functions and features to design sub systems of an engine. It also involves with performance and emission characteristics of different engines and fuels.

Prerequisite

- 14ME240: Engineering Thermodynamics
- 14ME340: Fluid Mechanics
- 14ME540: Heat and Mass Transfer

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the engine power train system and make conceptual layout.	Understand
CO 2.	Interpret the requirement of cooling and lubrication systems in an IC engine	Understand
CO3.	Analyze gas exchange process and explain the functional requirement of induction and exhaust of an IC engine.	Analyze
CO 4.	Explain the emission trends, controlling techniques and norms for two and three wheeler application.	Apply
CO5.	Determine various engine performance and emission characteristics, measuring methods and principles of devices and sensors used.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	M	L	M	L	_	_	_	_	_	_	_	_	_	L	_
CO2.	M	L	M	L	_	_	_	_	_	_	_	_	_	L	_
CO3.	S	S	S	S	_	_	_	_	_	_	_	_	_	S	_
CO4.	S	M	S	M	_	_	_	_	_	_	_	_	_	M	_
CO5.	S	M	S	M	_	_	_	_	_	_	_	_	_	M	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	20	20	20	20
Apply	60	40	40	40
Analyse	0	20	20	20

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the various subsystems of engine and its functions in detail.
2. Name the components of engine power train.
3. Draw the valve train layout of a SI engine.

Course Outcome 2 (CO2):

1. State different lubricating oil and its major properties.
2. With reference to viscosity, how are the lubricating oils rated? Explain the meaning of SAE 15W-50.
3. Explain the principle of evaporative cooling system.

Course Outcome 3 (CO3):

1. Define volumetric efficiency and explain parameters that affect it.
2. Plot energy balance of typical engine (1litre SI with petrol engine), draw its P-v and T-s cycle, calculate its potential benefit if its compression ratio increased by 10%.
3. Correlate air-fuel mixture ratios with changing vehicle demands with driving conditions.

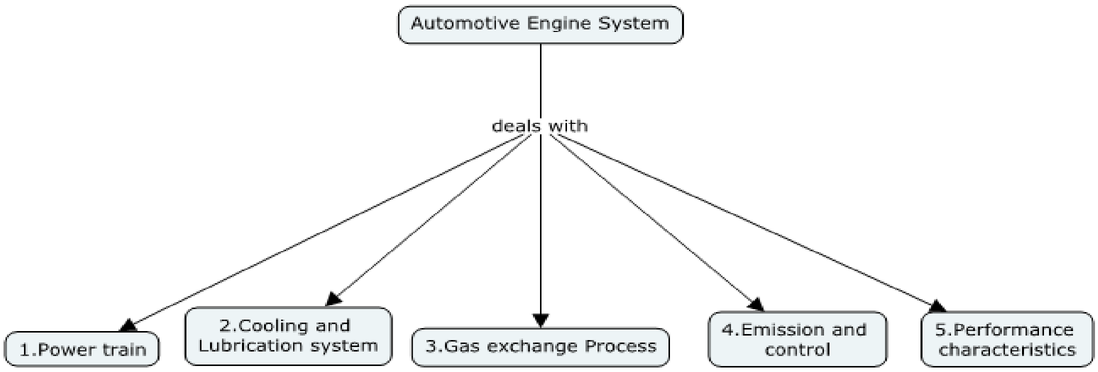
Course Outcome 4 (CO4):

1. Compare performance graphs of different fuels of same engine capacity and its emission characteristics (Petrol, Diesel of 1Ltre engine and 200 CC engine).
2. State emission norms followed for 4 wheeler (cars).
3. Explain the methods used of controlling NOx emissions from diesel engines.

Course Outcome 5 (CO5):

1. A turbocharged, 6.4-liter, V8 SI engine operates on an air-standard Otto cycle at WOT with an engine speed of 5500 rpm. The compression ratio is 10.4:1, and the conditions in the cylinders at the start of compression are 65°C and 120 kPa. Crevice volume is equal to 2.8% of clearance volume and has pressure equal to cylinder pressure and temperature equal to 185°C. Evaluate (i) total engine crevice volume (ii) percent of fuel that is trapped in the crevice volume at the start of combustion at TDC.
2. A pickup truck has a five-litre, V6, SI engine operating at 2400 rpm. The engine has a compression ratio of 10.2:1 and its volumetric efficiency is 0.91. The bore and the stroke are related as L= 0.92 B. Calculate (i) stroke length (ii) average piston speed (iii) clearance volume of one cylinder and (iv) airflow rate into the engine.
3. With a schematic drawing explain the principle of magnetic inductive speed sensor circuit.

Concept Map



Syllabus

Engine power train -Power train and its types, engine (SI and CI), Engine and its subsystems. Combustion chamber and its types, Valve train layout & Crank train layout, valve timing and timing chain layout, piston and piston rings, gaskets, importance of B/S and L/r, crank offset.
Cooling and Lubrication system - Energy balance and cooling load estimation, types of cooling system. Typical operating temperatures of engine parts, Cooling system design (Air cooled and water cooled), Schematic layout of Cooling system for a two wheeler engine, Lubrication requirements of engine, Functions of Lubricating oil, Parts to be lubricated and not to be lubricated, Schematic layout of lubricating system, oil filtering, Engine friction, Lubricating oils and its types and properties,
Gas Exchange Process - Functions of Induction system, Schematic layout (2W and 4W), Air Filtering and its importance, Functions of exhaust system, Schematic layout of exhaust system (2W and 4W), Noise and Emission norms, Volumetric efficiency, factors affecting volumetric efficiency, ram effect, engine tuning, Fuel control systems (Carburetor, Fuel Injection) Meeting demands of Vehicle (drivability, emissions and fuel economy) by controlling air and fuel, Muffler layout. Fuel properties and characteristics.
Emission and its Control – Chemistry of combustion, Stoichiometric equations of combustion. Emission relation with AFR - combustion chamber design – temperature - fuel (include load /speed) - Alternate fuels (performance, emission and practical issues). After treatment devices (include SAI, 2WC), Chemical reactions involved in after treatment- Emission norms (Indian, European, US emission norms, Emission testing and certification), Fuel Norms (BS1, BS2), Environmental effects of Emissions, SI and CI combustion introduction, engine knocking.
Performance characteristics and Automotive sensors – Engine parameters- Work, Mean effective pressure, Torque and Power, Specific fuel consumption, Engine efficiencies, Sensors and devices used for performance and emission measurements.

Text Book

1. Edward F. Obert, "**Internal Combustion Engines and Air Pollution**", First Edition, Addison-Wesley Educational Publishers, Incorporated, reprint, 2012.
2. Ganesan V, "**Internal Combustion Engines**", McGraw Hill Education (India) Pvt Ltd, 2012.

Reference Books

1. Heywood J.B., **"Internal Combustion Engine Fundamentals**", McGraw-Hill International Edition, Reprint 2012.
2. Richard Stone, **"Introduction to Combustion Engines**" 3rd Edition, Society of Automotive Engineers, Inc. 1999.

Web Resources

1. http://nptel.ac.in/courses/112104033/1
2. http://nptel.ac.in/courses/112104033/9
3. http://www.iitg.ernet.in/scifac/qip/public_html/cd_cell/chapters/uk_saha_internal_combustion_engine/qip-ice-06-valve%20timing%20diagrams.pdf

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Engine power train**	
1.1	Power train and its types, engine (SI and CI), Engine and its subsystems	2
1.2	Combustion chamber and its types	1
1.3	Valve train layout & Crank train layout, valve timing and timing chain layout	2
1.4	piston and piston rings, gaskets, importance of B/S and L/r, crank offset	2

Module No.	Topic	No. of Lectures
2	**Cooling and Lubrication system**	
2.1	Energy balance and cooling load estimation, types of cooling system.	1
2.2	Typical operating temperatures of engine parts, Cooling system design (Air cooled and water cooled),	2
2.3	Schematic layout of Cooling system for a two wheeler engine,	1
2.4	Lubrication requirements of engine, Functions of Lubricating oil, Parts to be lubricated and not to be lubricated	1
2.5	Schematic layout of lubricating system, oil filtering, Engine friction, Lubricating oils and its types and properties	2
3	**Gas Exchange Process**	
3.1	Functions of Induction system, Schematic layout (2W and 4W), Air Filtering and its importance,	2
3.2	Functions of exhaust system, Schematic layout of exhaust system (2W and 4W),	2
3.3	Noise and Emission norms, Volumetric efficiency, factors affecting volumetric efficiency, ram effect, engine tuning	2
3.4	Fuel control systems (Carburetor, Fuel Injection) Meeting demands of Vehicle (drivability, emissions and fuel economy) by controlling air and fuel	2
3.5	Muffler layout. Fuel properties and characteristics.	1
4	**Emission and its Control**	
4.1	Chemistry of combustion, Stoichiometric equations of combustion. Emission relation with AFR	2
4.2	combustion chamber design – temperature - fuel (include load /speed)	1
4.3	Alternate fuels (performance, emission and practical issues)	2
4.4	After treatment devices (include SAI, 2WC), Chemical reactions involved in after treatment-Emission norms (Indian, European, US emission norms, Emission testing and certification),	2
4.5	Fuel Norms (BS1, BS2), Environmental effects of Emissions, SI and CI combustion introduction, engine knocking.	2
5	**Performance characteristics and Automotive sensors**	
5.1	Engine parameters- Work, Mean effective pressure, Torque and Power, Specific fuel consumption, Engine efficiencies,	2
5.2	Sensors and devices used for performance and emission measurements	2
	TOTAL	**36**

Course Designers:

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2. Lakshmi Narasimhan, V V.LakshmiNarasimhan@tvsmotor.co.in

14MEPL0	MANUFACTURING SYSTEM ENGINEERING	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble:

Manufacturing Systems Engineering is a systematic approach to integrate the entire manufacturing process, from raw material purchase through production to sales, in order to produce the maximum volume of high-quality product at the lowest cost and in the shortest time. Manufacturing Systems Engineering is a discipline built upon a collection of methodological tools brought together to effect an integrated or "total" approach to problem-solving in Manufacturing Engineering, Industrial Economics and Production Management with productivity improvement as its overall objective.

Prerequisite

- 14ME530 - Manufacturing Systems and Automation

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the different approaches of production systems and its types.	Understand
CO 2.	Identify and analyse the types of waste through value added and non value added analysis.	Analyse
CO 3.	Determine flow production and level production rate using JIT tools	Apply
CO 4.	Explain about the maintenance and safety.	Understand
CO 5.	Implement JIT Manufacturing concept at cell level	Apply
CO 6.	Explain the fourth industrial revolution.	Understand

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1.	M	L	L	L	L	_	_	_	_	_	_	_	M	_	M
CO2.	S	S	M	S	M	_	_	_	_	_	_	_	M	_	M
CO3.	S	M	M	M	M	_	_	_	_	_	_	_	L	_	L
CO4.	M	M	M	M	M	M	_	_	_	_	_	_	_	_	_
CO5.	S	M	M	M	M	_	_	_	_	_	_	_	L	_	L
CO6.	M	L	L	L	L	_	_	_	_	_	_	_	_	_	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	20	30	30	20
Apply	40	50	50	40
Analyse	20	0	0	20
Evaluate	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. List the types of production system
2. What do you understand by Push and Pull Production?

Course Outcome 2 (CO2):

1. From the following data select the most advantageous location for setting a plant for making automobile axles.

Sl.No.	Category	Site X Rs.	Site Y Rs.	Site Z Rs.
1	Total initial investment	2,00,000	2,00,000	2,00,000
2	Total expected sales	2,50,000	3,00,000	2,50,000
3	Distribution expenses	40,000	40,000	75,000
4	Raw material expenses	70,000	80,000	90,000
5	Power and water supply expenses	40,000	30,000	20,000
6	Wages and salaries	20,000	25,000	20,000
7	Other expenses	25,000	40,000	30,000
8	Community attitude	Indifferent	Want business	Indifferent
9	Employee housing facilities	Poor	Excellent	Good

2. From the given information box, identify the wastes and suggest suitable methods for removal.

Part Number	WP/CAS/001	WP Casting
Family	Casting	Machine shop
Customer demand	4000/month	variation +400
Manufacturing data		Operation
Data collected by		Vinayaga
Cycle time(Minutes)		2
Change over time(Minutes)		20
Uptime		90%
% Defective		5% rework
Batch size		110 (10 numbers added to demand)

Number of shifts		2(8.5 hr per shift)
Number of Operators		1 per shift
Available time (Minutes)		450
Work in progress		650 numbers

3. Explain in detail how waste occurs.
4. Differentiate Value added activity and Non Value added activity.
5. What is the purpose of reducing waste?
6. Define Muda, Mura & Muri.

Course Outcome 3 (CO3):

1. A production manager is working in a cellular manufacturing system for automobile parts. He has to process an average of 250 parts per hour in the cell. The capacity of each container is 30 parts and one Kanban is attached to all the containers. The time to receive new parts from the previous workstation is 25 minutes. Factory maintains a safety stock factor of 15%. Determine the Kanbans needed for the plant.

2. The forecast for a group of items manufactured in a firm is shown below

Quarter	1	2	3	4	5	6	7	8
Demand	370	320	570	670	550	370	350	480

The firm estimates that it costs Rs.200 per unit to increase the production rate, Rs.250 per unit to decrease the production rate, Rs.75 per unit per quarter to carry the items on inventory and Rs.125 per unit if subcontracted. Compare the cost incurred in each of the strategy and arrive at a decision if the three strategies planned are varying the workforce, changing the inventory levels and subcontracting.

3. Explain the seven requirements of flow manufacturing.
4. Explain the various Production Levelling techniques.
5. What are the ten arguments against JIT Implementation?

Course Outcome 4 (CO4):

1. Discuss the ways to prevent defects.
2. List the type of maintenance.
3. Write the significance of maintenance.

Course Outcome 5 (CO5):

1. The MS 800 car is to be assembled on a conveyor belt. Five hundred cars are required per day. Production time per day is 420 minutes, and the assembly steps and times for the wagon are given below. Find the balance that minimizes the number of workstations, subject to cycle time and precedence constraints.
2.

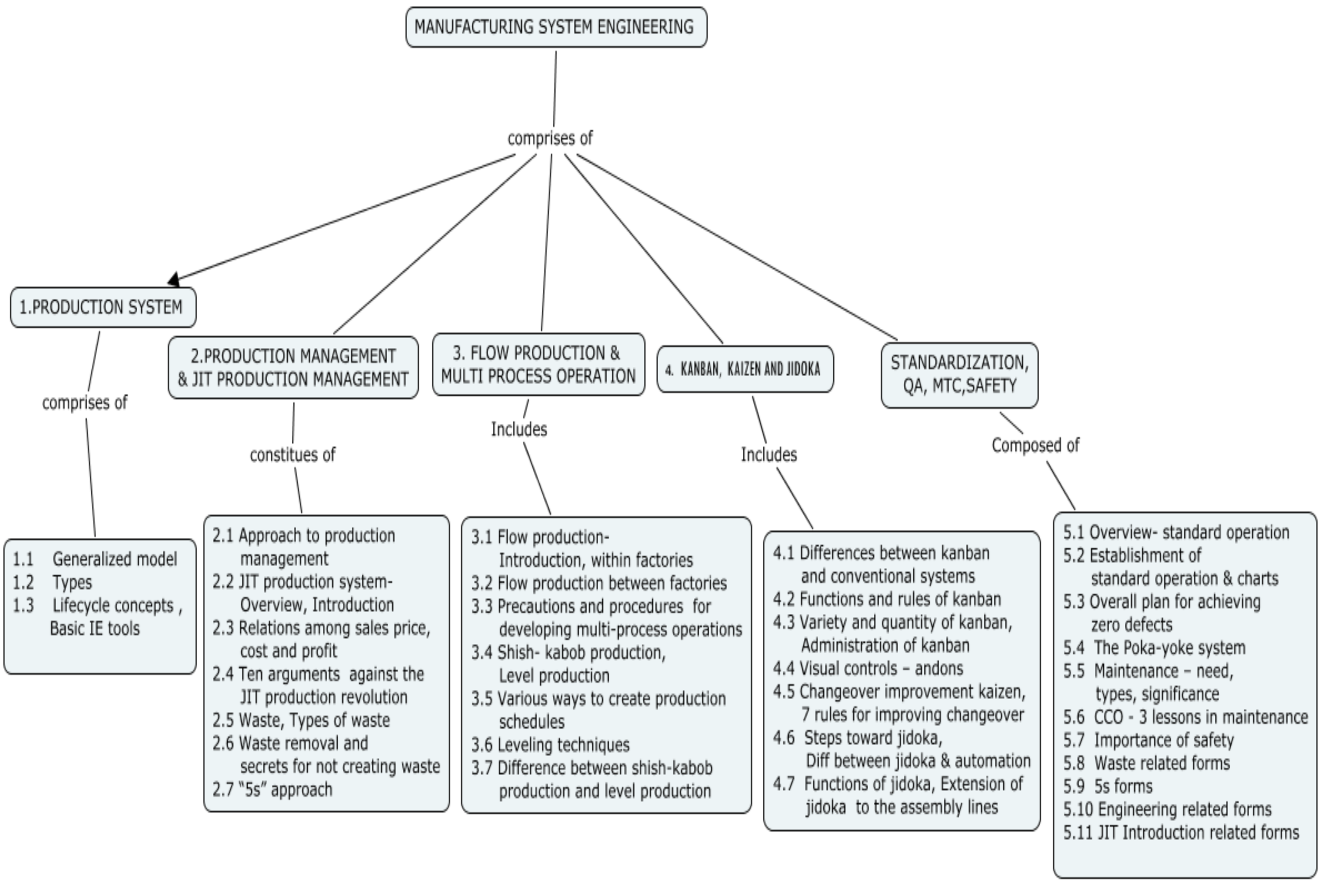
Task	Task	Description	Tasks that must precede
A	45	Position rear axle support -and hand fasten	-
B	11	Four screws to nuts	A
C	9	Insert rear axle	B
D	50	Tighten rear axle support screws to nuts	-
E	15	Position front axle assembly	D
F	12	Fasten with four screws to nuts	C
G	12	Tighten front axle assembly screws	C
H	12	Position rear wheel 1 and fasten hubcap	E
I	12	Position rear wheel 2 and fasten hubcap	E
J	8	Position front wheel 1 and fasten hubcap	F, G, H, I
K	9	Position front wheel 2 and fasten hubcap	J

3. Define Jidoka.

Course Outcome 5 (CO5):

1. Define IoT.
2. Define IoS.
3. Define IoD.
4. Explain fourth industrial revolution and usage of internet in manufacturing.

CONCEPT MAP



Syllabus

PRODUCTION SYSTEM: Generalized model of production systems, types of production systems and its impact on system design, lifecycle concepts of production systems, Basic IE tools.

PRODUCTION MANAGEMENT AND JIT PRODUCTION MANAGEMENT: Approach to production management, Introduction & overview of JIT production system, Relations among sales price, cost and profit, ten arguments against the JIT, production revolution. Waste - types of waste, waste removal and secrets for not creating waste, the "5s" approach.

FLOW PRODUCTION AND MULTI PROCESS OPERATION: Introduction to flow production, flow production within factories & between factories, precautions and procedures for developing multi-process operations, shish-kabob production, level production, various ways to create production schedules, levelling techniques, difference between shish-kabob production and level production.

BASICS OF KANBAN, KAIZEN AND JIDOKA: Differences between kanban and conventional systems, functions and rules of kanban, variety and quantity of kanban, administration of kanban, visual controls – andons, changeover improvement kaizen, seven rules for improving changeover, steps toward jidoka, difference between jidoka and automation, functions of jidoka, extension of jidoka to the assembly lines, labour cost reduction steps.

STANDARD OPERATIONS, QUALITY ASSURANCE, MAINTENANCE AND SAFETY: overview of standard operation, establishment of standard operation and charts, overall plan for achieving zero defects, the poka-yoke system. Maintenance – need, types, significance, CCO -three lessons in maintenance, importance of safety, waste related forms, 5s forms, engineering related forms, JIT Introduction related forms

Text Books:

1. Chase, Jacobs, Aquilano, **"Production and Operations Management"**, 8th Edition, Tata McGraw Hill Companies Inc, 2008.
2. Paneer Selvam R**, "Production and Operations Management"**, Prentice Hall of India, 2010.
3. Hiroyuki Hirano, **"JIT Implementation Manual"**, English Translation Copy Right, Productivity Press, 2009.

Reference Books:

1. Katsundo Hitomi, **“Manufacturing Systems Engineering”,** Second Edition 1996, Taylor & Francis.
2. Chary, “**Theory and Problems in Production and Operations Management”** Tata Mc-Hraw Hill, 2009.
3. Mikell P. Groover., “ **Fundamentals of Modern Manufacturing**”, Fourth Edition, John Wiley & Sons, 2011.
4. Ovidu vermisan., Peter Friess, “ **Digitising the Industry Internet of Things connecting the Physica, Digital, Virtual worlds**”, River publishers, 2016.
5. Alasdair Gilchrist **“ Industry 4.0: The Industrial Internet of Things”**, Apress, 2016.

Course Contents and Lecture schedule

S.No	Topics	No. of Lecture hour
1.0	**INTRODUCTION TO PRODUCTION SYSTEM**	
1.1	Generalized model of production systems	1
1.2	Types of production systems and its impact on system design	1
1.3	Lifecycle concepts of production systems, Basic IE tools	1
2.0	**PRODUCTION MANAGEMENT AND JIT PRODUCTION MANAGEMENT**	
2.1	Approach to production management	1
2.2	JIT production system- Overview, Introduction	1
2.3	Relations among sales price, cost and profit	1
2.4	Ten arguments against the JIT production revolution	1
2.5	Waste, Types of waste	1
2.6	Waste removal and secrets for not creating waste	1
2.7	“5s” approach	1
3.0	**FLOW PRODUCTION AND MULTI PROCESS OPERATION**	
3.1	Flow production- Introduction, within factories	1
3.2	Flow production between factories	1
3.3	Precautions and procedures for developing multi-process operations	1
3.4	shish-kabob production, Level production	1
3.5	Various ways to create production schedules, Leveling techniques	1
3.6	Difference between shish-kabob production and level production	1
4.0	**BASICS OF KANBAN, KAIZEN AND JIDOKA**	

S.No	Topics	No. of Lecture hour
4.1	Differences between kanban and conventional systems	1
4.2	Functions and rules of kanban	1
4.3	Variety and quantity of kanban, Administration of kanban	1
4.4	Visual controls – andons	1
4.5	Changeover improvement kaizen, Seven rules for improving changeover	1
4.6	Steps toward jidoka, Difference between jidoka and automation	1
4.7	Functions of jidoka, Extension of jidoka to the assembly lines	1
4.8	Labour cost reduction steps	1
5.0	**STANDARD OPERATIONS, QUALITY ASSURANCE, MAINTENANCE AND SAFETY**	
5.1	Overview of standard operation	1
5.2	Establishment of standard operation and charts	1
5.3	Overall plan for achieving zero defects	1
5.4	The Poka-yoke system	1
5.5	Maintenance – need, types, significance	1
5.6	CCO -three lessons in maintenance	1
5.7	Importance of safety, Waste related forms	1
5.8	5s forms, Engineering related forms	1
5.9	JIT Introduction related forms	1
6.0	**INDUSTRY 4.0**	
6.1	Introduction , smart manufacturing	1
6.2	Internet of Things (IoT)	1
6.3	Internet of Services (IoS), Internet of Data (IoD)	1
	TOTAL	**36**

Course Designers

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2. R.Sivasankaran rssmech@tce.edu

14MEPM0	VEHICLE DESIGN ENGINEERING	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

Knowledge on vehicle design is generally expected from a mechanical engineering graduate seeking placement in automotive industries. Vehicle design engineering is the branch of automobile engineering dealing with customer demands, design and failure analysis of automobile components or sub systems. This course covers House of Quality (HoQ), FMEA, design of vehicle layout, engine and transmission selection, vehicle vibration, vehicle aerodynamics, standards, tests and norms for automotive parts/system.

Prerequisite

- 14MEPH0 – Automotive Engineering

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Formulate customers' voice into vehicle specifications using HoQ and FMEA for an automotive component/system.	Apply
CO 2.	Select engine and transmission for an automobile.	Apply
CO 3.	Design suspension for minimum vehicle vibration	Apply
CO 4.	Explain aerodynamics of an automobile	Understand
CO 5.	Explain standards, tests and norms for an automotive parts/system.	Understand

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	M	M	S	M	M	_	_	_	_	_	_	_	M	_	M
CO2.	S	M	S	M	L	_	_	_	_	_	_	_	M	_	_
CO3.	S	M	S	M	L	_	_	_	_	_	_	_	M	_	_
CO4.	L	L	M	L	L	_	_	_	_	_	_	_	L	_	_
CO5.	L	L	M	L	_	_	_	_	_	_	_	M	L	_	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	10	10	10	10
Understand	30	30	30	30
Apply	60	60	60	60

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define "QFD". List its benefits and applications.

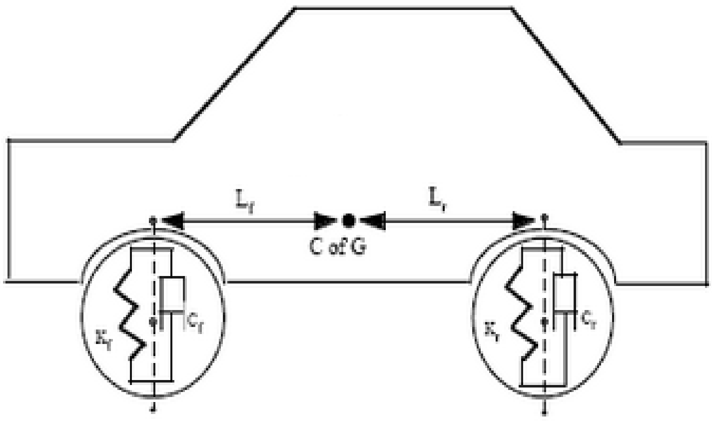
2. Discuss on methods of collecting customer feedback.
3. Demonstrate using House of Quality diagram, how typical customer needs are converted into specifications for braking system of a two wheeler.

Course Outcome 2 (CO2):

1. Discuss on the factors considered in selecting orientation of engine, fuel, method of cooling for given vehicle layout and requirement.
2. A car weighing 21336.75 N, has a static weight distribution on the axles 50:50. The wheel base is 3 m and the height of the centre of gravity above ground is 0.55 m. If the coefficient of friction on the highway is 0.6, prove that rear wheel drive offers higher gradeability than front wheel drive, if engine power is not a limitation.
3. Explain how is a transmission is chosen for given engine characteristics? Discuss on selection of gear ratios and final drive ratios for given vehicle requirement.

Course Outcome 3 (CO3):

1. Define “Degrees of freedom”. Give examples for single, two and three degree of freedom systems.
2. The automobile has a ratio of 40:60 load sharing between front Vs. rear. The LH side of the car is pictorially represented below. The car load factor shall rise to 3 times max during poor road conditions. Design the required spring characteristics of front and rear suspension. Explain what will happen to the front spring stiffness when they are fitted in 75 degrees with respect to ground.



3. Explain why under damping is preferred over critical damping and over damping?

Course Outcome 4 (CO4):

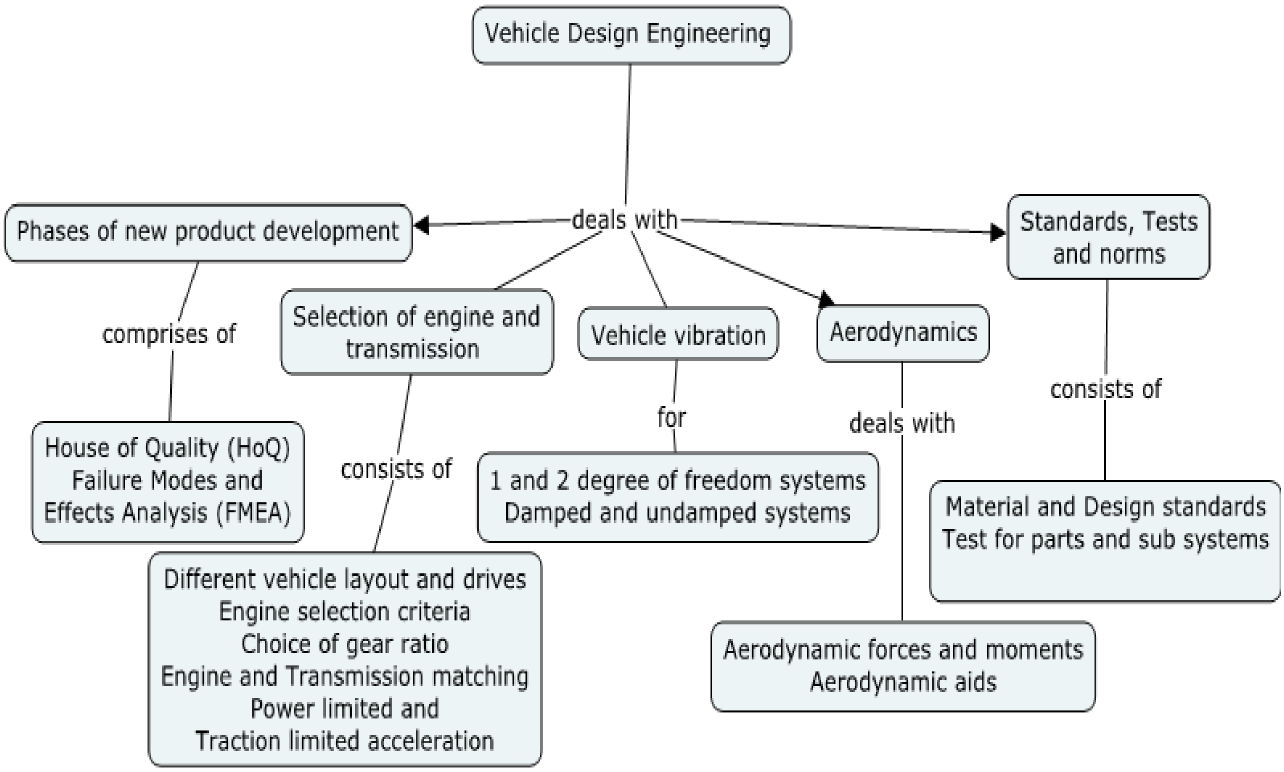
1. How vortex formation is avoided in cars?
2. List the various factors affecting drag coefficient. Give the typical values of different shapes of the vehicles.

3. Discuss on moments created by aerodynamic forces about different axes.

Course Outcome 5 (CO5):

1. List the various design standards followed globally for automotive tyres.
2. Discuss on various regulation tests conducted on braking system of an automobile, as per Indian standards.
3. Explain the Euro norms for pollution from 2 and 3-wheeled vehicles.

Concept Map



Syllabus

Translation of customer's voice into engineering requirements – Different phases of new product development, QFD, HoQ for converting customer voice into technical specifications, Feedback collection from customers. Enlisting design parameters against each voice - Mapping customers' voice & technical specification of different manufacturers, Interactions between technical requirement & specifications. Case studies – HoQ for cars/motorcycles, any part/subsystem. Failure Mode and Effects Analysis (FMEA), Essential components of Design FMEA, Case studies - chassis frame, component/system in transmission , steering, suspension and braking.

Selection of engine and transmission for an automobile – Merits and demerits of different vehicle layouts. Mechanics of Hotchkiss drive and torque tube drive. Engine selection criteria, Power to Weight ratio. Transmission selection - over gearing and under gearing, fuel economy, engine life and pollution. Matching engine and transmission, Selection of gear ratios, final drive ratio and wheel size for chosen engine specifications.

Comparison of manual and automatic transmission characteristics. Power limited acceleration - Effect of inertia and equivalent vehicle weight. Traction limited acceleration - Effect of suspension design, non-locking and locking differentials.

Vehicle vibration – Load distribution, spring stiffness at front and rear, vertical springs, inclined springs, springs in series, parallel springs, equivalent stiffness, Quarter car model and half car model, single and two degree of freedom systems - free and forced vibrations, damped and undamped vibrations, frequency, mode shapes, critical velocity, Transmissibility ratio, combined pitch and bounce, pitch centre and bounce centre.

Aerodynamics of an automobile - Mechanics of air flow around a vehicle, Aerodynamic forces (Drag, side force and lift) and moments (Rolling, pitching and yawing), Aerodynamic aids (Bumper spoilers, air dams and Deck lid spoilers), optimization.

Standards, tests and norms for an automotive part/system - Global material/design/regulatory & automotive standards for automobile industry - Working environment of part / sub system / vehicle in usage & handling by various stake holders – Tests & test conditions to verify part against all failure modes - case studies.

Text Books

1. N.K.Giri, "**Automobile Mechanics**", 8th Edition, Khanna Publishers, Delhi, 2008.
2. Kirpal Singh, "**Automobile Engineering**", Volume-1&2, 13th Edition, Standard Publishers Distributers, Delhi, 2013.

Reference Books

1. Thomas D.Gillespie, **"Fundamentals of vehicle dynamics"** Premiere Series Books, 1992.
2. Harald Naunheimer, Bernd Bertsche, Joachim Ryborz, Wolfgang Novak, **"Automotive Transmissions - Fundamentals, Selection, Design and Application",** in Collaboration with Peter Fietkau, Second Edition, Springer, 2010.
3. G. K. Grover, "Mechanical Vibrations", 8th Edition, Nem Chand & Bros, Rooekee, U.K., India, 2009.
4. Various standards for automotive components/systems.

Course Contents and Lecture Schedule

S.No	Topics	No. of periods
1	**Translation of customer's voice into engineering specifications**	
1.1	Different phases of new product development.	1
1.2	QFD, HoQ for converting customer voice into technical specifications, Feedback collection from customers.	1
1.3	Enlisting design parameters against each voice -Mapping customers'	2

	voice & technical specification of different manufacturers, Interactions between technical requirement & specifications.	
1.4	Case studies – HoQ for cars/motorcycles, any part/subsystem	1
1.5	Introduction, types of FMEA, Essential components of Design FMEA	1
1.6	Case studies - chassis frame, component/system in transmission, steering, suspension and braking.	2
2	**Selection of engine and transmission for an automobile**	
2.1	Merits and demerits of different vehicle layouts.	1
2.2	Mechanics of Hotchkiss drive and torque tube drive.	1
2.3	Engine selection criteria for a vehicle.	1
2.4	Transmission selection - over gearing and under gearing, fuel economy, engine life and pollution.	1
2.5	Matching engine and transmission, Selection of gear ratios, final drive ratio and wheel size for chosen engine specifications.	1
2.6	Comparison of manual and automatic transmission characteristics.	1
2.7	Power limited acceleration - Effect of inertia and equivalent vehicle weight.	2
2.7	Traction limited acceleration - Effect of suspension design, non-locking and locking differentials.	1
3	**Vehicle vibration**	
3.1	Load distribution, spring stiffness at front and rear, vertical springs, inclined springs, springs in series, parallel springs, equivalent stiffness	1
3.2	Quarter car model and half car model, single and two degree of freedom systems.	1
3.3	Free and forced vibrations, damped and undamped vibrations, frequency, mode shapes.	2
3.4	Critical velocity, Transmissibility ratio.	2
3.5	Combined pitch and bounce, pitch centre and bounce centre.	2
4	**Aerodynamics of an automobile**	
4.1	Mechanics of air flow around a vehicle	1
4.2	Aerodynamic forces (Drag, side force and lift)	1
4.3	Aerodynamic moments (Rolling, pitching and yawing)	2
4.4	Aerodynamic aids (Bumper spoilers, air dams, Deck lid spoilers), optimization.	1
5	**Standards, tests and norms for an automotive part/system**	
5.1	Global material/design/emission standards.	1
5.2	Working environment of part / sub system / vehicle in usage & handling by various stake holders.	1

5.3	Tests & test conditions to verify part against all failure modes – Case study – Wheel, Brake drum, tyre.	2
5.4	Tests & test conditions to verify sub system against all failure modes – Case study – braking system of all classes of vehicles.	2
	Total	**36**

Course Designer:

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2. S.B. Sridhar SB.Sridhar@tvsmotor.co.in

14MEPP0	**DESIGN FOR WELDING**	Category	L	T	P	Credit
		PC	3	0	0	3

Preamble

Welding is an inevitable process in the fabrication of parts. So in order to make the process effective and improve the quality of the product, there is a need to design weld joints and know the engineering and science behind the process. In order to perform Welding in some applications, the design of Welding fixtures is also essential to improve productivity of the process. This course aims to provide knowledge on Welding joints and its design techniques to optimize productivity and cost and design of Welding Fixtures based on applications.

Prerequisite

- 14ME330 Metal Joining Processes and Manufacturing Practices

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the fixture inspection, validation, maintenance & calibration.	Understand
CO 2.	Explain the quality requirement for welders and processes.	Understand
CO 3.	Choose Metal Inert Gas (MIG) welding and resistance welding process for a given application.	Apply
CO 4.	Select a welding fixture with reference of datum, location, orientation, resting and clamping of the part and materials used for fixture.	Apply
CO 5.	Select the welding process for productivity and cost.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	M	M	M	M	_	_	L	L	_	_	_	_	_	S
CO2.	S	L	_	_	_	_	_	S	_	_	M	L	_	_	S
CO3.	S	S	S	_	M	_	_	_	_	_	_	_	_	_	S
CO4.	S	_	_	_	_	_	_	_	_	L	M	_	M	_	S
CO5.	S	M	L	_	_	_	_	_	_	_	S	_	_	_	S

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	40	40	40	40
Apply	40	40	40	40
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Summarize about the calibration procedure of Weld fixture.
2. Classify the different types of fixture based on the types of applications.

3. Distinguish between Welding fixture and machining fixture.

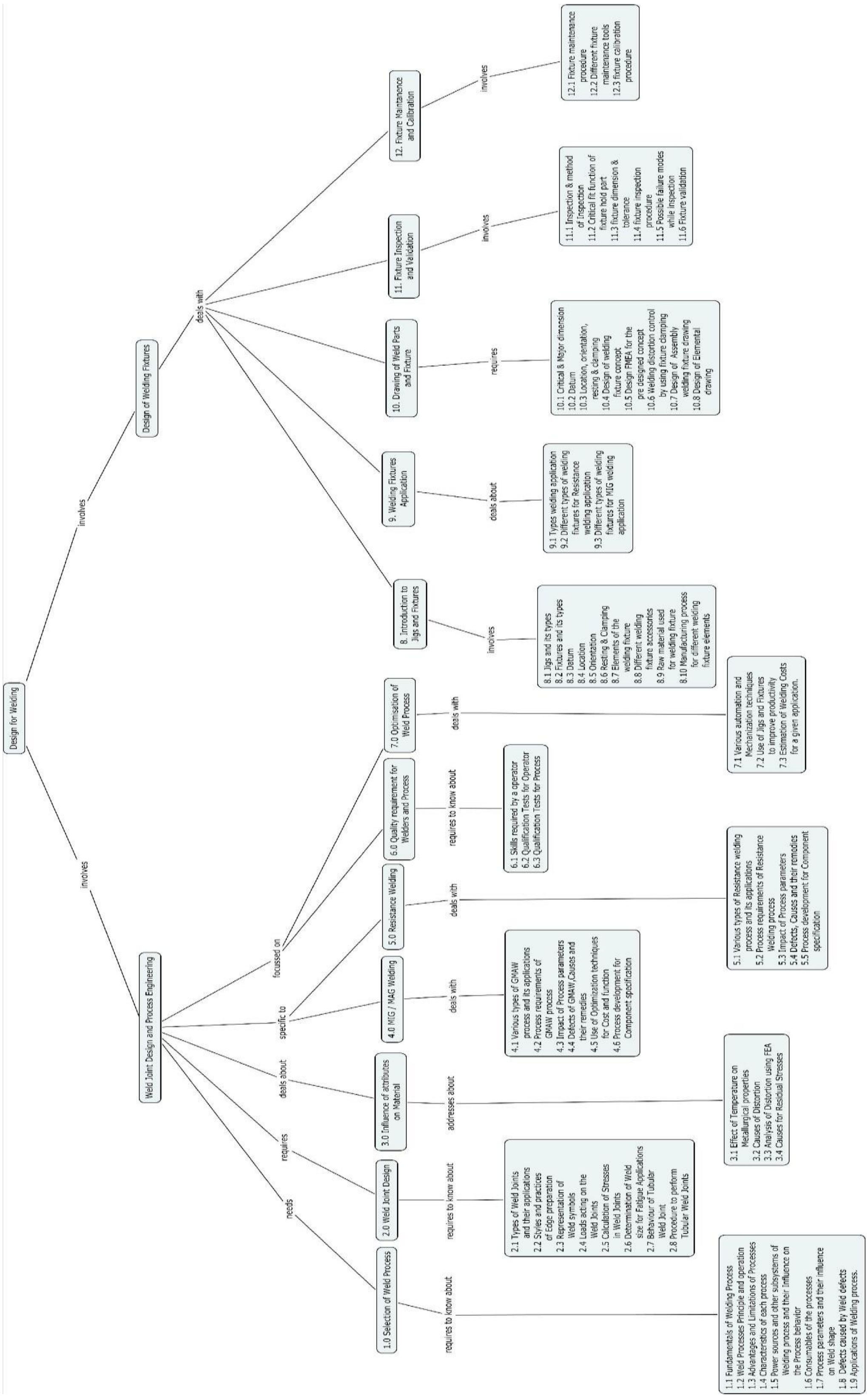
Course Outcome 2 (CO2):
1. List the skill sets that are required for a Welding Operator.
2. Discuss about the various automation and mechanization techniques in Welding.
3. Describe about the various parameters and its influence on Weld shape.

Course Outcome 3 (CO3):
1. Mention the Power Source required for Resistance Welding
2. Discuss about the causes for Welding Defects in MIG/GMAW Welding.
3. Design a lap joint for a plate of 10 mm thickness as per AWS 1.1.

Course Outcome 4 (CO4):
1. Mention the different elements of weld fixture.
2. Suggest the possible approaches to design the weld joints for constructing a steel bridge.
3. Construct a weld fixture for a U shaped tube welding. Justify the construction of fixture with suitable illustration.

Course Outcome 5 (CO5):
1. Select a welding process that requires no filler material and explain its types and factors influencing the Weld with suitable applications.
2. Select a suitable welding process that is used widely to weld the chassis of two wheelers. Explain the construction and working of process with suitable justification.
3. Select a suitable welding process to weld a component that requires high power density and capable to create keyholes. Explain the construction and working of process with suitable justification.

Concept Map



Syllabus

Selection of Weld Process Fundamentals of Welding Process - Weld Processes Principle and operation - Advantages and Limitations of Processes - Characteristics of each process -

Power sources and other subsystems of Welding process and their Influence on the Process behavior - Consumables of the processes - Process parameters and their influence on Weld shape - Defects caused by Weld defects Applications of Welding process. **Design of Weld Joints** Types of Weld Joints and their applications - Styles and practices of Edge preparation - Representation of Weld symbols - Loads acting on the Weld Joints - Calculation of Stresses in Weld Joints - Determination of Weld size for Fatigue Applications - Behaviour of Tubular Weld Joint - Procedure to perform Tubular Weld Joints **Influence of Attributes on Material -** Effect of Temperature on Metallurgical properties - Causes of Distortion - Analysis of Distortion using FEA - Causes for Residual Stresses - **MIG / GMAW Welding -** Various types of GMAW process and its applications - Process requirements of GMAW process - Impact of Process parameters - Defects of GMAW, Causes and their remedies - Use of Optimization techniques for Cost and function - Process development for Component specification - **Resistance Welding -** Various types of Resistance welding process and its applications - Process requirements of Resistance Welding process - Impact of Process parameters - Defects, Causes and their remedies - Process development for Component specification - **Quality requirement for Welders and Process** - Weldment, Testing of Weldment and classifications, Skills required by a operator - Qualification Tests for Operator - Qualification Tests for Process - **Optimization of Weld Process -** Various automation and Mechanization techniques - Use of Jigs and Fixtures to improve productivity - Estimation of Welding Costs for a given application. **Introduction to Jigs and Fixtures -** Jigs and its types - Fixtures and its types - Datum and its importance of the Part - Location and its importance of the Part - Orientation and its importance of the Part - Resting & Clamping and its importance of the Part - Elements of the welding fixture - Different welding fixture accessories used for different welding application - Raw material used for welding fixture - Manufacturing process for different welding fixture elements - **Welding Fixtures Application -**Types of welding application -Different types of welding fixtures for Resistance welding application (Manual/Auto) -Different types of welding fixtures for MIG welding application (Manual/Auto) -**Drawing of Weld Parts and fixtures -** Critical & Major dimension of the part -Datum used in the weld part - Location, orientation, resting & clamping for the weld part - Design of welding fixture concept for given part- Design FMEA for the pre designed concept fixture -Welding distortion control by using fixture clamping - Design of Assembly welding fixture drawing for a given part - Design of Elemental drawing of given welding fixture - **Fixture Inspection and Validation -** Inspection & method of Inspection - Critical fit function of fixture hold part - fixture dimension & tolerance - fixture inspection procedure - Possible failure modes while inspection - Fixture validation - **Fixture Maintenance and Calibration -** Fixture maintenance procedure - Different fixture maintenance tools - fixture calibration procedure

Text Book

1. Robert and Messler, "**Principles of Welding (Processes, Physics, Chemistry and Metallurgy)**", Wiley Interscience Publishers, 1st Edition, 1999.

