B.E. DEGREE (Mechanical Engineering) PROGRAMME

DETAILED SYLLABI FOR

SECOND TO EIGHTH SEMESTER

FOR THE STUDENTS ADMITTED FROM THE

ACADEMIC YEAR 2018 -2019 ONWARDS

THIAGARAJAR COLLEGE OF ENGINEERING
(A Government Aided Autonomous Institution affiliated to Anna University)

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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	Theor y					Theory/ Theory cum Practical	Practical			Mandatory Audit Courses	Credits
	1	2	3	4	5	6	7	8	9	10	
I	18MA110 Engineerin gCalculus (4)	18PHB20 Physics (3)	18CHB30 Chemistry (3)	18EG180 English (2)	18ES150 Engineering Exploration (3)	18ME160 Engineering Graphics(TCP) (4)	18EG170 English Laboratory (1)	18PH180 Physics Laboratory (1)	18CH190 Chemistry Laboratory (1)	-	22
II	18MA210 Matrices and ordinary differential equations (3)	18ME220 Engineering Mechanics (3)	18ME230 Metal Casting and Forming Processes (3)	18ME240 Engineering Thermodynamics (3)	18ME250 Materials Engineering (3)		18ME270 Strength of Material and Material Science Lab (1)	18ME280 Workshop (1)	18ES290 Lateral Thinking (1)	18CHAA0 Environment al Sciences	18
III	18ME310 Fourier series and Numerical Methods (3)	18ME320 Mechanics of Materials (3)	18ME331 Metal Joining Processes and Manufacturing Practices (TCP) (2)	18ME340 Thermal Engineering (3)	18ME350 Mechanical Measurements and Metrology (3)	18ME360 Problem solving using Computer (TCP) (3)	18ME370 Mechanical Measurements & Metrology Lab (1)		18ES390 Design Thinking (2)	-	20
IV	18ME410 Operations Research (3)	18ME420 Design of Machine Elements (3)	18ME430 Machining Processes (3)	18ME440 Fluid Mechanics (3)	18ME450 Production Drawing (TCP) (3)	18EG460 Professional Communication (TCP) (2)	18ME470 Thermal Engineering Lab (1)	18YYFX0 Foundation Elective I (3)	18ME490 Project Management (3)	18CHAB0 Constitution of India	24
V	18ME510 Kinematics andDynamics of Machinery (3)	18ME520 Heat and Mass Transfer (3)	18ME530 Statistical Quality Control (3)	18MEPX0 Prog. Elective -I (3)	18YYGX0 Gen. Elective (3)	18ME560 Accounting and Finance (3)	18ME570 Fluid Mechanics and CFD Lab (1)	18ME580 Machining Practices Lab (1)	18ES590 System Thinking (2)	18CHAC0 Essence of Indian Knowledge	22
VI	18ME610 Manufacturin g Systems and Automation (2)	18ME620 Design of Transmission Systems (2)	18MEPX0 Prog. Elective II (3)	18MEPX0 18YYFX0 Program / Foundation Elective (3)	18ESEX0 Engineering Sciences Elective (3)		18ME670 Heat Transfer Lab (1)	18ME680 CAD/CAM Lab (1)	18ES690 Engineering Design Project (3)		18
VII	18ME710 Industrial Engineerin g(3)	18MEPX0 Prog. Elec.III (3)	18MEPX0 Prog. Elec IV (3)	18MEPX0 Prog. Elec.V (3)	18XXPX0 18YYGX0 Prog. Elec. VI Gen Elective (3)	18ME770 Finite Element Analysis (TCP) (3)		-	18ES790 Capstone Design Project (3)	-	21
VIII	18ME810 Project (9)	18MEPX0 Prog. Elec. VII (3)	18MEPX0 Prog. Elec. VIII (3)	-	-	-	-	-	-	-	15

Total Credits: 160

BS	HSS	ES	Design	Manufacturing	Thermal	Industrial Engineering	Electives	Project
21	11	25	18	19	15	3	33	15

18MA210	MATRICES AND ORDINARY DIFFERENTIAL EQUATIONS

Category	L	T	P	Credit
BS	3	0	0	3

Preamble

In engineering, particularly Solid Mechanics, Aerodynamics, Fluid Flow, Heat Flow and Robotics have application that requires an understanding of Vector Calculus and Differential Equations. Also Mathematical tool Laplace Transforms is very much essential to solve ordinary differential equations that occur in the above areas. Eigen values and Eigenvectors are extremely important while creating engineering models in control systems, designing bridges, communication systems and searching algorithms. The course is designed to impart the knowledge and understanding of the above concepts to all Engineers and apply them in their areas of specialization.

Prerequisite

18MA110 Engineering Calculus

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage in %
CO1	ute the Laplace transform and inverse Laplace transform of different functions	
CO2	the given initial value problem using Laplace transform	
CO3	matrix algebra techniques for transformations of conic sections into principle axes	
CO4	the model developed for the given system using ordinary differential equation	
CO5	ute divergence and curl of vector functions	
CO6	Apply the concepts of vector differentiation and vector integration to fluid flow and heat transfer problems	

CO Mapping with CDIO Curriculum Framework

CO	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components
		Cognitive	Affective	Psychomotor	
CO1	TPS2	K2	A2	-	1.1
CO2	TPS3	K3	A3	-	1.1
CO3	TPS3	K3	A3	-	1.1
CO4	TPS3	K3	A3	-	1.1
CO5	TPS2	K2	A2	-	1.1
CO6	TPS3	K3	A3	-	1.1

Mapping with Programme Outcomes and Programme Specific Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1.	S	M			-	-	-	-		-	-	
CO2.	S	S	S		-	-	-	-	M	-	-	M
CO3.	S	S		S	-	-	-	-		-	-	S
CO4.	S	S	S	S	-	-	-	-	M	-	-	M
CO5.	S	M										
CO6.	S	S	S									

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	10	10	10				10
Understand	30	30	30				20
Apply	60	60	60	100	100	100	70
Analyse	00	00	00				00
Evaluate	00	00	00				00
Create	00	00	00				00

Sample Questions for Course Outcome Assessment**

Course Outcome 1

1. Show that Laplace transform of $\frac{1}{\sqrt{t}}$ is $\frac{\sqrt{\pi}}{s}$.
2. Identify the inverse Laplace transform of $\log\left(\frac{s^2+1}{(s-1)^2}\right)$.
3. Discuss any three properties of Laplace transforms.

Course Outcome 2

1. Apply Laplace transform solve $y''+9y=\delta\left(t-\frac{\pi}{2}\right)$, $y(0)=2,\ y'(0)=0$.
2. By using Laplace transform, solve $x''(t)+3x'(t)+2x(t)=2(t^2+t+1)$; with $x(0)=2, x'(0)=0$.
3. Apply convolution theorem, Solve the Voltera integral equation of the second kind $y(t)-\int_0^t y(\tau)\sin(t-\tau)d\tau=t$.

Course Outcome 3

1. An elastic membrane in the $x_1\ x_2$ plane with boundary circle $x_1^{\ 2}+x_2^{\ 2}=1$ is stretched so that a point $P;(x_1,x_2)$ goes over into the point $Q;(y_1,y_2)$ given by $\begin{matrix} y_1=5x_1+3x_2 \\ y_2=3x_1+5x_2 \end{matrix}$

   Find the principal directions that is the directions of the position vector X of P for which the direction of the position vector Y of Q is the same or exactly opposite. Predict the boundary circle take under this deformation?
2. Discover the type of conic section the following quadratic form represents and transform it to principal axes: $Q=17x_1^{\ 2}-30x_1x_2+17x_2^{\ 2}=128$.
3. Diagonalize the matrix $\begin{bmatrix} 6 & 0 & 0 \\ 12 & 2 & 0 \\ 21 & -6 & 9 \end{bmatrix}$

Course Outcome 4

1. Reduce to first order and solve $y''-y'=0$
2. Compute the general solution for $y''+y'+(\pi^2+1/4)y=e^{-x/2}\sin\pi x$
3. Solve $(x^2D^2-4xD-6)y=c$