Reference Books

1. "**Welding Hand Book**" Vol. 5; 7th edition, AWS, 1984.
2. S.J Maddox, "**Fatigue Strength of Welded Structures**", Woodhead Publishing, 1991.
3. T.R Gurney, Tim Gurney, "**Fatigue Strength of Transverse Fillet Welded Joints: A Study of the Influence of Joint Geometry**", Woodhead Publishing, 1991.
4. Omer. W.Blodgett, James F.Lincoln, "**Design of Welded Structures, Arc Welding Foundation**", 1st Edition 1996.
5. http://nptel.ac.in/courses/112101005/21
6. http://nptel.ac.in/courses/112101005/22
7. http://nptel.ac.in/courses/107103012/module6/lec2.pdf

8. http://nptel.ac.in/courses/Webcourse-contents/IIT%20Kharagpur/Machine%20design1/pdf/mod10les4.pdf
9. http://nptel.ac.in/courses/Webcourse-contents/IIT%20Kharagpur/Machine%20design1/pdf/mod11les2.pdf
10. https://www.youtube.com/watch?v=LQpxTqHB_p8

Course Contents and Lecture Schedule

S.No.	Topic	No. of Lectures
1.	**Selection of Weld Process**	
1.1	Fundamentals of Welding Process	1
1.2	Weld Processes Principle and operation	
1.3	Advantages and Limitations of Processes	1
1.4	Characteristics of each process	
1.5	Power sources and other subsystems of Welding process and their Influence on the Process behavior	1
1.6	Consumables of the processes.	
1.7	Process parameters and their influence on Weld shape.	1
1.8	Defects caused by Weld defects.	
1.9	Applications of Welding process.	1
2.	**Design of Weld Joints**	
2.1	Types of Weld Joints and their applications	1
2.2	Styles and practices of Edge preparation	
2.3	Representation of Weld symbols	1
2.4	Loads acting on the Weld Joints	
2.5	Calculation of Stresses in Weld Joints	1
2.6	Determination of Weld size for Fatigue Applications	
2.7	Behaviour of Tubular Weld Joint	1
2.8	Procedure to perform Tubular Weld Joints	
3.	**Influence of Attributes on Material**	
3.1	Effect of Temperature on Metallurgical properties	1
3.2	Causes of Distortion	
3.3	Analysis of Distortion using FEA	2
3.4	Causes for Residual Stresses	1
4.	**MIG / MAG Welding**	
4.1	Various types of GMAW process and its applications	1
4.2	Process requirements of GMAW process	1
4.3	Impact of Process parameters	1

S.No.	Topic	No. of Lectures
4.4	Defects of GMAW, Causes and their remedies	1
4.5	Use of Optimization techniques for Cost and function	
4.6	Process development for Component specification	1
5.	**Resistance Welding**	
5.1	Various types of Resistance welding process and its applications	1
5.2	Process requirements of Resistance Welding process	1
5.3	Impact of Process parameters	1
5.4	Defects, Causes and their remedies	
5.5	Process development for Component specification	1
6.	**Quality requirement for Welders and Process**	
6.1	**W**eldment, Testing of Weldment and classifications	1
6.2	Skills required by a operator	1
6.3	Qualification Tests for Operator	
6.4	Qualification Tests for Process	1
7.	**Optimization of Weld Process**	
7.1	Various automation and Mechanization techniques	1
7.2	Use of Jigs and Fixtures to improve productivity	
7.3	Estimation of Welding Costs for a given application	1
8.	**Introduction to Jigs and Fixtures**	
8.1	Jigs and its types	1
8.2	Fixtures and its types	
8.3	Datum and its importance of the Part	1
8.4	Location and its importance of the Part	
8.5	Orientation and its importance of the Part	1
8.6	Resting & Clamping and its importance of the Part	
8.7	Elements of the welding fixture	1
8.8	Different welding fixture accessories used for different welding application	1
8.9	Raw material used for welding fixture	1
8.10	Manufacturing process for different welding fixture elements	
9.	**Welding Fixtures Application**	
9.1	Types of welding application	1
9.2	Different types of welding fixtures for Resistance welding	1

S.No.	Topic	No. of Lectures
	application (Manual/Auto)	
9.3	Different types of welding fixtures for MIG welding application (Manual/Auto)	
10.	**Drawing of Weld Parts and Fixture**	
10.1	Critical & Major dimension of the part	1
10.2	Datum used in the weld part	
10.3	Location, orientation, resting & clamping for the weld part	1
10.4	Design of welding fixture concept for given part.	
10.5	Design FMEA for the pre designed concept fixture	1
10.6	Welding distortion control by using fixture clamping	1
10.7	Design of Assembly welding fixture drawing for a given part	1
10.8	Design of Elemental drawing of given welding fixture	1
11.	**Fixture Inspection and Validation**	
11.1	Inspection & method of Inspection	1
11.2	Critical fit function of fixture hold part	
11.3	fixture dimension & tolerance	1
11.4	fixture inspection procedure	
11.5	Possible failure modes while inspection	1
11.6	Fixture validation	
12.	**Fixture Maintenance and Calibration**	
12.1	Fixture maintenance procedure	1
12.2	Different fixture maintenance tools	
12.3	fixture calibration procedure	1
	Total	46

Course Designers:

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14MEPQ0	DESIGN FOR SHEET METAL MANUFACTURING	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

Sheet metal manufacturing involves a wide range of processes that manufacture parts for a vast amount of purposes, both seen and unseen. Sheet metal refers to metal that has a high surface area to volume ratio. Sheet metal is used in the manufacture of cars, trains, aircraft, farm equipment, office equipment, furniture, house appliances, computers, machine components and beverage cans to name a few. Some of the sheet metal manufacturing processes may be applicable to plate metal as well. Sheet metal manufacturing produces parts that typically have high strength, good surface and accurate tolerances. Hence considering the importance the course drives to impart knowledge on Sheet metal processes and Design for manufacturing of sheet metal parts.

Prerequisite

- 14ME230 – Metal Casting and Forming Processes

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO1.	Explain the Sheet metal Cutting and Non-cutting operations.	Understand
CO2.	Compute Cutting, Bending and Drawing Forces for a given part.	Apply
CO3.	Perform strip layout and find stripping force for a given part	Apply
CO4.	Design press tool die sets with required elements for a given part.	Apply
CO5.	Identify the Cost drivers to decide the Cost of part.	Understand

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	L	L	_	_	_	_	_	L	_	_	M	M	_	L
CO2.	S	S	L	_	_	_	_	_	L	_	_	M	M	_	L
CO3.	S	L	S	L	_	_	_	_	L	_	_	M	S	_	M
CO4.	S	S	S	L	_	_	_	_	L	_	_	S	S	_	M
CO5.	S	L	L	L	_	_	_	_	L	_	_	M	M	_	S

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	40	40	40	40
Apply	40	40	40	40
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. List the types of Sheet metal Cutting operations.
2. Discuss about the types of Relief.
3. Define Spring back.

Course Outcome 2 (CO2):

1. Determine the cutting Force required to cut a dimension of diameter 200 mm on sheet of thickness 2 mm. Also calculate the pitch and strip width required for nesting and suggest a suitable type of nesting layout and justify.
2. Determine the bending force required to perform a perpendicular bend on a part having width of 100 mm and thickness of 5 mm. Also find the wiping force and suggest a suitable type of bending process and justify.
3. Determine the no. of Draws required for making a hollow cylinder of diameter 45 mm and height of 90 mm and also calculate the blank size, Draw Force, Holding Force and Press Tonnage. Prepare a schematic diagram of the draw tool.

Course Outcome 3 (CO3):

1. Develop a strip layout for the given part and also determine the utilization factor for the layout. Prepare a schematic diagram of the layout with orientation of your choice in order to have minimum utilization.
2. Discuss about the various types of orientations that can be used in strip layout of Sheet metal nesting with help of neat sketches.
3. Determine the cutting Force required to cut a dimension of diameter 200 mm on sheet of thickness 2 mm. Also calculate the pitch and strip width required for nesting and suggest a suitable type of nesting layout and justify.

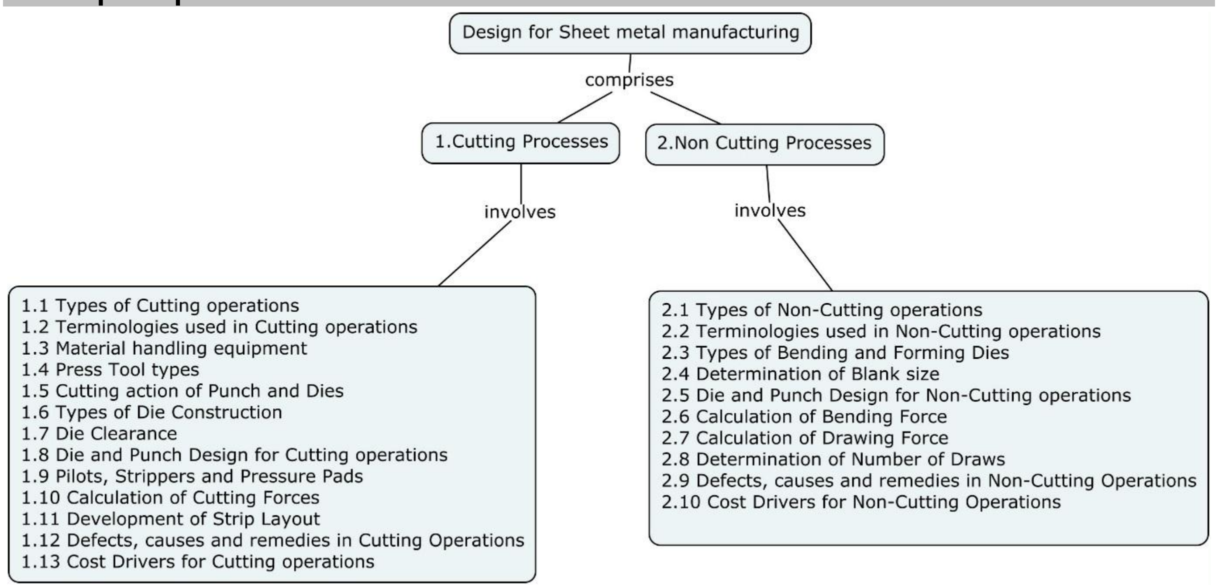
Course Outcome 4 (CO4):

1. Discuss about Progressive tools and Combination Tools.
4. List the types of Pressing Machines.
5. Design a suitable die set for making a washer of outer dia 30mm and inner dia 10mm.

Course Outcome 5 (CO5):

2. List the Cost drivers used to determine the cost of tube bend parts.
6. Discuss about the effect of Dimensional accuracy on the Cost of Formed part.
7. Explain the various consideration that are required to estimate the Tooling cost.

Concept Map



Course Contents

Sheet Metal Cutting operations: Types of Cutting operations, Terminologies in Cutting operations, Material handling equipment, Press Tool types, Cutting action of Punch and Dies, Types of Die Construction Die Clearance, Die Design for Cutting operations, Pilots, Strippers and Pressure Pads, Calculation of Cutting Forces, Development of Strip Layout, Defects, causes and remedies in Cutting Operations, Cost Drivers for Cutting operations **Sheet Metal Non-Cutting Operations:** Types of Non-Cutting operations, Terminologies in Non-Cutting operations, Types of Bending and Forming Dies, Determination of Blank size, Calculation of Bending Force, Calculation of Drawing Force, Determination of Number of Draws, Defects, causes and remedies in Non-Cutting Operations, Cost Drivers for Non-Cutting Operations.

Text Books

1. Cyril Donaldson, George H Le Cain, V C Goold and Joyjeet Ghose, **"Tool Design"**, Tata McGraw Hill Education Pvt. Ltd, New Delhi, Fourth Edition, 2012.
2. Serope Kalpakjian and Steven R. Schmid, "**Manufacturing Engineering and Technology**", Addition Wesley Longman Pvt. Ltd., First Indian reprint, 2000.

Reference Books

1. Nagpal, G.R, **"Tool Engineering & Design"**, Khanna Publishers, Delhi, Sixth edition, Fourth Reprint, 2011.
2. **"Design Data Handbook"**, PSG College of Technology, Coimbatore, 2016.
3. Semiatin, S.L, "**ASM Handbook Volume 14B: Metalworking: Sheet Forming",** 2006.
4. ASTME, **"Fundamentals of Tool Design"**, Prentice Hall of India, 2003.

Lecture Schedule

S.No	Topic	No. of Lectures
1.	**Sheet Metal Cutting operations**	
1.1	Types of Cutting operations	2
1.2	Terminologies used in Cutting operations	1
1.3	Material handling equipment	1
1.4	Press Tool types	1
1.5	Cutting action of Punch and Dies	1
1.6	Types of Die Construction	3
1.7	Die Clearance	1
1.8	Die and Punch Design for Cutting operations	3
1.9	Pilots, Strippers and Pressure Pads	2
1.10	Calculation of Cutting Forces	1
1.11	Development of Strip Layout	2
1.12	Defects, causes and remedies in Cutting Operations	1
1.13	Cost Drivers for Cutting operations	1
2.	**Sheet Metal Non-Cutting Operations**	
2.1	Types of Non-Cutting operations	2

2.2	Terminologies used in Non-Cutting operations	2
2.3	Types of Bending and Forming Dies	2
2.4	Determination of Blank size	1
2.5	Die and Punch Design for Non-Cutting operations	3
2.6	Calculation of Bending Force	1
2.7	Calculation of Drawing Force	2
2.8	Determination of Number of Draws	1
2.9	Defects, causes and remedies in Non-Cutting Operations	1
2.10	Cost Drivers for Non-Cutting Operations	1
	Total	36

Course Designer:

1. M.Balamurali balacim82@tce.edu

14MEPR0	ASSEMBLY ENGINEERING	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

The increasing need for finishing goods in large quantities has led engineers to search for and to develop new methods for manufacturing. As a result of developments in the various manufacturing processes, it is now possible to mass-produce high quality durable goods at low cost. One of the manufacturing processes is assembly process that is required when two or more components are to be secured together. The history of assembly process development is closely related to the history of the development of mass-production methods. The assembly process is concerned with prediction of time taken to accomplish the various tasks such as grasp, orient, insert and fasten. This process can be carried out manually and/or automatically based on its cost estimation.Besides, Design for Assembly (DFA) provides systematic procedure and guidelines for evaluating and improving the product design for both manufacture and assembly economically.

Prerequisite

- 14ME330 – Metal Joining Processes and Manufacturing Practices
- 14ME450 – Production Drawing
- 14ME530 – Manufacturing Systems and Automation

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO1 :	Implement dimensional and geometrical tolerances for the given assembly/part to meet its specified functional requirement.	Apply
CO2:	Determine feasible assembly sequences for the given set of parts using Liaison Sequence diagram and precedence constraints.	Apply
CO3:	Determine the time and number of workers required for the given assembly requirement.	Apply
CO4:	Estimate the cost involved in indexing and free-transfer machines in an assembly.	Apply
CO5:	Implement design modifications on the given component using DFA guidelines.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	M	L	_	_	_	_	_	L	_	_	L	M	_	_
CO2.	S	M	L	_	_	_	_	_	L	_	_	L	M	_	_
CO3.	S	M	L	_	_	_	_	_	L	_	_	L	M	_	_
CO4.	S	M	L	_	_	_	_	_	L	_	_	L	M	_	_
CO5.	S	M	L	_	_	_	L	_	L	_	_	L	M	_	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	0	0
Understand	20	20	30	30
Apply	60	60	70	70
Analyse	-	-	-	-

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. A 30mm diameter hole is made on a turret lathe to the limits, 30.035 and 30.00. The followingtwo grades of shafts are used to fit in the hole:(*a*) ϕ29.955mm and 29.925mm, and (*b*) ϕ 30.055mm and 30.050mm.Calculate the maximum tolerance, clearance and indicate the type of fit in each case by a sketch.
2. Interpret and write the specification of all the feature control frames in the drawing as shown in figure 1 and draw their respective tolerance zones.

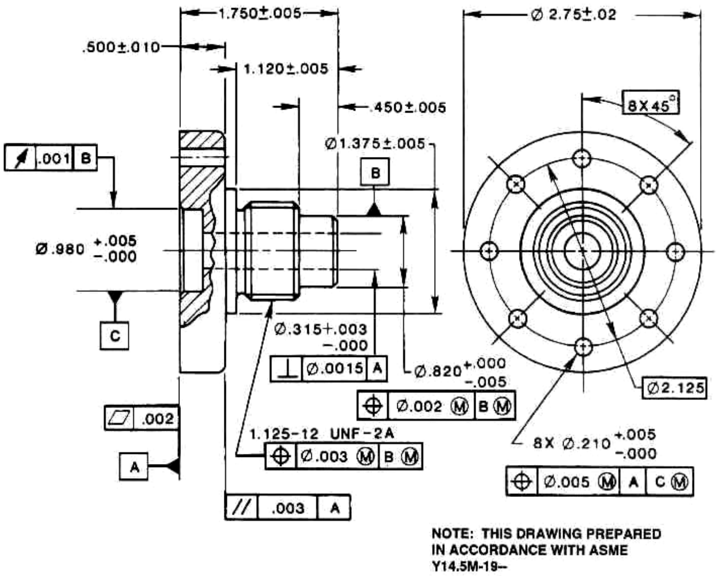


Figure 1

3. The following two components as shown in Figure 2 are to be assembled with a tolerance of fit +0.002±0.002 mm. Design a selective assembly structure and justify the same. Is there any change in selective assembly structure, if the tolerance of fit is set to be +0.004±0.002 mm ? Justify the same.

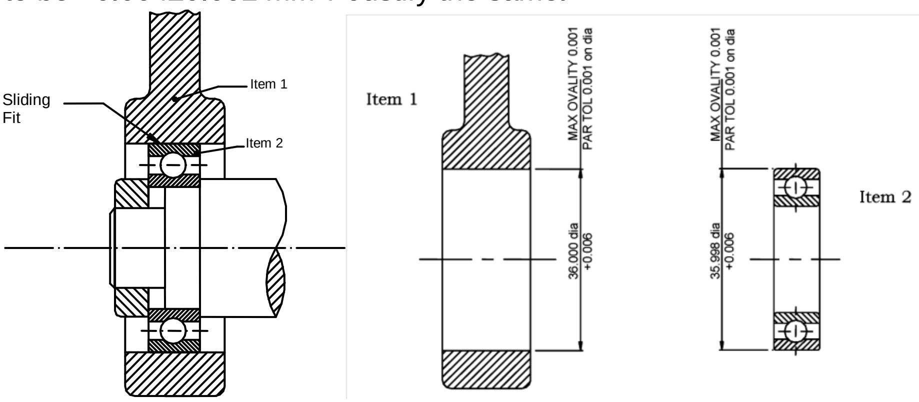


Figure 2

Course Outcome 2 (CO2):

1. Prepare an assembly sequence for the following exploded view of assembly as given in figure 3.

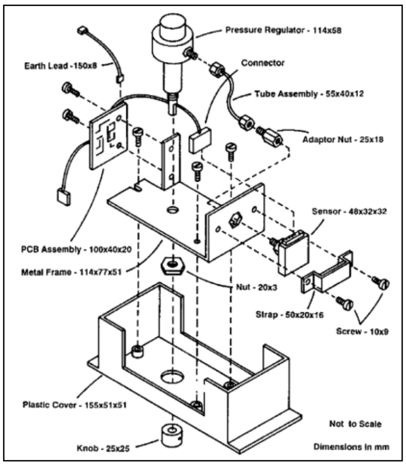
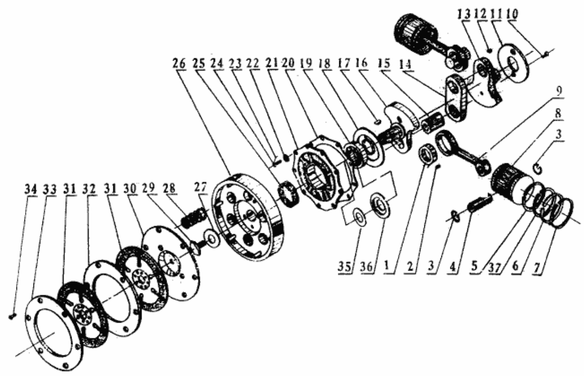


Figure 3

2. The exploded view of a crank shaft and clutch assembly shown in Figure 4. Suggest assembly plan for this assembly with its precedence diagram of its assembly sequence where its part numbers are on the node. Justify the assumptions made if any.



Part #	CJ 750 Parts name	Qty	Part #	CJ 750 Parts name	Qty	Part #	CJ 750 Parts name	Qty
1	Retainer	2	9	Link rod copper insert SV	1	31	Friction wafer	4
2	CJ750 Rollers	24		Link rod copper insert OHV	1	32	Drive wafer	4
3	Piston pin circlip or clasp SV	4	10	Screw	1	33	Supporting plate	1
	Piston pin circlip OHV		11	Front oil slinger	1	34	Screw	1
4	Piston pin SV	2	12	Crank shaft front part key	1	35	Washer	1
	Piston pin OHV		13	Crank shaft front part	1	36	Rear oil proof disc	1
5	OHV oil seal piston ring +0.00	2	14	Crank cheek	9	37	SV Oil seal piston ring +0.00	1
	SV Oil seal piston ring +0.00	2	15	Crank pin	1		OHV oil seal piston ring +0.00	1
	SV oil seal piston ring +0.25	2	16	Crank shaft rear part	9		SV oil seal piston ring +0.25	
	SV Oil seal piston ring +0.50	2	17	Crank shaft rear part key	1		SV oil seal piston ring +0.50	1
	SV Oil seal piston ring +0.75		18	Rear oil slinger	1		SV oil seal piston ring +0.75	
	SV Oil seal piston ring +1.00	2	19	Bearing	1		SV oil seal piston ring +1.0	
	SV Oil seal piston ring +1.25		20	Washer	6		SV oil seal piston ring +1.25	1
6	OHV air seal pistin ring +0.00		21	Rear bearing fitting body	1	3-8	Piston, pins, rings and clips	
	SV Air seal piston ring +0.00	2	22	Washer	1	37	combination	
	SV Air seal piston ring +0.25	1	23	Fuse		1-2		
	SV Air seal piston ring +0.50	1	24	Screw		9	Crank shaft combination	
	SV Air seal piston ring +0.75	1	25	Sealing leather cup and spring		13-16		
	SV Air seal piston ring +1.0	1	26	Flywheel combination		1-2		
	SV Air seal piston ring +1.25	2	27	Lock wafer		18	Crank shaft combination w/oil	
7	OHV air seal piston ring +0.00		28	Clutch spring		9-11	proof key	
	SV Air seal piston ring +0.00		29	Crank shaft rear screw		13-16		
	SV Air seal piston ring +0.25		30	Platen				
	SV Air seal piston ring +0.50							
	SV Air seal piston ring +0.75							
	SV Air seal piston ring +1.00							
	SV Air seal piston ring +1.25							
8	Pistons							
	SV high speed pistons and rings							
	SV oversize pistons & rings +0.25							

Figure 4

3. Suggest a suitable assembly processes and appropriate tools for the gear box assembly as shown in figure 5. Identify the expected bottleneck operation in this assembly and predict the estimated time for the same.

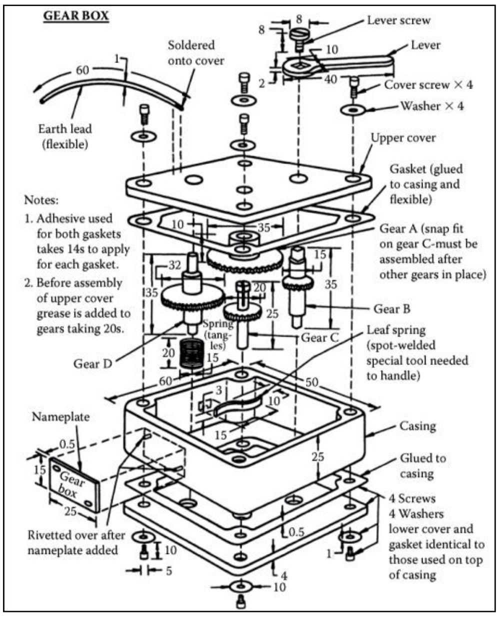


Figure 5

Course Outcome 3 (CO3):

1. The following data have been obtained for a vehicle assembly.

Customer demand for Vehicle	: 2500 / day
No of Shifts working	: 2
Working time	: 8.5 hrs/ shift
Lunch Break	: 30 min/ shift
Tea time	: 2 times/shift at 10 min/tea break

   Calculate the TAKT time and the number of workers required to meet the demand.

2. The hourly production rate and work content time for two models to be produced on a mixed model assembly line are given in the table below.

Model j	Production Rate R_{pj}	Time T_{wcj}(min)
A	4	27.0
B	6	25.0

   Also, given is that line efficiency E=0.96 and manning level M=1. Determine the theoretical minimum number of workers required on the assembly line.

3. A small electrical appliance is to be produced on a single model assembly line. The work content of assembling the product has been reduced to the work elements listed in Table 1. The table also lists the standard times that have been established for each element as well as the precedence order in which they must be performed. The line is to be balanced for an annual demand of 100,000 units/yr. The line will operate 50 weeks/year, 5 shifts/week and 7.5 hours/shift. Manning level will be one worker per station. Previous experience suggests that the uptime efficiency for the line will be 96%, and repositioning time lost per cycle will be 0.08 min. Determine:
   (i) total work content time T_{wc},
   (ii) required hourly production rate R_p to achieve the annual demand,
   (iii) cycle time T_c
   (iv) theoretical minimum number of workers required on the line, and
   (v) service time T_s, to which the line must be balanced.

Table 1 Work elements

No.	Work element description	Time, T_{ek} (min)	Must be preceded by
1.	Place frame in work-holder and clamp	0.2	-
2.	Assemble plug, grommet to power cord	0.4	-
3.	Assemble brackets to frame	0.7	1
4.	Wire power cord to motor	0.1	1,2
5.	Wire power cord to switch	0.3	2
6.	Assemble mechanism plate to bracket	0.11	3
7.	Assemble blade to bracket	0.32	3
8.	Assemble motor to brackets	0.6	3,4
9.	Align blade and attach to motor	0.27	6,7,8
10.	Assemble switch to motor bracket	0.38	5,8
11.	Attach cover, inspect, and test	0.5	9,10
12.	Place in tote pan for packing	0.12	11

Course Outcome 4 (CO4):

1. Differentiate indexing and free-tranfser machine.
2. Discuss the effect of part quality on downtime of indexing machines.
3. A 20--station transfer line is being proposed to machine a certain component currently produced by conventional methods. The proposal received from the machine tool builder states that the line will operate at a production rate of 50 pc/hr at 100% efficiency. From similar transfer lines, it is estimated that breakdowns of all types will occur with a frequency F = 0.10 breakdown per cycle and that the average downtime per line stop will be 8.0 min. The starting casting that is machined on the line costs Rs.3.00 per part. The line operates at a cost of Rs.*75.00/hr.* The 20 cutting tools (one tool per station) last for 50 parts each, and the average cost per tool = Rs.2.00 per cutting edge Based on this data, compute the following: (a) production rate, (b) line efficiency, and *(c)* cost per unit piece produced on the line.

Course Outcome 5 (CO5):

1. The controller assembly as in figure 6 has been assembled manually. If the company is interested to assemble this equipment through an automated assembly system in order to avoid errors in manual assembly and availability of skilled labours, suggest suitable modification in design of this assembly for the improvement of its assembly efficiency.

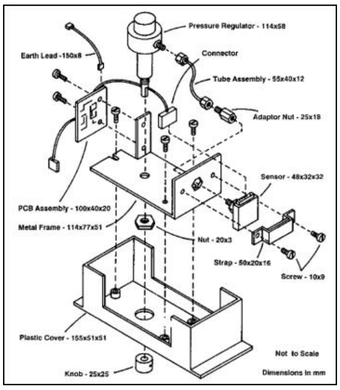


Figure 6

2. Suggest and justify the suitable modifications on the design of the following components as shown in figure 7to ensure proper assemblywith minimum effort.

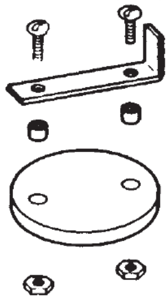


Figure 7

3. Recommend necessary modifications in part design of the following alternator assembly as shown in figure 8 and its assembly sequences in order to improve the efficiency of its manual assembly.

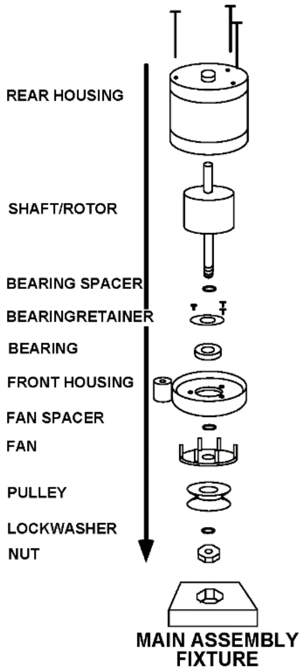
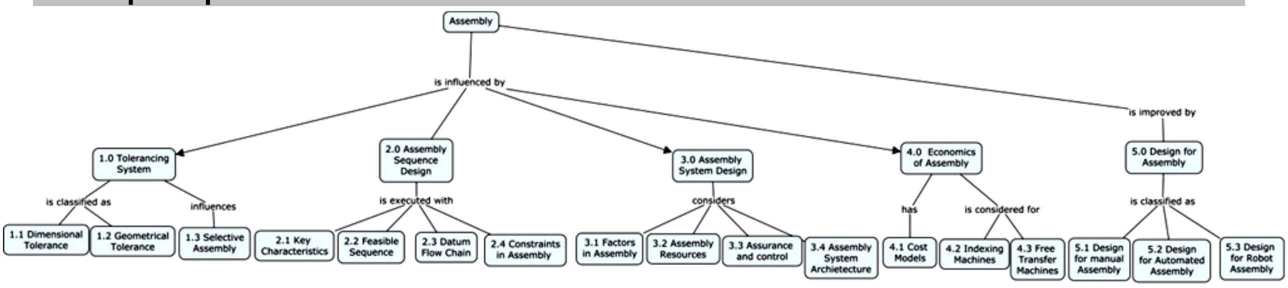


Figure 8

Concept Map



Syllabus

Tolerancing System: Importance- Dimensional and geometric tolerances - Process capability - surface finish– Fit of an assembly - Cumulative effect of tolerances. Datum systems: Degrees of freedom. True position theory: Virtual size concept - Projected tolerance zone - Selective Assembly:Interchangeable part manufacture and selective assembly - Deciding the number of groups - Group tolerances of mating parts equal - Total and group tolerances of shaft equal.

Assembly Sequence Design: Key Characteristics (KC) – Flow down of KC –Ideal KC process – KC Conflicts. Assembly Sequence Design Process: Methods for finding feasible sequences - Liaison diagram – Governing Rule – Generating the feasible sequences- Cutset method. Datum Flow Chain: Nominal Design – Variation Design – Assumptions – Role of assembly features. Constraints in Assembly: Completely constrained assemblies – Partially constrained assemblies - Assembly precedence constraints. Design Procedure for assemblies.

Assembly System Design: Factors in system design – capacity planning, available time & required number of units per year, assembly resources choice, assignment of operations of resources, floor layout, workstation design, material handling and work transport, parts feeding and presentation and quality. Assembly Resources: Characteristics of manual, fixed and flexible automation. Parts feeding and presentation: Automatic feeding and orienting - feed tracks – escapements – part placement mechanism and robots.Assurance and control: Elements of testing strategy – Effect of assembly faults on assembly cost and assembly system capacity. Assembly System Architectures: Single serial line, team assembly, fishbone serial line with sub-assembly feeder, loop architecture, U-shaped cell and cellular assembly line.

Economics of Assembly System: Kinds of cost – Cost models of assembling – Unit cost models of manual, fixed and flexible automation. Indexing machines: Effect of parts quality on downtime, production time and cost of assembly. Free-transfer machines: performance – average production time – Number of personnel for fault correction. Economic comparisons of automation equipment – effect of production volume.

Design for Assembly (DFA): Need and applications - Role of Design for Manufacture and Assembly in concurrent engineering - General guidelines of Design for Assembly - Design for manual assembly: guidelines for part handling, insertion and fastening - Effect of symmetry, part thickness and size and weight on handling time and on grasping and manipulation - Effect of chamfer design on insertion operations. Design for automated assembly: effect of feed rate on cost – high speed automatic insertion - Design for feeding and orienting - Design for Robot assembly: types of robot assembly system - design rules – Case studies.

Text Book

1. Daniel E Whitney, “Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development”, Oxford University Press, 2009.

Reference Books/Learning Resources

1. Alex Krulikowski, “Fundamentals of Geometric Dimensioning and Tolerancing”, Third Edition, Cengage Learning, 2012.
2. Geoffrey Boothroyd, “Assembly Automation and Product Design”, Second Edition, Manufacturing Engineering and Materials Processing Series, CRC Press, Taylor & Francis, 2005.
3. Geoffrey Boothroyd, Peter Dewhurst, Winston A Knight, “Product Design for Manufacture and Assembly”, Third Edition, CRC Press, 2010.
4. David M. Anderson, “Design for Manufacturability & Concurrent Engineering; How to Design for Low Cost, Design in High Quality, Design for Lean Manufacture, and Design Quickly for Fast Production”, CIM Press, 2010.
5. E-Learning source on Mechanical Assembly and Its Role in Product Development - https://ocw.mit.edu/courses/mechanical-engineering/2-875-mechanical-assembly-and-its-role-in-product-development-fall-2004/
6. Web source on DFMA Case Studies: Boothroyd Dewhurst, Inc.2016: https://www.dfma.com/resources/studies.htm

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.	**Tolerancing System:**	
1.1	Tolerancing System: Importance - Dimensional and geometric tolerances	1
1.1.1	Process capability - surface finish – Fit of an assembly	1
1.1.2	Cumulative effect of tolerances	1
1.2	Datum systems: Degrees of freedom	1
1.3	True position theory: Virtual size concept - Projected tolerance zone	2
1.3	Selective Assembly:Interchangeable part manufacture and selective assembly	1
1.3.1	Deciding the number of groups - Group tolerances.	1
2.	**Assembly Sequence Design:**	
2.1	Key Characteristics (KC) – Flow down of KC – Ideal KC process – KC Conflicts.	1
2.2	Assembly Sequence Design Process: Methods for finding feasible sequences	1
2.2.1	Liaison diagram – Governing Rule	1
2.2.2	Generating the feasible sequences- Cutset method.	1
2.3	Datum Flow Chain: Nominal Design – Variation Design – Assumptions – Role of assembly features.	1
2.4	Constraints in Assembly: Completely constrained assemblies – Partially constrained assemblies	1
2.4.1	Assembly precedence constraints	1
2.4.2	Design Procedure for assemblies	1
3.	**Assembly System Design**	
3.1	Factors in system design: capacity planning, available time & required number of units per year, assembly resources choice, assignment of operations of resources, floor layout, workstation design, material handling and work transport, parts feeding and presentation and quality.	1
3.2	Assembly Resources: Characteristics of manual, fixed and flexible automation.	1
3.2.1	Parts feeding and presentation: Automatic feeding and orienting	1
3.2.2	Feed tracks – escapements – part placement mechanism and robots	1
3.3	Assurance and control: Elements of testing strategy	1
3.3.1	Effect of assembly faults on assembly cost and assembly system capacity.	1
3.4	Assembly System Architectures: Single serial line, team assembly	1
3.4.1	Fishbone serial line with sub-assembly feeder, loop architecture, U-shaped cell and cellular assembly line	1
4.	**Economics of Assembly System**	
4.1	Cost models of assembling – Kinds of cost	1
4.1.1	Unit cost models of manual automation.	1
4.1.2	Unit cost models of fixed automation.	1
4.1.3	Unit cost models of flexible automation.	1
4.2	Indexing machines: Effect of parts quality on downtime, production time and cost of assembly	1
4.3	Free-transfer machines: performance – average production time – Number of personnel for fault correction.	1

Module No.	Topic	No. of Lectures
4.3.1	Economic comparisons of automation equipment – effect of production volume.	1
5.	**Design for Assembly (DFA)**	
5.1	Concurrent Engineering: Need and applications - Role of Design for Manufacture and Assembly in concurrent engineering	1
5.1.1	General guidelines of Design for Assembly	1
5.2	Design for manual assembly: guidelines for part handling, insertion and fastening	1
5.2.1	Effect of symmetry, part thickness and size and weight on handling time and on grasping and manipulation	1
5.2.2	Effect of chamfer design on insertion operations.	
5.3	Design for automated assembly: effect of feed rate on cost – high speed automatic insertion	1
5.3.1	Design for feeding and orienting	1
5.4	Design for Robot assembly: types of robot assembly system - design rules Case studies.	1
	Total	**38**

Course Designers:

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14MEPS0	METAL CUTTING ENGINEERING	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

Metal cutting processes are the core manufacturing processes and the economy of these processes depends on the proper selection of cutting tool materials and control of parameters. In this elective course, the fundamental mechanisms of the metal cutting are presented, which are very essential for any manufacturing engineer.

Prerequisite

- 14ME430 - Machining Processes

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the tool materials and cutting tools nomenclature	Understand
CO 2.	Explain the Mechanics of the machining process and the thermal aspects of cutting and cutting fluids	Understand
CO 3.	Examine the tool wear, tool life, machinability, surface finish and surface integrity	Apply
CO 4.	Optimize the cutting parameters and machining cost	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1.	S	M	M	M	_	_	_	_	_	_	_	_	S	_	S
CO2.	S	S	S	S	_	_	_	_	_	_	_	_	M	M	S
CO3.	S	S	S	S	_	_	_	_	_	_	_	_	M	_	S
CO 4.	S	S	S	S	_	_	_	_	_	_	_	_	M	_	S

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	30	20	20	20
Understand	70	50	50	50
Apply	0	30	30	30
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Objective 1 (CO1):

1. List the properties of a cutting tool material.
2. Define rake angle.

3. Explain the desirable properties of a tool material.
4. Discuss the different elements of a single point cutting tool.

Course Objective 2 (CO2):

1. What do you mean by continuous chip?
2. Define rake angle.
3. Explain the oblique cutting process with necessary sketch.
4. Discuss the different elements of a single point cutting tool.
5. Find the suitable mechanics during the milling operation
6. Identify a suitable cutting fluid for the mild steel machining operation and also discuss its properties.

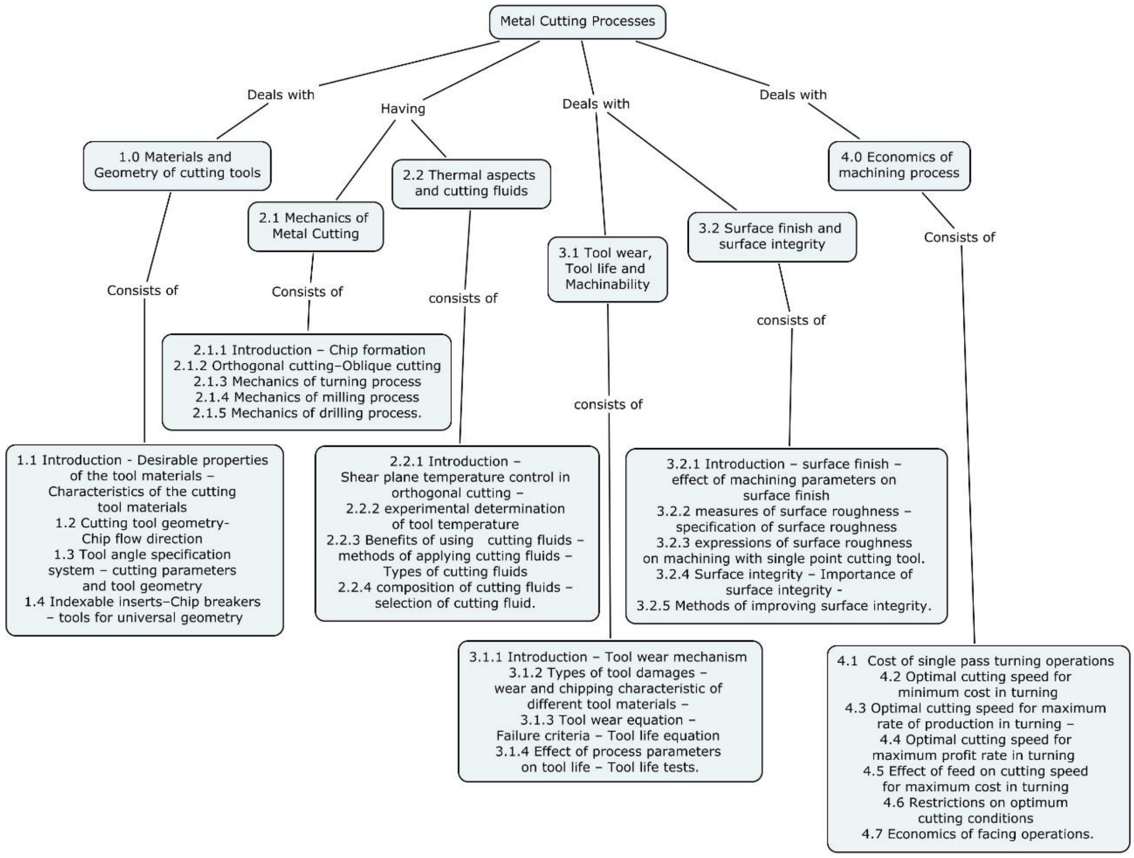
Course Objective 3 (CO3):

1. Define Tool life.
2. What is the need of better surface finish?
3. Explain the chipping characteristic of tool materials.
4. Discuss the different elements of a single point cutting tool.
5. Find the various parameters which will affect the tool life.
6. Identify a suitable technique to improve the surface integrity of the machined surface.

Course Objective 4 (CO4):

1. List the various machining costs?
2. What is machining?
3. Explain the various economic aspects involved in machining.
4. Discuss the effect of cutting speed on machining.
5. Find and explain the various restrictions on optimum cutting conditions.
6. List the various economics of facing operations and also explain in detail.

Concept Map



Syllabus

Materials and Geometry of cutting tools: Introduction - Desirable properties of the tool materials – Characteristics of the cutting tool materials – Cutting tool geometry- Chip flow direction – Tool angle specification system – cutting parameters and tool geometry – Indexable inserts – Chip breakers – tools for universal geometry

Mechanics of metal cutting – Introduction – Chip formation – Orthogonal cutting – Oblique cutting – Mechanics of turning process - Mechanics of milling process - Mechanics of drilling process.

Thermal aspects and cutting fluids - Introduction – Shear plane temperature control in orthogonal cutting – experimental determination of tool temperature – Benefits of using cutting fluids – methods of applying cutting fluids – Types of cutting fluids – composition of cutting fluids – selection of cutting fluid.

Tool wear, Tool life and Machinability – Introduction – Tool wear mechanism – Types of tool damages – wear and chipping characteristic of different tool materials – Tool wear equation – Failure criteria – Tool life equation – Effect of process parameters on tool life – Tool life tests.

Surface finish and surface integrity- Introduction – surface finish – effect of machining parameters on surface finish – measures of surface roughness – specification of surface roughness – expressions of surface roughness on machining with single point cutting tool. Surface integrity – Importance of surface integrity - Methods of improving surface integrity.

Economics of machining process: Introduction – Cost of single pass turning operations – Optimal cutting speed for minimum cost in turning – Optimal cutting speed for maximum rate of production in turning – Optimal cutting speed for maximum profit rate in turning – Effect of feed on cutting speed for maximum cost in turning – Restrictions on optimum cutting conditions - Economics of facing operations.

Text Books

1. Juneja. B L, Sekhon G S and Nitin Seth, "**Fundamentals of Metal Cutting and MachineTools**", Second Edition, New Age International (P) Ltd Publishers, New Delhi, 2015.
2. David A. Stephenson and John S Agapiou, "**Metal Cutting Theory and Practice**", 3rd Edition, CRC Press, 2016.

Reference Books

1. Bhattacharya, A., "**Metal Cutting Theory and Practice**", PB 01 Edition, New Central Book Agency (P) Ltd., Kolkatta, 2008.
2. Milton C Shaw, "**Metal Cutting Principles**" Oxford Series on Advanced Manufacturing, **Second Edition, Oxford University Press, 2005**.
3. Geoffrey Boothroyd, "**Fundamentals of Metal Machining and Machine Tools**", 3rd Edition, CRC Press, 2006.
4. Paul K Wright and Edward M Trent, "**Metal Cutting**"4th Edition, Butterworth-Heinemann, 2000.
5. Serope Kalpakjian and Steven R. Schmid, "**Manufacturing Engineering and Technology**", Fourth Edition, Pearson Education, 2001.

Course Contents and Lecture Schedule

Sl. No.	Topic	No. of Lectures
1	**Materials and Geometry of cutting tools:**	
1.1	Introduction - Desirable properties of the tool materials – Characteristics of the cutting tool materials	2
1.2	Cutting tool geometry- Chip flow direction	1
1.3	Tool angle specification system – cutting parameters and tool geometry.	1
1.4	Indexable inserts – Chip breakers – tools for universal geometry	2
2.1	**Mechanics of metal cutting**	
2.1.1	Introduction – Chip formation	1
2.1.2	Orthogonal cutting – Oblique cutting	2
2.1.3	Mechanics of turning process.	2
2.1.4	Mechanics of milling process.	2

Sl. No.	Topic	No. of Lectures
2.1.5	Mechanics of drilling process.	2
2.2	**Thermal aspects and cutting fluids**	
2.2.1	Introduction – Shear plane temperature control in orthogonal cutting	2
2.2.2	Experimental determination of tool temperature	1
2.2.3	Benefits of using cutting fluids – methods of applying cutting fluids – Types of cutting fluids	2
2.2.4	Composition of cutting fluids – selection of cutting fluid.	2
3.1	**Tool wear, Tool life and Machinability**	
3.1.1	Introduction – Tool wear mechanism	1
3.1.2	Types of tool damages – wear and chipping characteristic of different tool materials.	1
3.1.3	Tool wear equation – Failure criteria – Tool life equation	1
3.1.4	Effect of process parameters on tool life – Tool life tests.	1
3.2	**Surface finish and surface integrity**	
3.2.1	Introduction – surface finish – effect of machining parameters on surface finish	1
3.2.2	measures of surface roughness – specification of surface roughness	1
3.2.3	expressions of surface roughness on machining with single point cutting tool	2
3.2.4	Surface integrity – Importance of surface integrity	1
3.2.5	Methods of improving surface integrity.	1
4.0	**Economics of machining process**	
4.1	Introduction – Cost of single pass turning operations	2
4.2	Optimal cutting speed for minimum cost in turning	1
4.3	Optimal cutting speed for maximum rate of production in turning	1
4.4	Optimal cutting speed for maximum profit rate in turning	1
4.5	Effect of feed on cutting speed for maximum cost in turning	1
4.6	Restrictions on optimum cutting conditions	1
4.7	Economics of facing operations.	1
	Total	**40**

Course Designers:

1. M. Kathiresan, umkathir@tce.edu

14MEPT0	INTERNAL COMBUSTION ENGINES	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

This course studies the fundamentals of how the design and operation of internal combustion engines affect their performance, operation, fuel requirements, and environmental impact.

Prerequisite

- 14ME240: Engineering Thermodynamics
- 14ME340: Fluid Mechanics
- 14ME540: Heat and Mass Transfer

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Calculate the performance characteristics of engines and compare ideal and actual cycles.	Apply
CO 2.	Explain air and fuel induction system, fluid motion in the cylinder and exhaust blowdown operation	Understand
CO 3.	Examine the combustion process by correlating the operating parameters	Analyze
CO 4.	Determine the effects of engine variables on heat transfer and tribology	Apply
CO 5.	Understand the pollutant formation and control mechanism and the recent developments in I.C.Engines	Understand

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1.	S	M	S	M	_	_	_	_	_	_	_	_	_	S	_
CO2.	M	L	M	L	_	_	_	_	_	_	_	_	_	M	_
CO3.	S	S	S	S	_	_	_	_	_	_	_	_	_	S	_
CO4.	S	M	S	M	_	_	_	_	_	_	_	_	_	S	_
CO5.	M	L	M	L	_	_	_	_	_	_	_	_	_	M	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	30	30	30	30
Apply	50	40	40	40
Analyse	0	10	10	10
Evaluate	0	0	0	**0**
Create	0	0	0	**0**

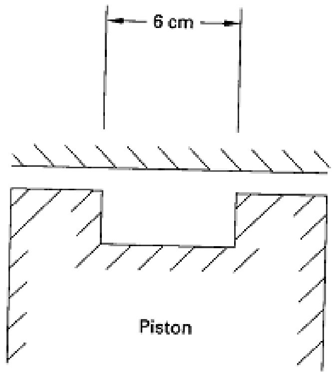
Course Level Assessment Questions

Course Outcome 1 (CO1):

1. It is desired to increase the output of an SI engine working on ideal Otto cycle, either by (i) increasing the compression ratio (ii) increasing the inlet pressure from 1 to 1.5 bar which one will give higher peak pressure in the cycle and what is its value? Assume heat supplied at the constant volume process is the same in both the cases which is 420 kJ. Take T_1 = 27°C, p_1 = 1 bar, γ = 1.4. Comment on the result.
2. What will be the effect on the efficiency of an Otto cycle having a compression ratio of 8, if C_v increases by 1.6%?
3. Find the mean piston speed of a diesel engine running at 1500 rpm. The engine has a 100 mm bore and L/d ratio is 1.5.

Course Outcome 2 (CO2):

1. As speed increases in an engine with throttle body fuel injection, does the temperature of the air-fuel mixture at the intake manifold exit increase or decrease? Explain what parameters affect your answer.
2. A V8 engine with 7.5-cm bores is redesigned from two valves per cylinder to four valves per cylinder. The old design had one inlet valve of 34 mm diameter and one exhaust valve of 29 mm diameter per cylinder. This is replaced with two inlet valves of 27 mm diameter and two exhaust valves of 23 mm diameter. Maximum valve lift equals 22% of the valve diameter for all valves. Calculate: (a) Increase of inlet flow area per cylinder when the valves are fully open (b) Give advantages and disadvantages of the new system.
3. A 2.4 litre, three-cylinder, four-stroke cycle SI engine with a 9.79 cm stroke is running are 2100 rpm. During the compression stroke, the air-fuel mixture has a swirl ratio of 4.8. At TDC the mixture, which consists of 0.001 kg in each cylinder, is compressed into a clearance into a clearance volume that can be approximated as a cylindrical bowl in the face of the piston, as shown in the figure given below. It can be assumed that angular momentum is conserved.



Calculate (i) Angular speed of swirl at TDC (ii) tangential speed at the outer edge of the bowl (iii) swirl ratio at TDC

Course Outcome 3 (CO3):

1. A CI engine with a 3.2-inch bore and 3.9-inch stroke operates at 1850 RPM. In each cycle, fuel injection starts at 16° bTDC and lasts for 0.0019 second. Combustion starts at 8° bTDC. Due to the higher temperature, the ignition delay of any fuel injected after combustion starts is reduced by a factor of two from the original ID. Calculate: (a) ID of first fuel injected. (b) ID of first fuel injected in degrees of engine rotation. (c) Crank angle position when combustion starts on last fuel droplets injected.
2. It is desired to build an engine with a low height for a high-speed sports car with a very low profile. Design the intake manifold and combustion chamber for a modern fast burn valve-in-block engine. The engine must have high turbulence, swirl, squish, and tumble, with a short flame travel distance.
3. Isooctane is burned with air in an engine at an equivalence ratio of 0.8333. Assuming complete combustion; write the balanced chemical reaction equation. Calculate: (a) Air-fuel ratio. (b) How much percentage of excess air is used?

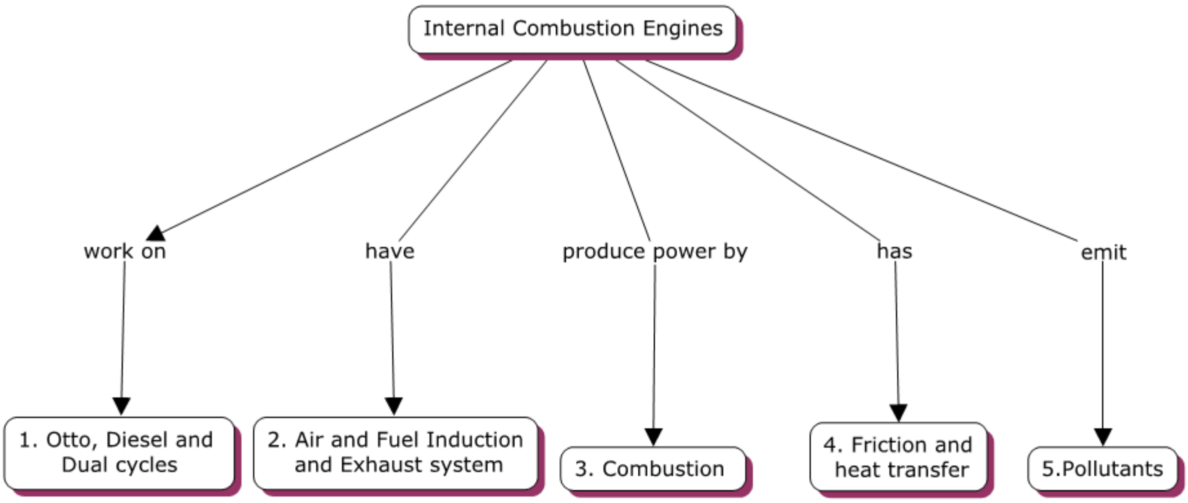
Course Outcome 4 (CO4):

1. An in-line, six-cylinder, 6.6-liter, four-stroke cycle SI engine with multipoint port fuel injection operates at 3000 RPM, with a volumetric efficiency of □$_v$ = 89%. The intake manifold runners can be approximated as round pipes with an inside diameter of 4.0 cm. Inlet temperature to the manifold is 27°C. Calculate: (a) Average velocity and mass flow rate of air to each cylinder, using inlet temperature to evaluate properties. [m/sec, kg/see] (b) Reynolds number in the runner to cylinder #1, which is 40 cm long (use standard interior pipe flow equations).
2. Explain the six classes of mechanical friction and the various factors affecting them.
3. Mention the various parameters which affect the engine heat transfer and explain their effect.

Course Outcome 5 (CO5):

1. (a) List five reasons why there are HC emissions in the exhaust of an automobile. (b) To reduce emissions from an SI engine, should AF be set at rich, lean, or stoichiometric? Explain the advantages and disadvantages of each. (c) Why is it good to place a catalytic converter as close to the engine as possible? Why is this bad?
2. It is desired to use electricity to preheat the catalytic converter on a four-cylinder SI engine of 2.8-liter displacement. The preheat zone of the converter consists of 20% of the total alumina volume. The specific heat of the ceramic is 765 J/kg-K and the density p = 3970 kg/m^3 Energy is obtained from a 24-volt battery supplying 600 amps. Calculate: (a) Electrical energy needed to heat the preheat zone from 25°C to a light off temperature of 150°C. [KJ] (b) Time needed to supply this amount of energy.
3. Explain the concept of homogenous charge compression ignition (HCCI) engine and list out the benefits of it.

Concept Map



Syllabus

Introduction and Operating Characteristics -Engine classifications, Terminology and Abbreviations, Engine components, Comparison of basic Engine Cycles - Otto, Diesel, Dual, Fuel –Air cycle, Real Engine cycle -Performance parameters and their relationship, Air-Fuel ratio and Equivalence ratio.

Air and Fuel Induction, Fluid Motion within the Cylinder and Exhaust flow - Intake manifold**,** Volumetric efficiency of SI engines, Intake valves, Fuel Injectors, Carburettors, Supercharging and Turbo charging, Stratified charge engines and Dual fuel engines, Intake for 2 stroke and CI engines- -Swirl, Turbulence, Squish and Tumble, Divided combustion chambers, Crevice flow and blow-by. Exhaust Blowdown, Exhaust stroke, Exhaust valves, Exhaust temperature, Exhaust manifold, Tailpipe and Muffler.

Combustion -Combustion stoichiometry, Hydrocarbon fuels, Octane rating, Cetane rating, Performance number, Alternate fuels-Combustion in SI engines, Combustion in divided chamber engines and stratified charge engines, Combustion CI engines, Abnormal combustion in SI and CI engines.

Heat Transfer in Engines, Friction and Lubrication – Energy distribution, Engine temperatures, Heat transfer in intake system, combustion chamber, exhaust system, Effect of engine operating variables, Direct and Indirect cooling systems, Modern trends in engine cooling. – Mechanical Friction and Lubrication, Engine Friction, Lubrication systems, Lubricating oil properties.

Emissions and Air Pollution, Recent Trends in I.C.Engine development - Air pollution, Formation and control mechanism of HC, CO, NOx emissions from gasoline engines. Catalytic converters, CI engine emissions. SCR and EGR methods. Passive emission. - Engine development prospects Stratified charge, direct injection systems Homogeneous charge, compression ignition Low temperature diesel combustion Advanced electronic-controlled engines Hybrids and fuel cells.

Text Book

7. Willard W. Pulkrabek, "**Engineering Fundamentals of the Internal Combustion Engine**", Pearson New International Edition, 2013.
8. Ganesan V, "**Internal Combustion Engines**", McGraw Hill Education (India) Pvt Ltd, 2012.

Reference Books

9. Heywood J.B., **"Internal Combustion Engine Fundamentals**", McGraw-Hill International Edition, 1998.
10. Taylor C.F, "**Internal Combustion Engine in Theory and Practice, Second Edition, Revised, Volume 1-Thermodynamics, Fluid Flow, Performance**." MIT Press.1985.
11. Taylor C.F, "**Internal Combustion Engine in Theory and Practice, Second Edition, Revised, Volume 2-Combustion Fuels, Matter**." MIT Press.1985.
12. Gill P W., J H. Smith, E J. Ziurys, "**Fundamentals of Internal Combustion Engines**" 4th Revised Edition, English Oxford & IBH Publishing Co., New Delhi, 2007.

Web Resources

1. https://ocw.mit.edu/courses/mechanical-engineering/2-61-internal-combustion-engines-spring-2008/download-course-materials/
2. http://nptel.ac.in/courses/112104033/1

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Introduction and Operating Characteristics**	
1.1	Engine classifications, Terminology and Abbreviations, Engine components	1
1.2	Comparison of basic Engine Cycles - Otto, Diesel, Dual	1
1.3	Fuel –Air cycle, Real Engine cycle	2
1.4	Performance parameters and their relationship, Air-Fuel ratio and Equivalence ratio.	1
2	**Air and Fuel Induction, Fluid Motion within the Cylinder and Exhaust flow**	
2.1	Intake manifold, Volumetric efficiency of SI engines, Intake valves	1

Module No.	Topic	No. of Lectures
2.2	Fuel Injectors, Carburettors	1
2.3	Supercharging and Turbo charging	1
2.4	Stratified charge engines and Dual fuel engines	1
2.5	Intake for 2 stroke and CI engines- -Swirl, Turbulence, Squish and Tumble, Divided combustion chambers	2
2.6	Crevice flow and blow-by. Exhaust Blowdown	2
2.7	Exhaust stroke, Exhaust valves, Exhaust temperature, Exhaust manifold, Tailpipe and Muffler	1
3	**Combustion**	
3.1	Combustion stoichiometry, Hydrocarbon fuels, Octane rating, Cetane rating, Performance number	2
3.2	Alternate fuels-Combustion in SI engines, Combustion in divided chamber engines and stratified charge engines	2
3.3	Combustion CI engines, Abnormal combustion in SI and CI engines	3
4	**Heat Transfer in Engines, Friction and Lubrication**	
4.1	Energy distribution, Engine temperatures, Heat transfer in intake system, combustion chamber, exhaust system	1
4.2	Effect of engine operating variables	2
4.3	Direct and Indirect cooling systems, Modern trends in engine cooling	2
4.4	Mechanical Friction and Lubrication, Engine Friction, Lubrication systems, Lubricating oil properties.	2
5	**Emissions and Air Pollution, Recent Trends in I.C.Engine development**	
5.1	Air pollution, Formation and control mechanism of HC, CO, NOx emissions from gasoline engines	2
5.2	Catalytic converters, CI engine emissions. SCR and EGR methods. Passive emission	2
5.3	Engine development prospects, Stratified charge, direct injection systems	1
5.4	Homogeneous charge, compression ignition Low temperature diesel combustion Advanced electronic-controlled engines	2
5.5	Hybrids and fuel cells	1
	TOTAL	**36**

Course Designers:

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2. Lakshmi Narasimhan, V V.LakshmiNarasimhan@tvsmotor.co.in

		Category	L	T	P	Credit
14MEPU0	**SPARK IGNITION ENGINES- DESIGN**	PE	3	0	0	3

Preamble

Internal combustion engines and the industries that develop and manufacture them and support their use, now play a dominant role in the fields of power, propulsion and energy. Spark ignition engines find major applications in the two wheeler manufacturing industries because of their high speed and light weight. This course deals with from a design and engineering point of view, following the complexity involved in it.

Prerequisite

- 14MEPT0 - Internal Combustion Engines

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain general ideas and concepts behind various engine layout schemes	Understand
CO 2.	Perform mechanical design calculations to arrive at the design specs for critical mechanical elements comprising the engine	Apply
CO 3.	Select appropriate materials to be used in the engine based on functional and life requirements	Understand
CO 4.	Propose and develop a design verification process to prove engine for performance, durability and reliability	Analyze
CO 5.	Explain various NVH, thermal and other attributes issues that are connected with the engine behaviour	Understand
CO 6.	Articulate solution for design of engines from manufacturing, service and assembly perspective	Analyze

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	M	L	M	L	_	_	_	_	_	_	_	_	L	_	_
CO2.	S	M	S	M	_	_	_	_	_	_	_	_	S	_	_
CO3.	M	L	M	L	_	_	_	_	_	_	_	_	L	_	_
CO4.	S	S	S	S	_	_	_	_	_	_	_	_	S	_	_
CO5.	M	L	M	L	_	_	_	_	_	_	_	_	_	L	_
CO6.	S	S	S	S	_	_	_	_	_	_	_	_	S	_	S
	2.5	1.83	2.5	1.83	0	0	0	0	0	0	0	0	1.83	0.17	0.5
	S	M	S	M	_	_	_	_	_	_	_	_	M	_	L

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	40	20	20	20
Apply	40	40	40	40
Analyse	0	20	20	20
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. List the major differences between liquid cooled engines and air cooled engines.
2. Discuss the elements to be considered and taken care in valve train dynamics analysis.
3. Draw a schematic layout for a 4 valve and 3 valve cylinder head concept for the same bore size. Assuming a single overhead cam, determine the power potential for these two configurations, considering dynamic limitations.

Course Outcome 2 (CO2):

1. **Identify the type of decks shown in the figure below.**

Fig. a

Fig. b

Fig. c

2. Explain the factors that decide the number cylinders and configuration in the process of engine design.
3. A 4-stroke internal combustion engine has the following specifications: BP = 7.5 kW; speed = 1000 rpm; IMEP =0.35 N/mm^2; Maximum gas pressure = 3.5 N/mm^2; Mechanical Efficiency = 80%. Determine: 1. The dimensions of the cylinder, if the length of stroke is 1.4 times the bore of the cylinder 2. Wall thickness of the cylinder, if the hoop stress is 35 MPa; 3. Thickness of the cylinder head and the size of studs when the permissible stresses for the cylinder head and stud materials are 45 MPa and 65 MPa respectively.

Course Outcome 3 (CO3):

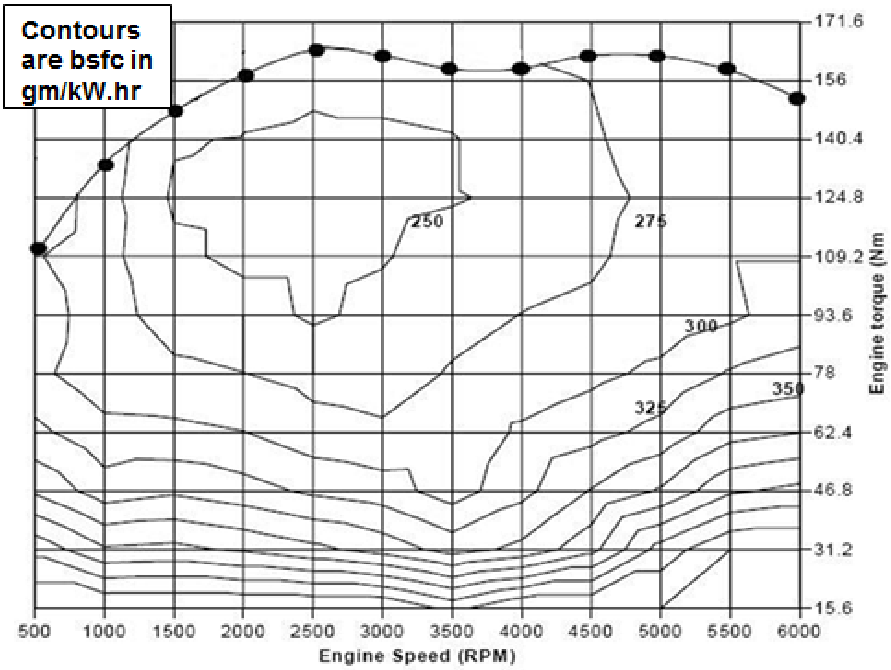
1. Mention the significance of valve size and numbers in combustion chamber design.
2. Explain the various types of cylinder head casting options available for manufacture.
3. Show the difference between full floating and semi floating type piston pins using a schematic drawing.

Course Outcome 4 (CO4):

1. Mention the significance of valve size and numbers in combustion chamber design
2. Explain the various stages of engine development process in detail
3. Discuss the three types of cooling circuits used for an in-line four cylinder engine. Suggest a way to modify the cooling jacket for optimized performance.

Course Outcome 5 (CO5):

1. List the major sources of engine noise.
2. List out the benefits of offset crank design and how does it functions.
3. Give the reasons why the curves in the diagram given below are the shapes that they are. The "Best economy" line can be moved by improving combustion system design - what chamber performance parameter must be changed in order to move that line and why will the HC curve shape change with it?



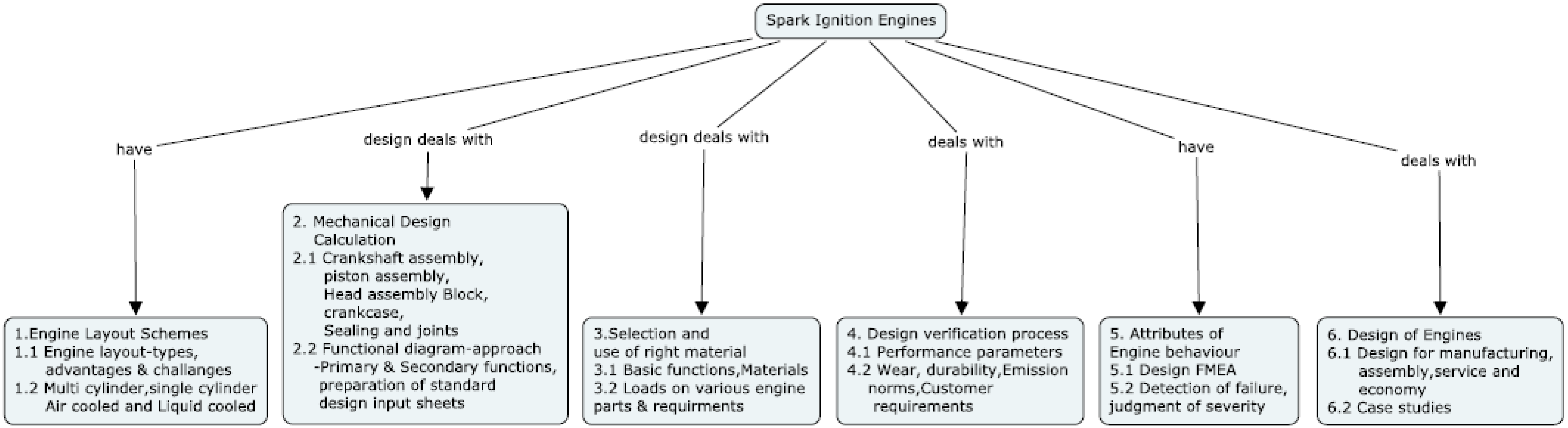
Course Outcome 6 (CO6):

1. Two automobile engines have the same total displacement volume and the same total power produced within the cylinders. List the possible advantages of:
   (a) A V6 over a straight six.
   (b) A V8 over a V6.
   (c) A V6 over a V8.
   (d) An opposed cylinder four over a straight four.
   (e) An in-line six over an in-line four

2. It has been suggested that to reduce crevice volume in a cylinder, the top piston compression ring should be located at the top of the piston (i.e., the top of the compression ring is flush with the piston face). Design a piston-ring-groove system in which this is possible. Give careful attention to reducing crevice volume and blow by.

3. A single cylinder engine with bore: 50 mm, stroke: 50 mm is designed to operate at 7000 rpm. Size the induction and exhaust system for maximum power. List the assumptions.

Concept Map


Spark Ignition Engines
have
design deals with
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1.Engine Layout Schemes
1.1 Engine layout-types, advantages & challanges
1.2 Multi cylinder,single cylinder Air cooled and Liquid cooled
2. Mechanical Design Calculation
2.1 Crankshaft assembly, piston assembly, Head assembly Block, crankcase, Sealing and joints
2.2 Functional diagram-approach -Primary & Secondary functions, preparation of standard design input sheets
3.Selection and use of right material
3.1 Basic functions,Materials
3.2 Loads on various engine parts & requirments
4. Design verification process
4.1 Performance parameters
4.2 Wear, durability,Emission norms,Customer requirements
5. Attributes of Engine behaviour
5.1 Design FMEA
5.2 Detection of failure, judgment of severity
6. Design of Engines
6.1 Design for manufacturing, assembly,service and economy
6.2 Case studies

Syllabus

Engine layout schemes: Introduction – types of engine layout – various types of engines.
Mechanical Design Calculation - Mechanical construction details - Functional diagram – approach – Primary & Secondary functions – preparation of standard design input sheets-Design procedure for Cylinder block, Piston, Connecting rod, Crankshaft,and Valves.
Selection and use of right material for engine: Introduction – functions of critical parts – materials used in automotive engines – types of loads on engine – other requirements.
Design verification Process: Introduction –performance parameters - Types of wear – wear limit study – Durability – Emission norms – Customer requirements.
Attributes of engine behaviour: Various attributes contributing to engine behaviour – Design FMEA – function, cause, occurrence level - Detection of failure – judgment of severity – opportunities to detect severity.
Design of Engines: Design for manufacturing – Design for assembly – design for service – Design for economy – Design for performance.

Text Book

1. Charles Fayette Taylor, **"Internal Combustion Engine in Theory and Practice"**, Second edition, revised, Volume 1 and Volume 2 – MIT Press, 1985.
2. Kevin L. Hoag, **"Vehicular Engine Design"**, Springer Wein New York, 2007.

Reference Books

1. Heywood J.B., **"Internal Combustion Engine Fundamentals**", McGraw-Hill International Edition, 2011.
2. Gordon P. Blair, **"Design and simulation of Four-stroke Engines"**, Society of Automotive Engineers, 1999.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Engine layout schemes**	
1.1	Introduction , types of engine layout	2
1.2	Various types of engines	2
2	**Mechanical Design Calculation**	
2.1	Mechanical construction details, Functional diagram – approach	2
2.2	Primary & Secondary functions, Preparation of standard design input sheets.	1
2.3	Design procedure for Cylinder block	2
2.4	Design procedure for Piston	2
2.5	Design procedure for Connecting rod	2
2.6	Design procedure for Crankshaft	2
2.7	Design procedure for Valves	1
3	**Selection and use of right material for engine**	
3.1	Introduction – functions of critical parts.	2
3.2	Materials used in automotive engines	1
3.3	Types of loads on engine and other requirements	2
4	**Design verification Process**	
4.1	Introduction, performance parameters	2
4.2	Types of wear, wear limit study, Durability	2
4.3	Emission norms, Customer requirements.	2
5	**Attributes of engine behaviour**	
5.1	Various attributes contributing to engine behaviour	2
5.2	Design FMEA – function, cause, occurrence level	2

Module No.	Topic	No. of Lectures
5.3	Detection of failure judgment of severity, opportunities to detect severity	2
6	**Design of Engines**	
6.1	Design for manufacturing	1
6.2	Design for assembly	1
6.3	Design for service ,Design for economy, Design for performance	1
	TOTAL	**36**

Course Designers:

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		Category	L	T	P	Credit
14MEPV0	**VEHICLE DYNAMICS**	PE	3	0	0	3

Preamble

Knowledge on vehicle dynamics generally expected from a mechanical engineering graduate seeking placement in automotive industries. Vehicle dynamics is the branch of automobile engineering dealing with road loads, performance of steering, suspension and braking systems. This course covers determination of road loads, vehicle performance under steady state cornering, effect of suspension design and tyre dynamics and performance of steering and braking systems with various geometries.

Prerequisite

- 14MEPH0 – Automotive Engineering

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Determine road loads on an automobile and their effect on fuel economy.	**Apply**
CO 2.	Analyze acceleration and braking performance of a vehicle under different conditions.	**Analyze**
CO 3.	Determine vehicle performance under steady state cornering.	**Apply**
CO 4.	Analyze the effect of various suspension systems on ride behaviour of an automobile.	**Analyze**
CO 5.	Determine vehicle steering performance with various steering geometries.	**Apply**
CO 6.	Explain dynamics of an automotive tyre.	**Understand**

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	M	S	M	L	_	_	_	_	_	_	_	S	_	_
CO2.	S	S	S	S	L	_	_	_	_	_	_	_	S	_	_
CO3.	S	M	S	M	L	_	_	_	_	_	_	_	S	_	_
CO4.	S	S	S	S	L	_	_	_	_	_	_	_	S	_	_
CO5.	S	M	S	M	L	_	_	_	_	_	_	_	S	_	_
CO6.	M	L	M	L	L	_	_	_	_	_	_	_	M	_	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	10	10	10	10
Understand	30	30	30	30
Apply	30	30	30	30
Analyse	30	30	30	30
Evaluate	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Discuss the mechanics of air flow around a vehicle.
2. Explain in detail the various factors affecting rolling resistance of an automotive tyre.
3. A heavy truck weighing 32000 kg is running at 108 km/h. The air temperature is 55°F and barometric pressure is 66 cm Hg. The truck is 2.4 m wide and 4.11 m high and has an aerodynamic drag coefficient of 0.65. The truck has radial ply tyres. Calculate the aerodynamic drag, rolling resistance and road load horse power at these conditions.

Course Outcome 2 (CO2):

1. Find the traction limited acceleration for rear drive for a passenger car with and without a locking differential on a surface of moderate friction level (μ=0.62). Use the following data.

   Weight: Front: 954 kg Rear: 841 kg

   CG Height: 53 cm Wheelbase: 275 cm

   Final-drive ratio: 2.9:1 Tread: 150 cm Tyre size: 33 cm

   Roll Stiffness: Front: 160 kN cm/deg Rear: 38 kN cm/deg
2. Explain “Brake proportioning”.
3. Discuss on “Rear wheel lockup” in automobiles.

Course Outcome 3 (CO3):

1. Differentiate lateral acceleration gain and yaw velocity gain.
2. Discuss on suspension effects on cornering.
3. A car has a mass of 864 kg on front axle and 705 kg on the rear with a wheelbase of 2.55 m. The tires have the following cornering stiffness values.

Load (kg)	cornering stiffness (N/deg)	cornering coefficient (N/N/deg)
102	299	0.298
205	540	0.269
307	763	0.253
409	1003	0.25
511	1146	0.228
614	1338	0.222

Determine the following cornering properties for the vehicle.

a) Ackerman steer angles for 15, 6, 3 and 1.5 m turn radius

b) Understeer gradient

c) Characteristic speed

d) Lateral acceleration gain at 96 kmph

e) Yaw velocity gain at 96 kmph

f) Sideslip angle at the CG on an 24 m turn radius at 96 kmph

g) Static margin

Course Outcome 4 (CO4):

1. Explain Anti-dive suspension geometry with neat sketch.
2. Discuss on positive and negative swing arm geometry with sketches.
3. Analyze suspension characteristics of parallel horizontal links and inclined parallel links with neat sketches and force analysis.

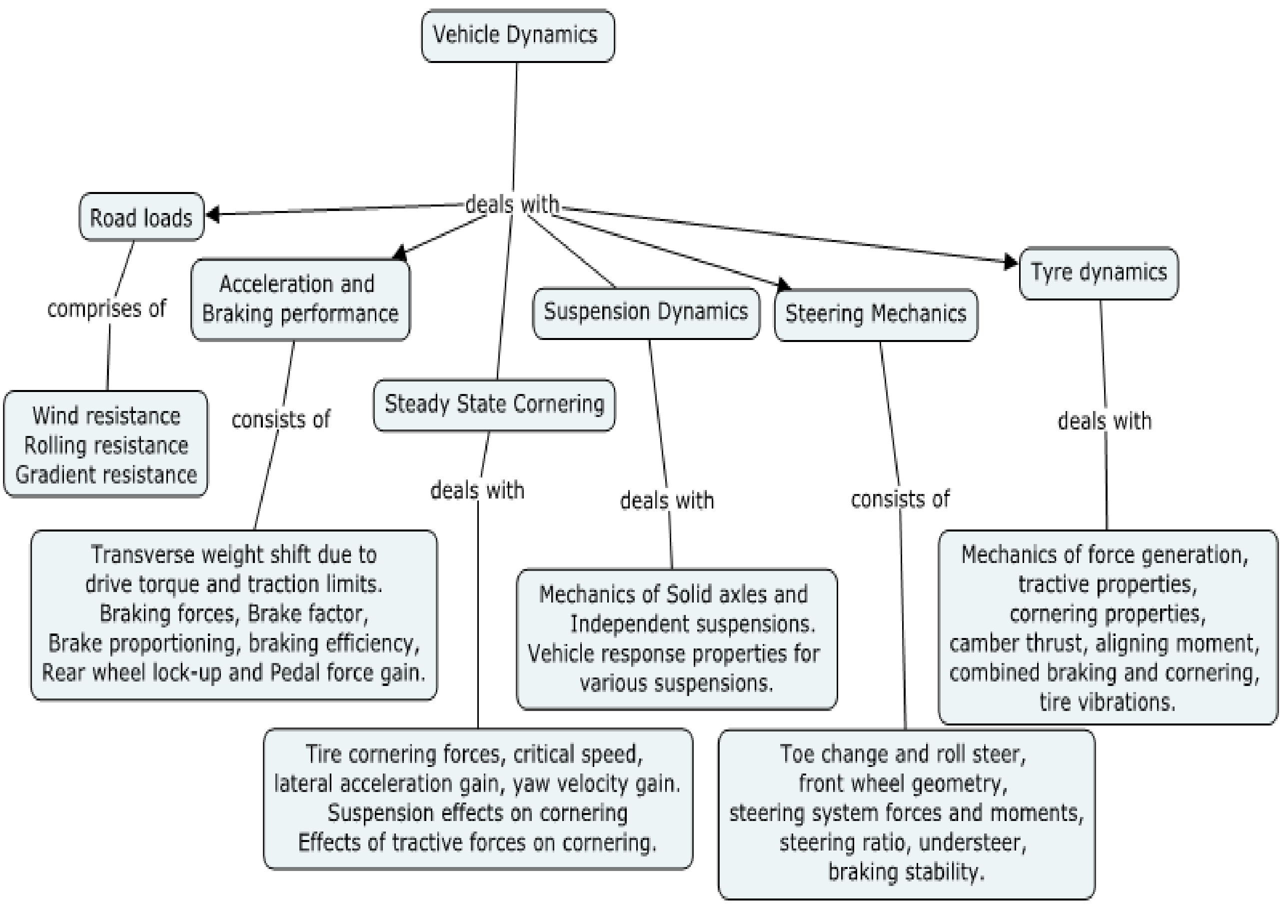
Course Outcome 5 (CO5):

1. Define "Steering geometry error".
2. List and explain various forces and moments acting on steering system.
3. Explain how low speed turning and high-speed cornering are influenced by four wheel steering influence.

Course Outcome 6 (CO6):

1. Explain how lateral force and aligning torque vary with tractive force?
2. Discuss on "Automotive tyre vibrations".
3. How braking efficiency is reduced during cornering? Explain.

Concept Map



Syllabus

Road loads – Mechanics of air flow around a vehicle, pressure distribution on a vehicle, aerodynamic forces, Rolling resistance, total road loads, fuel economy effects.

Acceleration and Braking Performance – Power limited acceleration, Traction limited acceleration – Transverse weight shift due to drive torque, traction limits. Braking forces, Brake factor, Brake proportioning, braking efficiency, rear wheel lockup, Pedal force gain.

Steady State Cornering – Low speed turning, High speed cornering – tire cornering forces, cornering equations, understeer gradient, characteristic speed, critical speed, lateral acceleration gain, yaw velocity gain, sideslip angle. Suspension effects on cornering – roll moment distribution, camber change, roll steer, lateral force compliance steer, aligning torque, effect of tractive forces on cornering. Understeer effects.

Suspension Dynamics – Mechanics of Solid axles and Independent suspensions, Anti-squat, Anti-dive and Anti-pitch suspension geometry, Roll centre analysis, Active suspensions. Vehicle response properties for various suspensions.

Steering Mechanics – steering linkages, steering geometry error – toe change and roll steer, front wheel geometry, steering system forces and moments, steering system models, examples of steering system effects – steering ratio, understeer, braking stability. Influence of front wheel drive. Four wheel steer – low-speed turning and high-speed cornering.

Tyre Dynamics – Mechanics of force generation, tractive properties, cornering properties, camber thrust, aligning moment, combined braking and cornering, tire vibrations.

Text Books

1. Thomas D.Gillespie, **"Fundamentals of vehicle dynamics"** Premiere Series Books, 1992.

Reference Books

1. N.K.Giri, "**Automobile Mechanics**", 8th Edition, Khanna Publishers, Delhi, 2008.
2. Kirpal Singh, "**Automobile Engineering**", Volume-1&2, 13th Edition, Standard Publishers Distributers, Delhi, 2013.
3. G. K. Grover, "Mechanical Vibrations", 8th Edition, Nem Chand & Bros, Rooekee, U.K., India, 2009.

Course Contents and Lecture Schedule

S.No	Topics	No. of periods
1	**Road loads**	
1.1	Mechanics of air flow around a vehicle, pressure distribution on a	1

	vehicle	
1.2	Aerodynamic forces acting on an vehicle	1
1.3	Rolling resistance of an automotive tyre	2
1.4	Total road loads, fuel economy effects.	1
2	**Acceleration and Braking Performance**	
2.1	Power limited acceleration, Traction limited acceleration	2
2.2	Transverse weight shift due to drive torque, traction limits.	2
2.3	Braking forces, Brake factor, Brake proportioning	2
2.4	Braking efficiency, rear wheel lockup, Pedal force gain.	1
3	**Steady State Cornering**	
3.1	Low speed turning, High speed cornering	1
3.2	Tire cornering forces, cornering equations	1
3.3	Understeer gradient, characteristic speed, critical speed,	1
3.4	Lateral acceleration gain, yaw velocity gain, sideslip angle.	1
3.5	Suspension effects on cornering – roll moment distribution, camber change, roll steer, lateral force compliance steer.	1
3.6	Aligning torque, effect of tractive forces on cornering. Understeer effects.	1
4	**Suspension Dynamics**	
4.1	Mechanics of Solid axles and Independent suspensions,	2
4.2	Anti-squat, Anti-dive and Anti-pitch suspension geometry,	2
4.3	Roll centre analysis, Active suspensions.	2
4.4	Vehicle response properties for various suspensions.	1
5	**Steering Mechanics**	
5.1	steering linkages, steering geometry error – toe change and roll steer,	1
5.2	Front wheel geometry, steering system forces and moments, steering system models.	2
5.3	Examples of steering system effects – steering ratio, understeer, braking stability.	2
5.4	Influence of front wheel drive. Four wheel steer – low-speed turning and high-speed cornering.	1
6	**Tyre Dynamics**	
6.1	Mechanics of force generation, tractive properties.	1
6.2	Cornering properties, camber thrust, aligning moment,	2

6.3	Combined braking and cornering, tire vibrations.	2
	Total	**36**

Course Designer:

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14MEPW0	**MOTORCYCLE DYNAMICS**	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

Knowledge on motorcycle engineering is generally expected from a mechanical engineering graduate seeking placement in two wheeler industries. Motorcycle engineering is the branch of automobile engineering dealing with motorcycle behaviour under various operating environments. This course covers determination of motorcycle behaviour in rectilinear motion, steady turning and study of In-Plane Dynamics, Motorcycle trim, vibration modes and ergonomics.

Prerequisite

- 14MEPH0 – Automotive Engineering

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Determine the effect of motorcycle geometry on motorcycle kinematics.	**Apply**
CO 2.	Analyze motorcycle behaviour in rectilinear motion.	**Analyze**
CO 3.	Determine forces and moments in steady turning of motorcycle.	**Apply**
CO 4.	Analyze in-plane Dynamics of motorcycle.	**Analyze**
CO 5.	Determine motorcycle trim and frequency of various vibration modes.	**Apply**

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	M	S	M	L	_	_	_	_	_	_	_	S	_	_
CO2.	S	S	S	S	L	_	_	_	_	_	_	_	S	_	_
CO3.	S	M	S	M	L	_	_	_	_	_	_	_	S	_	_
CO4.	S	S	S	S	L	_	_	_	_	_	_	_	S	_	_
CO5.	S	M	S	M	L	_	_	_	_	_	_	_	S	_	_
	3	2.4	3	2.4	1	0	0	0	0	0	0	0	3	0	0
	S	S	S	S	L	_	_	_	_	_	_	_	S	_	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	10	10	10	10
Understand	30	30	30	30
Apply	30	30	30	30
Analyse	30	30	30	30

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Prove that lowering of front wheel centre is reduced with steering offset.
2. Explain in detail the various factors affecting motorcycle pitch with graphs.
3. Consider a motorcycle with the following characteristics.

    Wheelbase = 1400 mm;

    The radii of the rear and front tire cross sections are 100 mm and 40 mm respectively;

    If the motorcycle changes from straight line to turning (roll angle =45°), calculate the yaw angle of the rear frame.

Course Outcome 2 (CO2):

1. Explain how centre of gravity of a motorcycle is determined.
2. Consider a racing motorcycle with the following characteristics. Determine the equivalent mass.

    Total mass: (motorcycle + rider) = 205 kg;

    Front wheel radius = 0.3 m;

    Rear wheel radius = 0.32 m;

    Front wheel moment of inertia = 0.6 kgm^2

    Rear wheel moment of inertia = 0.8 kgm^2

    Engine moment of inertia = 0.05 kgm^2

    Primary shaft moment of inertia = 0.005 kgm^2

    Secondary shaft moment of inertia = 0.007 kgm^2

    Transmission ratio for driving-wheel sprockets = 2.6

    Transmission ratio for the primary-secondary gear shafts = 0.9 (in IV gear)

    Transmission ratio for the engine-primary shafts = 2
3. Consider a motorcycle with the following properties. Compare the wheeling limited acceleration at 0 km/h and 100 km/h.

    Total mass = 200 kg.

    Frontal are = 0.7 m^2

    Drag coefficient = 0.6

    Lift coefficient = 0

    Longitudinal distance of CG from rear axle = 0.58 m

    Height of CG = 0.62 m

    Wheelbase = 1.35 m

Course Outcome 3 (CO3):

1. What is effective roll angle? How driving style of rider influence roll angle?

2. Draw the simplified model of a motorcycle and obtain expressions for forces and moments acting during steady turning.
3. Discuss in detail on various factors affecting steering torque for a motorcycle. Also state whether increase in each parameter produces aligning or disaligning effect.

Course Outcome 4 (CO4):

1. Obtain expressions for natural frequencies of undamped, combined bouncing and pitching. Also discuss on pitch and bounce centre.
2. Deduce an expression for change in distance between centre of driving and driven sprockets in a motorcycle, for a given wheel travel. Suggest methods to minimize it, for different input constraints.
3. Calculate the change in wheel base for the following data for a motorbike.

   Horizontal distance between driving sprocket centre and swing arm pivot = 80 mm.

   Vertical distance between driving sprocket centre and swing arm pivot = 2 mm.

   Swing arm length = 500 mm.

   Inclination of swing arm from horizontal = 4° clockwise.

   Vertical wheel travel = 100 mm.

   What design would you suggest for minimum change in wheel base? Justify your answer.

Course Outcome 5 (CO5):

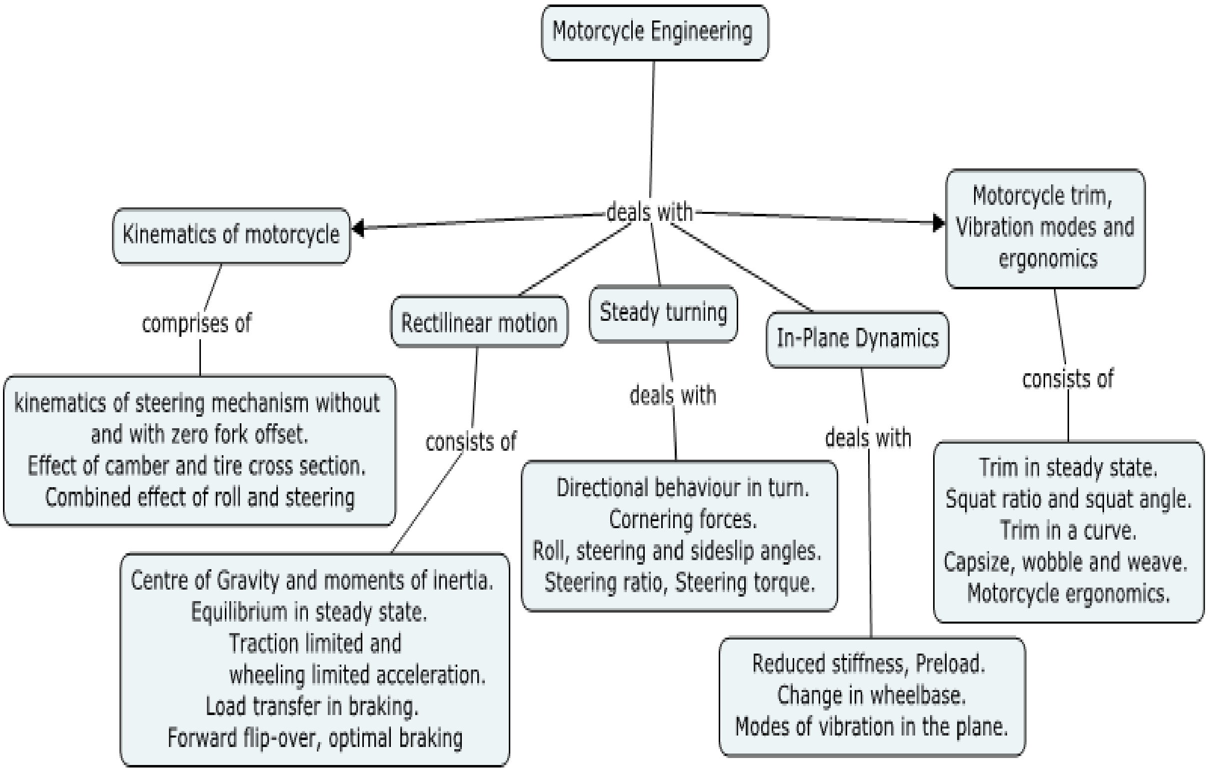
1. Discuss on the following for motorcycle trim in steady state motion.
   a) Rear suspension equilibrium
   b) Inclination of angle of chain
2. Consider a motorcycle with following characteristics:

   Wheelbase: 1370 mm; Height of centre of gravity = 600 mm; Chain force: 4000 N; Reduced stiffness of the rear suspension: 20 kN/m;

   Reduced stiffness of the rear suspension: 13 kN/m;

   Find the variation in trim for squat ratios of 0.7, 1.0 and 1.3 and give your inferences.
3. Explain in detail how rider ergonomics affect motorcycle design, with recommended lengths, angles and driving postures.

Concept Map



Syllabus

Kinematics of motorcycle – Definition and geometry of motorcycle, trail, kinematics of steering mechanism without and with zero fork offset, Roll motion and steering, motorcycle pitch, rear wheel contact point – effect of camber and tire cross section, combined effect of roll and steering, the influence of contact point lateral displacement on roll motion, front wheel camber angle, the kinematic steering angle, the path curvature, effective trail in a curve, effect of tire size on rear frame yaw.

Rectilinear motion – Resistance forces, Centre of Gravity and moments of inertia, equilibrium in steady state, transitory motion, traction limited and wheeling limited acceleration, load transfer in braking, forward flip-over, optimal braking.

Steady turning – Motorcycle roll in steady turning, directional behaviour in turn, Cornering forces, Linearized model in a turn, multi-body model in steady turning, Roll, steering and sideslip angles, steering ratio, steering torque.

In-Plane Dynamics – Front and rear suspension, reduced stiffness, preload, change in distance between centres of driving and driven sprockets, change in wheelbase, models with one, two and four degrees of freedom, modes of vibration in the plane, influence of unsprung mass, Motorcycle response, rear suspension of scooter.

Motorcycle trim, vibration modes and ergonomics – Trim in steady state – rear suspension equilibrium with chain and shaft transmission, inclination of angle of chain, Squat ratio and squat angle, trim in a curve. Capsize, wobble and weave modes of vibration, motorcycle ergonomics.

Text Books

1. V.Cossalter, "Motorcycle Dynamics", 2nd Edition, Race dynamics, 2002.

Reference Books

1. Tony Foale, **"Motorcycle Handling and chassis design"** Tony Foale designs, 2006.
2. Thomas D.Gillespie, **"Fundamentals of vehicle dynamics"** Premiere Series Books, 1992.
3. N.K.Giri, "**Automobile Mechanics**", 8th Edition, Khanna Publishers, Delhi, 2008.
4. G. K. Grover, "Mechanical Vibrations", 8th Edition, Nem Chand & Bros, Roorkee, U.K., India, 2009.