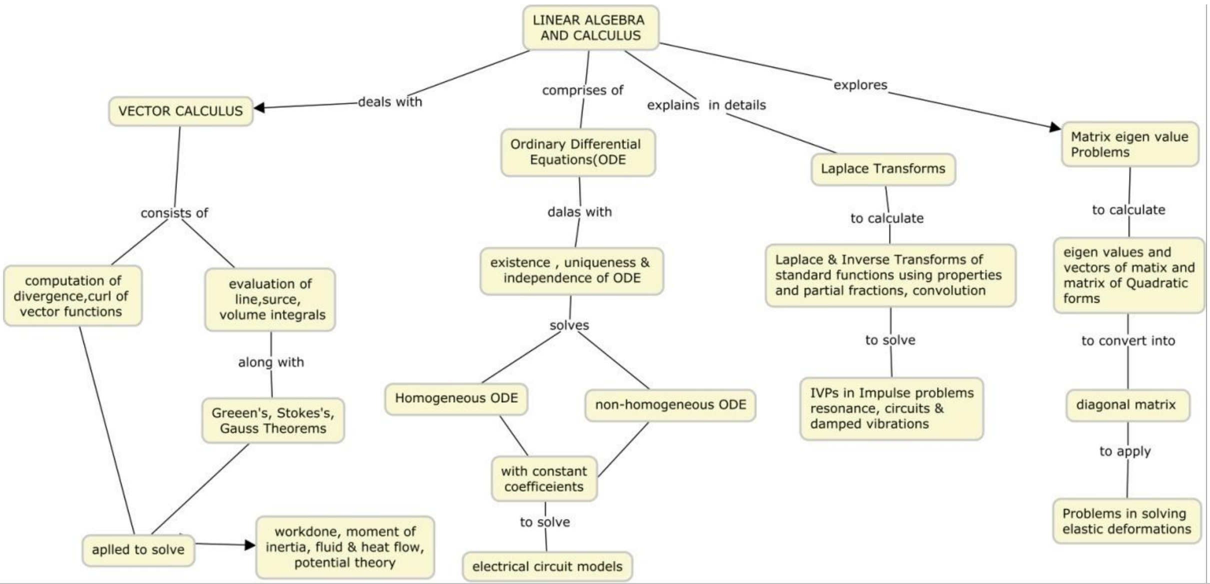
Course Outcome 5

1. Predict the value of $div(curl\vec{F})$.
2. If ϕ_1 and ϕ_2 are scalar point functions and $\vec{F}$ is a vector point function such that $\phi_1 \vec{F} = \nabla\phi_2$ then identify $\vec{F}.curl\,\vec{F}$.
3. Estimate $curl\,\vec{v}$, where $\vec{v} = \left[e^{-z^2}, e^{-x^2}, e^{-y^2}\right]$.

Course Outcome 6

1. Predict the work done by the force $\vec{F} = [y^2, -x^2]$ acting on a particle in $y = 4x^2$ from (0,0) to (1,4).
2. **Compute 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.**
3. **Apply Stokes theorem to compute** $\int_C \vec{F}.\vec{r}'\,ds$ where $\vec{F} = [y, xz^3, -zy^3]$ and C is circle $x^2 + y^2 = 4, z = -3$.

Concept Map



Syllabus

LAPLACE TRANSFROMS: Laplace transform, Linearity, First Shifting theorem – Transforms of derivatives and integrals, ODEs – Unit step function, Second shifting theorem – Short Impulses, Dirac's delta function, partial fractions – Convolution, Integral Equations – Differentiation and integration of transforms. **MATRIX EIGEN VALUE PROBLEM:** The Matrix Eigen value Problem, Determining Eigenvalues and Eigenvectors – Some Applications of Eigen value Problems – Symmetric, Skew symmetric and orthogonal matrices – Eigen bases, Diagonalization, Quadratic forms. **ORDINARY DIFFERENTIAL EQUATION:** Homogeneous Linear ODEs of second order – Homogeneous Linear ODEs with constant coefficients – Euler Cauchy Equation – Existence and uniqueness of solutions, Wronskian - Nonhomogeneous ODE – Modelling: Electric Circuits- Solution by Variation of Parameters. **VECTOR CALCULUS:** Divergence of a Vector Field- Curl of a Vector Field- Line Integrals- Path independence of line integrals- Green's Theorem in the plane- Surface Integrals- Triple Integrals, Divergence Theorem of Gauss- Applications of the Divergence Theorem- Stoke's Theorem.