Course Contents and Lecture Schedule

S.No	Topics	No. of periods
1	**Kinematics of motorcycle**	
1.1	Definition and geometry of motorcycle.	1
1.2	Trail, kinematics of steering mechanism without and with zero fork offset	2
1.3	Roll motion and steering, motorcycle pitch.	1
1.4	rear wheel contact point – effect of camber and tire cross section, combined effect of roll and steering, the influence of contact point lateral displacement on roll motion,	2
1.5	Front wheel camber angle, the kinematic steering angle, the path curvature.	2
1.6	Effective trail in a curve, effect of tire size on rear frame yaw.	2
2	**Rectilinear motion**	
2.1	Resistance forces, Centre of Gravity and moments of inertia.	2
2.2	Equilibrium in steady state, transitory motion, traction limited and wheeling limited acceleration.	2
2.3	Load transfer in braking, forward flip-over, optimal braking.	2
3	**Steady turning**	
3.1	Motorcycle roll in steady turning, directional behaviour in turn.	2
3.2	Cornering forces, Linearized model in a turn, multi-body model in steady turning.	2
3.3	Roll, steering and sideslip angles, steering ratio, steering torque.	2
4	**In-Plane Dynamics**	

4.1	Front and rear suspension, reduced stiffness, preload.	1
4.2	Change in distance between centres of driving and driven sprockets, change in wheelbase.	2
4.3	Models with one, two and four degrees of freedom, modes of vibration in the plane.	2
4.4	Influence of unsprung mass, Motorcycle response, rear suspension of scooter.	1
5	**Motorcycle trim, vibration modes and ergonomics**	
5.1	Trim in steady state – rear suspension equilibrium with chain and shaft transmission.	2
5.2	Inclination of angle of chain, Squat ratio and squat angle.	2
5.3	Motorcycle trim in a curve.	1
5.4	Vibration modes – Capsize, wobble and weave	1
5.5	Motorcycle ergonomics	2
	Total	**36**

Course Designers:

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		Category	L	T	P	Credit
14MEPY0	**COMPUTATIONAL FLUID DYNAMICS**	PE	3	0	0	3

Preamble

Computational Fluid Dynamics (CFD) provides an introduction to the use of computational techniques to analyze fluid flow and heat transfer in problems of practical engineering interest. By studying a variety of flow situations students will develop a better intuition of fluid mechanics more quickly than is possible with traditional analytical approaches. At the end of the course students will understand the process of developing a geometrical model of the flow, applying appropriate boundary conditions, meshing, specifying solution parameters, and visualizing the results. They will also have an appreciation for merits of different solutions and the factors limiting the accuracy of CFD solutions.

Prerequisite

- 14ME240-Thermodynamics
- 14ME340-Fluid Mechanics
- 14ME410-Numerial Methods

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the physics of various heat flow and fluid flow problems in engineering fields, the different computational techniques and solution procedures.	**Understand**
CO 2.	Apply the governing equation to formulate numerical solution for steady diffusion problem using finite difference method.	**Apply**
CO 3.	Analyse one dimensional unsteady diffusion problem using finite difference method.	**Analyse**
CO 4.	Apply the governing equations to formulate numerical solution for diffusion, convection and one dimensional convection-diffusion problems using finite volume method.	**Apply**
CO 5.	Explain turbulence model and combustion model.	**Understand**

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	M	L	L	_	_	_	_	_	_	_	_	_	_	L	_
CO2.	S	M	L	_	_	_	_	_	_	_	_	_	_	M	_
CO3.	S	S	M	_	_	_	_	_	_	_	_	_	_	S	_
CO4.	S	M	L	_	_	_	_	_	_	_	_	_	_	M	_
CO5.	M	L	L	_	_	_	_	_	_	_	_	_	_	L	_
	2.6	1.8	1.2	0	0	0	0	0	0	0	0	0	0	1.8	0
	S	M	M	_	_	_	_	_	_	_	_	_	_	M	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	30	30	40	40
Apply	50	40	30	30
Analyse	-	10	10	10

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Write the governing equations for a heat and fluid flow problem.
2. Write the one dimensional transient heat conduction equation.
3. Write the energy equation for a one dimensional unsteady state convection-diffusion problem?
4. Explain the types of partial differential equations.
5. Explain the procedure for conducting a grid independent test.
6. Develop the momentum equations for two dimensional laminar fluid flow in Cartesian co-ordinate system.

Course Outcome 2 (CO2):

1. List the types of numerical errors.
2. Give a practical example for one dimensional steady state head conduction.
3. Under what circumstance you will choose a coarse grid in the computational domain?
4. Compare the temperature distribution in a rod fin having a diameter of 2cm and length of 10 cm and exposed to a convection environment h = 25 W/m^2 K for the three fin materials: a) copper (k=385 W/mK) b) stainless steel (k = 17 W/mK) and c) glass (k=0.8 W/mK). Assume that the tip is convection and T_o = 500 ^oC, T_{inf} =25 ^oC. Also, calculate the relative heat transfer and fin efficiencies. Check your numerical results with analytical solution.
5. Solve $\frac{\partial^2 T}{\partial x^2} = 200$ in a computational domain of x = 0 to x=1 using five equally divided grid point. T(0) = 900 K and T(1) = 500 K.
6. Solve $\frac{\partial^2 u}{\partial x^2} = 0$ in a computational domain of x = 0 to x=1 using five equally divided grid point. u(0) = 1 and u(1) = 0.

Course Outcome 3 (CO3):

1. Define time step
2. Define transient state.
3. Write the two dimensional transient heat conduction equation.
4. Obtain the finite difference equation for one dimensional transient heat conduction equation.
5. A large diameter steel cylindrical rod of 120 mm long having a thermal diffusivity (α) of 56.25 x 10^{-6} m^2/s is initially at 30^o C. One end of the rod is maintained at $80\ ^o$ C and the other end is at $180\ ^o$ C. Assuming that there is no heat transfer through the lateral surface, find the temperature distribution in the rod due to heat diffusion in the rod at the end of 10 second and 20 seconds. Take 8 elements. Draw the cooling curves.
6. Analyse the effect of thermal diffusivity on cooling rate in the above problem.

Course Outcome 4(CO4):

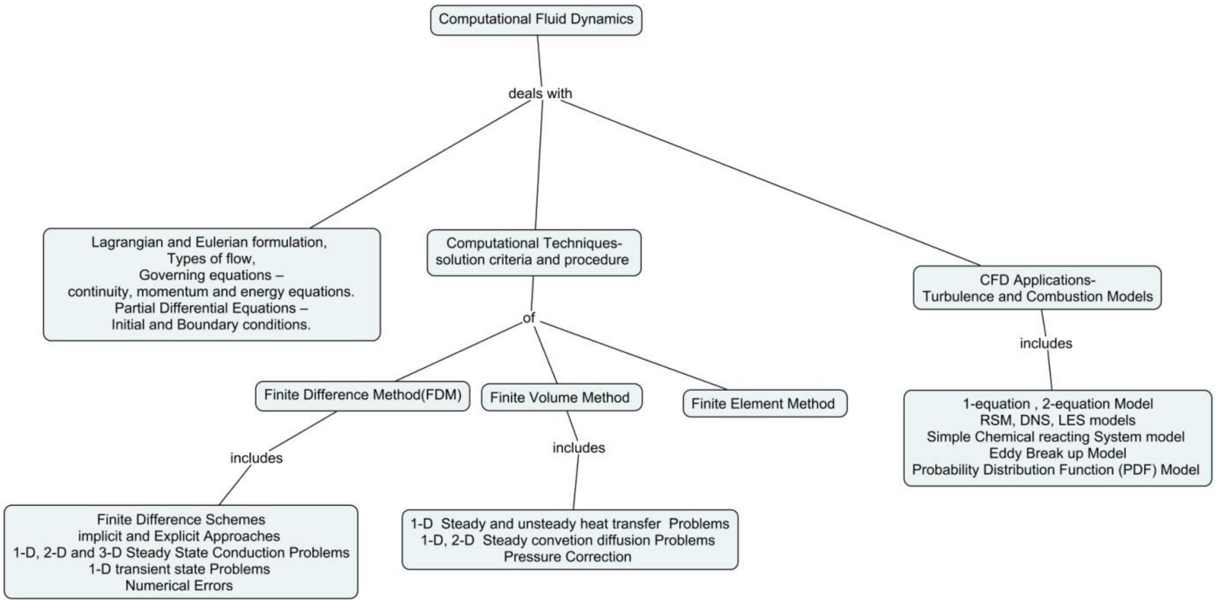
1. Describe the SIMPLE Algorithm.
2. With a neat sketch, explain the staggered grid system.
3. Draw the flow chart for solving a two dimensional convection – diffusion problem
4. Find the steady state temperature distribution using FDM in a square plate of size 40 cm x 40 cm, one side of which is maintained at 500 ^oC, with the other three sides maintained at 200 ^oC. Use five nodes in each side of the plate.
5. Solve $\frac{\partial^2 T}{\partial x^2} = 0$ in a computational domain of x = 0 to x=1 using five equally divided grid point. T(0) = 620 K and T(1) = 320 K
6. A property ϕ is transported by means of convection diffusion in a one dimensional domain having a length of x=0 to x = 1. The boundary conditions are ϕ =1 at x = 0 and $\phi = 0$ at x = 1. Using five equally spaced cells and central differencing scheme, calculate the distribution of ϕ in the computational domain.

Course Outcome 5 (CO5):

1. Differentiate laminar and turbulence model
2. Name the types of turbulence models.
3. List the advantages of LES model.
4. Explain k-ε turbulence model.
5. Name the types of combustion model.

6. Describe eddy break–up model for simulating combustion system

Concept Map



Syllabus

Basics of CFD: Overview of CFD – Definition, stages, applications. Fluid Flow- Continuum hypothesis, Lagrangian and Eulerian formulation, Types of flow, Governing equations - continuity equation and momentum equation in differential and integral forms. Heat flow: governing equation - energy equation, Heat and fluid flow: Governing equations – continuity, momentum and energy equations. Partial Differential Equations – Initial and Boundary conditions. **Computational Techniques:** Definition, Methods – Finite difference, Finite volume and Finite element, Solution procedure, solution criteria – stability and convergence, grid independent test, types of grid.

Finite Difference Method (FDM): Finite difference schemes-forward, central and backward difference, properties of discretization schemes, Implicit and explicit approaches. FDM for steady state diffusion - one-dimensional(1-D), two dimensional (2-D) and three dimensional (3-D) steady state conduction problems, 1-D transient state problems, Numerical errors. **Finite Volume Method:** Basics of Finite volume schemes, Finite Volume formulation for 1-D steady and unsteady heat transfer. 1-D and 2-D steady convection–diffusion - SIMPLE algorithm, staggered gird, pressure correction equations.

Turbulence model: One equation and two equations models – advantages of RSM, DNS, LES models. **Combustion model:** Simple chemical reacting system model, Eddy break–up model and probability distribution function model.

Text Books

1. Muralidhar, K., and Sundararajan, T., "**Computational Fluid Flow and Heat Transfer**", Narosa Publishing House, New Delhi, 2009.
2. H.K.Versteeg, "**An Introduction to Computational Fluid Dynamics, The Finite Volume Method**", Pearson; 2 edition, 2008.

Reference Books

1. Anderson, Jr., John D.., "**Computational fluid Mechanics the Basics with Applications**" McGraw Hill Education, 2012.
2. Oleg Zikanov, "**Essential Computational Fluid Dynamics**", Wiley India Pvt Ltd, 2012.
3. Fletcher, C.A.J. "**Computational Techniques for Fluid Dynamics 1 (Fundamental and General Techniques)**", Springer – Verlag,2005.
4. Gautam Biswas and Somenath Mukherjee "**Computational Fluid Dynamics**" Narosa 2013.
5. John F Wendt **"Computational Fluid Dynamics"** Springer, 2012.

Course Contents and Lecture Schedule

No.	Topic	No. of hours
1.0	**Basics of CFD**	
1.1	Overview of CFD	1
1.2	Definition and stages	1
1.3	Applications	1
1.4	Fluid Flow	1
1.4.1	Continuum hypothesis	
1.4.2	Lagrangian and Eulerian formulation	1
1.4.3	Types of flow	1
1.4.4	Governing equations – Continuity and momentum in differential and integral forms	2
1.5	Heat flow: Governing equation – energy equation	1
1.6	Heat and fluid flow: Governing equations - continuity equation, momentum equation, energy equation	1
1.7	Partial Differential Equations	2
1.8	Initial and Boundary conditions	1
2.0	**Computational Techniques**	
2.1	Methods– finite difference, finite volume, finite element	1
2.2	Solution Procedure	1
2.3	Solution Criteria - stability and convergence	1
2.4	Grid independent test, types of grid.	1
3.0	**Finite Difference Method**	
3.1	Finite difference schemes - forward difference scheme, central difference scheme, backward difference scheme	2
3.2	Properties of discretization	1
3.3	FDM for Steady state diffusion - one-dimensional (1-D), Two dimensional (2-D), Three dimensional (3-D) conduction	3

	problems	
3.4	One dimensional transient state heat conduction problems	1
3.5	Numerical errors	1
4.0	**Finite Volume Method**	
4.1	Basics of Finite volume schemes	1
4.2	Finite Volume formulation – 1-D steady and unsteady state heat transfer	3
4.3	1-D and 2-D steady Convection – Diffusion	3
4.4	SIMPLE Algorithm, Staggered gird, pressure correction equation	2
5.0	CFD Applications	
5.1	Introduction	1
5.2	**Turbulence model**	
5.2.1	One equation and two equations models	1
5.2.2	Advantages of RSM, DNS, LES models	1
5.3	**Combustion model**	
5.3.1	Simple chemical reacting system model	1
5.3.2	Eddy break–up model	1
5.3.3	Probability Distribution Function model.	1
	Total	**40**

Course Designers:

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2. M.S. Govardhanan govardhanans07@gmail.com

14MEPZ0	**TURBOMACHINES**	Category	L	T	P	Credit
		PE	2	2	0	3

Preamble

Turbo machines are energy conversion devices in which energy is transferred either to, (or) from, a continuously flowing fluid by the dynamic action of one (or) more moving blade rows on a rotor. This course deals with the study of construction, working, energy transfer and performance calculations of both compressible and incompressible flow turbo machines like turbines, compressors, and pumps.

Prerequisite

- 14ME240-Thermodynamics
- 14ME340-Fluid Mechanics
- 14ME440-Thermal Engineering

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Describe the energy transfer, reheating and preheating effects, and efficiencies of turbomachines and blade and cascade nomenclatures	Understand
CO 2.	Apply dimensional and model analysis to turbomachines	Apply
CO 3.	Calculate the performance parameters of Centrifugal and Axial flow Compressors	Apply
CO 4.	Compute the performance parameters of Steam and Gas Turbines	Apply
CO 5.	Calculate the performance parameters of Centrifugal Pumps	Apply
CO 6.	Compute the performance parameters of Hydraulic Turbines	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	M	_	_	M	_	_	_	_	_	_	_	_	_	L	_
CO2.	S	M	_	S	_	_	_	_	_	_	_	_	_	M	L
CO3.	S	M	_	S	_	_	_	_	_	_	_	_	_	M	L
CO4.	S	M	_	S	_	_	_	_	_	_	_	_	_	M	L
CO5.	S	M	_	S	_	_	_	_	_	_	_	_	_	M	L
CO6.	S	M	_	S	_	_	_	_	_	_	_	_	_	M	L

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	10	10	10	10
Understand	40	40	40	40
Apply	50	50	50	50

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Classify a turbo machine based on the direction of fluid flow?

2. What is the effect of preheating in a compressor?
3. List out the various losses in cascades.
4. Explain the nomenclatures of a blade with a neat diagram.
5. Derive the polytropic efficiency expression for turbine.

Course Outcome 2 (CO2):

1. How the repeating variables are selected in the Buckingham's Pi theorem?
2. Define dynamic similarity.
3. What do you mean by similitude?
4. By using Buckingham's Pi theorem, show that dimensionless expression ΔP is given by

$$\Delta P = \frac{4f\, lV^2\, \rho}{2D}$$

Where ΔP- pressure drop in a pipe, V- mean velocity of the flow, l - length of the pipe, D - diameter of the pipe, f - average roughness of the pipe, and ρ - density of the fluid.

5. A turbine model of 1:10 develops 1.84 kW under a head of 5m of water at 480 rpm. Find the power developed by the prototype under a head of 40 m. Also find the speed of the prototype. Assume efficiency of both the turbines to be same. Find and verify the specific speeds.

Course Outcome 3 (CO3):

1. Define slip factor.
3. Discuss the effect of blade profile on the performance of centrifugal compressor.
4. Elucidate the phenomenon of surging and stalling in centrifugal compressor.
5. The impeller tip speed of a centrifugal compressor is 370 m/s, slip factor is 0.90, and the radial velocity component at the exit is 35 m/s. If the flow area at the exit is $0.18m^2$ and compressor efficiency is 0.88, determine the mass flow rate of air and the absolute Mach number at the impeller tip. Assume air density = 1.57 kg/m^3 and inlet stagnation temperature is 290 K. Neglect the work input factor. Also, find the overall pressure ratio of the compressor.
6. A multistage axial compressor is required for compressing air at 293 K through a pressure ratio of 5. Each stage is to be 50% reaction and the mean blade speed 275 m/s, flow co-efficient 0.5, and the stage loading factor 0.3 are taken as constant for all stages. Determine the flow angles and the number of stages required if the stage efficiency is 88.8%. Take C_p=1.005 kJ/kgK and =1.005 kJ/kgK and Gamma = 1,4 for air. Also find the overall efficiency of the compressor.

Course Outcome 4 (CO4):

1. Define stage loading coefficient.
2. Derive the degree of reaction of axial flow turbine in terms of blade angles.
3. Consider an axial flow gas turbine in which air enters at the stagnation temperature of 1050 K. The turbine operates with a total pressure ratio of 4:1. The rotor turns at 15500 rpm and the overall diameter of the rotor is 30 cm. If the total-to-total efficiency is 0.85, find the power output per kg per second of airflow if the rotor diameter is reduced to 20 cm and the rotational speed is 12,500 rpm. Take γ = 1.4.
4. Steam enters the first row of a series of stages at a static pressure of 10 bars and a static temperature of 300°C. The blade angles for the rotor and stator of each stage are: $\alpha 1$ = 25°, $\beta 1$ = 60°, $\alpha 2$ =70.2°, $\beta 2$ = 32°.If the blade speed is 250 m/s, and the rotor efficiency is 0.94, find the degree of reaction and power developed for a 5.2 kg/s of steam flow. Also find the static pressures at the rotor inlet and exit if the stator efficiency is 0.93 and the carryover efficiency is 0.89.

5. A small inward radial flow gas turbine operates at its design point with a total-to-total efficiency of 0.90. The stagnation pressure and temperature of the gas at nozzle inlet are 310 kPa and 1145 K respectively. The flow leaving the turbine is diffused to a pressure of 100 kPa and the velocity of flow is negligible at that point. Given that the Mach number at exit from the nozzles is 0.9, find the impeller tip speed and the flow angle at the nozzle exit. Assume that the gas enters the impeller radially and there is no whirl at the impeller exit. Take Cpg = 1.147 kJ/kg K; γ =1.33

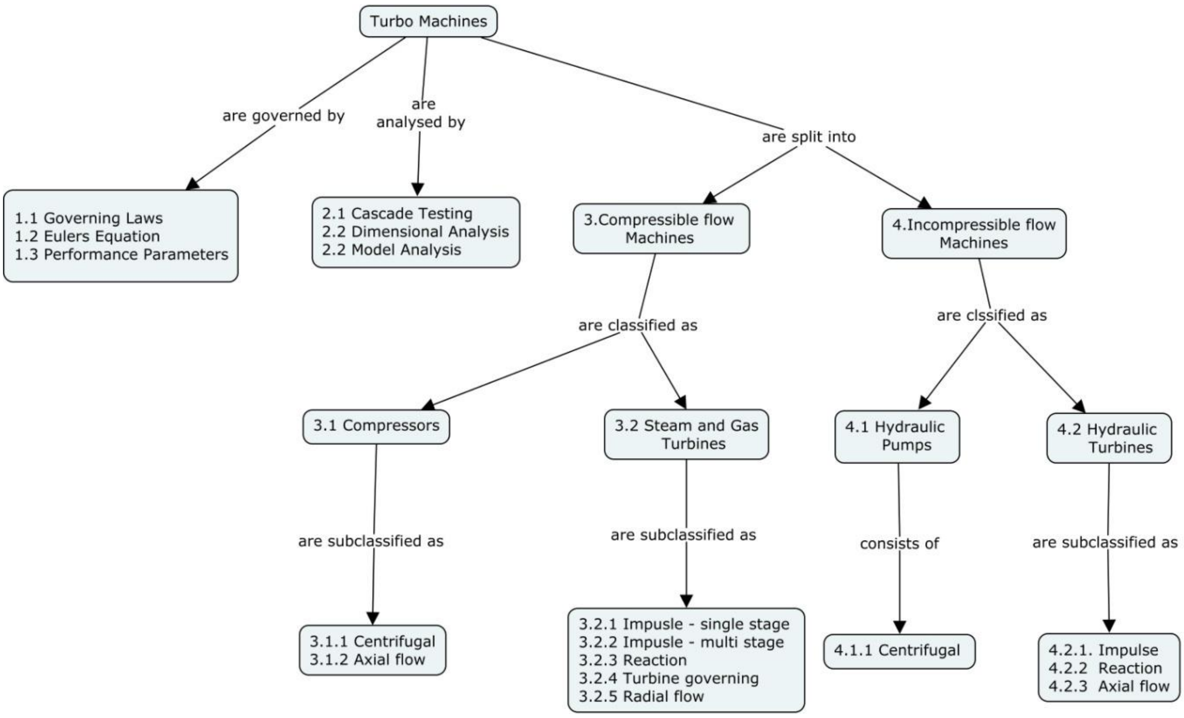
Course Outcome 5 (CO5):

1. What is NPSH?
2. Deduce the minimum speed expression for a centrifugal pump.
3. Explain with help of neat sketches the working of multistage pumps in series and in parallel.
4. A centrifugal pump impeller runs at 1400 rpm, and vanes angle at exit is 25°. The impeller has an external diameter of 0.4m and an internal diameter of 0.2 m. Assuming a constant radial flow through the impeller at 2.6 m/s; calculate (1) the angle made by the absolute velocity of water at exit with the tangent, (2) the inlet vane angle, and (3) the work done per kg of water.
5. Water is to be lifted through 110 m height from a well. Number of identical pumps having speed 1000 rpm, specific speed 25 rpm with a rated discharge of 6000lpm are available. Determine how many pumps will be required and how they should be connected?

Course Outcome 6 (CO6):

1. Classify hydraulic turbines based on the energy available at inlet.
2. Define the hydraulic efficiency of Pelton wheel.
3. A Pelton wheel is having a mean bucket diameter of 0.8 m and is running at 1000 rpm. The net head on the Pelton wheel is 400 m. If the side clearance angle is 15^o and discharge through the nozzle is 150 lit/s, find (a) power available at the nozzle and (b) hydraulic efficiency of the turbine.
4. An inward flow reaction turbine develops 70 kW at 370 rpm. The inner and outer diameters of the wheel are 40 and 80 cm, respectively. The velocity of the water at exit is 2.8 m/s. Assuming that the discharge is radial and that the width of the wheel is constant, find the actual and theoretical hydraulic efficiencies of the turbine and the inlet angles of the guide and wheel vanes. Turbine discharges 545 liters/s under a head of 14 m.
5. A Kaplan turbine is to be designed to develop 9100 kW. The net available head is 5.6 m. If the speed ratio = 2.09, flow ratio = 0.68, overall efficiency is 86% and the diameter of the boss is 1/3 of the diameter of the runner.

Concept Map



Syllabus

Turbomachines: Introduction, Classification, Continuity equation, Laws of thermodynamics, Newton's second law of motion, Energy Transfer in Turbo machinery- Euler's Turbine Equation, Components of energy transfer, Performance Parameters, Work done, Preheating and Efficiencies of Compressor, Numerical problems. Work done, Reheating and Efficiencies of Turbine, Numerical problems. **Cascade, Dimensional and Model Analysis**: Cascade Testing- Blade Types, Forces acting on blades, Blade nomenclature, Compressor cascade and Turbine cascade nomenclatures, Cascade testing and losses, Dimensional analysis - Dimensions and equations, Advantages, Buckingham Pi Theorem, Model Analysis -Advantages, Similarity – Geometric, Kinematic and Dynamic, Specific speed, Unit quantities, **Compressible Flow Machines: Compressors** - Centrifugal Compressors - Velocity triangle, Slip factor, Work done, Impeller blade types, Numerical problems. Characteristics-Stall, Surging and Choking. Axial Flow Compressors - Velocity triangle, Degree of reaction, Stage loading, Numerical problems, Multi-stage performance, Characteristics – Stalling. **Steam and Gas Turbines** - Axial Flow Impulse Turbine – Single stage, Velocity triangles and Work output, Mollier diagram, Degree of reaction, Blade-loading coefficient, Numerical problems, Multi Stage-Pressure compounding, Velocity Compounding and Pressure-velocity compounding, Numerical Problems. Reaction Turbine- Velocity diagram, Stage efficiency. Reheat factor, Numerical problems, Losses in turbines, Governing of turbines. Radial Flow Gas Turbine-Velocity diagrams and Mollier diagram, Spouting velocity, Efficiency, Numerical problems. **Incompressible Flow Machines**: **Hydraulic Pumps** - Centrifugal Pumps – Velocity triangles, Work done, Slip factor, Pump losses, Numerical problems, Impeller Blade Shape, NPSH, Specific speed, Cavitation. **Hydraulic Turbines** - Impulse Turbine-Pelton wheel, Velocity triangles, Work done and Efficiencies, Numerical problems, Reaction Turbine-Francis turbine, Velocity triangles, Work done, Efficiencies, Turbine characteristics, Numerical problems, Axial Flow Turbine- Kaplan turbine, Velocity triangles, Work done, Efficiencies, Numerical problems, Cavitation..

Text Book

1. S. M. Yahya, "Turbines, Compressors & Fans", Tata-McGraw Hill, 3rd edition, 2011.
2. A.Valan Arasu, "Turbo Machines", Second Edition, Vikas publishing house Pvt Ltd, 2013.

Reference Books

1. S.L.Dixon, "Fluid Mechanics, Thermodynamics of Turbo machinery" Butterworth-Heinemann Publishers, 7th edition, 2014.
2. Rama S. R. Gorla and Aijaz A. Khan "Turbo machinery Design and Theory", Marcel Dekker Inc. USA, 2003.
3. V. Kadambi and Manohar Prasad "An Introduction to Energy Conversion, Volume III – Turbomachinery", New Age International Publishers (P) Ltd. 2011.
4. B.K. Venkanna, 'Fundamentals of Turbomachinery', PHI Learning Pvt. Ltd., 2009.
5. William W Perg, "Fundamentals of Turbomachinery", John Wiley & Sons, Inc. 2008.
6. G.Gopalakrishnan and D.Prithvi Raj, "A Treatise of Turbomachines", Scitech Publications, 2008.

Reference Materials

1. NPTEL Material on Basics of Turbomachines:
   http://nptel.ac.in/courses/Webcourse-contents/IIT-KANPUR/machine/ui/TOC.htm
2. NPTEL material on Turbomachinery Aerodynamics:
   http://nptel.ac.in/courses/101101058/

Course Contents and Lecture Schedule

Module No.	Topic	No. of hours
	Turbo machines	
1.1	Introduction, Classification, Continuity equation, Laws of thermodynamics, Newton's second law of motion.	1
1.2	Energy Transfer in Turbo machinery- Euler's Turbine Equation, Components of energy transfer.	1
1.3	Performance Parameters- Compression and expansion processes on T-S diagrams, Work done.	1
1.3.1	Preheating and Efficiencies of Compressor, Numerical problems.	2
1.3.2	Reheating and Efficiencies of Turbine, Numerical problems.	2
2.	**Cascade, Dimensional and Model Analysis**	
2.1	Cascade Testing	
2.1.1	Blade Types, Forces acting on blades, Blade nomenclature	1
2.1.2	Compressor cascade and Turbine cascade nomenclatures, Cascade testing and losses	2
2.2	Dimensional analysis	
2.2.1	Dimensions and equations, Advantages, Buckingham Pi Theorem	2
2.3	Model Analysis	
2.3.1	Advantages, Similarity – Geometric, Kinematic and Dynamic	1
2.3.2	Specific speed, Unit quantities	2
3.	**Compressible Flow Machines**	
3.1	**Compressors**	
3.1.1	Centrifugal Compressors - Velocity triangle, Slip factor, Work done, Impeller blade types	1
3.1.1.1	Numerical problems.	2
3.1.1.2	Characteristics-Stall, Surging and Choking	1
3.1.2	Axial Flow Compressors - Velocity triangle, Degree of reaction, Stage loading, Numerical problems	2
3.1.2.1	Multi-stage performance, Characteristics – Stalling.	1
3.2.2.2	Numerical problems.	2
3.2	**Steam and Gas Turbines**	
3.2.1	Axial Flow ImpulseTurbine – Single stage, Velocity triangles and Work	1

Module No.	Topic	No. of hours
	output, Mollier diagram,	
3.2.1.1	Degree of reaction, Blade-loading coefficient, Numerical problems.	1
3.2.2.2	Numerical problems.	2
3.2.2	Multi Stage-Pressure compounding, Velocity Compounding and Pressure-velocity compounding, Numerical Problems.	1
3.2.3	Reaction Turbine- Velocity diagram, Stage efficiency. Reheat factor,	2
3.2.3.1	Numerical problems.	2
3.2.4	Losses in turbines, Governing of turbines.	1
3.2.5	Radial Flow Gas Turbine-Velocity diagrams and Mollier diagram, Spouting velocity, Efficiency, Numerical problems.	2
4	**Incompressible Flow Machines:**	
4.1	**Hydraulic Pumps**	
4.1.1	Centrifugal Pumps – Velocity triangles, Work done, Slip factor, Pump losses,	2
4.1.1.1	Numerical problems.	2
4.1.1.2	Impeller Blade Shape, NPSH, Specific speed, Cavitation.	1
4.2	**Hydraulic Turbines**	
4.2.1	Impulse Turbine-Pelton wheel, Velocity triangles, Work done and Efficiencies, Numerical problems.	2
4.2.2	Reaction Turbine-Francis turbine, Velocity triangles, Work done, Efficiencies, Turbine characteristics	1
4.2.2.1	Numerical problems	2
4.2.3	Axial Flow Turbine- Kaplan turbine, Velocity triangles, Work done, Efficiencies, Numerical problems, Cavitation.	2
	Total	48

Course Designers:

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14MERA0	MECHANICAL VIBRATIONS	Category	L	T	P	Credit
		PC	2	2	0	3

Preamble

Vibration is the motion of a particle or a body or a system of connected bodies displaced from a position of equilibrium. Most vibrations produce increased stresses, energy losses, wear and bearing loads. Predicting and measuring the vibration in a dynamic system is essential to improve the system performance. This course covers the basic principles of vibration, modeling and their application in mechanical systems.

Prerequisites

- 14ME250 –Kinematics and Dynamics of Machinery

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the importance of vibration in design of Machine parts	Understand
CO 2.	Develop the mathematical model and determine the natural frequency of single degree of freedom vibrations.	Apply
CO 3.	Develop the mathematical model and determine the natural frequency of two degree of freedom vibrations.	Apply
CO 4.	Develop the mathematical model, equation of motion and determine the natural frequency of multi degree of freedom.	Apply
CO 5.	Suggest suitable methods for measuring and controlling the motions of mechanical systems.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	M	M	M	M	_	_	_	_	_	_	_	_	S	_	S
CO2.	S	S	S	S	_	_	_	_	_	_	_	_	S	_	S
CO3.	S	S	S	S	_	_	_	_	_	_	_	_	S	_	S
CO4.	S	S	S	S	_	_	_	_	_	_	_	_	S	_	S
CO5.	S	S	S	S	M	_	_	_	_	_	_	_	S	_	S

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	10
Understand	20	20	20	20
Apply	60	60	60	70
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course outcome 1:

1. Define the term Vibration Isolation and Transmissibility
2. Differentiate between viscous, coulomb and hysteretic damping.
3. Explain the term Logarithmic Decrement as applied to damped vibrations.

Course outcome 2:

1. A vibrating system having mass 1kg is suspended by a spring of stiffness 1000N/m and it is put to harmonic excitation of 10N. Assuming viscous damping, determine
   a) the resonant frequency
   b) the phase angle at resonance
   c) the amplitude at resonance
   d) the frequency corresponding to the peak amplitude
   e) damped frequency.

   Take C= 40N-sec/m.
2. A mass of 1kg is to be supported on a spring having a stiffness of 9800N/m. The damping coefficient is 4.9N-sec/m. Determine the natural frequency of the system. Find also the logarithmic decrement and the amplitude after three cycles if the initial displacement is 0.30cm.

3. A machine of mass one tonne is acted upon by an external force of 2450N at a frequency of 1500rpm. To reduce the effects of vibration, isolator of rubber having a static deflection of 2mm under the machine load and an estimated damping ξ=0.2 are used. Determine
   a) Force transmitted to the foundation
   b) The amplitude of vibration of machine
   c) Phase lag.

Course outcome 3:

1. Find the natural frequencies of car with the following conditions.

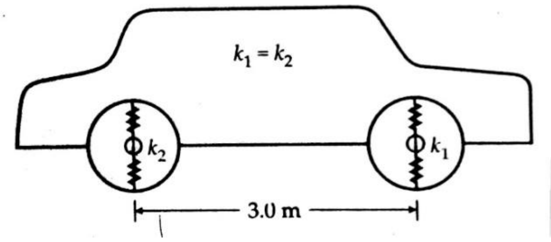
   Total mass of car = 300kg

   Wheel base = 3.0m

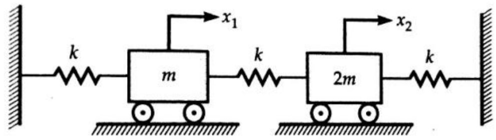
   C.G is 1.50m from front axle

   Radius of gyration is 1.0m

   Spring constants of front and rear springs are 70×10^3 N/m each.



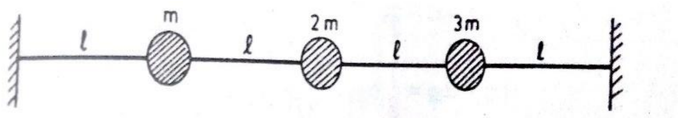
2. Find the natural frequency and amplitude ratio of the system shown in figure.



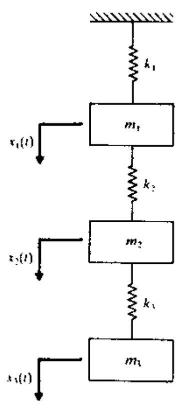
3. Two equal masses of weight 400N each and radius of gyration 40cm are keyed to the opposite ends of a shaft 60cm long. The shaft is 7.5cm diameter for the first 25cm of tis length, 12.5cm diameter for the next 10cm and 8.5cm diameter for the remaining of its length. Find the frequency of free torsional vibrations of the system and position of node. Assume $G=0.84\times10^{11}$ N/m^2.

Course outcome 4:

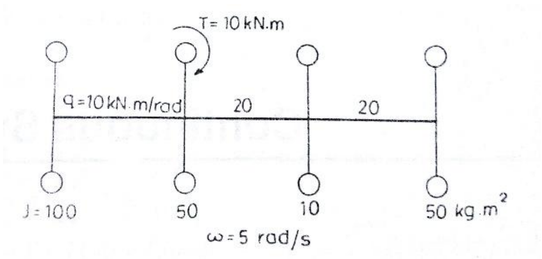
1. Calculate the natural frequency and mode shapes of the vibrating string system shown in figure by influence coefficient method.



2. Estimate the fundamental frequency of vibration of the astern shown in Figure, Assume that $m_1 = m_2 = m_2 = m$. $k_1 = k_2 = k_3 = k$ and the mode shape is X={1 2 3}



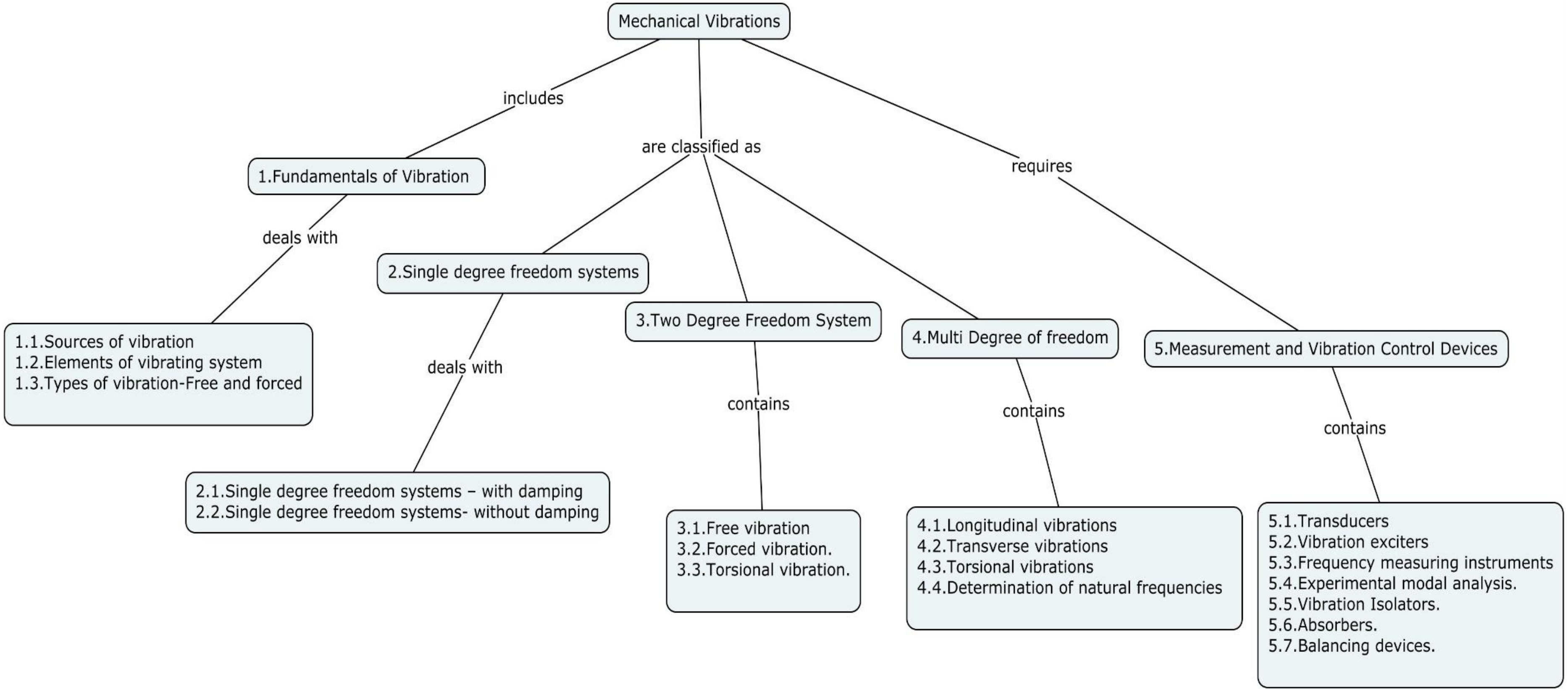
3. Determine the natural frequency of the system shown in figure by Holzer's method



Course outcome 5:

1. Propose the suitable vibration transducer which works on its magnetic field variation. Explain its working principle with suitable application.
2. Suggest the suitable frequency measuring instruments and explain its working principle with suitable diagram in each category.

Concept Map


Mechanical Vibrations
includes
are classified as
requires
1.Fundamentals of Vibration
deals with
1.1.Sources of vibration
1.2.Elements of vibrating system
1.3.Types of vibration-Free and forced
2.Single degree freedom systems
deals with
2.1.Single degree freedom systems – with damping
2.2.Single degree freedom systems- without damping
3.Two Degree Freedom System
contains
3.1.Free vibration
3.2.Forced vibration.
3.3.Torsional vibration.
4.Multi Degree of freedom
contains
4.1.Longitudinal vibrations
4.2.Transverse vibrations
4.3.Torsional vibrations
4.4.Determination of natural frequencies
5.Measurement and Vibration Control Devices
contains
5.1.Transducers
5.2.Vibration exciters
5.3.Frequency measuring instruments
5.4.Experimental modal analysis.
5.5.Vibration Isolators.
5.6.Absorbers.
5.7.Balancing devices.

Syllabus

Fundamentals of Vibration: Sources of vibration-Elements of vibrating system-Mathematical models-Types of vibration-Free and forced. **Singledegree freedom system:**Single degree freedom systemwith and without damping –Types of Damping-Viscous coulomb and hysteretic damping, translational system and torsional system, logarithmic decrement- vibration isolation and force transmissibility- vibration analysis -Critical speed. **Two Degree Freedom System:** Equations of motions-free, forced and torsional vibration of Undamped and damped system. Torsional system-Spring coupled system – mass coupled system –coordinates coupling and principles coupling, orthogonal properties. **Multi-Degree Freedom System:** Free vibrations of damped and Undamped system, Longitudinal, Transverse, Torsional systems, influence coefficients – Eigen values and Eigen vectors — Determination of natural frequencies- Rayleigh, Dunkerley and Holzer methods. **Measurements and Control:** Vibration Measuring Devices: Transducers, vibration pickups-Vibration exciters: mechanical, hydraulic, –Frequency measuring instruments: single reed, multi reed and stroboscope. Experimental modal analysis.- FFT analyzers - Vibration control devices- isolators, absorbers and balancing.

Text Book

1. Rao, S.S.,**" Mechanical Vibrations,"** Addison Wesley Longman, Reprint 2015.
2. G.K.Groover., **"Mechanical Vibrations"**, New Chand &Bros, Roorkee, Repint 2014.

Reference Books

1. Ramamurti. V, **"Mechanical Vibration Practice with Basic Theory"**, Narosa, New Delhi, Reprint 2015.
2. Rao V. Dukkipati and J,Srinivas, **"Text book of Mechanical Vibrations"**, Prentice Hall of India, New Delhi, Reprint 2014
3. Thomson, W.T. **"Theory of Vibration with Applications"**, CBS Publishers and Distributors, New Delhi, 1990.
4. Ambekar.A.G. **"Mechanical Vibrations and Noise Engineering"**, Prentice Hall of India, New Delhi, 2006.
5. Den Hartog, J.P, **"Mechanical Vibrations"**, Dover Publications, 1990.

Course Contents and Lecture Schedule

S.No.	Topic	No. of Lectures
1	**Fundamentals of Vibration – Basic Concepts**	
1.1	Sources of vibration.	1
1.2	Elements of vibrating system-Mathematical models.	1
1.3	Types of vibration-Free and forced.	1
2	**Single degree freedom systems**	
2.1	Single degree freedom systems – with damping.	1
2.1.1	Types of Damping-Viscous coulomb and hysteretic damping.	1
2.1.2	Logarithmic decrement.	1
2.1.3	Vibration isolation and force transmissibility.	1
2.2	Single degree freedom systems- without damping.	2
2.2.1	Vibration analysis.	1
2.2.2	Critical speed.	1
3	**Two Degree Freedom System:**	
3.1	Equations of motions-free vibration of Undamped and damped system.	2
3.2	Equations of motions-forced vibration of Undamped and damped system.	2
3.3	Equations of motions-torsional vibration of Undamped and damped system.	2
3.3.1	Coordinates coupling and principles coupling, Orthogonal properties.	2
4	**Multi-Degree Freedom System**	
4.1	Longitudinal vibrations. Free vibrations of damped and Undamped system	2
4.2	Transverse vibrations.	1
4.3	Torsional vibrations. Influence coefficients – Eigen values and Eigen vectors	1
4.4	Determination of natural frequencies.	
4.4.1	Rayleigh method	1
4.4.2	Dunkerley method	1
4.4.3	Holzer method	2
5	**Measurement and Vibration Control Devices**	
5.1	Transducers- vibration pickups.	1
5.2	Vibration exciters: Mechanical and Hydraulic.	1

S.No.	Topic	No. of Lectures
5.3	Frequency measuring instruments: single reed, multi reed and stroboscope.	1
5.4	Experimental modal analysis – FFT analyzers	2
5.5	Vibration Isolators.	1
5.6	Absorbers.	1
5.7	Balancing devices.	1
	Total	**36**

Course Designers

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14MERB0	INTEGRATED PRODUCT DEVELOPMENT	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

A dynamic and highly competitive business environment requires an increasingly efficient and controllable product development process. This dynamic process demand more creative and innovative solutions that provide the challenging and diverse requirements of the customer. This course aims to prepare the students to move forward in innovative settings.

Prerequisite

- 14ME420-Engineering Design

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO1.	Explain concept of product development , Sustenance Engineering and End of life ,Product development in Industry versus Academia, Trade-offs, Intellectual Property Rights and Confidentiality	Understand
CO2.	Classify the Product Development Methodologies.	Understand
CO3.	Perform the PESTLE Analysis and Requirement Engineering Analysis.	Apply
CO4.	Develop System Integration, Testing, Certification and Documentation.	Apply
CO5.	Identify the specific product development process for a given industry.	Apply
CO6.	Transform customer needs into technical specification of a product.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	M	L	L	L	L	M	S	_	_	_	_	M	L	_	M
CO2.	M	L	L	L	L	_	_	_	_	_	_	_	L	_	L
CO3.	S	M	M	M	M	M	S	_	_	_	_	M	L	_	M
CO4.	S	M	M	M	_	_	M	_	_	_	_	_	L	_	S
CO5.	S	M	M	M	L	L	_	_	_	_	_	_	L	_	S
CO6.	S	M	M	M	_	M	M	_	_	_	_	_	L	_	S

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	30	30	30	30
Apply	50	50	50	50
Analyse	-	-	-	-
Evaluate	-	-	-	-
Create	-	-	-	-

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define product design.
2. Define Intellectual Property.
3. Define proto typing.

Course Outcome 2 (CO2):

1. Distinguish between functional design and production design, with suitable examples.
2. Discuss the different types of product validation techniques.
3. Explain the concept selection process with example.

Course Outcome 3 (CO3):

1. As a customer identify the basic needs in the selection of a new car.
2. Select the suitable product development methodology for software companies and criticize your selection.
3. Construct the house of quality for a basic mobile phone.

Course Outcome 4 (CO4):

1. Select the innovation criteria for product success in the life cycle of a product.
2. How concept selection methods can is used to benchmark or evaluate the existing product?
3. Evaluate concept selection methods for five automobiles you might consider for purchasing.

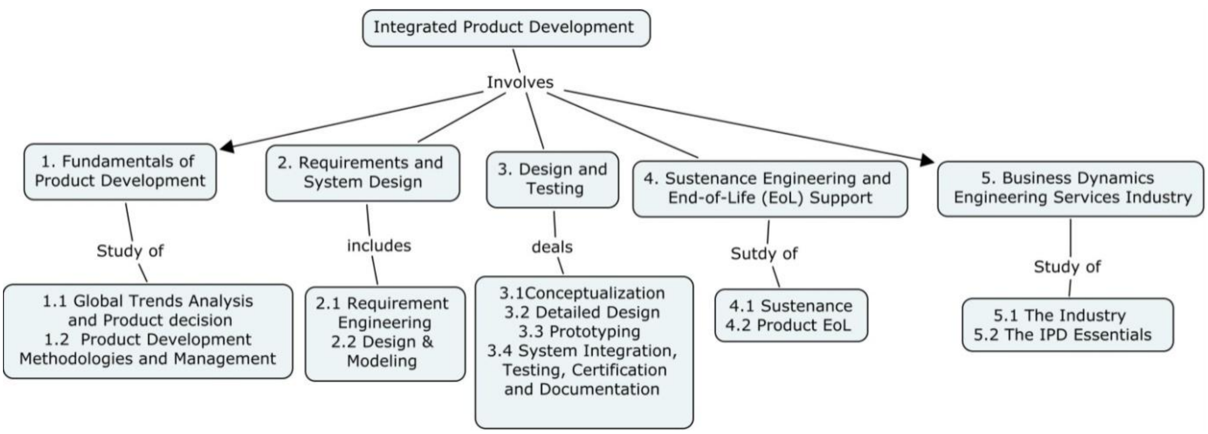
Course Outcome 5 (CO5):

1. As a customer Identify the basic needs while selection a new car
2. Decompose a micro oven into its assemblies, components, electrical circuits.
3. Draw the product architecture for a ink jet printer

Course Outcome 6 (CO6):

1. Develop different concepts to design an orange ripeness tester and evaluate
2. List your needs with respect to two wheeler motorcycle suspension and convert to a product specification.
3. Determine and evaluate the force flow in a car door being opened

Concept Map



Syllabus

Product Development -Global Trends Analysis and Product decision- Types of various trends affecting product decision - Social Trends (Demographic, Behavioral, Psychographic), Technical Trends(Technology, Applications, Tools, Methods), Economical Trends(Market, Economy, GDP, Income Levels, Spending Pattern, target cost, Total Cost of Ownership), Environmental Trends (Environmental Regulations and Compliance), Political/Policy Trends(Regulations, Political Scenario, IP Trends and Company Policies).

PESTLE Analysis-Introduction to Product Development Methodologies and Management Overview of Products and Services (Consumer product, Industrial product, Specialty products etc.,)- Types of Product Development (NPD/ Re-Engineering (Enhancements, Cost Improvements)/ Reverse Engineering/ Design Porting & Homologation)- Overview of Product Development methodologies (Over the Wall/ Waterfall/ V-Model/ Stage-Gate Process/ Spiral/Systems Engineering/ Agile)- Product Life Cycle (S-Curve, Reverse Bathtub Curve)- Product Development Planning and Management (Budgeting, Risk, Resources and Design Collaboration, Scheduling, Change Management, Product Cost Management) Requirements and System Design- Requirement Engineering-Types of Requirements (Functional, Performance, Physical, Regulatory, Economical, Behavioral, Technical, Stakeholder, Environmental, Industry specific, Internal-Company Specific)- Requirement Engineering (Gathering (VOC), Analysis (QFD), Design Specification)- Traceability Matrix and Analysis-Requirement Management- Design and Testing-Conceptualization Industrial Design and User Interface Design-Introduction to Concept generation Techniques- Concept Screening & Evaluation -Concept Design -S/W Architecture -Hardware Schematics and simulation - Detailed Design -component Design and Verification-High Level Design/Low Level Design of S/W Programs, S/W Testing Hardware Schematic, Component design, Layout and Hardware Testing Prototyping –Types of Prototypes (Mockups, Engineering Assessment Prototype, Alpha, Beta, Gama)- Rapid prototyping Techniques-System Integration, Testing, Certification and Documentation.

Manufacturing/Purchase and Assembly of Systems-: Integration of Mechanical, Embedded and S/W systems-: Introduction to Product verification processes and stages – Industry specific (DFMEA, FEA)- Introduction to Product validation processes and stages - Industry specific (Sub-system Testing/ Integration Testing/ Functional Testing/ Performance Testing / Compliance Testing)- Product Testing standards and Certification – Industry specific-Product Documentation overview only (Compliance Documentation, Catalogue, Brochures, user manual, maintenance Manual, Spares Parts List, Warranty, Disposal Guide, Interactive Electronic Technical Manual, Web Tools)-Sustenance Engineering and End-of-Life (EoL) Support-Sustenance-Maintenance and Repair-Enhancements, Obsolesce - Obsolescence Management- Configuration Management- EoL Disposal- Business Dynamics – Engineering Services Industry-The Industry- Engineering Services Industry – overview- Product development in Industry versus Academia The IPD Essentials -Introduction to vertical specific product development processes- Product development Trade-offs-: Intellectual Property Rights and Confidentiality- Security and configuration management

Text Book

1. **Foundation skills in Integrated product development (FSIPD)** , NASSCOM, Edition 2015

Reference Books

1. Karl T.Ulrich and Steven D.Eppinger , **“Product Design and Development”**, McGraw – Hill International Edns.2007.
2. David G.Ullman, **“The Mechanical Design Process”**, Tata McGraw Hill, 2011.
3. Stephen Rosenthal, **“Effective Product Design and Development”**, Business One Irwin, Homewood, 1992.
4. Stuart Pugh, **“Tool Design – Integrated Methods for Successful Product Engineering”**, Addison Wesley Publishing, Newyork,NY,1991.
5. Kevin Otto, and Kristin Wood, **“Product Design – Techniques in Reverse Engineering and New Product Development”**, Pearson Education, 2003.
6. **Product Design – Techniques in Reverse Engineering and New Product Development,** Kevin Otto, and Kristin Wood, Pearson Education, ISBN 81-7758-821-4

Course Contents and Lecture Schedule

S.No.	Topic	No. of Lectures
1.1	**Global Trends Analysis and Product decision**	
1.1.1	Types of various trends affecting product decision - Social Trends (Demographic, Behavioral, Psychographic), Technical Trends(Technology, Applications, Tools, Methods),	1
1.1.2	Economical Trends(Market, Economy, Gross Domestic Product, Income Levels, Spending Pattern, target cost, Total Cost of Ownership)	1
1.1.3	Environmental Trends(Environmental Regulations and Compliance), Political/Policy Trends(Regulations, Political Scenario, IP Trends and Company Policies.	1
1.1.4	PESTLE Analysis	1
1.2	**Introduction to Product Development Methodologies and Management**	
1.2.1	Overview of Products and Services (Consumer product, Industrial product, Specialty products etc.,)	1
1.2.2	Types of Product Development (NPD/ Re-Engineering (Enhancements, Cost Improvements)/ Reverse Engineering/ Design Porting & Homologation)	1
1.2.3	Overview of Product Development methodologies (Over the Wall/ Waterfall/ V-Model/ Stage-Gate Process/ Spiral/Systems Engineering/ Agile)	1
1.2.4	Product Life Cycle (S-Curve, Reverse Bathtub Curve)	1
1.2.5	Product Development Planning and Management (Budgeting, Risk, Resources and Design Collaboration, Scheduling, Change Management, Product Cost Management)	1
2.1	**Requirement Engineering**	
2.1.1	Types of Requirements (Functional, Performance, Physical, Regulatory, Economical, Behavioral, Technical, Stakeholder, Environmental, Industry specific, Internal-Company Specific)	1
2.1.2	Requirement Engineering (Gathering (VOC), Analysis (QFD), Design Specification)	1
2.1.3	Traceability Matrix and Analysis	1
2.1.4	Requirement Management	1
3.1	**Conceptualization**	
3.1.1	Industrial Design and User Interface Design	1
3.1.2	Introduction to Concept generation Techniques	
3.1.3	Concept Screening & Evaluation -Concept Design – Software Architecture- Hardware Schematics and simulation	1
3.2	**Detailed Design**	
3.2.1	Component Design and Verification	1
3.2.2	High Level Design/Low Level Design of Software Programs, Software Testing	1
3.2.3	Hardware Schematic, Component design, Layout and Hardware Testing	1
3.3	**Prototyping**	
3.3.1	Types of Prototypes (Mockups, Engineering Assessment Prototype, Alpha, Beta, Gama)- Rapid prototyping Techniques	2
3.4	System Integration, Testing, Certification and Documentation	
3.4.1	Manufacturing/Purchase and Assembly of Systems - Integration of Mechanical, Embedded and S/W systems	1
3.4.2	Introduction to Product verification processes and stages – Industry specific (DFMEA, FEA)	1

S.No.	Topic	No. of Lectures
3.4.3	Introduction to Product validation processes and stages - Industry specific (Sub-system Testing/ Integration Testing/ Functional Testing/ Performance Testing / Compliance Testing)	1
3.4.4	Product Testing standards and Certification – Industry specific	1
3.4.5	Product Documentation – overview only (Compliance Documentation, Catalogue, Brochures, user manual, maintenance Manual, Spares Parts List, Warranty, Disposal Guide, Interactive Electronic Technical Manual, Web Tools)	1
4.1	**Sustenance**	
4.1.1	Maintenance and Repair, Enhancements.	2
4.2	Obsolesce	
4.2.1	Obsolescence Management - Configuration Management- EoL Disposal	2
5.1	**Business Dynamics – Engineering Services Industry**	
5.1.1	Engineering Services Industry – overview-	1
5.1.2	Product development in Industry versus Academia	2
5.2	**The IPD Essentials**	
5.2.1	Introduction to vertical specific product development processes	1
5.2.2	Product development Trade-offs	1
5.2.3	Intellectual Property Rights and Confidentiality Security and configuration management	2
	Total	**36**

Course Designers:

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14MERC0	RELIABILITY ENGINEERING	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

Reliability engineering is engineering that emphasizes dependability in the lifecycle management of a product. Dependability, or reliability, describes the ability of a system or component to function under stated conditions for a specified period of time.
The students can able to identify and manage asset reliability risks that could adversely affect plant or business operations.

Prerequisite

- 14ME310 - Statistical techniques

Course Outcomes

At the end of the course, the students will be able to:

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the basic concepts of Reliability Engineering and its measures.	Understand
CO 2.	Predict the Reliability at system level using various models.	Apply
CO 3.	Design the test plan to meet the reliability Requirements.	Apply
CO 4.	Predict and estimate the reliability from failure data.	Apply
CO 5.	Develop and implement a successful Reliability programme.	Apply
CO6.	Assess the reliability factor related to the performance of the equipment and process	Analyse

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	M	L	_	_	_	_	_	L	_	_	_	L	_	_	_
CO2.	S	M	M	M	S	_	_	L	_	_	_	L	_	_	_
CO3.	S	M	S	M	M	_	_	L	_	_	_	L	_	_	M
CO4.	S	L	M	M	M	_	_	L	_	_	_	L	_	_	M
CO5.	S	L	M	M	M	_	M	L	_	_	_	L	_	_	M
CO6	S	S	M	M	M	L	M	L	_	_	_	L	_	_	M

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	40	40	40	40
Apply	40	40	40	40
Analyse	-	-	-	-
Evaluate	-	-	-	-
Create	-	-	-	-

Course Level Assessment Questions

Course Outcome 1 (CO1):
1. Write the concept of Reliability
2. Define the term "Reliability management
3. Explain the term "Bath Tub Curve

Course Outcome 2 (CO2):

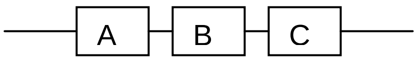
1. State and explain the possible causes of low reliability of modern engineering systems
2. Compare the availability of the following two unit systems with repair facilities: a)Series system with one repair facility, b)Series system with two repair facilities

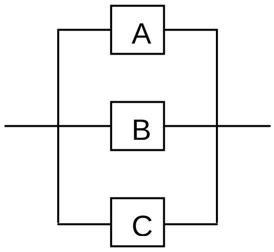
Course Outcome 3 (CO3):

1. Calculate a) the expectation b)the second moment about the origin and c)the variance for the following probability distributions.

X =	8	12	16	20	24
p(X) =	1/8	1/6	3/8	1/4	1/12

2. Draw Fault –tree diagrams for the systems shown in the following figures:

a) 

b) 

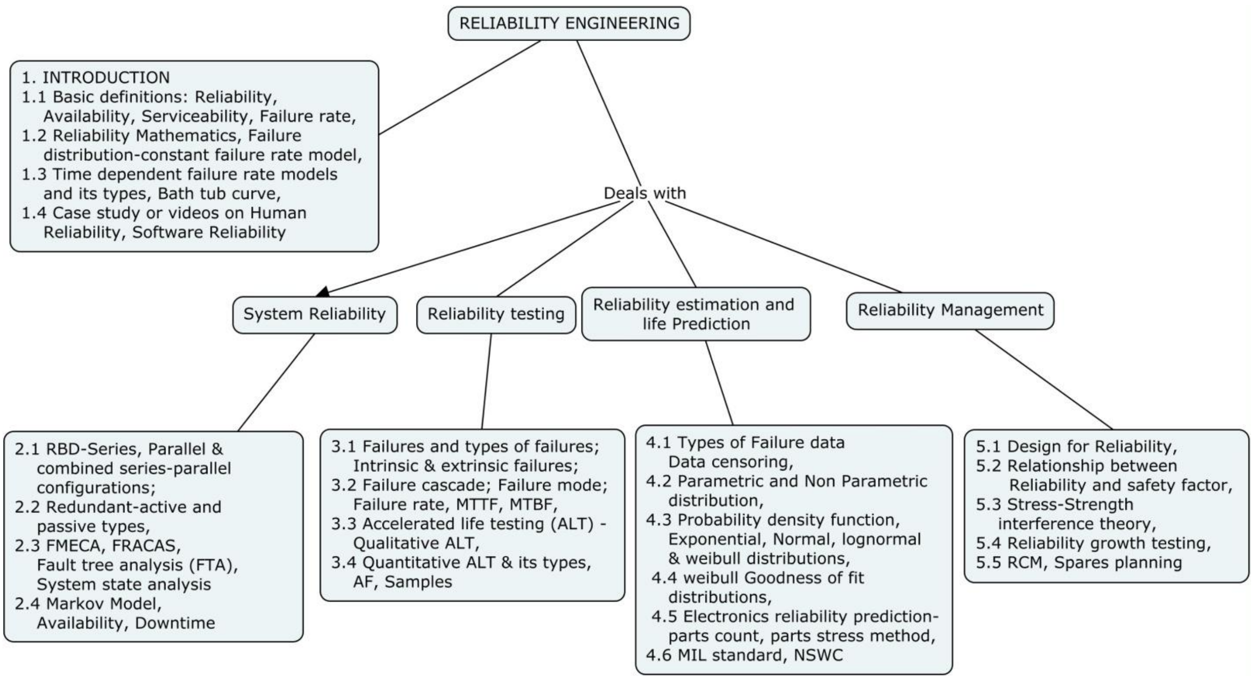
Course Outcome 4 (CO4):

1. What is failure data analysis
2. What are the different techniques of risk analysis?
3. How do you assess the design process in safety

Course Outcome 5 (CO5):

1. Explain the various risk measurement systems in modern industrial scenario
2. Explain about various risk reduction resources in a chemical industry
3. How the risk assessment will support the industrial safety.

Concept Map



Syllabus

Introduction : Basic definitions: Reliability, Availability, Serviceability, Failure rate, Reliability Mathematics, Failure distribution - constant failure rate model, Time dependent failure rate

models and its types, Bath tub curve. case study or Videos on Human Reliability, Software Reliability.
System Reliability: Reliability Block Diagram - Series, Parallel & combined series-parallel configurations; redundant-active and passive types, Failure Mode, Effects and Criticality Analysis (FMECA), Failure Reporting, Analysis and Corrective Action System (*FRACAS*), Fault Tree Analysis (FTA), System state analysis-Markov Model, Availability, Downtime.
Reliability testing: Failures and types of failures; Intrinsic & extrinsic failures; Failure cascade; Failure mode; Failure rate, MTTF, MTBF, Accelerated life testing (ALT) - Qualitative ALT, Quantitative ALT & its types, AF, Samples
Reliability estimation and life Prediction: Types of Failure data - Data censoring, Parametric and Non Parametric distribution, Probability density function, Exponential, Normal, lognormal & weibull distributions, weibull Goodness of fit distributions, Electronics reliability prediction-parts count, parts stress method, MIL standard, Naval Surface Warfare Center (NSWC).
Reliability Management: Design for Reliability, Relationship between Reliability and safety factor, Stress-Strength interference theory, Reliability growth testing, Reliability centered maintenance (RCM), Spares planning.

Text Book

1. Kailash C. Kapur, Michael Pecht, **Reliability Engineering**, John Wiley & Sons, 2014.

Reference Books

1. Srinath L.S**, “Reliability Engineering”**, Affiliated East-West Press Pvt Ltd, New Delhi, 1998.
2. Modarres, **“Reliability and Risk analysis”**, Marshal Dekker Inc.1993.
3. John Davidson, **“The Reliability of Mechanical system”** published by the Institution of Mechanical Engineers, London, 1988.
4. Smith C.O. **“Introduction to Reliability in Design”**, McGraw Hill, London, 1976.
5. Charles E. Ebeling, “**An introduction to Reliability and Maintainability engineering”**, TMH, 2004
6. Roy Billington and Ronald N. Allan, **“Reliability Evaluation of Engineering Systems”**, Springer, 2007.
7. Handbook of Reliability Prediction Procedures for Mechanical Equipment Logistics Technology Support CARDEROCKDIV, NSWC-11 May 2011, West Bethesda, Maryland 20817-5700.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**INTRODUCTION**	
1.1	Basic definitions: Reliability, Availability, Serviceability, Failure rate	1
1.2	Reliability Mathematics, Failure distribution-constant failure rate model	2
1.3	Time dependent failure rate models and its types, Bath tub curve	1
1.4	Case study or videos on Human Reliability, Software Reliability	1
2.	**SYSTEM RELIABILITY**	
2.1	RBD-Series, Parallel & combined series-parallel configurations	2
2.2	Redundant-active and passive types	2

2.3	FMECA, FRACAS, Fault tree analysis (FTA), System state analysis	1
2.4	Markov Model, Availability, Downtime	2
3	**RELIABILITY TESTING**	
3.1	Failures and types of failures; Intrinsic & extrinsic failures	2
3.2	Failure cascade; Failure mode; Failure rate, MTTF, MTBF	2
3.3	Accelerated life testing (ALT) - Qualitative ALT	1
3.4	Quantitative ALT & its types, AF, Samples	2
4	**RELIABILITY ESTIMATION AND LIFE PREDICTION**	
4.1	Types of Failure data - Data censoring	1
4.2	Parametric and Non Parametric distribution	2
4.3	Probability density function, Exponential, Normal, lognormal & weibull distributions	2
4.4	Weibull Goodness of fit distributions	2
4.5	Electronics reliability prediction-parts count, parts stress method	2
4.6	MIL standard, NSWC	1
5	**RELIABILITY MANAGEMENT**	
5.1	Design for Reliability	2
5.2	Relationship between Reliability and safety factor	1
5.3	Stress-Strength interference theory	2
5.4	Reliability growth testing	1
5.5	RCM, Spares planning	1
	TOTAL	**36**

Course Designers:

1. S. Karthikeyan skarthikeyanlme@tce.edu

		Category	L	T	P	Credit
14MERD0	**ORGANIZATIONAL BEHAVIOR**	PE	3	0	0	3

Preamble:

For engineers who take up varied positions either in the middle level or top level of organizations, managing people becomes an all the more important responsibility. People are recognized to be the keys in organizations. Understanding and the effective management of people is all about this course. Organizational behavior is involved with the study and application of the human side of management and organization.

Pre-requisite:

- Nil

Course outcomes:

On the successful completion of course students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the basics of the organization behavior and its relationship with other fields, OB model, today's organizational challenges.	Understand
CO 2.	Identify the determinants of individual behavior like perception, personality, motivation and their influence on individual behavior	Apply
CO 3.	Manage diverse groups and its effects on organization behavior and select and exhibit an appropriate leadership style	Apply
CO 4.	Build organizational systems namely communication, decision making and adopt suitable organizational culture, change and development	Apply

Mapping with program outcomes:

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	_	_	_	_	_	_	_	_	M	S	_	_	_	_	L
CO2.	_	_	_	_	_	L	_	L	M	_	L	_	_	_	_
CO3.	_	_	_	_	_	_	_	_	_	_	M	_	_	_	_
CO4.	_	_	_	_	_	_	_	_	S	_	M	_	_	_	_

Assessment pattern:

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	30	30	30	30
Apply	50	50	50	50
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course outcome 1 (CO 1):

1. What do you understand by the term "organization behavior"?

2. What according to you are the determinants of individual behavior?
3. What does the term personality mean to you?
4. Sketch the process of motivation.
5. What is Maslow's need hierarchy?

Course outcome 2 (CO 2):

1. Explain the term "Group Dynamics".
2. What is proximity theory on group formation?
3. List out the stages of group formation.
4. Explain the term group conflict.
5. What are all the strategies to solve group conflicts?

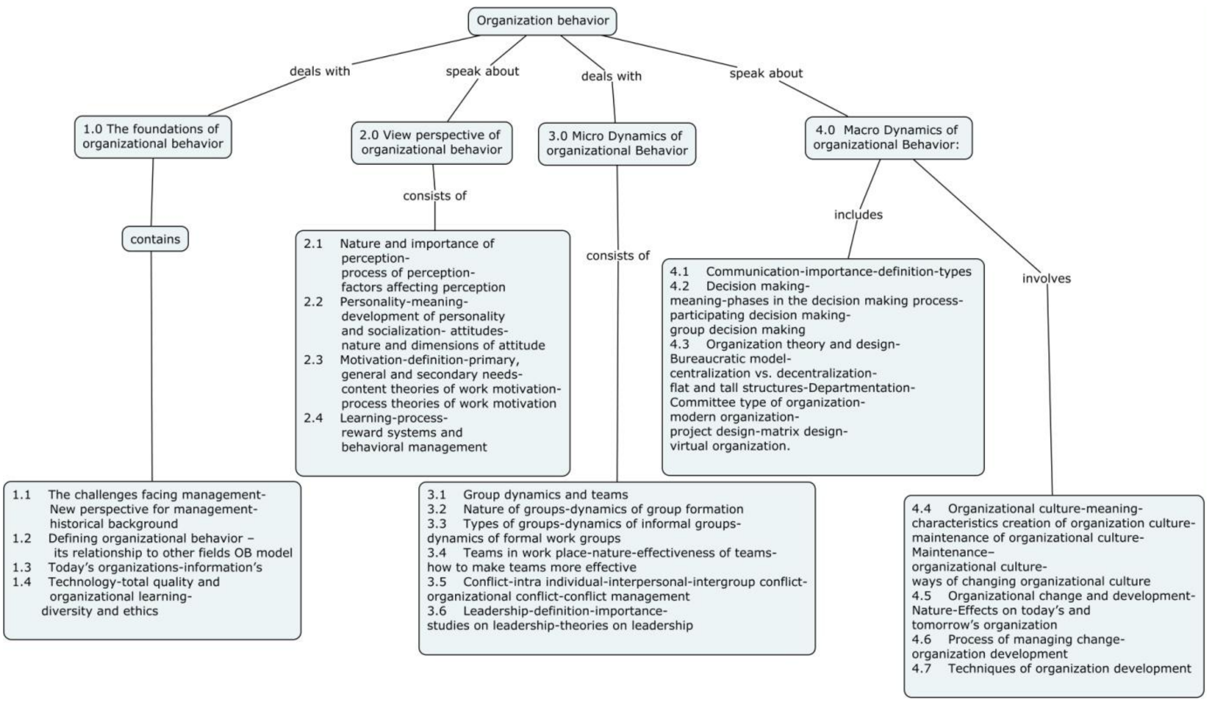
Course outcome 3(CO 3):

1. Explain the various factors that cause organizational change.
2. Write the meaning of organization development.
2. Explain the various organizational structures.
3. Explain the trait theory on leadership.

Course outcome 4(CO 4):

1. Define the term decision making.
2. Label the factors which include changes in organization.
3. Understand organization culture organizational change and development.
4. Build the ways by which organizational culture get developed. Plan the steps that are involved.
5. Explain the process of communication.

Concept map:



Syllabus:

The foundation for organizational behavior: The challenges facing management-New perspective for management-historical background - Defining organizational behavior –its relationship to other fields OB model - Today's organizations-Information Technology-Total Quality and Organizational Learning- Contemporary challenges -Diversity and ethics
View perspective of organizational behavior- Nature and importance of perception-process of perception-factors affecting perception - Personality-meaning-Development of personality and socialization-Attitudes-Nature and dimensions of attitude - Motivation-definition-primary, general and secondary needs-Content theories of work motivation-Process theories of work motivation - Motivating performance through job design and goal setting - Learning-process-Reward systems and behavioral management.

Micro Dynamics of organizational Behavior: Group dynamics and teams - Nature of groups-dynamics of group formation - Types of groups-dynamics of informal groups-dynamics of formal work groups - Teams in work place-nature-effectiveness of teams-how to make teams more effective - Conflict-intra individual-interpersonal-intergroup conflict-organizational conflict-conflict management - Leadership-definition-importance-studies on leadership-theories on leadership.

Macro Dynamics of organizational Behavior: Communication-importance-definition-types-Decision making-meaning-phases in the decision making process-participating decision making-group decision making - Organization theory and design-Bureaucratic model-centralization vs. decentralization-flat and tall structures- Departmentation -Committee type of organization-modern organization-project design-matrix design-virtual organization.
Organizational culture-meaning-characteristics creation of organization culture-maintenance of organizational culture-Maintenance–organizational culture-ways of changing organizational culture - Organizational change and development-Nature-Effects on today's and tomorrow's organization - Process of managing change-organization development - Techniques of organization development.

Text books:

1. Fred Luthans, "**Organizational Behavior**", Twelfth edition, McGraw-Hill/Irwin 2011.

2. Stephen P. Robbins "**Organization behavior**" , fifteenth edition, Prentice Hall,2012

Reference books:

1. Keith Davis, Jhon w.Newstrom "**Organizational behavior at work**", McGraw Hill series in management, 2012
2. Prasad,L.M, "**Organizational behavior**", Sultan Chand & Sons publishers, fifth revised edition,2014.

Course content and lecture schedule:

S.NO	Topics	No. of. lectures
1.	**The foundation for organizational behavior:**	
1.1	The challenges facing management-New perspective for management-historical background	2
1.2	Defining organizational behavior –its relationship to other fields OB model	1
1.3	Today's organizations-information's	1
1.4	Technology-total quality and organizational learning-diversity and ethics	2
2.	**View perspective of organizational behavior.**	
2.1	Nature and importance of perception-process of perception-factors	2

	affecting perception	
2.2	Personality-meaning-development of personality and socialization-attitudes-nature and dimensions of attitude	2
2.3	Motivation-definition-primary, general and secondary needs-content theories of work motivation-process theories of work motivation	2
2.4	Learning-process-reward systems and behavioral management	2
3	**Micro Dynamics of organizational Behavior**:	
3.1	Group dynamics and teams	
3.2	Nature of groups-dynamics of group formation	1
3.3	Types of groups-dynamics of informal groups-dynamics of formal work groups	2
3.4	Teams in work place-nature-effectiveness of teams-how to make teams more effective	2
3.5	Conflict-intra individual-interpersonal-intergroup conflict-organizational conflict-conflict management	2
3.6	Leadership-definition-importance-studies on leadership-theories on leadership	2
4	**Macro Dynamics of organizational behavior**	
4.1	Communication-importance-definition-types	2
4.2	Decision making-meaning-phases in the decision making process-participating decision making-group decision making	2
4.3	Organization theory and design-Bureaucratic model-centralization vs. decentralization-flat and tall structures-Departmentation-Committee type of organization-modern organization-project design-matrix design-virtual organization.	2
4.4	Organizational culture-meaning-characteristics creation of organization culture-maintenance of organizational culture-Maintenance–organizational culture-ways of changing organizational culture	3
4.5	Organizational change and development-Nature-Effects on today's and tomorrow's organization	2
4.6	Process of managing change-organization development	1
4.7	Techniques of organization development	2
	Total	**38**

Course Designers

Dr.S.Dhanasekaran sdmech@tce.edu
Dr.R.Muruganandam rmmech@tce.edu

14MERE0	GAS TURBINE AND PROPULSION SYSTEMS	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

Gas turbine and propulsion systems deal with the basic cycles of gas turbine and its different components. It also includes fundamentals of propulsion theory along with various rocket propulsion and jet propulsion systems. Further, it deals with the combustion process in the gas turbine.

Prerequisite

- 14ME240-Thermodynamics
- 14ME340-Fluid Mechanics
- 14ME440-Thermal Engineering

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO1.	Solve the thermodynamic cycles involved in the gas turbine.	Apply
CO2.	Discuss the working components of gas turbines.	Understand
CO3.	Demonstrate the types of Jet propulsion system and calculate the thrust induced.	Apply
CO4.	Describe the working principles of different rocket propulsion systems and compute its performances.	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	M	_	_	_	_	_	_	_	_	_	_	_	M	_
CO2.	M	L	_	_	_	_	_	_	_	_	_	_	_	L	_
CO3.	S	M	_	_	_	_	_	_	_	_	_	_	_	M	_
CO4.	S	M	_	_	_	_	_	_	_	_	_	_	_	M	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	60	60	50	50
Apply	20	20	30	30

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. State the assumption made in an ideal cycle analysis of gas turbines.
2. Show that the specific work output is maximum when the pressure ratio is such that the compressor outlet and turbine outlet temperatures are equal.
3. In a gas turbine, the pressure ratio to which air at 15°C is compressed is 6. The same air is then heated to a maximum temperature of 750°C. First in a heat exchanger and then combustion chamber . it is then expanded in two stages such that the expansion work is maximum. The air is reheated to 750°C after first stage. Determine the cycle thermal efficiency, the work ratio and shaft work per kg of air .

Course Outcome 2 (CO2):

1. With a suitable sketch explain the working principle of an axial compressor.
2. Describe briefly the factors affecting the combustion chamber design.
3. Explain the various factors to be considered in the selection of blade materials.

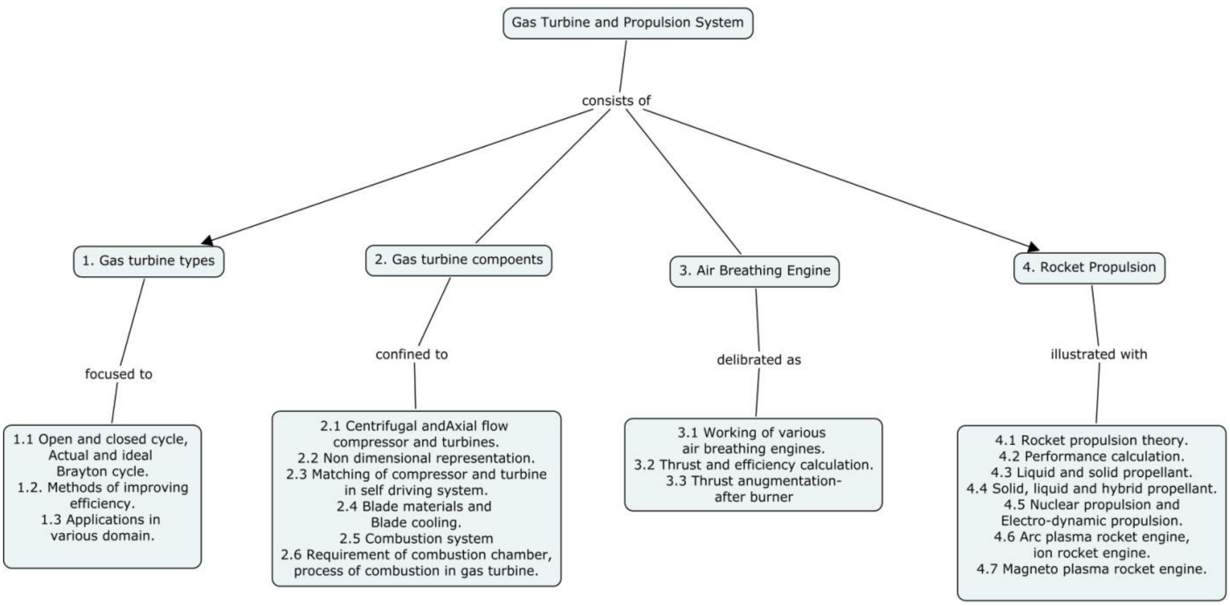
Course Outcome 3 (CO3):

1. What is meant by jet propulsion? .
2. Draw the thermodynamic cycle of the ramjet engine and derive the equation for thrust.
3. The effective jet exit velocity from a jet engine is 2700 m/s. The forward flight velocity is 1350m/s and the air flow rate is 78.6 kg/s .Calculate (i) Thrust (ii) Thrust Power (iii) Propulsive efficiency.

Course Outcome 4 (CO4):

1. How rockets are classified?
2. Discuss, with suitable sketches, the three systems of electro dynamic rocket propulsion system
3. A rocket flies at 10,080 Kmph with an effective exhaust jet velocity of 1400 m/s and the propellant flow rate of 5 kg/s. if the heat of reaction of the propellant is 6500 kJ/kg of the propellant mixture, Determine (i) Propulsive efficiency and Propulsion power (ii) Engine output and thermal efficiency and (iii) Overall efficiency .

Concept Map



Syllabus

Types of gas turbines-open and closed cycle, air standard Brayton cycle, Actual Brayton cycle, methods of improving the efficiency and the specific output of simple cycle- regeneration, re-heating and inter cooling.
Applications-electric power generation, marine, automotive and process applications.

Compressors and Turbine – Centrifugal and Axial flow compressor and turbine-principle of operation, Non dimensional representation of compressor and turbine- performance characteristics of turbine and compressor- Matching of compressor and turbine in a simple self-driving system- Blade materials, factors to be considered in the selection of materials, Blade cooling: external, internal, liquid cooling and air cooling.

Combustion system - types, factors affecting combustion chamber design and its performance- requirements of the combustion chamber- the process of combustion in a gas turbine, combustion chamber geometry.

Jet Propulsion - Air breathing engines: Working of turbo jet, turbo prop, turbo fan, ramjet and pulse jet engines - Performance calculation: Thrust equation, specific thrust, propulsive efficiency thermal efficiency and overall efficiency- Thrust Augmentation-after burner.

Rocket Propulsion - Comparison of air breathing and the rocket engines, classification of rockets- Performance calculations- specific impulse, specific propellant consumption, thrust power, Jet velocity, overall efficiency, propellant flow rate - Propellants and its desirable characteristics: liquid and solid propellant, working of solid, liquid and hybrid propellant rocket engines -Nuclear propulsion-Electro-dynamic propulsion- arc plasma rocket engine- ion rocket engine- magneto plasma rocket engine.

Text Book

1. V. Ganesan, "**Gas Turbines**" McGraw Hill Education, 3rd Edition, 2010.

Reference Books

1. P.R. Khajuria and S.P.Dubey, "**Gas Turbines and Propulsive Systems**", Dhanpat Rai Publications, 2012.
2. M L. Mathur, "**Gas Turbine and Jet Rocket Propulsion**", Standard Publishers Distributors, 2010.
3. P. Balachandran, "**Fundamentals of Compressible Fluid Dynamics**", PHI Learning Private Ltd, 2006.
4. S.M. Yahya, "**Turbine, Compressors and Fans**", McGraw Hill, 2010.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.	**Gas turbine Types**	
1.1	Open and closed cycle, air standard Brayton cycle, Actual Brayton cycle	2
1.2	Methods of improving the efficiency and the specific output of simple cycle- regeneration, re-heating and inter cooling.	3
1.3	Applications-electric power generation applications, marine applications, automotive applications and process applications.	1
2.	**Gas turbine components**	
2.1.	Compressors and Turbine – Centrifugal and Axial flow compressor and turbine-principle of operation.	2
2.2	Non dimensional representation of compressor and turbine-performance characteristics of turbine and compressor.	2
2.3	Matching of compressor and turbine in a simple self-driving system.	2
2.4	Blade materials, factors to be considered in the selection of materials, Blade cooling: external, internal, liquid cooling and air cooling.	2
2.5	Combustion system - types, factors affecting combustion chamber design and its performance.	2
2.6	Requirements of the combustion chamber- the process of combustion in a gas turbine, combustion chamber geometry.	2
3.	**Air breathing engines**	
3.1	Working of turbo jet, turbo prop, turbo fan, ramjet and pulse jet engines.	2
3.2	Performance calculation: Thrust equation, specific thrust,	2

Module No.	Topic	No. of Lectures
	propulsive efficiency thermal efficiency and overall efficiency	
3.4	Thrust Augmentation-after burner.	2
4.	**Rocket propulsion**	
4.1	Rocket Propulsion - Comparison of air breathing and the rocket engines, classification of rockets.	2
4.2	Performance calculations- specific impulse, specific propellant consumption, thrust power, Jet velocity, overall efficiency, and propellant flow rate.	2
4.3	Propellants and its desirable characteristics: liquid and solid propellant.	2
4.4	Working of solid, liquid and hybrid propellant rocket engines.	2
4.5	Nuclear propulsion-Electro-dynamic propulsion.	2
4.6	Arc plasma rocket engine- ion rocket engine.	2
4.7	Magneto plasma rocket engine.	1
	Total	**37**

Course Designers:

1. Dr. K. Srithar ksrithar@tce.edu
2. Mr. M.S. Govardhanan govardhanans@tce.edu

14MERF0	**HYDRAULICS AND PNEUMATICS**	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

The fluid power is used extensively in every branch of industry due to its simplicity, economy, ease and accuracy of control. Fluid power become important part of most vehicles in the transportation industry. In manufacturing, the application of fluid power is continuously increased the productivity of workers and thus had a direct impact on the standard of living. Also today's industry depend more on automation in order to increase productivity..Electrical control of fluid power began to enter the commercial sector with the development of servo controlled valves. The manufacturing process could be simplified by integrating fluid power systems with the automation products.

This course aims at giving adequate exposure to the function of hydraulic and pneumatic components, its selection and application in the design of hydraulic and pneumatic circuits. The knowledge of electrically controlled servo valves ,design of Electrical and PLC based pneumatic and hydraulic circuits helps the students in developing a innovative mechatronics system.

Prerequisite

- NIL

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	**Course Outcomes**	**Blooms level**
CO1:	Classify the properties of pneumatic and hydraulic systems and their applications	Understand
CO2:	Classify and select the pumps and motors for the required applications.	Understand
CO3:	Design the fluid systems with speed, pressure and direction control	Apply
CO4:	Design the hydraulic and pneumatic circuits for the given application.	Apply
CO5.	Design and development of PLC ladder diagram	Apply

Mapping with Programme Outcomes

COs	**PO 1**	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**	**PS O1**	**PS O2**	**PS O3**
CO1.	M	L	L	L	_	_	_	_	_	_	_	_	M	_	_
CO2.	M	L	L	L	_	_	_	_	_	_	_	_	M	_	_
CO3.	S	M	M	M	_	_	_	_	_	_	_	_	S	_	M
CO4.	S	M	M	M	_	_	_	_	_	_	_	_	S	_	M
CO5.	S	M	M	M	_	_	_	_	_	_	_	_	S	_	M

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	20	20	20	20
Apply	60	60	60	60
Analyse	-	-	-	-
Evaluate	-	-	-	-
Create	-	-	-	-

Course Level Assessment Questions

CO1: Classify the properties of pneumatic and hydraulic systems and their applications

1. Define positive displacement pump
2. Name some positive displacement pump
3. List the parameters for selection a pump
4. What are the various type of hydraulic motors?
5. What is the control required for hydraulic circuits?
6. Name some pressure control valves
7. Why flow control is essential
8. What is FRL unit

CO2: Classify and select the pumps and motors for the required applications

1. Compare the hydraulic and pneumatic
2. Distinguish between external and internal gear pump.
3. Describe the working principle cushioned cylinder
4. Distinguish between mechanical and Electro Hydraulic Servo Systems
5. Classify the pumps
6. Compare the meter-in and meter-out circuits

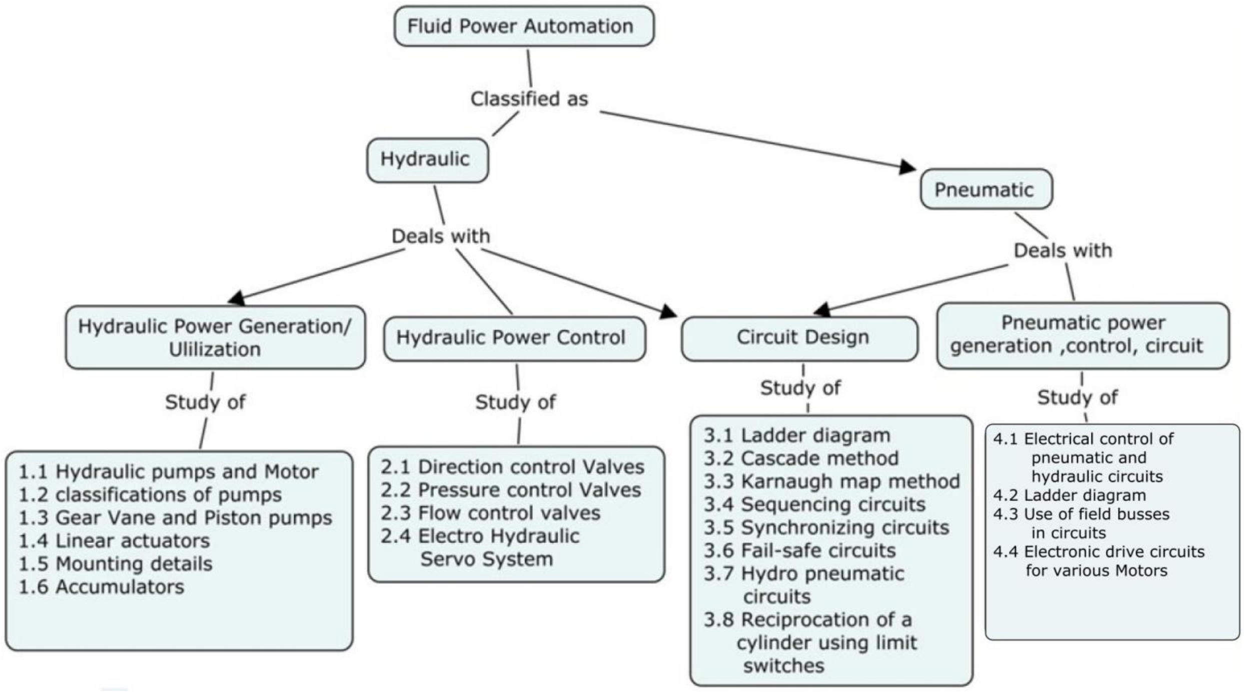
CO3: Design the fluid systems with speed, pressure and direction control

1. Discuss in detail the 4/3 direction control valve with example
2. Justify the use of compound relief valve
3. Analyse the need for flow control value using an application circuit

CO4: Design the hydraulic and pneumatic circuits for the given application.

1. With neat sketch explain the working of the gear pump
2. Explain the cascade method of circuit design with example
3. Design a circuit for the A+B+A-B- using step-counter method
4. Draw the ladder diagram for A+B+C-A-B-C+ and explain its operation

Concept Map



Syllabus

INTRODUCTION: Need for Automation, Hydraulic, pneumatic – Properties of hydraulic fluids – General types of fluids – Applications of Pascals Law- Properties of air Kinetic theory of gases – Boyle's Law - Laminar and Turbulent flow – Reynold's number Selection criteria.

FLUID POWER GENERATING/UTILIZING ELEMENTS: Hydraulic pumps and motor gears, vane, piston pumps-motors-selection and specification- pump performance – Variable displacement pumps .Drive characteristics – Compressors – Filter, Regulator, Lubricator Unit – Air control valves -Linear actuator – Single acting, Double acting special cylinders like tanden, Rodless, Telescopic, Cushioning mechanism, Construction of double acting cylinder, Limited rotation motor, mounting details, power packs – construction. Reservoir, accumulators – standard circuit symbols.

CONTROL AND REGULATION ELEMENTS: Direction flow and pressure control valves- Directional control valve – 3/2 way valve – 4/2 way valve – 5/2 way valve . Shuttle valve – check valve . Pressure control valve – Simple and compound relief valve ,pressure reducing valve, sequence valve, counter balance valve. Flow control valve Fixed and adjustable . Methods of actuation, electro hydraulic servo valves

HYDRAULIC /PNEUMATIC CIRCUIT DESIGN: Speed control circuits, synchronizing circuit, Penumo hydraulic circuit,Fail safe circuit, Sequential circuit design for simple applications using cascade method, step counter method. Electrical control of pneumatic and hydraulic circuits-use of relays, timers, counters, Ladder diagram. Programmable logic control of Hydraulics Pneumatics circuits, PLC wiring diagram for various circuits.

Text Book

1. Anthony Esposito ,Fluid Power with Applications, Prentice-Hall, March 17, 2016
2. Andrew Parr, Hydraulics and Pneumatics: A technician's and engineer's guide [Kindle Edition]

Reference Books

1. W.Bolton, Mechatronics, Electronic control systems in Mechanical and Electrical Engineering Pearson Education, 2011.
2. Peter Rohner, Fluid Power Logic Circuit Design, Mcmelan Prem, 1994.

3. Eaton Hydraulics Training Services (Vickers), Industrial Hydraulics Manual 5th Ed. 2nd Printing 2008
4. Frank Yeaple, Fluid Power Design Handbook, Third Edition, CRC Press
5. James L. Johnson "Introduction to Fluid Power" Delmar Thomson Learning Publishers 2003.
6. CMTI Handbook
7. James R. Daines -Fluid Power: Hydraulics and Pneumatics Second Edition, Textbook Edition,GW publisher lab manual
8. Peter croser,Frank abel, Pneumatics,Basic level ,Festo Manual,Edition 10/2002
9. Festo Hydraulics manual advanced level Edition 1999.