Learning Resources

1. Erwin Kreszig, "Advanced Engineering Mathematics",10th edition, Wiley, 2017.
    a. Laplace transforms : [sections 6.1,6.2,6.3,6.4,6.5,6.6]
    b. Matrix eigen value problem : [sections 8.1,8.2,8.3,8.4]
    c. Ordinary differential equations : [sections 2.1,2.2,2.5,2.6,2.7,2.9,2.10]
    d. Vector calculus : [sections 9.8.9.9,10.1,10.2,10.4,10.6, 10.7,10.8,10.9]
2. Peter V.O'Neil, "Advanced Engineering Mathematics", 7th edition, Cengage Learning, 2017.
3. Glyn James, "Advanced Modern Engineering Mathematics", Pearson Education, New Delhi, 2016.
4. Jain R.K. and Iyengar S.R.K., "Advanced Engineering Mathematics", Narosa Publications, New Delhi, 3rd Edition, 2007.
5. Made Easy Team, Engineering Mathematics, Made Easy Publications, 2018.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Hours	Course Outcome
1.	**LAPLACE TRANSFORMS**		
1.1	Laplace Transform. Linearity. First Shifting Theorem (*s*-Shifting)	2	CO1
1.2	Transforms of Derivatives and Integrals. ODEs	2	CO2
1.3	Unit Step Function (Heaviside Function). Second Shifting Theorem (*t*-Shifting)	1	CO1
1.4	Short Impulses. Dirac's Delta Function. Partial Fractions	1	CO1
1.5	Convolution. Integral Equations	2	CO2
1.6	Differentiation and integration of transforms	1	CO1
2	**MATRICES EIGEN VALUE PROBLEMS**		
2.1	Determining Eigenvalues and Eigenvectors	2	CO3
2.2	Some Applications of Eigenvalue Problems	1	CO3
2.3	Symmetric, Skew-Symmetric, and Orthogonal Matrices	2	CO3
2.4	Eigenbases. Diagonalization.	2	CO3
2.5	Quadratic Forms	2	CO3
3	**ORDINARY DIFFERENTIAL EQUATION**		
3.1	Homogeneous Linear ODEs of Second Order	2	CO4
3.2	Homogeneous Linear ODEs with Constant Coefficients	1	CO4
3.3	Euler–Cauchy Equations	1	CO4
3.4	Existence and Uniqueness of Solutions. Wronskian	1	CO4
3.5	Nonhomogeneous ODEs	2	CO4
3.6	Solution by Variation of Parameters	2	CO4
4	**VECTOR CALCULUS**		
4.1	Divergence and Curl of a Vector Field	2	CO5
4.2	Line Integrals	2	CO6
4.3	Green's Theorem in the Plane	1	CO6
4.4	Surface Integrals	1	CO6
4.5	Triple Integrals. Divergence Theorem of Gauss	1	CO6
4.6	Applications of the Divergence Theorem	1	CO6
4.7	Stoke's Theorem	1	CO6
	TOTAL No. of Hours	36	

Course Designers

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18ME220	ENGINEERING MECHANICS	Category	L	T	P	Credit
		PC	2	1	0	3

Preamble

Mechanics can be defined as that science which describes and predicts the conditions of rest or motion of bodies under the action of forces. 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. The branch of mechanics is divided into three parts: Mechanics of Rigid Bodies, Mechanics of Deformable Bodies, and Mechanics of Fluids. The mechanics of rigid bodies is subdivided into **Statics** and **Dynamics (Kinematics & Kinetics)**, the former dealing with bodies at rest, the latter with bodies in motion. In the current part of the study, bodies are assumed to be perfectly rigid. Actual structures and machines, however, are never absolutely rigid and deform under the loads to which they are subjected. But these deformations are usually small and do not appreciably affect the conditions of equilibrium or motion of the structure under consideration. This course covers the fundamentals of statics and dynamics of particles and rigid bodies.