Course Contents and Lecture Schedule

No	Topic	No. of Lectures
1	**INTRODUCTION**	
1.1	Need for Automation, Hydraulic & Pneumatic basics	**1**
1.2	Properties of hydraulic fluids – General types of fluids – Applications of Pascals Law- Properties of air Kinetic theory of gases – Boyle's Law - Laminar and Turbulent flow – Reynold's number Selection criteria	**2**
2	**FLUID POWER GENERATING/UTILIZING ELEMENTS**	
2.1	Hydraulic pumps and Motor	2
2.2	Gear, Vane and Piston motors	1
2.3	Gear, Vane and Piston pumps	1
2.3.1	Selection and specification-Drive characteristics	1
2.3.2	pump performance – Variable displacement pumps	1
2.4	Compressors – Filter, Regulator, Lubricator Unit – Air control valves	2
2.5	Linear actuator – Single acting, Double acting special cylinders like tandem, Rod less, Telescopic, Cushioning mechanism, Construction of double acting cylinder, Limited rotation motor	2
2.6	Cylinder mounting details	1
2.7.1	power packs – construction	1
2.7.2	Reservoir , Accumulators	1
2.8	standard circuit symbols	2
3	**CONTROL AND REGULATION ELEMENTS**	
3.1	Direction control Valves 3/2 way valve – 4/2 way valve – 5/2 way valve . Shuttle valve – check valve	2
3.2	Flow control valves - Fixed and adjustable	2
3.3	pressure control - Simple and compound relief valve ,pressure reducing valve, sequence valve, counter balance valve	2
3.4	Methods of actuation – types	1

2.4	electro hydraulic servo valves- Different types- characteristics and performance	2
3	**hydraulic and pneumatic Circuit Design**	
3.1	Speed control circuits	1
3.2	synchronizing circuit	1
3.3	Penumo hydraulic circuit,Fail-safe circuit	1
3.4	Sequential circuit design for simple applications using cascade method, step counter method.	2
3.5	Electrical control of pneumatic and hydraulic circuits-use of relays, timers, counters	2
3.6	Ladder diagram. Programmable logic control of Hydraulics Pneumatics circuits	1
3.7	PLC wiring diagram for various pneumatic circuits.	1
	Total	**36**

Course Designers:

1. Dr. M. Elango memech@tce.edu

14MEGA0	SYSTEMS APPROACH FOR ENGINEERS	Category	L	T	P	Credit
		GE	3	0	0	3

Preamble

In the Global economy, it is required that every engineer simultaneously performs as a scientist/engineer/manager, with a constant eye on the most value added output relevant for the company. Such interdisciplinary thinking also promotes the ability to acquire and use all available resources (Knowledge Integration) from within the company and outside. Such System Thinking and its effectiveness in problem resolution is very much the need in the industry today.

Prerequisite

-NIL-

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain about the context, principles and working of systems	Understand
CO 2.	Choose the various types of Inputs and transformations required to achieve the desired outputs of a System.	Apply
CO 3.	Prepare suitable diagnostics tools to identify the vital signs in transformations occurring in System.	Apply
CO 4.	Apply System approach frame work to real world problems	Apply
CO 5.	Use System thinking for engineering the solutions as an Engineer and also as a Manager	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	L	L	L	_	L	_	_	L	_	_	M	_	_	_
CO2.	S	L	L	L	_	L	_	_	L	_	_	M	_	_	_
CO3.	S	L	L	L	_	L	_	_	L	_	_	M	_	_	_
CO4.	S	L	L	L	_	L	_	_	L	_	_	M	_	_	_
CO5.	S	L	L	L	_	L	_	_	L	_	_	M	_	_	_
	3	1	1	1	0	1	0	0	1	0	0	2	0	0	0
	S	L	L	L	_	L	_	_	L	_	_	M	_	_	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	40	30	30	30
Understand	40	30	30	30
Apply	20	40	40	40
Analyse	-	-	-	-
Evaluate	-	-	-	-
Create	-	-	-	-

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define system based on your perspective.

2. Show the different context of systems with suitable examples.
3. State the principles of system.

Course Outcome 2 (CO2):

1. List the various input categories used in system approach.
2. Differentiate Technical outputs and System outputs.
3. Discuss about the importance of transformation in system.

Course Outcome 3 (CO3):

1. Define Vital signs.
2. List few commonly used diagnostic devices to measure transformation.
3. Discuss about Signature analysis with suitable examples.

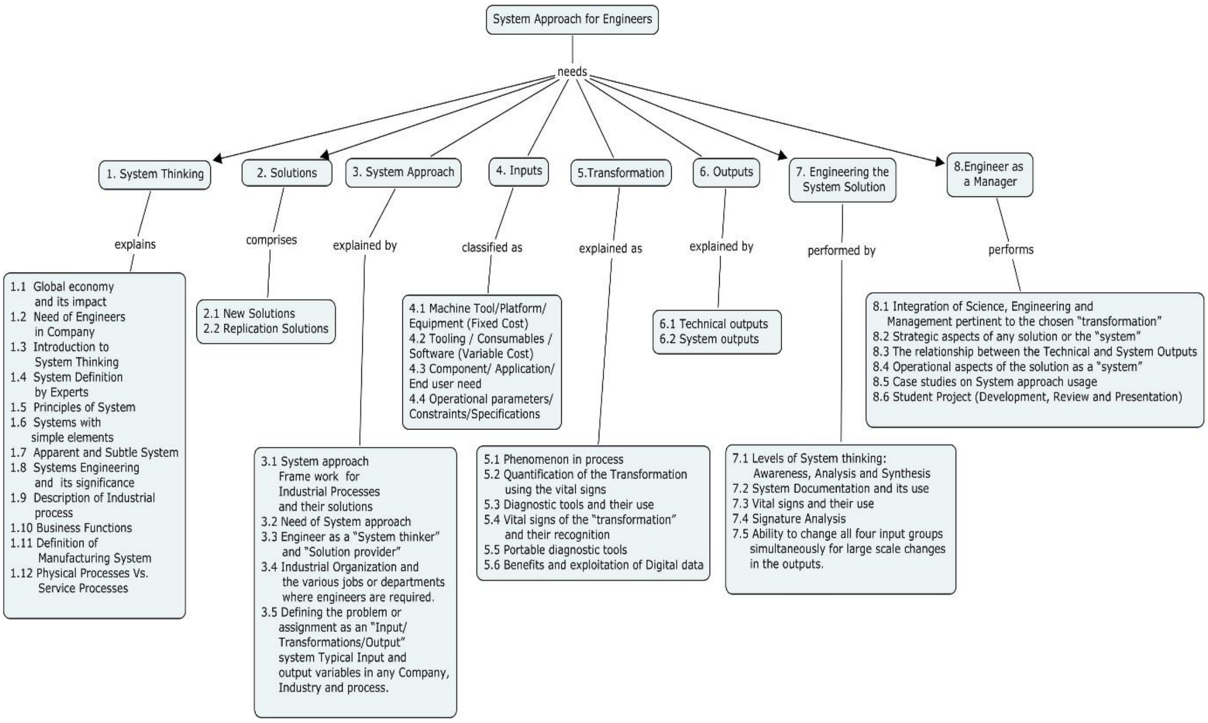
Course Outcome 4 (CO4):

1. Discuss about the System approach framework.
2. Write about the need for system documentation.
3. Summarise about the importance digital data.

Course Outcome 5 (CO5):

1. Discuss an case study of System approach implementation.
2. Illustrate the system implementation methodology.
3. Justify the role of an Engineer as a Manager in finding Engineering Solutions.

Concept Map



Syllabus

System Thinking - Global economy and its impact on the workers – across the globe; & inside of India - Need of Engineers in Company - – Introduction – System Definition by Experts – Principles of System – Systems with simple elements – Apparent and Subtle System - Systems Engineering - its Significance- Description of Industrial processes – Business Functions - Definition of Manufacturing System - Physical Processes Vs. Service Processes - **Solutions** - New Solutions Vs. Replication Solutions - System approach Frame work for Industrial Processes and their solutions – Need of System approach. Engineer as a "System thinker" and "Solution provider" - Industrial Organization and the various jobs or

departments where engineers are required. Defining the problem or assignment as an “Input/Transformations/Output” system. Typical Input and output variables in any Company, Industry and process. **Inputs** - Machine Tool/Platform/Equipment (Fixed Cost) - Tooling / Consumables /Software (Variable Cost) - Component/ Application / End user need - Operational parameters / Constraints/Specifications. **Transformation:** Phenomenon in process - Quantification of the Transformation using the vital signs -Diagnostic tools and their use - Vital signs of the “transformation” and their recognition - Portable diagnostic tools - Benefits and exploitation of Digital data. **Outputs:** Technical outputs - System outputs
Engineering the solution system - Levels of System thinking: Awareness, Analysis and Synthesis - System Documentation and its use - Vital signs and their use - Signature Analysis - Ability to change all four input groups simultaneously for large scale changes in the outputs. **Engineer as a Manager:** Integration of Science, Engineering and Management pertinent to the chosen “transformation” - Strategic aspects of any solution or the “system” - The relationship between the Technical and System Outputs - Operational aspects of the solution as a “system” – Case studies on System approach usage - Student Project (Development, Review and Presentation)

Reference Books

1. Dr.K.Subbu Subramanian, **“The System Approach”** Hanser Gardner Publications, 1st Edition 2000
2. Lecture Materials and Hand Outs prepared by Course Designers

Course Contents and Lecture Schedule

S.No	Topics	No. of Lectures
1.	**System Thinking**	
1.1	Global economy and its impact on the workers – across the globe; & inside of India	1
1.2	Need of Engineers in any Company or Organization	
1.3	Introduction to System Thinking	1
1.4	System Definition by Experts	
1.5	Principles of System	1
1.6	Systems with simple elements	1
1.7	Apparent and Subtle System	
1.8	Systems Engineering and its significance	1
1.9	Description of Industrial processes	1
1.10	Business Functions	
1.11	Definition of Manufacturing System	1
1.12	Physical Processes Vs. Service Processes	
2.	**Solutions**	
2.1	New Solutions	1
2.2	Replication Solutions	
3.	**System approach**	
3.1	System approach Frame work for Industrial Processes and their solutions	1
3.2	Need of System approach	1
3.3	Engineer as a “System thinker” and “Solution provider”	
3.4	Industrial Organization and the various jobs or departments where engineers are required.	1
3.5	Defining the problem or assignment as an “Input/Transformations/Output” system	1
3.6	Typical Input and output variables in any Company, Industry and process	1
4	**Inputs**	

4.1	Machine Tool/Platform/Equipment (Fixed Cost)	1
4.2	Tooling / Consumables /Software (Variable Cost)	
4.3	Component/ Application / End user need	1
4.4	Operational parameters / Constraints/Specifications	
5	**Transformation**	
51	Phenomenon in process	1
5.2	Quantification of the Transformation using the vital signs	1
5.3	Diagnostic tools and their use	1
5.4	Vital signs of the “transformation” and their recognition	1
5.5	Portable diagnostic tools	1
5.6	Benefits and exploitation of Digital data	1
6	**Outputs**	
6.1	Technical outputs	1
6.2	System outputs	1
7	**Engineering the solution system**	
7.1	Levels of System thinking: Awareness, Analysis and Synthesis	1
7.2	System Documentation and its use	1
7.3	Vital signs and their use	1
7.4	Signature Analysis	2
7.5	Ability to change all four input groups simultaneously for large scale changes in the outputs.	1
8	**Engineer as a Manager**	
8.1	Integration of Science, Engineering and Management pertinent to the chosen “transformation”	1
8.2	Strategic aspects of any solution or the “system”	1
8.3	The relationship between the Technical and System Outputs	1
8.4	Operational aspects of the solution as a “system”	1
8.5	Case studies on System approach usage	1
8.6	Student Project (Development, Review and Presentation)	2
	Total	**36**

Course Designers:

1. M.Balamurali balacim82@tce.edu

14MEGB0	ENERGY CONVERSION TECHNIQUES	Category	L	T	P	Credit
		GE	3	0	0	3

Preamble

The development of energy conversion systems is constrained by the depletion of fossil fuel, local environmental impacts, the problem of global warming and associated climate change and search for alternative fuels to reduce the dependence on imported oil. The energy sector is in transition and needs engineering, design, research and development inputs in building efficient conventional energy systems, cost effective renewable sources and conversion devices.
This course is designed to enable the students to understand, demonstrate, and calculate the performance of various energy conversion systems and their applications. The course also focuses on combined use of fossil fuels and renewable energy for power generation.

Prerequisite

- Nil

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Compute the performance of steam power plant and discuss the fuel handling and ash handling systems.	Apply
CO 2.	Calculate the performance of Diesel engine and gas turbine power plants.	Apply
CO 3.	Describe the working of power plants using non-conventional energy sources such as nuclear, wind, biofuel.	Understand
CO 4.	Discuss the various energy conversion methods from solar energy.	Understand

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS O1	PS O2	PS O3
CO1.	S	M	L	_	_	L	L	_	_	_	_	L	_	M	_
CO2.	S	M	L	_	_	L	_	_	_	_	_	L	_	M	_
CO3.	M	L	L	_	_	L	L	_	_	_	_	L	_	L	_
CO4.	M	L	L	_	_	L	L	_	_	_	_	L	_	L	_
	2.5	1.5	1	0	0	1	0.75	0	0	0	0	1	0	1.5	0
	S	M	L	_	_	L	L	_	_	_	_	L	_	M	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	60	60	60	60
Apply	20	20	20	20
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define conventional energy source
2. What are fossil fuels?
3. Give example for non-conventional energy soruces.
4. Discuss the potential of conventional energy sources in India.
5. Describe the availability and consumption trend of non-conventional energy sources in the world.

Course Outcome 2 (CO2):

1. Explain the ash handling plant of thermal power station.
2. Describe the hydraulic ash handling system.
3. List the coal handling equipment.
4. Steam at 20 bar and 300 C enters the turbine of a steam power plant working on simple Rankine cycle and expands to a condenser pressure of 0.1 bar. Find the Rankine cycle efficiency, steam rate and heat rate. Find the increase in cycle efficiency if the condenser pressure is 0.02 bar.
5. Steam at 20 bar and 300 ^{o}C enters the turbine of a steam power plant working on simple Rankine cycle and expands to 0.1 bar. Find the Rankine cycle efficiency, steam rate and heat rate. Find the increase in cycle efficiency if steam temperature is 400 ^{o}C.

Course Outcome 3 (CO3):

1. Distinguish between brake power and indicated power
2. Describe the different methods to improve efficiency of gas turbine.
3. Compare two stroke and four stroke IC engines.
4. In a test on a single cylinder oil engine with 30 cm bore and 45 cm stoke and working on four stroke cycle, the following observations were made:

Duration of trial = 1 hour, TFC = 7.6 kg, Calorific value of the fuel = 45000 kJ/kg, Total revolution made = 12000, Room temperature = 20^{0} C, IMEP = 6 bar, Net brake load = 150 kg, Brake drum diameter = 180 cm, Rope diameter = 3 cm, Mass of the jacket cooling water = 550 kg, Inlet temperature of the jacket cooling water = 15^{0} C, Outlet temperature of the jacket cooling water = 60^{0} C, Temperature of exhaust gases = 300^{0} C, Total air consumption = 365 kg, Specific heat of exhaust gases = 1 kJ/kg K.

Calculate the Indicated power, brake power, mechanical efficiency, and indicated thermal efficiency.

5. In a simple gas turbine plant, the air enters the compressor at 1 bar abs 32°C and leaves at 6.9 bar abs. The temperature at the end of combustion chamber is 816°C. Determine the thermal efficiency, and temperatures in salient points.

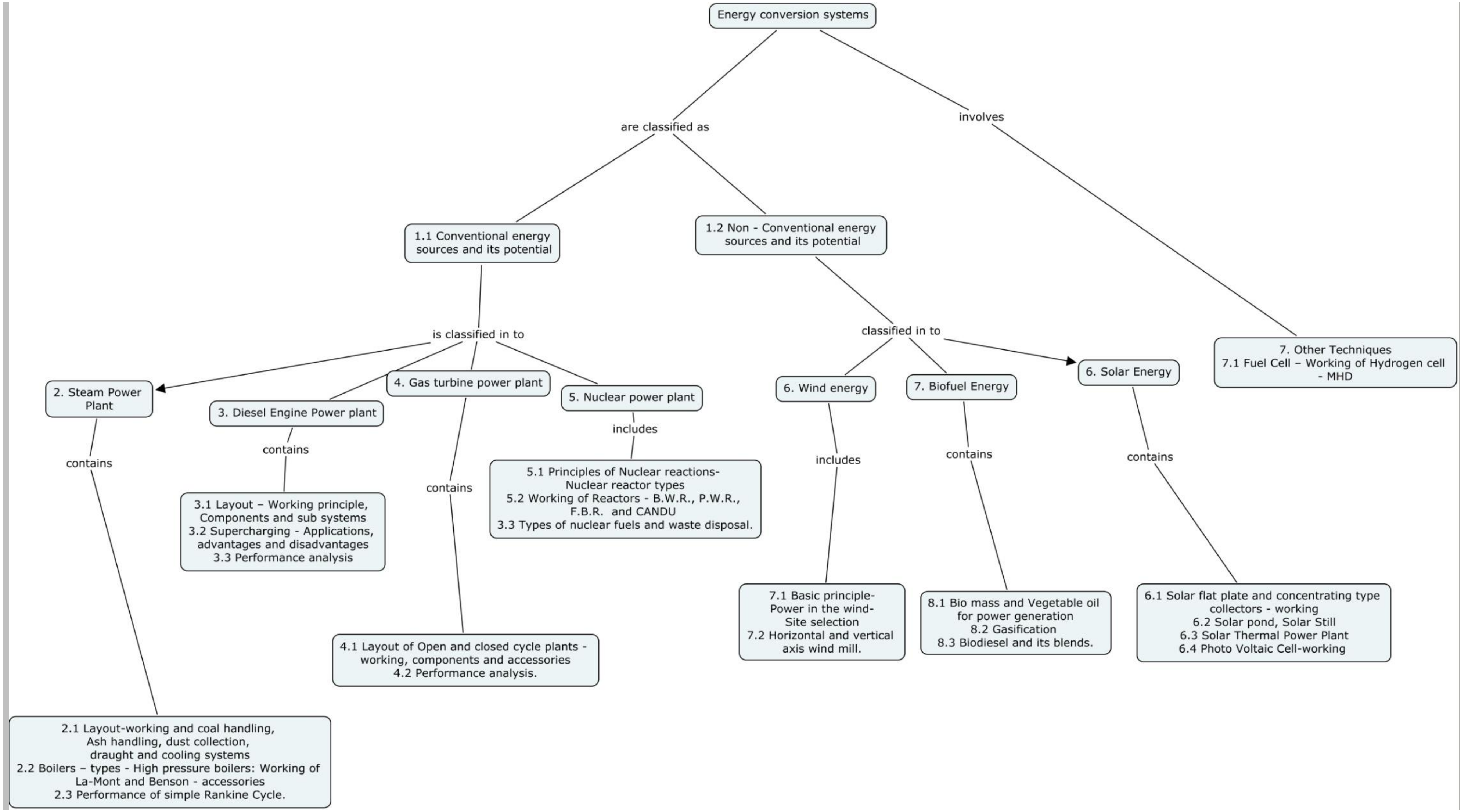
Course Outcome 4 (CO4):

8. Describe the fast breeder reactor.
9. Name the types of reactors.
10. List the advantages of wind power generation.
11. Define biomass
12. Name the different biofuels available for power generation.

Course Outcome 5 (CO5):

1. Describe the working of a solar box type cooker.
2. Compare the energy conversion performance of flat plate collector and concentrated collector.
3. Explain the principle of solar pond.
4. Describe the working of solar desalination system with a neat sketch.
5. Explain the working of solar photovoltaic system.

Concept Map


Energy conversion systems
are classified as
involves
1.1 Conventional energy sources and its potential
1.2 Non - Conventional energy sources and its potential
is classified in to
classified in to
7. Other Techniques
7.1 Fuel Cell – Working of Hydrogen cell - MHD
2. Steam Power Plant
3. Diesel Engine Power plant
4. Gas turbine power plant
5. Nuclear power plant
6. Wind energy
7. Biofuel Energy
6. Solar Energy
contains
includes
2.1 Layout-working and coal handling, Ash handling, dust collection, draught and cooling systems
2.2 Boilers – types - High pressure boilers: Working of La-Mont and Benson - accessories
2.3 Performance of simple Rankine Cycle.
3.1 Layout – Working principle, Components and sub systems
3.2 Supercharging - Applications, advantages and disadvantages
3.3 Performance analysis
4.1 Layout of Open and closed cycle plants - working, components and accessories
4.2 Performance analysis.
5.1 Principles of Nuclear reactions- Nuclear reactor types
5.2 Working of Reactors - B.W.R., P.W.R., F.B.R. and CANDU
5.3 Types of nuclear fuels and waste disposal.
7.1 Basic principle- Power in the wind- Site selection
7.2 Horizontal and vertical axis wind mill.
8.1 Bio mass and Vegetable oil for power generation
8.2 Gasification
8.3 Biodiesel and its blends.
6.1 Solar flat plate and concentrating type collectors - working
6.2 Solar pond, Solar Still
6.3 Solar Thermal Power Plant
6.4 Photo Voltaic Cell-working

Syllabus

Energy source: Conventional energy sources- types - Non-conventional energy sources-types.
Steam power plant: Layout – Working, coal handling, Ash handling, dust collection draught and cooling systems – Boilers – types - High pressure boilers: Working of La-Mont and Benson – accessories – performance of simple Rankine cycle.
Diesel engine power plant: Layout – Working principle, Components and sub systems-Supercharging - Applications, advantages and disadvantages, Performance analysis.
Gas turbine power plant: Layout of open and closed cycle plants- working, components and accessories –Performance analysis of simple cycle.
Nuclear power plant: Principles of Nuclear reactions- Nuclear reactor types and working of reactors - Boiling water reactor (B.W.R.), Pressurised water reactor (P.W.R.) and Fast Breeder Reactor (FBR), CANDU type reactor- types of nuclear fuels and waste disposal.
Wind energy: Basic principle - Power in the wind- site selection- working of Horizontal and vertical axis wind mill.
Bio fuel Energy: Bio mass and vegetable oil for power generation – Gasification, Principle of Integrated Gasification- Biodiesel and its blends.
Solar Energy: Solar flat plate and concentrating type collectors – solar cooker, Solar pond, Solar Still, Solar Thermal Power Plant, Photo Voltaic Cell.
OtherTechniques: Fuel Cell – Working of Hydrogen cell - MHD.

Text Books

1. M.M. El-Wakil, **“Power Plant Technology”**, McGraw Hill, 2002.
2. A.K. Raja, Amit Prakash Srivastava, Manish Dwivedi, **“Power Plant Engineering**”, New Age International Publishers, 2006.
3. Aldo V. Da Rosa **“Fundamentals of Renewable Energy Process”**, Elsevier Academic Press, 2005.

Reference Books

1. Volker Quaschning, “**Understanding Renewable Energy Systems**”, Earth scan, 2005.
2. Rajput, R.K., “**Non-conventional Energy Sources and Utilisation (Energy Engineering**”, S. Chand & Company, 2012.
3. Rajput R.K., **“A Text Book of Power Plant Engineering”,** Laxmi Publications (P) Ltd., 2001.
4. Nag P.K., “**Power Plant Engineering**”- second edition, Tata McGraw Hill, New Delhi, 2001.
5. Rai G.D., **Non- Conventional Energy Sources**, Khanna Publishers, New Delhi, 2004.
6. John R Fanchi, **“Energy in the 21st Century”**, World Scientific Publishing Co. Pvt Ltd, 2005.
7. John R Fanchi, **“Energy – Technology and directions for future”**, Elsevier Academic Press, 2004.
8. David Pimentel, “**Bio Fuels, Solar and Wind as Renewable Energy Systems**”, Springer, 2008.
9. Bent Sorensen, “**Renewable Energy**”, Elsevier Academic Press, 2004.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.	**Energy source:**	
1.1	Conventional energy sources- types	2
1.2	Non-conventional energy sources-types	
2	**Steam power plant:**	
2.1	Layout – Working, coal handling, Ash handling, dust collection, draught and cooling systems	2
2.2	Boilers – types – High pressure boilers: Working of La-Mont and Benson – accessories	2
2.3	Performance of simple Rankine cycle	3
3.	**Diesel engine power plant:**	
3.1	Layout – Working principle, Components and sub systems	2
3.2	Supercharging - Applications, advantages and disadvantages	2
3.3	Performance analysis	2
4.	**Gas turbine power plant:**	
4.1	Layout of Open and closed cycle plants- working, components and accessories	1
4.2	Performance analysis.	2
5.	**Nuclear power plant**:	
5.1	Principles of Nuclear reactions- Nuclear reactor types	1
5.2	Working of Reactors - Boiling water reactor (B.W.R.), Pressurised water reactor (P.W.R.) Fast Breeder Reactor (FBR) and CANDU type reactor	3
5.3	Types of nuclear fuels and waste disposal.	1
6.0	**Wind energy:**	
6.1	Basic principle- Power in the wind- Site selection	1
6.2	Horizontal and vertical axis wind mill.	2
7.0	**Biofuel Energy:**	
7.1	Bio mass and Vegetable oil for power generation	1
7.2	Gasification, Principle of Integrated Gasification	1
7.3	Biodiesel and its blends.	1
6.0	**Solar Energy:**	
6.1	Solar Collectors - working and performance of flat plate and concentrating type	4
6.2	Solar pond, Solar Still	1
6.3	Solar Thermal Power Plant	*1*
6.4	Photo Voltaic Cell-working.	2
7.0	**Other Techniques:**	
7.1	Fuel Cell – Working of Hydrogen cell - MHD	3
	Total	**40**

Course Designers:

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2. Dr. P. Maran pmmech@tce.edu

		Category	L	T	P	Credit
14MEGC0	**INDUSTRIAL ROBOTICS**	GE	3	0	0	3

Preamble

Robotics is an interdisciplinary domain due to its nature of developing and building intelligent systems. In recent years, borders between the disciplines are dispersed in industrial and research scenario. A robot is an electrically actuated and electronically controlled mechanical system with artificial intelligence. This course focuses on industrial robot and it provides an interdisciplinary learning experience by integrating the concepts from core disciplines with the support of mathematical models. Concepts of industrial robot are the foundations for designing and development of robots and have been practiced in wide applications from pick and place operation to medical surgery.

Prerequisite

- Matrix Manipulations

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the working of the subsystems of robotic manipulator such as configuration, control schemes, sensors and interfaces used for the operation of an industrial robot	Understand
CO 2.	Determine the positions of end-effector using *forward kinematic model* of multi-degree of freedom (DOF) manipulator and the positions of joints using *inverse kinematic model* of two degrees of freedom robot for the given Cartesian position of end-effector	Apply
CO 3.	Examine dynamic behaviour of one and two degrees of freedom robot arm under specified loading conditions and kinematic constraints using *inverse dynamic model* for a cubic polynomial trajectory in joint space	Apply
CO 4.	Explain various types of control schemes, sensors and interfaces used in the operation of robot/ with the robot controller	Understand
CO 5.	Develop an offline robot program for point-to-point applications such as pick and place, palletizing, sorting and inspection of work-parts	Apply

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1.	M	L	_	_	_	_	_	_	_	_	_	_	_	_	_
CO2.	S	M	L	_	_	_	_	_	L	_	_	L	_	_	_
CO3.	S	M	L	_	_	_	_	_	L	_	_	L	_	_	_
CO4.	M	L	_	_	_	_	_	_	_	_	_	_	_	_	_
CO5.	S	M	L	_	L	_	_	_	L	_	_	L	_	_	_

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	10	10
Understand	40	20	30	30
Apply	40	60	60	60
Analyse	-	-	-	-
Evaluate	-	-	-	-

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define industrial robot.
2. State the function of controller.
3. With a block diagram, describe the construction features of an industrial robot.

Course Outcome 2 (CO2):

1. Write the coordinate transformation matrices for PUMA links as shown in figure 1 based on the following DH parameters

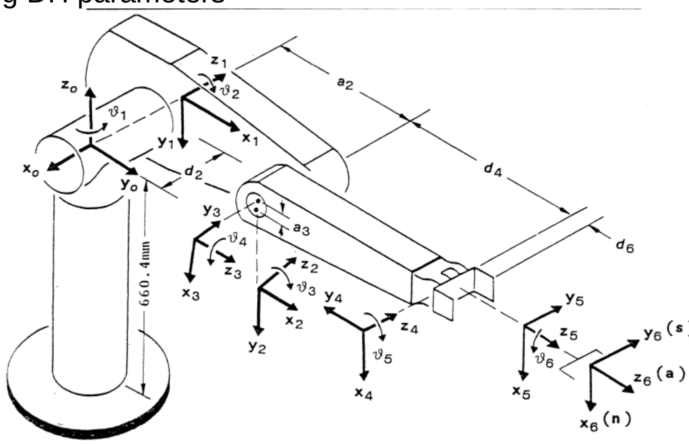


Figure 1

2. Consider the two-link planar arm of Figure 2. The joint axes z_0 and z_1 are normal to the page. The established base frame $x_0y_0z_0$ is as shown. The origin is chosen at the point of intersection of the z_0 axis with the page and the direction of the x_0 axis is completely arbitrary. Once the base frame is established, the $x_1y_1z_1$ frame is fixed as shown by the DH convention, where the origin, o_1 has been located at the intersection of z_1 and the page. The final frame $x_2y_2z_2$ is fixed by choosing the origin, o_2 at the end of link 2 as shown. Write the DH parameters and its corresponding transformation matrices.

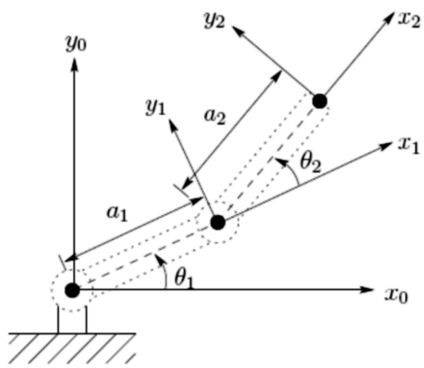


Figure 2

3. Develop an inverse model for two degree of freedom manipulator with two revolute joints.
4. Find the location of end-effector if the values of $b_1 = 1m$, $a_2 = 0.5m$ and $\theta_2 = 120^o$ with use of DH expressions.

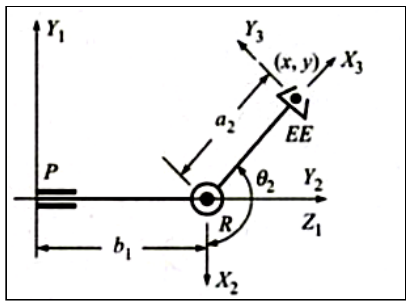
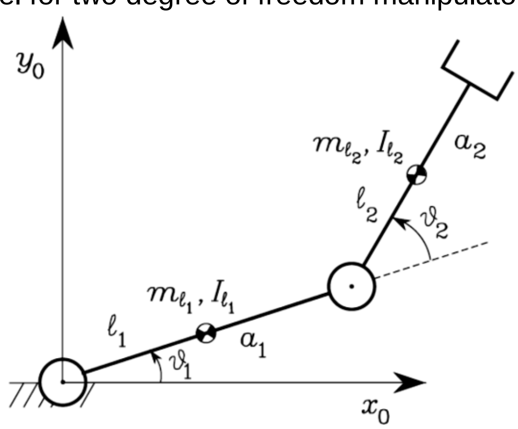


Figure 1

Course Outcome 3 (CO3):

1. Develop a dynamic model for two degree of freedom manipulator as shown in figure 2.



2. A two link planar manipulator is applying a force (newtons) of $\begin{bmatrix} 1.25 \\ 2 \\ 0 \end{bmatrix}^T$ in the end-effector frame on the environment. Find the required joint torques when $\theta_1 = \pi/4$ and $\theta_2 = \pi/2$, link lengths $l_1 = 1$ and $l_2 = 1$ assuming that gravity does not play any role.

3. Find the joint torques for a two DOF manipulator considering the acceleration due to gravity, when $\theta_1 = 0$, $\theta_2 = \pi/4$, $\dot{\theta}_1 = 0$ rad/s $\dot{\theta}_2 = 2$ rad/s link lengths $l_1 = 1$m and $l_2 = 1$m with mass m_1 and m_2 = 0.5 kg.
4. Develop a trajectory for a robot whose initial and final position are given as $\theta_i = -45^\circ$ and $\theta_f = 15^\circ$ and governing equation is $\theta(t) = -45 + 24t + 4t^2$. Determine the time period for this trajectory.

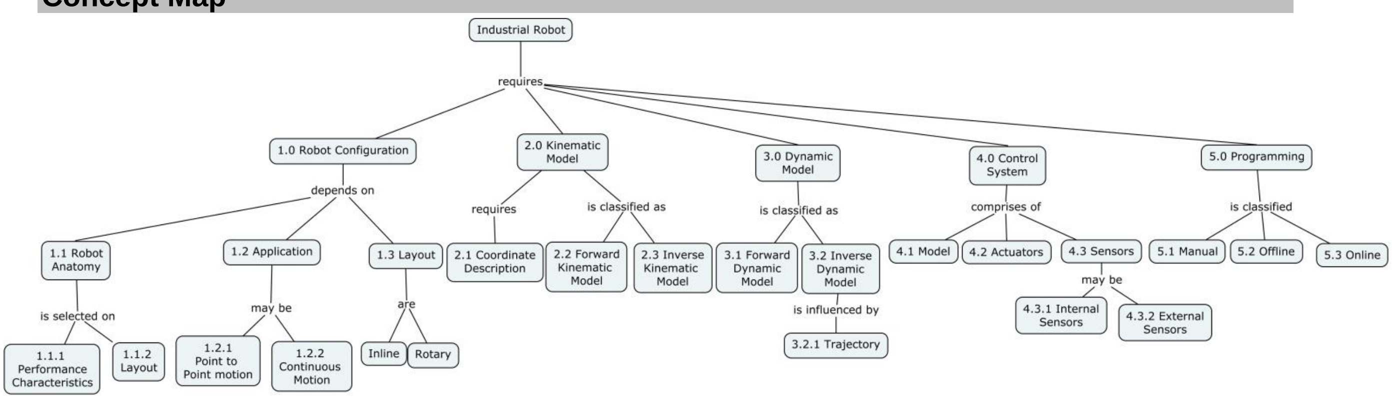
Course Outcome 4 (CO4):

1. Explain step by step procedure for implementation of Proportional-Derivate control for single joint robot arm.
2. Explain how optical encoder is used in the operation of robot.
3. With a neat sketch, explain the architecture of robot controller.

Course Outcome 5 (CO5):

1. Write a robot programming for a palletizing operation. The robot must pick up the parts from an incoming chute and deposit them onto a pallet. The pallet has four rows that are 50 mm apart and six columns that are 40 mm apart. The plane of the pallet is assumed to be parallel to XY plane. The rows of the pallet are parallel to the x-axis and the columns of the pallet are parallel to the Y-axis. The objects are to be picked up are about 25 mm tall.
2. Write a VAL statements for defining coordinate frame *'Grasp – Point 1'* which can be obtained by rotating coordinate frame '*Block – Point 2'* through an angle 65° about Y-axis and then translate it by 100 and 150 mm in X and Y axes respectively.
3. Write a program in VAL II to instruct the robot to pick up bottles from a fixed location on a conveyor and insert them into a cardboard carton. A mechanical stop along the conveyor is used to locate the parts in known position. The bottles are to be loaded into the carton about 12 in. away from the pickup point. Each carton holds two parts. Open cartons are presented to the robot and then subsequently closed and sealed at a different location. The open cartons are 4.0 in. tall and measure 5.0 by 10.0 in. The bottles to be loaded are 4.5 in. in diameter. Make a sketch of the workstation before programming and identify the various points used in the program.

Concept Map



Syllabus

Robot Configuration: Robot Anatomy - Sub-systems of an Industrial Robot – Performance characteristics of industrial Robots – Robot Specifications. Applications – Point to point and continuous motion applications. Layout of robotic cell: Inline and rotary robotic cell. Progressive advancement in Robots.

Kinematic model: Coordinate Description: Coordinate frames, Description of objects in space, Transformation of vectors, Fundamental rotation matrices (principal axes and fixed angle rotation). Forward Kinematics for two DOF manipulator: Algebraic method. Forward Kinematics for multi DOF manipulator - Mechanical structure and notations, Description of links and joints, Denavit-Hartenberg (DH) notation. Inverse kinematics of two DOF manipulator - Manipulator workspace.

Dynamic model: Euler-Lagrangian method – Inverse dynamic model for one and two DOF manipulator - Expression for forward dynamic model of one DOF manipulator. Trajectory planning: Definitions and planning tasks, Joint space techniques – Motion profiles – Cubic polynomial motion.

Control System: The manipulator control problem, Linear second-order model of manipulator. Functions of controller and power amplifier. Joint actuators- stepper motor, servo motor. Control Schemes: PID control scheme – Position and force control schemes. Robotic sensors and its classification, Internal sensors – Position, velocity, acceleration and force information, External Sensors – Contact sensors-Limit switches, piezo-elcetric, pressure pads, Non-contact sensors – Range sensors, Vision sensor- robotic vision system, Description of components of vision system.

Robot Programming: Manual Programming – Teach Pendant, Offline programming VAL programming – method - robot offline programming languages, Online Programming. Importance of artificial intelligence.

Reference Books/Learning Resources

1. K.S. Fu, R.C Gonzalez and C.S. Lee, Robotics- Control, Sensing, Vision and Intelligence, Tata McGraw-Hill Editions, 2008
2. S.K.Saha, “Introduction to Robotics”, Second Edition, Mc Graw Hill Education (India) Private Limited, New Delhi, 2014.
3. John J.Craig, Introduction to Robotics, Mechanics and control, Third edition, Pearson education, 2005.
4. Mark W.Spong, M.Vidyasagar, Robot dynamics and control, Wiley India, 2009.
5. Mikell P. Groover, Mitchell Weiss, Roger N.Nagel and Nicholas G. Odrey, “Industrial Robotics” – Technology, Programming and Applications” Tata McGraw-Hill Edition, 2008.
6. Robert J. Schiling, “Fundamentals of Robotics: Analysis and Control”, Indian Reprint, Prentice Hall of India Private Limited, 1990.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.	**Robot Configuration:**	
1.1	Robot Anatomy - Sub-systems of an Industrial Robot	1
1.1.1	Performance characteristics of industrial Robots – Robot specifications	1
1.2	Applications – Point to point and continuous motion applications.	1
1.2.1	Progressive advancement in Robots	
1.3	Layout of robotic cell: Inline and rotary robotic cell	1
2.	**Kinematic model:**	
2.1	Coordinate Description: Coordinate frames, Description of objects in space, Transformation of vectors, Fundamental	2

Module No.	Topic	No. of Lectures
	rotation matrices (principal axes and fixed angle rotation).	
2.2	Forward Kinematics Model	1
2.2.1	Forward Kinematics for two DOF manipulator - Algebraic method	1
2.2.2	Forward Kinematics for multi DOF manipulator - Mechanical structure and notations, Description of links and joints - Denavit-Hartenberg (DH) notation.	2
2.3	Inverse kinematic model of two DOF manipulator	2
2.3.1	Manipulator workspace	1
3.	**Dynamic model:**	
3.1	Lagrangian-Euler Formulation of dynamic model	1
3.1.1	Forward Dynamic Model for one DOF manipulaotor	2
3.1.2	Inverse dynamic model for one DOF manipulator	1
3.1.3	Inverse dynamic model for two DOF manipulator	2
3.2	Trajectory planning: Definitions and planning tasks	1
3.2.1	Joint space techniques – Motion profiles – Cubic polynomial motion	1
4.	**Control System:**	
4.1	The manipulator control problem	1
4.1.1	Linear second-order model of manipulator. Functions of controller and power amplifier.	1
4.2	Joint actuators- stepper motor, servo motor.	1
4.3	Control Schemes: PID control scheme – Position and force control schemes.	1
4.4	Robotic sensors and its classification	1
4.4.1	Internal sensors – Position, velocity, acceleration and force information	1
4.4.2	External Sensors – Contact sensors-Limit switches, piezo-elcetric, pressure pads.	1
4.4.3	Non-contact sensors – Range sensors, Vision sensor- robotic vision system, Description of components of vision system.	1
5.	**Robot Programming:**	
5.1	Manual Programming – Teach Pendant	1
5.2	Robot offline programming languages	1
5.2.1	Offline programming VAL programming – Pick and place and sorting applications	2
5.2.2	Offline programming VAL programming – Palletizing applications	1
5.3	Online Programming	1
5.4	Artificial intelligence - importance	1
	Total	**36**

Course Designer:

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14MEGD0	COMPOSITE MATERIALS	Category	L	T	P	Credit
		GE	3	0	0	3

Preamble

Composite materials (also called composition materials or shortened to composites) are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter or less expensive when compared to traditional materials. This course covers the fundamentals of composite material and manufacturing of various composite materials

Prerequisite

- Nil

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the various Fibers and Matrix Materials	Understand
CO 2.	Identify the various polymer matrix composites processing methods	Apply
CO 3.	Explain the Lamina Constitutive Equations	Apply
CO 4.	Choose the various processing methods of metal matrix composites	Apply
CO 5.	Processing of ceramic matrix composites and carbon - carbon Composites	Understand

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1.	S	M	L	L	_	_	_	_	_	_	_	_	M	_	M
CO2.	S	S	M	L	_	_	_	_	_	_	_	_	S	_	S
CO3.	S	M	S	L	_	_	_	_	_	_	_	_	S	_	S
CO4.	S	S	M	L	_	_	_	_	_	_	_	_	S	_	S
CO5.	S	M	L	L	_	_	_	_	_	_	_	_	S	_	S
	S	S	M	L	_	_	_	_	_	_	_	_	S	_	S

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	30	20	20	20
Understand	70	60	60	60
Apply	0	20	20	20
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define composite material
2. List the properties of glass fibre
3. Explain the various types of matrix materials

Course Outcome 2 (CO2):

1. Differentiate between thermosetting and thermo plastics
2. List the components manufactured using filament winding technique
3. Discuss the compression moulding technique for the fabrication of PMC.

Course Outcome 3 (CO3):

1. Write the transformation matrix for a lamina
2. List the lamina assumptions used in classic laminate theory.
3. Derive the rule of mixture equation.

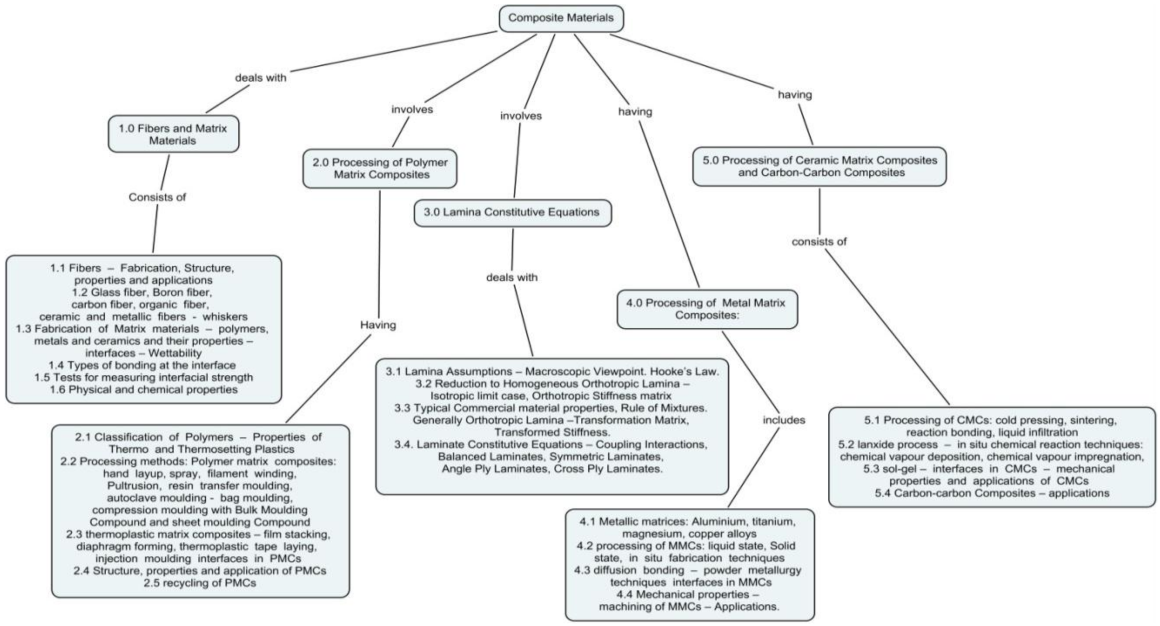
Course Outcome 4 (CO4):

1. Define Powder metallurgy.
2. Explain the In Situ fabrication technique.
3. Identify a manufacturing method for fabricating aluminium silicon composites.

Course Outcome 5 (CO5):

1. State the applications of ceramic matrix composites.
2. Explain the cold pressing technique with necessary illustrations.
3. Suggest a suitable method for fabricating carbon-carbon composites.

Concept Map



Syllabus

Fibers and Matrix Materials : Fibers – Fabrication, Structure, properties and applications – Glass fiber, Boron fiber, carbon fiber, organic fiber, ceramic and metallic fibers - whiskers– Fabrication of Matrix materials – polymers, metals and ceramics and their properties – interfaces – Wettability – Types of bonding at the interface – Tests for measuring interfacial strength - Physical and chemical properties.

Processing of Polymer Matrix Composites: Classification of Polymers – Properties of Thermo and Thermosetting Plastics – Extrusion, Polymer matrix composites: hand layup, spray, filament winding, Pultrusion, resin transfer moulding, autoclave moulding - bag moulding, compression moulding with Bulk Moulding Compound and sheet Moulding Compound – thermoplastic matrix composites – film stacking, diaphragm forming, thermoplastic tape laying, injection moulding – interfaces in PMCs - structure, properties and application of PMCs –recycling of PMCs.

Lamina Constitutive Equations: Lamina Assumptions – Macroscopic Viewpoint. Generalized Hooke's Law. Reduction to Homogeneous Orthotropic Lamina – Isotropic limit case, Orthotropic Stiffness matrix (Q_{ij}), Typical Commercial material properties, Rule of Mixtures. Generally Orthotropic Lamina –Transformation Matrix, Transformed Stiffness. Laminate Constitutive Equations – Coupling Interactions, Balanced Laminates, Symmetric Laminates, Angle Ply Laminates, Cross Ply Laminates.

Processing of Metal Matrix Composites: Metallic matrices: Aluminium, titanium, magnesium, copper alloys – processing of MMCs: liquid state, Solid state, in situ fabrication techniques – diffusion bonding – powder metallurgy techniques interfaces in MMCs – mechanical properties – machining of MMCs – Applications. Introduction to Nano composites.

Processing of Ceramic Matrix Composites and Carbon-Carbon Composites: Processing of CMCs: cold pressing, sintering, reaction bonding, liquid infiltration, lanxide process – in situ chemical reaction techniques: chemical vapour deposition, chemical vapour impregnation, sol-gel – interfaces in CMCs – mechanical properties and applications of CMCs – Carbon-carbon Composites – applications.

Reference Books

1. Krishnan K Chawla, Composite Materials: Science and Engineering, International Edition, Springer, 2012
2. Mallick P.K., Fiber Reinforced Composites: Materials, Manufacturing and Design, CRC press, New Delhi, 2010
3. Isaac M. Daniel, Ori Isha, Engineering Mechanics of Composite Materials, Oxford University Press, 2005
4. Mallick, P.K. and Newman.S., Composite Materials Technology, Hanser Publishers, 2003.
5. Said Jahanmir, Ramulu M. and Philp Koshy, Machining of Ceramics and Composites, Marcel Dekker Inc., New York, 1999
6. Bhagwan D. Agarwal, Lawrence J. Broutman, K. Chandrashekhara , Analysis and Performance of Fiber Composites, 3rd Edition, John Wiley & Sons,2006.
7. Robert M. Jones, Mechanics Of Composite Materials (Materials Science & Engineering Series), Taylor & Francis, 2015

Course contents and Lecture schedule

Module Number	Topics	No. of Lectures
1.0	**Fibers and Matrix Materials**	
1.1	Fibers – Fabrication, Structure, properties and applications	2
1.2	Glass fiber, Boron fiber, carbon fiber, organic fiber, ceramic and metallic fibers - whiskers	2
1.3	Fabrication of Matrix materials – polymers, metals and ceramics and their properties – interfaces – Wettability	2
1.4	Types of bonding at the interface	2
1.5	Tests for measuring interfacial strength	2
1.6	Physical and chemical properties	1
2.0	**Processing of Polymer Matrix Composites**	
2.1	Classification of Polymers – Properties of Thermo and Thermosetting Plastics	2
2.2	Processing methods: Polymer matrix composites: hand layup, spray, filament winding, Pultrusion, resin transfer moulding, autoclave moulding - bag moulding, compression moulding with Bulk Moulding Compound and sheet moulding Compound	3
2.3	thermoplastic matrix composites – film stacking, diaphragm forming, thermoplastic tape laying, injection moulding interfaces in PMCs	3
2.4	Structure, properties and application of PMCs	2
2.5	recycling of PMCs	1

Module Number	Topics	No. of Lectures
3.0	**Lamina Constitutive Equations**	
3.1	Lamina Assumptions – Macroscopic Viewpoint. Generalized Hooke's Law.	2
3.2	Reduction to Homogeneous Orthotropic Lamina – Isotropic limit case, Orthotropic Stiffness matrix	2
3.3	Typical Commercial material properties, Rule of Mixtures. Generally Orthotropic Lamina –Transformation Matrix, Transformed Stiffness.	3
3.4	Laminate Constitutive Equations – Coupling Interactions, Balanced Laminates, Symmetric Laminates, Angle Ply Laminates, Cross Ply Laminates.	3
4.0	**Processing of Metal Matrix Composites:**	
4.1	Metallic matrices: Aluminium, titanium, magnesium, copper alloys	3
4.2	processing of MMCs: liquid state, Solid state, in situ fabrication techniques	3
4.3	diffusion bonding – powder metallurgy techniques interfaces in MMCs	2
4.4	Mechanical properties – machining of MMCs – Applications. Introduction to Nano composites.	2
5.0	**Processing of Ceramic Matrix Composites and Carbon-Carbon Composites**	
5.1	Processing of CMCs: cold pressing, sintering, reaction bonding, liquid infiltration	2
5.2	lanxide process – in situ chemical reaction techniques: chemical vapour deposition, chemical vapour impregnation,	1
5.3	sol-gel – interfaces in CMCs – mechanical properties and applications of CMCs	2
5.4	Carbon-carbon Composites – applications.	2
	Total	47

Course Designers

1. M. Kathiresan umkathir@tce.edu
2. V. Balasubramani vbmec

14MEGE0	BASICS OF AUTOMOBILE ENGINEERING	Category	L	T	P	Credit
		GE	3	0	0	3

Preamble

This course is all about learning the general construction and working of an automobile. It covers needs, construction and working of various subsystems of an automobile such as prime mover (I.C.Engine), transmission, braking, suspension and steering. It also focuses on the recent developments in the field of automobile engineering.

Prerequisite

- 14PH120 - Physics
- 14ES150 - Basics of Civil and Mechanical Engineering

Course Outcomes

On the successful completion of the course, students will be able to

Sl. No	Course Outcomes	Blooms level
CO 1.	Classify automobiles and explain the major parts and its functions of an automobile.	Understand
CO 2.	Understand the construction and working of various sub systems of an automobile and their functions	Understand
CO 3.	Explain the recent developments in the field of automobile engineering	Understand

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1.	M	L	M	L	_	_	_	_	_	_	_	_	_	_	L
CO2.	M	L	M	L	_	_	_	_	_	_	_	_	_	_	L
CO3.	M	L	M	L	_	_	_	_	_	_	_	_	_	_	L
	M	L	M	L	_	_	_	_	_	_	_	_	_	_	L

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			Terminal Examination
	1	2	3	
Remember	20	20	20	20
Understand	80	80	80	80
Apply	0	0	0	0
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. What are the main components used in an automobile?
2. Tell the functions of piston rings.
3. List out the major subsystems of an automobile.

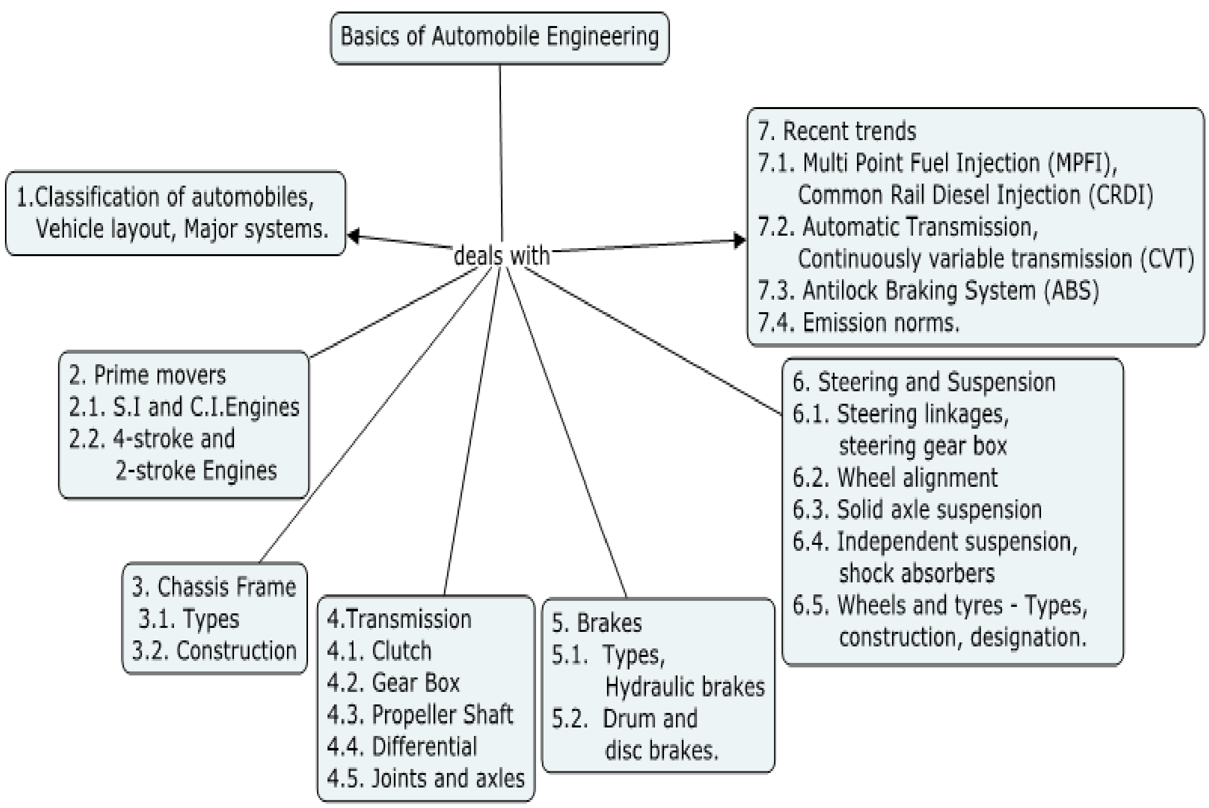
Course Outcome 2 (CO2):

1. Explain the working of a three speed sliding mesh gear box with the help of a diagram.
2. State the purpose of front and rear universal joints.
3. Describe tyre construction in brief.

Course Outcome 3 (CO3):

1. Tell the major benefits of anti lock braking system.
2. With a schematic layout explain the working principle of MPFI system used in modern cars.
3. Name the three basic components of a continuously variable transmission.

Concept Map



Syllabus

Introduction: Classification of automobiles, Vehicle layout, Major systems of an automobile.
Prime mover: Engines – Construction and working of 2-stroke and 4-stroke S.I and C.I.Engines, Major components.

Chassis frame: Construction, Types.
Transmission – Construction and working of Clutch, Gear Box, Differential, Propeller shaft, Joints and Axles.
Brakes- Types, layout of hydraulic brakes, construction of drum and disc brakes.
Steering and Suspension – steering linkages, steering gear box, wheel alignment, construction and working of solid axle suspension and independent suspension, working of shock absorbers. Wheels and tyres - Types, construction, designation.

Recent trends- Multi Point Fuel Injection (MPFI), Common Rail Diesel Injection (CRDI), Automatic Transmission, Continuously variable transmission (CVT). Antilock Braking System (ABS), Emission norms.

Text Books

1. Kirpal Singh, "**Automobile Engineering**", Volume 1 & 2, Seventh Edition, Standard Publishers, New Delhi, 2011.
2. Jain K.K and Asthana R.B, **"Automobile Engineering"** Tata McGraw Hill Publishers, New Delhi, 2002.

Reference Books

1. Joseph Heitner, **"Automotive Mechanics"** Second Edition, East-West Press, 1999
2. William Crouse and Donald Anglin, **"Automotive Mechanics"**, McGraw Hill Education, 10th edition, 2006.
3. Videos by "National Programme on Technology Enhanced Learning" available at "**www.nptelvideos.in**".

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Introduction**	
1.1	Classification of automobiles, Vehicle layout, Major systems of an automobile.	2
2	Prime Mover	
2.1	Engines – Construction and working of S.I and C.I.Engines	2
2.2	Construction and working of 2-stroke and 4-stroke Engines.	2
3	**Chassis frame**	
3.1	Types	1
3.2	Construction	1
4	**Transmission**	
4.1	Clutch	2
4.2	Gear Box	2
4.3	Differential	1
4.4	Propeller shaft	1
4.5	Joints and Axles	2
5	Brakes	
5.1	Types, layout of hydraulic brakes and its working	2
5.2	Disc and Drum brakes	2
6	Steering and Suspension	
6.1	Steering links, Steering gear	2
6.2	Wheel alignment	1
6.3	Solid axle suspension	2

Module No.	Topic	No. of Lectures
6.4	Independent suspension, shock absorbers.	2
6.5	Wheels and tyres- Types, construction, designation.	2
7	**Recent trends**	
7.1	MPFI, CRDI	2
7.2	Automatic Transmission, Continuously varying transmission (CVT)	2
7.3	Antilock Braking System (ABS)	2
7.4	Emission Norms	1
	TOTAL	**36**

Course Designers:

1. Karthikeyan, B bkmech@tce.edu
2. Samuel Raja, A samuel1973@tce.edu

14MEGF0	MANUFACTURING OF AUTOMOTIVE ELECTRICAL AND ELECTRONICS PARTS	Category	L	T	P	Credit
		GE	3	0	0	3

Preamble:

This course 'Manufacturing of automotive electrical and electronics engineering, a departmental Elective course, is preceded by courses "Utilization of Electrical energy", Basic Electrical and Electronics Engineering and 'Basics of Mechanical Engineering' The course mainly discusses the manufacturing process of different automotive electrical, Electronics and lighting parts and its implantation in the vehicle.

Prerequisite

- Nil

Course Outcomes

Sl. No	Course Outcomes	Blooms level
CO 1.	Explain the Vehicle Integration, Mounting methods, Routing methods, Fastening and Clearance/Interference fit	Understand
CO 2.	Explain the Process flow, process specifications and Inspection methodologies for Starter Motor, relay, horn, switches and wiring harness	Understand
CO 3.	Explain the PCB fabrication process	Understand
CO 4.	Discuss the automotive lighting systems in the vehicle	Understand

Assessment pattern:

S. NO	Bloom's Category	Test 1	Test 2	Test 3/End-semester examination
1	Remember	40	40	40
2	Understand	60	60	60
3	Apply	0	0	0
4	Analyze	0	0	0
5	Evaluate	0	0	0
6	Create	0	0	0

Mapping with Programme Outcomes

COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1.	M	M	M	L	L	M	_	_	_	_	_	_	L	_	M
CO2.	L	L	M	L	M	M	_	_	_	_	_	_	L	_	M
CO3.	M	M	M	L	L	L	_	_	_	_	_	_	L	_	L
CO4.	M	M	L	L	L	M	_	_	_	_	_	_	L	_	M
	M	M	M	L	M	M	_	_	_	_	_	_	L	_	M

Course Level Learning Objectives

CO1:

1. List the parts used for routing wiring harness along a vehicle frame
2. How is a battery mounted on a vehicle frame?

CO2:

1. How is a Starter Motor mounted on an engine?
2. Why is a rubber boot generally used for mounting an electronic unit on a vehicle frame?
3. Why is a corrugated tube used in a wiring harness?

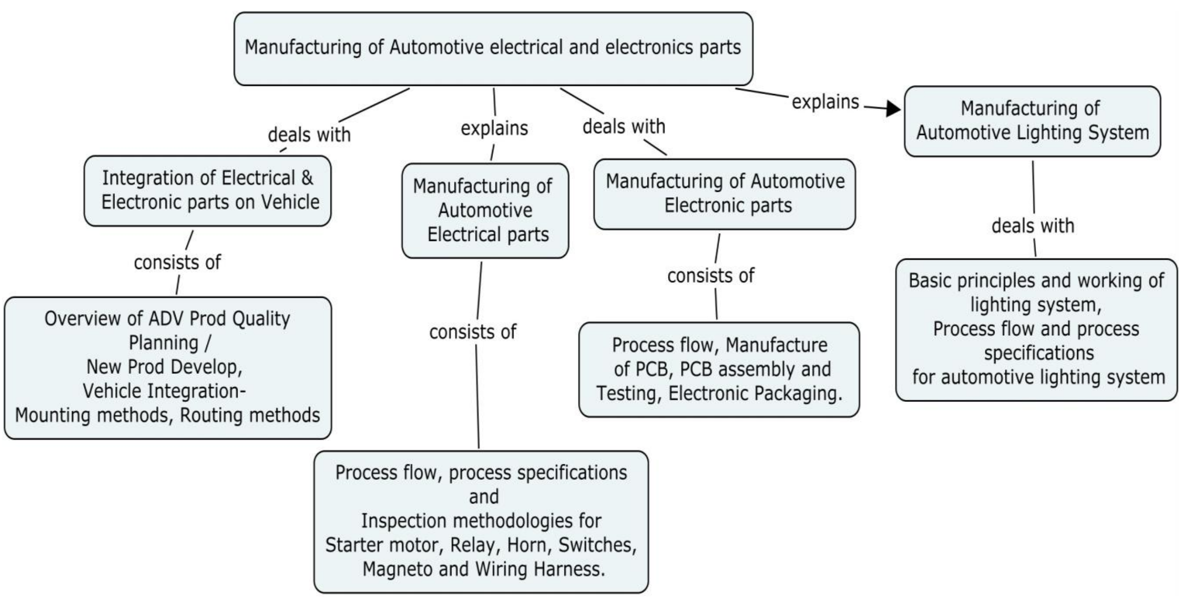
CO3:

1. Explain the reflow soldering process? How is it different from wave soldering?
2. How are PCBs tested for correct assembly and soldering at end of line?

CO4:

1. Explain the process of manufacturing a vehicle headlamp?
2. What are the critical process parameters that affect light intensity in a vehicle headlamp? How do they affect the light intensity?

Concept Map



Syllabus

Integration of Electrical & Electronic parts on Vehicle: Overview of ADV Prod Quality Planning /New Prod Develop, Vehicle Integration- Mounting methods, Routing methods, Fastening, Clearance/Interference fit. **Manufacturing of Automotive Electrical parts:** Process flow, process specifications and Inspection methodologies for Starter motor, Relay, Horn, Switches, Magneto and Wiring Harness. **Manufacturing of Automotive Electronic parts:** Process flow, Manufacture of PCB, PCB assembly and Testing, Electronic Packaging. **Manufacturing of Automotive Lighting System:** Basic principles and working of lighting system, Process flow and process specifications for automotive lighting system

References:

1. APQP Manual

Course Contents and lecture schedule

S.No	Topic	No of Lectures
1.	**Integration of Electrical & Electronic parts on Vehicle**	
1.1	Overview of APQP/NPD	4
1.2	Vehicle Integration- Mounting methods, Routing methods, Fastening, Clearance/Interference fit	4
2.	**Manufacturing of Automotive Electrical parts**	
2.1	Process flow, process specifications and Inspection methodologies for Starter Motor	3
2.2	Process flow, process specifications and Inspection methodologies for Relay	2
2.3	Process flow, process specifications and Inspection methodologies for Horn	2
2.4	Process flow, process specifications and Inspection methodologies for Switches	2
2.5	Process flow, process specifications and Inspection methodologies for Magneto	3
2.6	Process flow, process specifications and Inspection methodologies for Wiring Harness	2
3.	**Manufacturing of Automotive Electronic parts**	
3.1	Process flow for manufacture of PCB	4
3.2	Methods of manufacturing of PCB	4
3.3	PCB assembly and Testing	3
3.4	Electronic Packaging	3
4.	**Manufacturing of Automotive Lighting System**	
4.1	Process flow for manufacturing automotive lighting system	2
4.2	Process specifications and Inspection methodologies for automotive lighting system	2

Course designers:

1. Dr. S. Arockia Edwin Xavier - saexeee@tce.edu

CURRICULUM AND DETAILED SYLLABI

FOR

B.E DEGREE (Mechanical Engineering) PROGRAMME

ONE CREDIT COURSES

FOR THE STUDENTS ADMITTED FROM THE

ACADEMIC YEAR 2014-2015 ONWARDS

THIAGARAJAR COLLEGE OF ENGINEERING
(A Government Aided ISO 9001-2008 certified
Autonomous Institution affiliated to Anna University)

MADURAI – 625 015, TAMILNADU

Phone: 0452 – 2482240, 41
Fax: 0452 2483427
Web: www.tce.edu

ONE credit courses to be passed in 52nd Academic Council Meeting

14 ME1A0	Product Life Cycle Management
14ME1B0	Mechanical Engineering Perspective in Rocketry Systems.
14ME1C0	Basics of HVAC
14ME1D0	Nuclear engineering
14ME1F0	Industrial Hydraulics
14ME1G0	3D Printing
14ME1H0	Finite Element Method for Product Development
14ME1K0	Non Destructive Testing
14ME1L0	Gas Turbine Engines
14ME1M0	Value Engineering
14ME1N0	Six Sigma

14 ME1A0	PRODUCT LIFE CYCLE MANAGEMENT	Category	L	T	P	Credit
		PC	1	0	0	1

Preamble

Product life cycle management (PLM) is the process of managing the entire lifecycle of a product from its conception, through design and manufacture, to service and disposal. PLM integrates people, data, processes and business systems and provides a product information backbone for companies and their extended enterprise. PLM systems help organizations in coping with the increasing complexity and engineering challenges of developing new products for the global competitive markets.

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Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO 1.	Explain the basic concepts of Product Life Cycle Management (PLM).	Understand
CO 2.	Explain the NPDI processes and its various challenges.	Understand
CO3.	Map PLM Functional Capabilities versus Product Lifecycle Challenges.	Apply
CO 4.	Explain the various functionalities / solutions present in PLM Software.	Understand
CO 5.	Explain the product data and product design changes that can be managed in PLM.	Understand

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	P10	P11	P12
CO1		L							M			L
CO2		M							M			L
CO3		M							L			L
CO4		L							L			L
CO5		L							L			S

S- Strong; M-Medium; L-Low

Assessment Pattern

1. Out of 100 Marks, 50 Marks (Internal) will be for Mini project/Assignment and 50 Marks will be for End Semester Exam.
2. End Semester Question pattern will be a combination of both multiple choice and descriptive questions.

Bloom's Category	Terminal Examination
Remember	20
Understand	20
Apply	60
Analyse	
Evaluate	
Create	

Syllabus

Product Life Cycle Management- Introduction, Overview of PLM-Concept of Product Life Cycle, NPDI-Product development Stage Gate Processes Overview- Product development Strategies for various industries, ETO, CTO, MTO, MTS Business scenarios, Product development & Lifecycle challenges, Challenges faced by Industries, Business Drivers for PLM, Definition –Applicable of PLM, Evolution of PLM, Past, Today and Future state of PLM, PLM core capabilities, Core Capabilities like Product Data Management, Product Structure, Workflow, Change Management etc. PLM advanced capabilities, Extended capabilities like Cost Management, Portfolio, Analytics, System Engineering, PLM Solutions, Tools and associated technology, Product Lifecycle Stages and IT Tools, PLM Vendors and their software Products, PLM Technologies, PLM Architecture, Student Exercise- Map PLM Functional Capabilities Versus Product Lifecycle Processes, Map PLM Functional Capabilities Versus NPDI Challenges, PLM Product Demonstration- Demonstrate PLM Part Release and Change Management, Student Exercise to use PLM system- Part Release Management - Exercise in PLM Software, Product Design Change Management - Exercise in PLM Software

Reference Books

1. Michael Grieves,"**Product Lifecycle Management: Driving the Next Generation of Lean Thinking"** McGraw-Hill, 2006.
2. John Stark, **"Product Lifecycle Management: 21st century Paradigm-Realization"**, Springer-Verlag GmbH, 2005
3. Kenneth B. Kahn, **"The PDMA Handbook of New Product Development**", Wiley, 2013.
4. Philip Kotler, "**A Framework for Marketing Management", ** Pearson, 2011.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	Introduction	
1.1	Product Life Cycle Management- Introduction, Overview of PLM- Concept of Product Life Cycle	1
1.2	NPDI-Product development Stage Gate Processes Overview,	2
1.3	Product development Strategies for various industries, ETO, CTO, MTO, MTS Business scenarios	3
1.4	Why PLM?-Product development & Lifecycle challenges, Challenges faced by Industries (OEM, Suppliers, Contractors, End Users), Business Drivers for PLM, Definition of PLM, Where PLM Applicable, Evolution of PLM, Past, Today and Future state of PLM,	1
1.5	PLM core capabilities- Core Capabilities like Product Data Management, Product Structure, Workflow, Change Management etc.	2
1.6	PLM advanced capabilities- Extended capabilities like Cost Management, Portfolio, Analytics, System Engineering	1
1.7	PLM Solutions, Tools and associated technology- Product Lifecycle Stages and IT Tools, PLM Vendors and their software Products, PLM Technologies, PLM Architecture	2
1.8	Student Exercise- Map PLM Functional Capabilities Versus Product Lifecycle Processes, Map PLM Functional Capabilities Versus NPDI Challenges,	1
1.9	PLM Product Demonstration- Demonstrate PLM Part Release and Change Management,	1
2.0	Student Exercise to use PLM system- Part Release Management - Exercise in PLM Software, Product Design Change Management - Exercise in PLM Software	2
	Total	**16**

Course Designers:

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14ME1B0	MECHANICAL ENGINEERING PERSPECTIVES IN ROCKETRY SYSTEMS	Category	L	T	P	Credit
		PC	1	0	0	1

Preamble

Rocketry is the branch of science that deals with rockets and rocket propulsion. In order to understand the behavior of rockets it is necessary to have a basic grounding in physics, in particular some of the principles of statics and dynamics, The course provides a fundamental Knowledge in rocketry system, selection of aerospace materials, control and navigation system, usage of avionics packages.

Prerequisites

- 14ME340 – Fluid Mechanics
- 14ME440 - Thermal Engineering

Course Outcomes

On the successful completion of the course, students will be able to

CO 1.	Explain the structural dynamics of rocketry systems.	**Apply**
CO 2	Select suitable aerospace materials and fasteners	**Apply**
CO 3.	Explain the working principles of propulsion system.	**Understand**
CO 4.	Explain the current avionics packages and technologies.	**Understand**

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1.	S	S	S	L	L	-	-	-	-	-	S	-
CO2.	S	S	S	L	M	-	-	-	-	-	S	-
CO3.	S	S	S	L	S	-	-	-	-	-	S	-
CO4.	S	S	M	M	M	-	-	-	-	-	S	-

S- Strong; M-Medium; L-Low

Assessment Pattern

1. Out of 100 Marks, 50 Marks (Internal) will be for Mini project/Assignment and 50 Marks will be for End Semester Exam.
2. End Semester Question pattern will be a combination of both multiple choice and descriptive questions.

Bloom's Category	Terminal Examination
Remember	40
Understand	40
Apply	20
Analyse	-
Evaluate	-
Create	-

Syllabus

Introduction-overview of flight vehicle systems, Flight vehicle configuration, configuration management, types of flight vehicles, multistage flight vehicles, hot and cold launch, stage sizing, technologies in flight vehicle systems, launch platforms, ground system, Structural Dynamics in rocket systems, fundamentals, mechanical parameters in vibration, mass spring system, quantifying vibration, signal types, resonance, isolation, base excitation, shock, isolation of vibration and shock.

Aerospace Materials-types of aerospace materials, re entry environment, materials properties, airframe and motor case materials, specific modulus, wave velocity, composites, testing and qualification, QA aspects. Aerospace Fasteners-Flight section joints, fasteners, classification of fasteners, methods of fastening, washers, corrosion, corrosion resistant fasteners, hydrogen embrittlement & de-embrittlement, stainless steel fasteners, fastener manufacturing, torque estimation.
Propulsion –Requirement- definition, types of propulsion, choosing a propulsion system, staging of flight vehicle, ordnances in flight system- Control, Guidance And Navigation System -Basic rocket motion, powered phase, coasting, centre of pressure and gravity, stability, gimballing, trajectory management, radars, actuators [hydraulics, electro mechanical- Mechanical Aspects Of Avionics Packages-EMI/EMC requirements, battery &power systems, telemetry systems , Centre of gravity and Moment of Inertia measurements, packaging acceptance and qualification- Challenges In Aerospace Technologies -ABC [Atomic Biological Chemical Weapon] systems, MIRVS[Multiple Independent Re entry Vehicle System], ENEC, thrust termination, ABMS [anti ballistic missile systems], Space Defence.

Reference Books

1. George P Sutton, Oscar Biblarz, “**Rocket Propulsion Elements**”. Eighth Edition , John Wiley & Sons. Inc. ,2010
2. WilliamT.Thomson,“**Theory of Vibrations and Applications**”, Fifth edition Pearson Education 2008.
3. Autar K Kaw , “**Mechanics of Composite Materials**” Second Edition, CRC Press, 2005

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	Introduction	
1.1	overview of flight vehicle systems, Flight vehicle configuration, configuration management, types of flight vehicles, multistage flight vehicles, hot and cold launch, stage sizing, technologies in flight vehicle systems, launch platforms, ground system,	2
1.2	Structural Dynamics in rocket systems, fundamentals, mechanical parameters in vibration, mass spring system, quantifying vibration, signal types, resonance, isolation, base excitation, shock, isolation of vibration and shock.	3
1.3	Aerospace Materials-types of aerospace materials, reentry environment, materials properties, airframe and motor case materials, specific modulus, wave velocity, composites, testing and qualification, QA aspects.	2
1.4	Aerospace Fasteners-Flight section joints, fasteners, classification of fasteners, methods of fastening, washers, corrosion, corrosion resistant fasteners, hydrogen embrittlement & de-embrittlement, stainless steel fasteners, fastener manufacturing, torque estimation.	2
1.5	Propulsion –Requirement- definition, types of propulsion, choosing a	2

Module No.	Topic	No. of Lectures
	propulsion system, staging of flight vehicle, ordnances in flight system,	
1.6	Control, Guidance And Navigation System -Basic rocket motion, powered phase, coasting, centre of pressure and gravity, stability, gimballing, trajectory management, radars, actuators [hydraulics, electro mechanical],	2
1.7	Mechanical Aspects Of Avionics Packages-EMI/EMC requirements, battery &power systems, telemetry systems , Centre of gravity and Moment of Inertia measurements, packaging acceptance and qualification,	1
1.8	Challenges In Aerospace Technologies -ABC [Atomic Biological Chemical Weapon] systems, MIRVS [Multiple Independent Re entry Vehicle System], ENEC, thrust termination, ABMS [anti ballistic missile systems], Space Defence.	2
	Total	**16**

Course Designers

1.	Mr. N.Manickam	Sc'G' ASL, DRDO, Hyderabad
2.	Mr. S.Balaji	Sc'E, ASL, DRDO, Hyderabad
3.	Mr. M.S.Govardhanan	govardhanans07@gmail.com

14ME1C0	**BASICS OF HVAC**	Category	L	T	P	Credit
		PC	1	0	0	1

Preamble

Heating Ventilating and Air Conditioning (HVAC) consumes nearly 25 % of the power being generated in India. Designing energy efficient HVAC system is inevitable, in order to save the energy. In addition to the text book knowledge, it is essential to expose the students and train them on the application part of HVAC as seen in the industry. When got exposed and trained students will come forward to take up HVAC for their career. They will design and develop energy efficient HVAC systems, which in turn benefit the society in energy saving aspects.

Prerequisite

- 14ME440 – Thermal Engineering

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Explain the potentials of HVAC system and its impact on environment.	Understand
CO2	Explain the basics of Psychrometry.	Understand
CO3	Explain the factors to be considered for designing air conditioners.	Understand
CO4	Explain various types of HVAC system and its components.	Understand
CO4	Perform cooling load calculation as per the industry procedure.	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	**S**	**S**	**L**		**M**				**L**	**L**		
CO2	**S**	**M**	**L**		**M**				**L**	**L**		
CO3	**M**	**M**	**L**		**M**				**L**	**L**		
CO4	**M**	**M**	**L**		**M**				**L**	**L**		
CO5	**M**	**L**	**L**									

S- Strong; M-Medium; L-Low

Assessment Pattern

1. Out of 100 Marks, 50 Marks (Internal) will be for Mini project/Assignment and 50 Marks will be for End Semester Exam.
2. End Semester Question pattern will be a combination of both multiple choice and descriptive questions.

Bloom's Category	**Terminal Examination**
Remember	10
Understand	50
Apply	40
Analyse	-
Evaluate	-
Create	-

Syllabus

Definition of HVAC, Market size, Growth, Penetration, opportunities, challenges, definition of Comfort, Benefits of air-conditioning, Difference between comfort / process air-conditioning., Energy usage of HVAC, Scope of Energy saving, HVAC and environment, Greenhouse effect, Global warming, Ozone Layer Depletion- Basic HVAC terminologies- Temperature,

Heat, Types of Heat, Modes of Heat transfer, Tons of Refrigeration, BTU/Hr / Dry bulb, Wet Bulb, Relative humidity, Specific Humidity, Psychrometry, Change of phase- Refrigeration cycle, Components of Refrigeration Cycle. Different types of Compressors- Comfort conditions, Different types of Heat Load, Building Survey, Sources of Heat, SHGC and U value of Glass, Factors to be considered before deciding on AC- Life Cycle Cost, Total cost of ownership, Star Rating of Air-conditioners, Energy Conservation Building Codes, Refrigerant Phase out Schedule, Indoor Air Quality – IAQ, Sick Building Syndrome – SBS, ASHRAE standard 62.1, Green Buildings, LEED Certification- Categories of HVAC System like Unitary, Semi-Central, Central HVAC and its Selection, Air-Cooled Systems – Water Cooled Systems- Variable Refrigerant Flow Systems – VRF, Vapour Absorption Systems, Air Distribution System and its Design- Study of Cost verses Benefit of different systems, Installation procedures of different types of HVAC System, Electrical Safety Precautions, Different types of Maintenance activities, Safety at Work.
Detailed heat load estimation as done in industry- Estimation heat load by students for different types of building.

Reference Books

1. Ibrahim Dincer and Mehmet Kanoglu, "**Refrigeration Systems and Applications**", John Wiley and Sons, 2010.
2. Domkundwar, Arrora and Domkundwar, "**Refrigeration and Air Conditioning**", Dhanpat Rai and Co, 2009.
3. Manohar Prasad, "**Refrigeration and Air Conditioning**", New Age Publishing Ltd, 2010.
4. Jones, W.P., "**Air Conditioning Engineering**",5th Edition, Butterworth Heinemann, 2005.
5. Rex Miller and Mark R. Miller, "**Modern Refrigeration and Air Conditioning**", McGraw-Hill, 2006.
6. Jordan and Priester, "**Air Conditioning and Refrigeration**", Prentice Hall of India, New Delhi, 1985.

Tables:

1. Khurmi,R.S, "**Steam Tables with Mollier Diagrams**", S.Chand and Co., 2010.
2. Maskara, P.N and Sathish Chand, "**Tables and Charts on Refrigerant and Psychrometric properties**", Technical Publishers of India, 2003.

Course Contents and Lecture Schedule

Module No.	Topic	No of Lectures
1,1	Definition of HVAC, Market size, Growth, Penetration, opportunities, challenges, definition of Comfort, Benefits of air-conditioning, Difference between comfort / process air-conditioning., Energy usage of HVAC, Scope of Energy saving, HVAC and environment, Greenhouse effect, Global warming, Ozone Layer Depletion,	1
1.2	Basic HVAC terminologies- Temperature, Heat, Types of Heat, Modes of Heat transfer, Tons of Refrigeration, BTU/Hr / Dry bulb, Wet Bulb, Relative humidity, Specific Humidity, Psychrometry, Change of phase,	1
1.3	Refrigeration cycle, Components of Refrigeration Cycle. Different types of Compressors,	1
1.4	Comfort conditions, Different types of Heat Load, Building Survey, Sources of Heat, SHGC and U value of Glass, Factors to be considered before deciding on AC	1
1.5	Life Cycle Cost, Total cost of ownership, Star Rating of Air-conditioners, Energy Conservation Building Codes, Refrigerant	1

Module No.	Topic	No of Lectures
	Phase out Schedule, Indoor Air Quality – IAQ, Sick Building Syndrome – SBS, ASHRAE standard 62.1, Green Buildings, LEED Certification,	
1.6	Categories of HVAC System like Unitary, Semi-Central, Central HVAC and its Selection, Air-Cooled Systems – Water Cooled Systems	1
1.7	Variable Refrigerant Flow Systems – VRF, Vapour Absorption Systems, Air Distribution System and its Design	1
1.8	Study of Cost verses Benefit of different systems, Installation procedures of different types of HVAC System, Electrical Safety Precautions, Different types of Maintenance activities, Safety at Work.	1
2.1	Detailed heat load estimation as done in industry	4
2.2	Estimation heat load by students for different types of building	4
	Total	**16**

Course Designers:

1. Mr. D.Balaji shreesrb@yahoo.com
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3. Dr. G.Kumaraguruparan gkgmech@tce.edu

		Category	L	T	P	Credit
14ME1D0	**NUCLEAR ENGINEERING**	PC	1	0	0	1

Preamble

Nuclear engineering is the branch of science that deals with theory of nuclear fission and fusion, nuclear reactors and preventive maintenance such as protection from radiation. In order to understand the construction and operation of nuclear reactors, it is necessary to have a basic grounding in atomic physics. The course provides a fundamental knowledge in nuclear power generation and nuclear power plant operation.

Prerequisite

- 14ME440 – Thermal Engineering

Course Outcomes

On the successful completion of the course, students will be able to

CO 1.	Explain theory of nuclear fission and fusion	Understand
CO 2.	Describe the layout of nuclear plant	Understand
CO 3.	Explain the working of various types of nuclear power plants	Understand
CO 4.	Explain preventive measures for radiation from nuclear power plants	Understand

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	S	S	-	-	-	-	-	-	S	-
CO2	S	S	S	S	-	-	-	-	-	-	S	-
CO3	S	S	S	S	-	-	-	-	-	-	S	-
CO4	S	S	S	S	-	-	-	-	-	-	S	-

S- Strong; M-Medium; L-Low

Assessment Pattern

1. Out of 100 Marks, 50 Marks (Internal) will be for Mini project/Assignment and 50 Marks will be for End Semester Exam.
2. End Semester Question pattern will be a combination of both multiple choice and descriptive questions.

Bloom's Category	Terminal Examination
Remember	30
Understand	30
Apply	40
Analyse	0
Evaluate	0
Create	0

Syllabus

Introduction- National and international scenario on nuclear power- Atoms, electrons, Protons, Nucleus, Neutrons, Scattering, Thermal neutrons, controlled and uncontrolled chain reactions- Fission of nucleus, basis for power generation, future power generation by fusion.

Nuclear power generating systems- Boiling water reactors (BWR), Pressurized water reactors(PWR), Pressurized heavy water reactors (PHWR)- Gas cooled thermal reactors (HTGR), Liquid metal cooled fast breed reactor (LMFBR), Light water breed reactor (LWBR).
Description of plant- Site characteristics, structures, components, equipment & systems, reactor- Coolant systems, safety features, instrumentation & controls - Electric power systems, auxiliary systems, radiative waste management.
Radiation Protection- History, units of radiation (Roentgen, exposure rate, imparted energy, Rad, Rem), Effects on the human cell- Radiation protection and dose limiting recommendation.
World's Nuclear reactors and plant operation- Nuclear plants in Limerick, south Texas and Kudan Kulam- Accidents occurred in three mile island plant, Chernobile and Fukushima plants and the variable causes (cooling water loss, control rod drive failure and insufficient training of operating personnel)- Plant operation in i) start-up (cold, hot and normal) ii) shut down (unloading of turbine-generator, maintain steam generator level, Boron dilution)- Preventive maintenance and corrective maintenance- Safety Standards for Nuclear power plant.

Reference Books

1. R.K.Rajput, "**A Textbook of Power Plant Engineering**", Laxmi Publications, 2007.
2. P.K.Nag, "**Power Plant Engineering**", Fourth Edition, Laxmi Publications, 2014.
3. Janet Wood, "**Nuclear Power (Energy Engineering)**", Institution of Engineering and Technology (IET) – Energy series, 2006.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Introduction**	
1.1	National and international scenario on nuclear power	1
1.2	Atoms, electrons, Protons, Nucleus, Neutrons, Scattering, Thermal neutrons, controlled and uncontrolled chain reactions	1
1.3	Fission of nucleus, basis for power generation, future power generation by fusion	2
2	**Nuclear power generating systems**	
2.1	Boiling water reactors (BWR), Pressurized water reactors (PWR), Pressurized heavy water reactors (PHWR)	1
2.2	Gas cooled thermal reactors (HTGR), Liquid metal cooled fast breed reactor (LMFBR), Light water breed reactor (LWBR)	
3	**Description of plant**	
3.1	Site characteristics, structures, components, equipment & systems, reactor	1
3.2	Coolant systems, safety features, instrumentation & controls	1
3.3	Electric power systems, auxiliary systems, radiative waste management	1
4	**Radiation Protection**	
4.1	History, units of radiation (Roentgen, exposure rate, imparted energy, Rad, Rem), Effects on the human cell	2
4.2	Radiation protection and dose limiting recommendation	1
5	**World's Nuclear reactors and plant operation**	

Module No.	Topic	No. of Lectures
5.1	Nuclear plants in Limerick, south Texas and Kudan Kulam	1
5.2	Accidents occurred in three mile island plant, Chernobile and Fukushima plants and the variable causes (cooling water loss, control rod drive failure and insufficient training of operating personnel)	1
5.3	Plant operation in i) start-up (cold, hot and normal) ii) shut down (unloading of turbine-generator, maintain steam generator level, Boron dilution)	1
5.4	Preventive maintenance and corrective maintenance	1
5.5	Safety Standards for Nuclear power plant	1
	Total	**16**

Course Designers:

1. Prof.C.Kothandaraman
2. Dr.A.Samuel Raja Samuel1973@tce.edu

		Category	L	T	P	Credit
14ME1F0	**INDUSTRIAL HYDRAULICS**	PC	1	0	0	1

Preamble

The use of hydraulics for power and motion control has been increasing dramatically in the fields of industrial automation, aviation, automotive, defence, construction and material handling. Unlike many mechanical systems, hydraulic systems can deliver a brute force with pin point accuracy in a split second – and all at the same time. With the advent of proportional and servo hydraulic technology, PLCs and PCs have started to interact with hydraulic actuators directly delivering the ultimate in precision and power transmission. Today industrial hydraulics is an important and matured topic, without which any discussion on power and motion control is incomplete.
This course attempts to expose the students to the basics of industrial hydraulics, fundamental design aspects, associated components, contemporary technologies in the field and application areas.

Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Explain the basics of hydraulics system.	Understand
CO2	Explain the working principles of Hydraulics components	Understand
CO3	Design and Select suitable Hydraulics components for the given Industrial application.	Apply
CO4	Develop the hydraulics circuits for the given application and approach to logical troubleshooting.	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	S	L	L	-	-		M	-	-		S
CO2	S	S	S	S	M	M	M	-	-	-	L	S
CO3	S	S	S	S	M	M	M	-	-	-	L	S
CO4	S	S	M	S	-	-	S	-	-	-	L	S

S- Strong; M-Medium; L-Low

Assessment Pattern

1. Out of 100 Marks, 50 Marks (Internal) will be for Mini project/Assignment and 50 Marks will be for End Semester Exam.
2. End Semester Question pattern will be a combination of both multiple choice and descriptive questions.

Bloom's Category	Terminal Examination
Remember	20
Understand	15
Apply	65
Analyse	
Evaluate	
Create	

Syllabus

Introduction- Types of fluid power systems- Method of power transmission Application areas - Advantages of fluid power- Limitations of Fluid power- Viscosity- Corrosiveness - Pour point -Flash and Fire Points – Demulsibility- Oxidation Stability- Types of Hydraulic Fluid - Mineral Oils- Water Glycols Phosphate esters-Standards for representing fluid power components- Basic Symbol Types -Energy Transmission- Pumps –Motors-Directional Control Valves-Pressure Valves-Flow control Valves-Actuation Methods-Measuring devices-Cylinders- Energy Storage devices- Hybrid or combined circuits-Servo / Proportional valves-Accessories- Reservoir-Pump - Prime Mover-Safety / Control Valves-Measuring gauges-Actuators- Function of reservoir-Atmospheric Vented-Pressurized-Stationary –Mobile Typical Cross section- Pump-Positive Displacement Vs Non Positive Displacement type-Gear-Vane-Piston-Screw-Internal Gear Pump -Principle / Construction –Operation--Advantages / Limitations-Flow , Pressure range-Cost and Brands --Preferred Application Areas -External Gear Pump , Vane Pump ,Axial Piston Pump ,Radial Piston Pump ,Screw pump- Control valves for hydraulics –function types – flow / pressure / direction; Actuation types – mechanical / electrical / pneumatic –design, working and use of variants in each function type.

Proportional and servo technology – advantages - differences between conventional valves / proportional valves / servo valves – typical application areas- Fluid contamination control – importance of clean fluid – key factor affecting reliability - evaluating cleanliness level – Setting target cleanliness levels – design philosophies to achieve and maintain the set target levels – filter types, element designs and criteria to select like Beta ratio- Mobile hydraulics – Special requirements – Reservoir design – Types of control valves – Hydraulic Power steering – Construction equipments.

Selection criteria for components for hydraulic circuits – Application based – Cost based and working environment based- Complete design of a typical industrial hydraulic system for an automatic drilling machine – define requirement and constraints – arrive at required power – design the circuit – choose the Bill Of Material – finalize design- Hydraulics controlled by PLC / PC – Typical set up details – Types of sensors – Solenoids – Preferred software platforms for control coding- Troubleshooting hydraulics – standard tools – logical approach – preventive maintenance.

Reference Books

1. John J. Pippenger, Tyler G. Hicks, "**Industrial Hydraulics**", McGraw-Hill Inc.,US; International 2nd revised edition.
2. Hand out

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.1	Introduction- Types of fluid power systems- Method of power transmission Application areas - Advantages of fluid power- Limitations of Fluid power	1

Module No.	Topic	No. of Lectures
1.2	Viscosity- Corrosiveness - Pour point -Flash and Fire Points – Demulsibility- Oxidation Stability- Types of Hydraulic Fluid -Mineral Oils- Water Glycols Phosphate esters	1
1.3	Standards for representing fluid power components- Basic Symbol Types -Energy Transmission- Pumps –Motors-Directional Control Valves-Pressure Valves-Flow control Valves-Actuation Methods-Measuring devices-Cylinders- Energy Storage devices- Hybrid or combined circuits-Servo / Proportional valves-Accessories	1
1.4	Reservoir-Pump - Prime Mover-Safety / Control Valves-Measuring gauges- Actuators- Function of reservoir-Atmospheric Vented-Pressurized-Stationary –Mobile Typical Cross section	1
1.5	Pump-Positive Displacement Vs Non Positive Displacement type-Gear-Vane-Piston-Screw-Internal Gear Pump -Principle / Construction –Operation--Advantages / Limitations-Flow , Pressure range-Cost and Brands --Preferred Application Areas -External Gear Pump , Vane Pump ,Axial Piston Pump ,Radial Piston Pump ,Screw pump-	1
1.6	Control valves for hydraulics –function types – flow / pressure / direction; Actuation types – mechanical / electrical / pneumatic – design, working and use of variants in each function type.	1
1.7	Proportional and servo technology – advantages - differences between conventional valves / proportional valves / servo valves – typical application areas.	1
1.8	Fluid contamination control – importance of clean fluid – key factor affecting reliability - evaluating cleanliness level – Setting target cleanliness levels – design philosophies to achieve and maintain the set target levels – filter types, element designs and criteria to select like Beta ratio.	2
1.9	Mobile hydraulics – Special requirements – Reservoir design – Types of control valves – Hydraulic Power steering – Construction equipments.	1
2.0	Selection criteria for components for hydraulic circuits – Application based – Cost based and working environment based.	1
2.1	Complete design of a typical industrial hydraulic system for an automatic drilling machine – define requirement and constraints – arrive at required power – design the circuit – choose the Bill Of Material – finalize design.	2
2.2	Hydraulics controlled by PLC / PC – Typical set up details – Types of sensors – Solenoids – Preferred software platforms for control coding	1
2.3	Troubleshooting hydraulics – standard tools – logical approach – preventive maintenance	2
	Total	**16**

Course Designers:

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14ME1G0	**3D PRINTING**	Category	L	T	P	Credit
		PC	1	0	0	1

Preamble

Traditional manufacturing driven by 'subtraction' saw a sign change in 1987: 3D Systems's launch of *Stereo-Lithography Apparatus (SLA)*, demonstrated a new way of manufacturing through 'addition'. The class of these new processes is known as *Rapid Prototyping (RP)* or *3D Printing (3DP)* or, more appropriately, *Layered Manufacturing (LM)* and *Additive Manufacturing (AM)*. 3D Printing realizes complex objects in layers directly from their CAD definitions. The result is *total automation* which revolutionized the way products are designed and manufactured today. These are effective tools for drastically compressing *time-to-market*. 3D Printing has come a long way in terms of materials, quality and process capabilities. It could initially make only polymer components whereas ceramic and metallic parts are possible today. In terms of geometric quality and material homogeneity and variety also, 3D printed parts have improved tremendously although they are still not comparable to machined parts. Several post-build processes have emerged today to improve the surface quality (e.g. liquid polishing) and material integrity (e.g. *Hot Iso-static Pressing (HIP)*). 3D Printing, in conjunction with these post-build processes, facilitates rapid development of even very serious products such as an aero-engine or an implant. 3D Printing and these allied post-build processes together are known as *Rapid Manufacturing (RM)*. RM is considered a very important driver of the ongoing "Third Industrial Revolution" driven by the Internet.

RM can handle with ease challenging geometric and material complexities which were hitherto impossible or extremely difficult. Some of these geometric capabilities are (a) conformal cooling channels, (b) assemblies without joints, (c) customized solutions for aesthetic, ergonomic and bio-medical applications and (d) difficult/impossible shapes by other means; these material capabilities are (a) a variety of monolithic materials, (b) lattice structure such as honeycomb, (c) gradient matrix and (d) non-equilibrium matrix. While traditional *Design for Manufacture (DFM)* restricts the designers, *Design for Rapid Manufacture (DFRA)* gives them more freedom with these deigns possibilities.

There are a variety of options available in RM processes today which fall into three major groups: (a) 3D Printing, (b) RM for polymers and (c) RM for all materials. By 3D printing, the author refers to cheaper AM processes (say, 1,000-15,000 USD) which can be part of any design office just as 2D printers. These are limited to only polymers, have hardly any material options and are not accurate for any serious applications of assembly or testing or durability. Its usage is in quick physical realization of a design for visualization and reviews. "RM for polymers" refers to the processes which cater to mostly polymer components but with assured quality, wide material variety and durability for more serious applications of form, fit and functional tests. "RM for all materials" is the highest level which includes metals and ceramics and it goes beyond prototyping. RM, through its many facets of direct and indirect routes (Vacuum Casting, Epoxy Tooling, Rapid Casting etc.), can be useful in regular production as well. While 3DP has linearity of cost with quantity, RM has the distinction of cost reducing with quantity. While "total automation" is the goal in 3D Printing, RM focuses on "optimal automation".

Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to,

CO 1.	Explain basic concepts of 3D Printing.	Understand
CO 2.	Select the suitable 3D Printing method for a specific application.	Apply
CO 3.	Explain Rapid Manufacturing of Metallic & Ceramic Objects - Direct Routes and indirect routes.	Understand

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	M	-	-	-	-	-	-	-	-	-	-
CO2	S	M	-	-	M	L	-	-	-	-	-	L
CO3	S	M	M	-	-	L	-	-	-	-	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern

1. Out of 100 Marks, 50 Marks (Internal) will be for Mini project/Assignment and 50 Marks will be for End Semester Exam.
2. End Semester Question pattern will be a combination of both multiple choice and descriptive questions.

Bloom's Category	Terminal Examination
Remember	20
Understand	40
Apply	40
Analyse	---
Evaluate	---
Create	---

Syllabus

Introduction to 3D Printing: Fundamental concepts of slicing and support mechanisms, types of materials, advantages and limitations, applications. Popular 3D Printing Processes: Classification of the processes, Fused Deposition Modeling (FDM), Stereo-Lithography Apparatus (SLA), Selective Laser Sintering (SLS), Multi-jet 3D Printing, Laminated Object Manufacturing (LOM) etc. Introduction to Reverse Engineering. An Overview of Rapid Manufacturing. Rapid Manufacturing of Polymeric Objects: Vacuum Casting, Epoxy Tooling, Spray Metal Tooling etc. Rapid Manufacturing of Metallic & Ceramic Objects - Direct Routes: Laminated Manufacturing, Powder-bed technologies like multi-jet 3D Printing, Selective Laser Sintering/ Melting (SLS/ SLM) and Selective Electron beam Melting, Deposition technologies using arc and laser. Rapid Manufacturing of Metallic & Ceramic Objects - Indirect Routes: Rapid Casting. *Demos on* CAD modeling using SolidWorks and Processing of STL files. Fused Deposition Modeling.

Reference Books

1. Chua, C.K. Leong, K.F. and Lim, C.S. **"Rapid Prototyping: Principles and Applications"**, World Scientific, New Jersey, 2010.
2. Kenneth G. Cooper **"Rapid prototyping Technology"** Selection and application, Marcel Dekker Inc. 2010
3. D.T.Pham, S.S.Dimov **"Rapid Manufacturing"** The technologies and applications of Rapid Prototyping and Rapid Tooling, Springer Publication, 2001.
4. I. Gibson, D. W. Rosen, B. Stucker **"Additive Manufacturing Technologies"** Rapid Prototyping to Direct Digital Manufacturing, Springer Publication, 2009.

Course contents and Lecture schedule

Module No.	Topic	No. of Lectures
1.	Introduction to 3D Printing: Fundamental concepts of slicing and support mechanisms, types of materials, advantages and limitations, applications	1.5
2.	Popular 3D Printing Processes: Classification of the processes, Fused Deposition Modeling (FDM), Stereo-Lithography Apparatus (SLA),	1.5
3.	Selective Laser Sintering (SLS), Multi-jet 3D Printing, Laminated Object Manufacturing (LOM) etc.	1.5
4.	Introduction to Reverse Engineering	1.5
5.	An Overview of Rapid Manufacturing	1.5
6.	Rapid Manufacturing of Polymeric Objects: Vacuum Casting, Epoxy Tooling, Spray Metal Tooling etc.	1.5
7.	Rapid Manufacturing of Metallic & Ceramic Objects - Direct Routes: Laminated Manufacturing, Powder-bed technologies like multi-jet 3D Printing, Selective Laser Sintering/ Melting (SLS/SLM) and Selective Electron beam Melting, Deposition technologies using arc and laser	1.5
8.	Rapid Manufacturing of Metallic & Ceramic Objects - Indirect Routes: Rapid Casting	1.5
	Demos	
9.	CAD modeling using SolidWorks and Processing of STL files	1.0
10.	Fused Deposition Modeling	3.0

Course Designers:

1. Dr. K.P. Karunakaran karuna@iitb.ac.in
2. Dr. K.Chockalingam kcmech@tce.edu

14ME1H0	**FINITE ELEMENT METHOD FOR PRODUCT DEVELOPMENT**	Category	L	T	P	Credit
		PC	1	0	0	1

Preamble

The course provides a fundamental knowledge in finite element technology, Composite materials and structures, Design and modelling of composite components with the knowledge of industrial case studies.

Prerequisite

- Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Explain basic concepts of finite element technology. .	**Understand**
CO2	Apply finite element techniques for designing, modelling and simulation applications for metals and composites	**Apply**

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1.	L	L	L	L	L	L	L	L	-	M	M	-
CO2.	L	L	M	L	L	M	L	L	M	M	M	-

S- Strong; M-Medium; L-Low

Assessment Pattern

1. Out of 100 Marks, 50 Marks (Internal) will be for Mini project/Assignment and 50 Marks will be for End Semester Exam.
2. End Semester Question pattern will be a combination of both multiple choice and descriptive questions.

Bloom's Category	**Terminal Examination**
Remember	20
Understand	60
Apply	20
Analyse	-
Evaluate	-
Create	-

Syllabus

Computers Aided Engineering - Overview, Engineering mechanics, strength of materials, Background to Finite element technology, Development of Finite elements (Mathematical model) - Modelling of the complex components, - Industrial case studies (including test correlations)
Composite Materials – Overview, Advanced Composite Structures, Design aspects of composites, Modelling aspects of composites, modelling of complex composite components, Industrial case studies.

Reference Books

1. Cook R.D, Malkus D.S and Plesha M.E, "**Concepts and applications of Finite Element Analysis**", John Wiley, 1988.
2. Jones R M, "**Mechanics of Composite Materials**", McGraw Hill, New York, 1975.

Course Contents and Lecture Schedule

Sl. No	Topics	No. of Lecture Hours
1	Computers Aided Engineering– Overview	1
1.1	Engineering Mechanics, Strength of Materials	1
1.2	Background to Finite element technology	1
1.3	Development of Finite elements (Mathematical model)	2
1.4	Modelling of the complex components	2
1.5	Industrial case studies (including test correlations)	1
2.1	Composites – Overview , Advanced Composite Structures	2
2.2	Design aspects of composites	2
2.3	Modelling aspects of composites,	2
2.4	Modelling of complex composite components, Industrial case studies	2
	Total	**16**

Course Designers:

1.	Mr. Ganapathi Manickam, Aerospace Engineering Services, Mahindra Satyam Services Ltd, Bangalore.	ganapathimanickam@gmail.com
2.	Dr. M. Kathiresan	umkathir@tce.edu

		Category	L	T	P	Credit
14ME1K0	**NON DESTRUCTIVE TESTING**	PC	1	0	0	1

Preamble

Non destructive testing (NDT) is the process of inspecting, testing, or evaluating materials, components or assemblies for discontinuities, or differences in characteristics without destroying the serviceability of the part or system. In other words, when the inspection or test is completed the part can still be used. Today modern nondestructive tests are used in manufacturing, fabrication and in-service inspections to ensure product integrity and reliability, to control manufacturing processes, lower production costs and to maintain a uniform quality level. During construction, NDT is used to ensure the quality of materials and joining processes during the fabrication and erection phases, and in-service NDT inspections are used to ensure that the products in use continue to have the integrity necessary to ensure their usefulness and the safety of the public. Common NDT methods include ultrasonic, magnetic-particle, liquid penetrant, radiographic, remote visual inspection (RVI), eddy-current testing, and low coherence interferometry. This course aim to provide knowledge on the working, types, advantages, limitations, and applications of various NDT techniques.

Prerequisite

- Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO 1.	Explain basic concepts of Non Destructive Testing (NDT).	Understand
CO 2.	Explain the various NDT methods and their principles, testing techniques, advantages, limitations and applications.	Understand
CO 3.	Apply the various NDT techniques like Penetrate Testing , Magnetic particle testing, Visual Testing, Radiography testing, Ultrasonic Testing.	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	L	M	-	-	-	M	-	-	-	-	M	M
CO2	S	M	-	-	-	S	-	-	-	-	M	M
CO3	S	S	-	-	-	L	-	-	-	-	M	M

S- Strong; M-Medium; L-Low

Assessment Pattern

1. Out of 100 Marks, 50 Marks (Internal) will be for Mini project/Assignment and 50 Marks will be for End Semester Exam.
2. End Semester Question pattern will be a combination of both multiple choice and descriptive questions.

Bloom's Category	Terminal Examination
Remember	20
Understand	40
Apply	40
Analyse	
Evaluate	
Create	

Syllabus

Introduction to NDT - Requirement for NDT - Basic NDT methods, Surface NDT methods – Penetrant Testing – Principle – consumables – testing techniques – advantages – Limitations - Application – Codes – Standards, Practicals – PT, Magnetic particle testing - Principle – consumables – testing techniques – advantages –Limitations - Application – Codes, Practicals – MT, Surface NDT method – Visual Testing – principle – testing Techniques – advantage – limitation – applications – Application – Codes, Practicals – VT, Radiography testing – Principle – equipment, Radiography testing – Consumables-Techniques, Radiography testing – Film interpretation, Safety- codes – standards, Radiography testing – Film interpretation – practicals, Ultrasonic Testing – principle – equipment, Ultrasonic Testing - techniques, Ultrasonic Thickness measurement, Through transmission testing technique, Resonance testing, Ultrasonic Testing practicals –Thickness measurement, weld testing.

Text Books

1. R Halmshaw, **"Introduction to the Non-Destructive Testing of Welded Joints"**- 2nd Edition ,Woodhead Publishing, 1997.
2. Little R.L, "**Welding and Welding Technology**" - Tata McGraw Hill Publishing Ltd, New Delhi, 1989.
3. Parmer R.S, **"Welding Engineering and Technology",** 2nd Edition, Khanna publishers, Delhi, 2010.

Reference Books

1. Davies, A.C, **"Welding**", 10th Edition, Cambridge University press, 1996.
2. Howard B. Cary, Scott Helzer "**Modern Welding Technology**", 6th Edition, Prentice Hall , 2005.
3. **ASM metals handbook** Vol 17: Non Destructive testing.
4. **ASME Sec V** - Non - Destructive Testing.
5. **ASTM standards**
   a. E 94, Standard Guide for Radiographic Examination.
   b. E 142, Standard Method for Controlling Quality of Radiographic Testing.
   c. E 164, Standard Practice for Ultrasonic Contact Examination of Weldments.
   d. E 165, Standard Test Method for Liquid Penetrant Examination.
   e. E 1444, Standard Practice for Magnetic Particle Examination.
6. AWS Welding Handbook**, Volume 1, Welding Science & Technology, American Welding Society, 2001.**
7. AWS Welding Handbook**, Volume 2, Welding Processes, Part 1**, **American Welding Society, 2004.**
8. AWS Welding Handbook**, Volume 3, Welding Processes, Part 2, American Welding Society, 2004.**

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	Introduction to NDT - Requirement for NDT - Basic NDT methods	1
1.1	Surface NDT methods – Penetrant Testing (PT) – Principle – consumables – testing techniques – advantages –Limitations - Application – Codes - Standards	2
1.2	Magnetic particle testing (MT) - Principle – consumables – testing techniques – advantages –Limitations - Application – Codes	2
1.3	Surface NDT method – Visual Testing (VT) – principle – testing	2

Module No.	Topic	No. of Lectures
	Techniques – advantage – limitation – applications – Application – Codes	
1.4	Radiography testing (RT) – Principle – equipment	2
1.4.1	Radiography testing – Consumables- Techniques	
1.4.2	Radiography testing – Film interpretation, Safety- codes - standards	
1.4.3	Radiography testing – Film interpretation	
1.5	Ultrasonic Testing (UT) – principle - equipment	2
1.5.1	Ultrasonic Testing - techniques	
1.5.2	Ultrasonic Thickness measurement, Through transmission testing technique, Resonance testing	
2.0	Practical Sessions-PT,MT, VT, RT, UT (Thickness measurement , weld testing)	5
	Total	**16**

Course Designers:

1. Mr. S S Ananathan ananreva@gmail.com
2. Mr. J. Umar Mohamed umar_tce_mech@tce.edu

		Category	L	T	P	Credit
14ME1L0	**GAS TURBINE ENGINES**	PC	1	0	0	1

Preamble

The course provides a fundamental knowledge in gas turbine system, different types of gas turbine engines, its components and sub systems including the starting and fuel control systems. The course also deals with the airframe-engine integrations aspects.

Prerequisite

- 14ME240-Thermodynamics
- 14ME340-Fluid Mechanics
- 14ME440-Thermal Engineering

Course Outcomes

On the successful completion of the course, students will be able to

CO 1.	Explain the working principle and purpose of jet propulsion.	Understand
CO 2.	Select suitable engine cycle parameters for different aircraft applications like civil, military, business jets etc	Apply
CO 3.	Explain the different components and sub systems of the gas turbine engine.	Understand
CO 4.	Explain the fundamental digital fuel control system of the aero engine.	Understand

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1.	S	M	M	L		M	M				S	
CO2.	S	S	S	S							S	
CO3.	S	M	M	L		S	S				S	
CO4.	S	S	M	M							S	

S- Strong; M-Medium; L-Low

Assessment Pattern

1. Out of 100 Marks, 50 Marks (Internal) will be for Mini project/Assignment and 50 Marks will be for End Semester Exam.
2. End Semester Question pattern will be a combination of both multiple choice and descriptive questions.

Bloom's Category	Terminal Examination
Remember	20
Understand	70
Apply	10
Analyse	
Evaluate	
Create	

Syllabus

Introduction- Principle of operation of Gas turbine engine, Principle and purpose of jet propulsion, Propulsion system classification- Gas turbine engine Components and Sub systems- Single and twin spool gas turbine engines, different types of Gas turbine engines-

Overview of Fuel control system, Starting and Ignition system- Engine testing and qualification.
Gas turbine engine components- Compressors, Combustors, Turbine- Exhaust system and Afterburner.
Full authority Digital engine Control (FADEC) system- Control system overview, Advantaged of FADEC system over Hydro mechanical system- Digital Electronic Control Unit(DECU) design features, Control laws, Control system testing aspects.
Airframe- Engine integration- Integration aspects- Installation effects and installed engine performance.

Reference Books

1. Liepmann, Roshko, "Elements of Gas Dynamics", John Wiley & Sons, 1957.
2. Hand out.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Introduction**	
1.1	Principle of operation of Gas turbine engine	1
1.2	Principle and purpose of jet propulsion, Propulsion system classification	1
1.3	Gas turbine engine Components and Sub systems	1
1.4	Single and twin spool gas turbine engines, different types of Gas turbine engines	1
1.5	Overview of Fuel control system, Starting and Ignition system	1
1.6	Engine testing and qualification	1
2	**Gas turbine engine components**	
2.1	Compressors, Combustors, Turbine	3
2.2	Exhaust system and Afterburner	2
3	**Full authority Digital engine Control (FADEC) system**	
3.1	Control system overview, Advantaged of FADEC system over Hydro mechanical system	1
3.2	Digital Electronic Control Unit(DECU) design features, Control laws, Control system testing aspects	1
4	**Airframe- Engine integration**	
4.1	Integration aspects	1
4.2	Installation effects and installed engine performance	1
	Total	**16**

Course Designers:

1.	Sundararajan V, Former Director GTRE, Bangalore.	sundararajan.v@quest-global.com
2.	Dr.K.Srithar	ksrithar@tce.edu

		Category	L	T	P	Credit
14ME1M0	**VALUE ENGINEERING**	PC	1	0	0	1

Preamble

New Product development is on rise and developing these products without compromising quality and cost is a challenge. In such development, it has become necessary to reduce the cost or eliminating the unnecessary cost, while improving the product performance or otherwise quality. This course deals with improving the quality in terms of the requirements of customer at the same or reduced cost by ensuring adequate system performance. Value engineering is a systematic approach for value improvement and contains seven broader phases. Hence, for product development, both cost and quality related issues need to be tackled concurrently.

Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Establish the Value engineering methodology	Understand
CO2.	Recognize the various phases of value engineering	Apply
CO3.	Perform function cost worth analysis and Life Cycle costing	Apply
C04.	Create the ideas for solving the problems	Create
C05.	Evaluate the functional importance and functional cost	Evaluate
CO6.	Recommend the facts and costs	Analyse

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	L			M				M		L	
CO2	S	M			M				S		S	
CO3	S	M			M				S		S	
CO4	S	M			M				S		S	
CO5	S	M			M				S		S	
CO6	S	M			M				S		S	

S- Strong; M-Medium; L-Low

Assessment Pattern

1. Out of 100 Marks, 50 Marks (Internal) will be for Mini project/Assignment and 50 Marks will be for End Semester Exam.
2. End Semester Question pattern will be a combination of both multiple choice and descriptive questions.

Bloom's Category	Terminal Examination
Remember	--
Understand	10
Apply	20
Analyse	10
Evaluate	10
Create	--

Syllabus

Introduction: Overview of VE methodology, **Reasons for unnecessary costs**: Definition of value, use value and prestige Value, **VE Job Plan:** Functional approach to value improvement, Orientation and Information phases, techniques of Job plan **Functional Analysis**: Function cost worth analysis, FAST diagram, Creative phase, Evaluation, Recommendation, Implementation and Audit phases**: Project presentation by teams** (After a gap of 3 weeks for students to complete project)

Reference Books

1. Mukhopadhyaya, Anil Kumar, "**Value Engineering**", Response Books, New Delhi, 2003, ISBN: 0-7619-9788-1
2. S S Iyer, "**Value Engineering – A How to Manual**", 3rd edition, New Age Publishers, Chennai, 2006, ISBN: 978-81-224-2405-8
3. Class handout.

Course Contents and Lecture Schedule

No.	Topic	No. of Lectures
1	**Introduction**	
1.1	Overview of Value Engineering methodology	1
2	**Reasons for unnecessary costs**	
2.1	Definition of value	1
2.2	Use value and Prestige value	1
3	**VE Job Plan**	
3.1	Functional approach to value improvement	1
3.2	Orientation and Information Phases	1
3.3	Techniques of Job Plan	1
4	**Functional Analysis**	
4.1	Function cost worth analysis	1
4.2	FAST Diagram	1
4.3	Creative Phase	1
4.4	Evaluation Phase	1
4.5	Recommendation, Implementation and Audit Phases	2
5	**Project Presentation by teams**	3
	Total	**15**

Course Designers:

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		Category	L	T	P	Credit
14ME1N0	**SIX SIGMA**	PC	1	0	0	1

Preamble

Six Sigma was originally developed at Motorola in the 1980's and has become one of the most widely discussed and reported trends in business over the past years, thanks largely to the phenomenal successes of the Six Sigma program at world's most successful companies. Six Sigma methodologies enable organizations to achieve high quality in their products. It can be applied to organization wide products, processes and services. This uses data and statistical tools to systematically improve processes and sustain their improvements. Organizations have developed and improved their business processes effectively by using Six Sigma tools and methodologies. Six Sigma starts with capturing customer requirements, translating them into product functional requirements, designing a product to meet these requirements, measuring the performance of the product to ensure that it meets the customer expectations and then deliver a quality product to the customers. The most important benefit of Six Sigma comes is in the form of financial gains that result from the elimination of defects and optimization of processes. This course enables students to know what six sigma is all about and how to apply it in real life problems and deals with a problem solving approach using a set of soft and statistical tools.

Prerequisite

- Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO1 :	Understand different six sigma stages	Understand
CO2:	Measure and reduce variations in processes	Apply
CO3:	Identify root causes and eliminate problems	Analyse
CO4:	Have a data driven approach to solve problems	Apply
CO5:	Apply 6 sigma concepts in any activity that needs continuous improvement	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1.	L										L	
CO2.	S	M	L								M	
CO3.	S	M	L								M	
CO4.	S	M	L								M	
CO5.	S	M	L								M	

S- Strong; M-Medium; L-Low

Assessment Pattern

1. Out of 100 Marks, 50 Marks (Internal) will be for Mini project/Assignment and 50 Marks will be for End Semester Exam.
2. End Semester Question pattern will be a combination of both multiple choice and descriptive questions.

Bloom's Category	Terminal Examination
Remember	10
Understand	20
Apply	20
Analyse	-
Evaluate	-
Create	-

Syllabus

Introduction: Six sigma Basics - Methodologies: DMAIC, IDDOV, DFSS - DMAIC Tools and Applications- Define: Project Charter, TPM, CTQs, SIPOC - Measure: Data types, Process Map, Histogram, Normality, Process Capability - Analyze: FMEA, QFD, Graphical Plots, SPC and Control Charts, Cause & Effect, RCA, Pareto Chart, ANOVA & DOE Fundamentals - Improve: Mistake Proofing, Improved Process Map - Control: Control Plan - One Mini Project Discussion - Project presentation by teams (After a gap of 4 weeks for students to complete project) - Project Completion and Certification (Certification by College or External body).

Reference Books/Learning Resources

1. Thomas Pyzdek and Paul Keller,"**The Six Sigma Handbook**", McGraw Hill, 3rd Edition, 2010
2. Hitoshi Kume, "**Statistical methods for Quality Improvement**", Productivity Press (India) Pvt Ltd, First Indian Edition, 2006
3. Jeffrey K. Liker, "**The Toyota Way**", Tata McGraw Hill, 2004
4. James P. Womack and Daniel T. Jones, "**Lean Thinking**", Simon & Schuster, 1996
5. SixSigma Discussion forum

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Introduction**	
1.1	Six sigma Basics, Why Six Sigma? Basic Statistics	2
2	**Methodologies**	
2.1	DMAIC, IDDOV, DFSS	1
3	**DMAIC Tools and Applications**	
3.1	Define: Project Charter, TPM, CTQs, SIPOC	2
3.2	Measure: Data types (Attribute & Variable, Discrete and Continuous), Process Map, Histogram, Normality, Process Capability	3
3.3	Analyze: FMEA, QFD, Box Plot, Dot Plot, Scatter Plot, Run Chart, SPC and Control Charts, Cause & Effect, RCA (Fishbone Diagram), Pareto Chart, ANOVA & DOE Fundamentals	4

Module No.	Topic	No. of Lectures
3.4	Improve: Mistake Proofing, Decision Analysis, Improved Process Map, Revised FMEA	2
3.5	Control: Control Chart, Control Plan	1
4	**One Mini Project Discussion**	1
5	**Project Presentation by teams**	
Total		**16**

Course Designers:

1. Mr. V. Venkatachalam venkatachalam.venkatachalam@gmail.com
2. Dr. S. Muralidharan murali@tce.edu

14ME1P0 MARINE SYSTEMS AND MAINTENANCE

Category	L	T	P	Credit
PC	1	0	0	1

Preamble

Shipping is the only sector in the transportation industry to carry heavy (over dimensional and overweight) and bulk quantity of cargo at economical freight rates. If ships were not present, then prices of various commodities would be sky high and may not be affordable to everyone. This course will give an outline of the maritime sector and their importance in the day to day life. Moreover, mechanical engineers should know how machineries play an important role in the shipping sector. For the present generation who wish to take up a sea career, this may be an eye opener.

Prerequisite

- 14ES150 - Basics of Civil and Mechanical Engineering
- 14ME440 - Thermal Engineering

Course Outcomes

On the successful completion of the course, students will be able to

CO1	explain how shipping caters to the world requirements.	Understand
CO2	explain the functions of the various machineries on board.	Understand
CO3	interpret how land is more polluted than seas.	Understand
CO4	Identify a proper maintenance schedule for marine energy systems.	Understand
CO5	describe corrosion protection system, safety and hygiene strands in Shipping	Understand

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	L	L	-	-	L	L	-	-	M	M	-
CO2	S	L	L	-	-	L	L	-	-	M	M	-
CO3	S	L	L	-	-	L	L	-	-	M	M	-
CO4	S	L	L	-	-	L	L	-	-	M	M	-

S- Strong; M-Medium; L-Low

Assessment Pattern

1. Out of 100 Marks, 50 Marks (Internal) will be for Assignment on one mind mapping scenario and a quick decision making in an emergency situation as a team leader with regard to marine energy systems and 50 Marks will be for End Semester Exam.
2. End Semester Question pattern will be a combination of both multiple choice and descriptive questions put together for 100 marks.

Bloom's Category	Terminal Examination
Remember	20
Understand	80
Apply	0
Analyze	0
Evaluation	0
Create	0

Syllabus

Introduction to Shipping, Present scenario of the shipping industry and major players, Various types of ships and their requirements - general cargo ships, container ships, reefer ships, gas carriers, oil tankers,

Various systems on board in a merchant ship - Compressed air systems, Fuel oil systems – purification and service systems, Lubrication oil systems – purification and service systems, Cooling water systems – sea water and fresh water, Sewage system and their treatment, bilge and ballast management, Fire fighting systems.

Power management – generators, capacities and types, maintenance, trouble shooting, Marine Internal Combustion Engines - basics and operation, maintenance, trouble shooting, Pumping systems - various types and uses, capacities, special types and applications,

Fresh water generating systems – operating principle, various types and capacities, Steam generating systems – requirements and types, operation, trouble shooting,

Management of marine energy systems under emergency situations.

Corrosion Protection System in Shipping - Types and reasons of corrosion in shipping, Methods to prevent Corrosion in shipping

Safety and Hygiene strands to be adopted in the shipping Industry

Reference Books

1. D.K.Sanyal, "**Principles and Practices of Marine Diesel Engines**", Bhandarkar Publications, India, 1981.
2. H.D. McGeorge, "**Marine Auxiliary Machinery**", Seventh Edition, Butterworth Heinemann, 2008.
3. D. A. Taylor, "**Introduction to Marine Engineering"**, Second Edition, Butterworth Heinemann, 2005

Course Contents and Lecture Schedule

Topic code	Topic	No of hours
1.0	Introduction to Shipping Present scenario of the shipping industry and major players	1
2.0	Various types of ships and their requirements General cargo ships (with and without self-geared material handling equipment) Container ships, Reefer ships, Gas carriers, Oil tankers	1
3.0 3.1 3.2	Various systems on board in a merchant ship Compressed air systems Fuel oil systems – purification and service systems	1
3.3 3.4	Lubrication oil systems – purification and service systems Cooling water systems – sea water and fresh water	1
3.5	Sewage system and their treatment	1
3.6 3.7	Bilge and ballast management Fire fighting systems	1

Topic code	Topic	No of hours
4.0 4.1 4.2 4.3	Power management – Generators. Capacities and types Maintenance Trouble shooting	1
5.0 5.1 5.2 5.3	Marine Internal Combustion Engines Basics and operation Maintenance Trouble shooting	2
6.0 6.1 6.2 6.3	Pumping systems Various types and uses. Capacities Special types and applications	1
7.0 7.1	Fresh water generating systems – operating principle. Various types & capacities.	1
8.0 8.1 8.2	Steam generating systems – requirements and types. Operation Trouble shooting.	1
9.0 9.1	Cargo pumping systems – types Safeties associated with them.	1
10.0	Management of marine energy systems under emergency situations.	1
11.0 11.1 11.2	Corrosion Protection System in Shipping Types and reasons of corrosion in shipping Methods to prevent Corrosion in shipping	1
12.0	Safety and Hygiene strands to be adopted in the shipping Industry	1
	Total	**16**

Course Designers:

1. **Mr. D.Nagasubramaniyam**, sdmnagu@yahoo.com
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2. **Dr.A.Valan Arasu** avamech@tce.edu

14ME1Q0	VISION BASED DIMENSIONAL MEASUREMENT	Category	L	T	P	Credit
		PE	1	0	0	1

Preamble

Customers demand flawless goods of the highest quality. Random checks cannot guarantee to deliver on quality products. Machine vision systems conduct a 100% quality check of individual components reliably and cost-effectively. When examining continuous flow of materials, machine vision systems keep pace with the highest speeds in detecting the smallest of flaws. In checking component parts, several different views of a component can be generated to check for surface defects, dimensional accuracy, completeness and other characteristics. For example, circuit boards are checked to ensure that strip conductors and soldered contacts are in order and all components are present in the electronics industry.
Dimensional or shape checking and gauging is one of the most demanding applications in industrial practices. It is actually possible to reach accuracies of just a few light wavelengths, but requires considerable effort. Precise results can be achieved with the selection of optics, illumination, mechanical set up and image capture. Moreover, dimensional checking can take many forms, relatively coarse measuring of part dimensions to high accuracy gauging in the micrometer range. On these considerations, this course aims to provide an experience in selecting suitable optics and illumination techniques which are the significant parameters in the successful implementation of machine vision system.

Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO1 :	Select the appropriate optics of machine vision system for the given dimensional measurement application	Apply
CO2:	Select the suitable illumination technique for the given dimensional measurement application	Apply

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1.	S	M	L			L					M	
CO2.	S	M	L			L					M	

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Terminal Examination
Remember	10
Understand	30
Apply	60
Analyse	-
Evaluate	-
Create	-

Syllabus

Image Acquisition Process: Workflow of Image acquisition - Solid State Sensors – Operation of Charge Coupled Device (CCD) and Complementary Metal Oxide Semiconductor (CMOS) Sensors. Types of cameras: Line Scan, Area scan and Smart cameras. Image Data Transfer – Digital Camera Interfaces – CameraLink, Fire Wire, USB and Gigabit Ethernet. **Optics:** Optical foundations: Depth of field, Field of view and focal point - F number, Thin Lens, Imaging Equation, Depth of Field, Typical Imaging Situations, Aberrations, Lens Selection – Mounts, Telecentric lens, Fisheye lenses and endoscopes. **Illumination**: Light Sources, Types of Light Filters, Types of Lighting: Front lighting –

Diffuse, Directed, Polarized, Ring and Structured; Back lighting – Diffuse, Directional, polarized, Collimated, Telecentric, Structured, Bright field, Dark Field, Incident and Transmitted Lighting. **Applications:** Dimensional Checking: Simple gauging – Linear Measurement – Calibration - Shape Checking.

Text Book

1. Christian Demant, Bernd Streicher-Abel, Carsten Garnica "Industrial Image Processing - Visual Quality Control in Manufacturing", Second Edition, Springer, 2013.

Reference Books/Learning Resources

1. Elias N. Malamas, Euripides G.M. Petrakis, Michalis Zervakis, Laurent Petit, Jean-Didier Legat, "A survey on industrial vision systems, applications and tools", Image and Vision Computing 21 (2003) 171–188.
2. H. Golnabi, A. Asadpour, "Design and application of industrial machine vision systems", Robotics and Computer-Integrated Manufacturing 23 (2007) 630–637.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.	**Image Acquisition Process**	
1.1	Workflow of Image acquisition	1
1.2	Solid State Sensors – Introduction	1
1.2.1	Operation of Charge Coupled Device (CCD) sensor	
1.2.2	Operation of Complementary Metal Oxide Semiconductor (CMOS) Sensors	
1.3	Types of cameras: Line Scan, Area scan and Smart cameras	1
1.4	Image Data Transfer – CameraLink, Fire Wire, USB and Gigabit Ethernet.	
2.	**Optics**	
2.1	Optical foundations: Depth of field, Field of view and focal point	1
2.1.1	F number, Thin Lens, Imaging Equation	1
2.1.2	Typical Imaging Situations – Aberrations	
2.3	Lens Selection – Macro lens, Telecentric lens, Fisheye lenses and endoscopes – C and CS Mounts	1
	Practice Session -1	1
2.4	Determination of FoV and Focal length, optical magnification, for the given application	1
3	**Illumination**	
3.1	Light Sources, Types of Light Filters	1
3.2	Types of Lighting: Front lighting – Diffuse, Directed, Polarized, Ring and Structured	1
3.2.1	Back lighting – Diffuse, Directional, polarized Telecentric, Structured, Bright field, Dark Field, Incident and Transmitted Lighting.	1
4	**Applications**	
4.1	Dimensional Checking: Simple gauging – Linear Measurement – Calibration	1
4.2	Shape Checking	1
	Practice Session – 2	1
	Total	14

Course Designers:

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2. Mr.Adarsha Sarpangala, VS Technology, Benguluru – 560 010 adarsha@vst.co.jp

		Category	L	T	P	Credit
14ME1R0	**Aerospace materials and manufacturing processes**	PC	1	0	0	1

Preamble

Materials used for aircraft are expected to be light weight and at the same time, they should possess required mechanical, thermal, physical, corrosion and tribological properties based on the intended application. In general, Aircraft structural application demands high strength to weight ratio, excellent fatigue, flexural and corrosion properties. In contrast, aeroengine parts demand high thermal fatigue, thermal stability, hot corrosion resistance and low cycle fatigue, creep resistance properties. These requirements make a choice of the material unique in aircrafts. In a brief, composites and Al, Mg, Ni and Ti alloys are used in aircraft structures whereas super alloys, MMC and Ti alloys are preferred for aeroengine applications. The components for aircraft are usually fabricated with casting, forging, powder metallurgy and machining processes. However, the product acceptance has very strict quality requirements in terms of NDTs. In this course, aircraft materials and manufacturing processes are offeredwith the aid of case studies.

Prerequisite

- Nil

Course Outcomes

On successful completion of the course, students will be able to

CO1	Suggest a suitable material for aerospace components	Apply
CO2	Suggest a suitable manufacturing process to manufacture the aerospace component	Apply
CO3	Suggest a suitable inspection process to inspect the aerospace materials	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3
CO1	S	-	-	-	S	-	-	M	-	-	L	S	-	M
CO2	S	L	S	-	S	L	-	M	M	-	M	S	-	S
CO3	S	L	S	-	S	L	-	M	M	-	M	S	-	M

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Test	Terminal Examination
Remember	10	10
Understand	40	40
Apply	50	50
Analyse	0	0
Evaluate	0	0
Create	0	0

Syllabus

Composite materials - Metal matrix composite, Nano Composites, Functional graded composite, High entropy alloy based composite, Quasi crystal based composite for aircraft structure and engine applications. Alloys - Al, Mg, Ni and Ti alloys and shape memory alloys for aircraft structures.

Manufacturing processes –Advanced manufacturing processes –Thixoforging- Multidirectional forging, Precision forging and Friction stir processing. Case studies on forging of aerospace components (Impeller and Landing gear modelling and processing), Case studies on powder metallurgy process of aircraft brake pad processing, Case studies on casting of aerospace components (aircraft mounted accessory gear box casting gear modelling and processing).NDT techniques for aircraft component qualification, Types – Flurocent penetrant inspection, Magnetic particle inspection, ultrasonic testing and Radiography testing. Tribological studies on aerospace materials, Types – Pin on disc and Brake dynamometer tests.

Reference Books

1. Eswara Prasad, N and Wanhill R. J. H, '**Aircraft Materials and Material Technologies: Volume 1: Aircraft Materials'**(Indian Institute of Metals Series), Springer,2017.
2. Eswara Prasad, N and Wanhill R. J. H, '**Aircraft Materials and Material Technologies: Volume 2: Aerospace Material Technologies'**(Indian Institute of Metals Series), Springer,2017.
3. Polmear, I, J, '**Light Alloys: Metallurgy of the Light Metals**', Wiley, 1995
4. George E Dieter,**'Mechanical metallurgy'**, 3rd Edition, Mc-Graw Hill Education Pvt. Ltd., Delhi, 2017.
5. Vijendra Singh, **'Physical Metallurgy'**, Standard Publications, New Delhi, 2010.
6. Balasubramaniam R, **'Callister's Materials Science and Engineering'**, 2nd Edition, Wiley,2014.
7. Serope Kalpakjian and Steven Schmid, **'Manufacturing Processes for Engineering Materials,** 5th Edition, Pearson, 2007
8. RaoP. N, **'Manufacturing Technology: Foundry, Forming and Welding'** - Volume 1, 4th Edition, Mcgraw Hill Education, New Delhi, 2013.
9. RaoP. N, **'Manufacturing Technology: Metal Cutting and Machine Tools'** - Volume 2, 3rd Edition, Mcgraw Hill Education, New Delhi, 2013.
10. Study notes from the presentation

Course Contents and Lecture Schedule

Module No.	Topics	No. of Lectures
1.0	**Composite materials**	
1.1	Composite materials - Metal matrix composite, Nano Composites, Functional graded composite.	2
1.2	High entropy alloy based composite, Quasi crystal based composite for aircraft structure and engine applications.	2
1.3	**Alloys**	
1.3.1	Alloys - Al, Mg, Ni and Ti alloys and	2
1.3.2	Shape memory alloys for aircraft structures.	1
2.0	**Manufacturing of Aerospace Components**	

Module No.	Topics	No. of Lectures
2.1	Advanced manufacturing processes –Thixoforging- Multidirectional forging, Precision forging and Friction stir processing.	2
2.2	Case studies on forging of aerospace components (Impeller and Landing gear modelling and processing),	1
2.3	Case studies on powder metallurgy process of aircraft brake pad processing,	1
2.4	Case studies on casting of aerospace components (aircraft mounted accessory gear box casting gear modelling and processing)	1
3	**Testing of Aerospace materials**	
3.1	NDT techniques for aircraft component qualification, Types – Flurocent penetrant inspection, Magnetic particle inspection, ultrasonic testing and Radiography testing.	2
3.2	Tribological studies on aerospace materials, Types – Pin on disc and Brake dynamometer tests.	1
	Total	**15**

Course Designers:

1. Dr. T. Ram Prabhu — Scientist-D/ Deputy Director, Defence R&D Organization Hyderabad, E-Mail - ramprabhu.t@gmail.com
2. Dr. M. Kathiresan — umkathir@tce.edu

		Category	L	T	P	Credit
14ME2A0	**DIGITAL TWIN TECHNOLOGY**	PC	2	0	0	2

Preamble

Digital twin in engineering aspect is a communicable virtual representation of any physical system or a group of inter-related systems that helps in predicting the future scenarios associated with that system. Advancement in the computing and unlimited storage further supported by the high bandwidth real-time communication has enabled engineers to take the full advantage of Digital Twin not only in engineering phase, but also during the operations of the industry. Support the whole lifecycle of that system through further simulation, analysis, understanding, learning, reasoning and dynamically recalibrating for improved decision making. Complete advantage of Digital Twin is possible only when connected technologies are used to make a unique Digital Thread for that Digital Enterprise. The course provides a fundamental knowledge in Digital twin technologies, IoT, Industry 4.0.

Prerequisite

- 14ME170 - Engineering Graphics

Course Outcomes

On the successful completion of the course, students will be able to

CO 1.	Explain the theory and advantages of Digital Twin	Understand
CO 2.	Explain the evolution of Industry 4.0	Understand
CO 3.	Develop a system/process of Digital twin in a Discrete and Process Industry	Apply

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO 1	PSO 2	PSO 3
CO1	M	L	L	M	M	-	-	-	-	-	L	-	M	-	M
CO2	S	M	M	S	S	-	-	-	-	-	M	-	S	-	S
CO3	M	L	L	M	M	-	-	-	-	-	L	-	M	-	M

S- Strong; M-Medium; L-Low

Assessment Pattern

1. Out of 100 Marks, 50 Marks (Internal) will be for Assignment and 50 Marks will be for End Semester Exam.
2. End Semester Question pattern will be a combination of both multiple choice and descriptive questions.

Bloom's Category	Terminal Examination
Remember	20
Understand	40
Apply	40
Analyse	0
Evaluate	0
Create	0

Syllabus

Introduction- Digital twin - Definition, types of Industry & its key requirements, Importance, Application of Digital Twin in process, product, service industries, History of Digital Twin, DTT role in industry innovation, Technologies/tools enabling Digital Twin

Industry 4.0

Industrial Revolutions, Industry 4.0 – Definition, principles, Application of Industry 4.0 in process & discrete industries, Benefits of Industry 4.0, challenges in Industry 4.0, Smart manufacturing, Internet of Things, Industrial Gateways, Basics of Communication requirements

Digital twin in a Discrete Industry

Basics of Discrete Industry, Trends in the discrete industry, control system requirements in a discrete industry, Digital Twin of a Product, Digital Thread in Discrete Industry, Data collection & analysis for product & production improvements, Automation simulation, Digital Enterprise

Digital twin in a Process Industry

Basics of Process Industry, Trends in the process industry, control system requirements in a process industry, Digital Twin of a plant, Digital Thread in process Industry, Data collection & analysis for process improvements, process safety, Automation simulation, Digital Enterprise

Advantages of Digital Twin

Improvement in product quality, production process, process Safety, identify bottlenecks and improve efficiency, achieve flexibility in production, continuous prediction and tuning of production process through Simulation, reducing the time to market.

Reference Books

1. Alp Ustundag, Emre Cevikcan, Industry 4.0: Managing The Digital Transformation, Springer Series in Advanced Manufacturing, 2017
2. Alasdair Gilchrist , Industry 4.0: The Industrial Internet of Things, Apress, 2015
3. Presentation notes

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Introduction**	
1.1	Digital twin - Definition, types of Industry & its key requirements, Importance	1
1.2	Application of Digital Twin in process, product, service industries	1
1.3	History of Digital Twin, DTT role in industry innovation	1
1.4	Technologies/tools enabling Digital Twin	1
2	**Digital twin in a Discrete Industry**	
2.1	Basics of Discrete Industry, Trends in the discrete industry	1
2.2	Control system requirements in a discrete industry	1
2.3	Digital Twin of a Product, Digital Thread in Discrete Industry,	1
2.4	Data collection & analysis for product & production improvements	2
2.5	Automation simulation, Digital Enterprise	1
3	**Digital twin in a Process Industry**	
3.1	Basics of Process Industry, Trends in the process industry	1

Module No.	Topic	No. of Lectures
3.2	Control system requirements in a process industry,	1
3.3	Digital Twin of a plant, Digital Thread in process Industry	1
3.4	Data collection & analysis for process improvements, process safety	2
3.5	Automation simulation, Digital Enterprise	1
4	**Industry 4.0**	
4.1	Industrial Revolutions	1
4.2	Industry 4.0 – Definition, principles	1
4.3	Application of Industry 4.0 in process & discrete industries	1
4.4	Benefits of Industry 4.0, challenges in Industry 4.0	1
4.5	Smart manufacturing	1
4.6	Internet of Things	1
4.7	Industrial Gateways, Basics of Communication requirements.	1
5	**Advantages of Digital Twin**	
5.1	Improvement in product quality, production process, process Safety	1
5.2	identify bottlenecks and improve efficiency	1
	achieve flexibility in production	1
5.3	continuous prediction and tuning of production process through Simulation, reducing the time to market.	2
	Total	**28**

Course Designers:

1. Mr.M.Thirumalai kumar, SIEMENS Ltd, Chennai.
2. Dr.S.Muralidharan, TCE, Madurai.
3. Dr.S.Karthikeyan, TCE, Madurai.
4. Mr.M.M.Devarajan, TCE, Madurai.