Prerequisite

- Nil

Course Outcomes

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

CO Number	Course Outcome Statement	Weight age In %
CO1	Solve problems on particles and rigid bodies using the concept of static equilibrium.	24
CO2	Compute the frictional forces for bodies in contact.	10
CO3	Calculate the centre of gravity and moment of inertia of the given geometry.	20
CO4	Select suitable method for solving problems on kinematics and kinetics of particles by applying the principles of D'Alembertz, Conservation of work, work energy and Impulse momentum.	23
CO5	Solve problems in kinetics of particles and rigid bodies subjected to general planar motion using various principles.	23

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.5, 3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3

CO2	TPS3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.5, 3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.5, 3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.5, 3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3
CO5	TPS3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.5, 3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3

Mapping with Programme Outcomes and Programme Specific 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	PSO 1	PSO 2	PSO 3
CO1.	S	S	M	L	-	-	-	-	-	-	-	-	L	-	M
CO2.	S	S	M	L	-	-	-	-	-	-	-	-	L	-	M
CO3.	S	S	M	L	-	-	-	-	-	-	-	-	L	-	M
CO4.	S	S	M	M	-	-	-	-	-	-	-	-	L	-	M
CO5.	S	S	M	M	-	-	-	-	-	-	-	-	L	-	M

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests (40)			Assignment (10)			Terminal Examination (50)
	1	2	3	1	2	3	
Remember	10	10	10	0	0	0	10
Understand	10	10	10	0	0	0	10
Apply	80	80	80	100	100	100	80
Analyse	0	0	0	0	0	0	0
Evaluate	0	0	0	0	0	0	0
Create	0	0	0	0	0	0	0

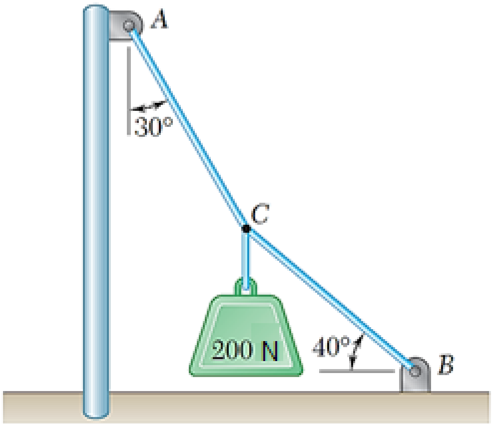
Assessment Pattern: Psychomotor

Psychomotor Skill	Mini Project/ Assignment/ Practical
Perception, Set	-
Guided Response	-
Mechanism	Assignment
Complex Overt Responses	-
Adaptation	-
Origination	-

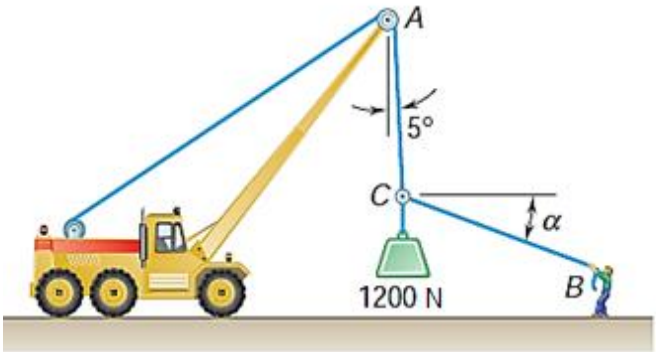
Sample Questions for Course Outcome Assessment

COURSE OUTCOME 1 (CO1):

1. Two cables are tied together at C and loaded as shown. Draw the free-body diagram and determine the tension in AC and BC.

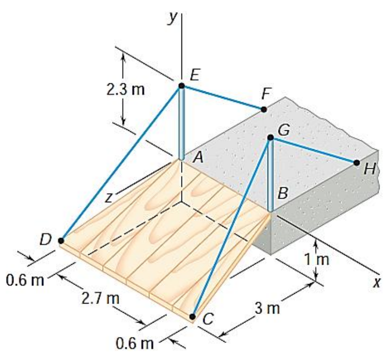


2. Knowing that a = 20^0, determine the tension (a) in cable AC, (b) in rope BC.



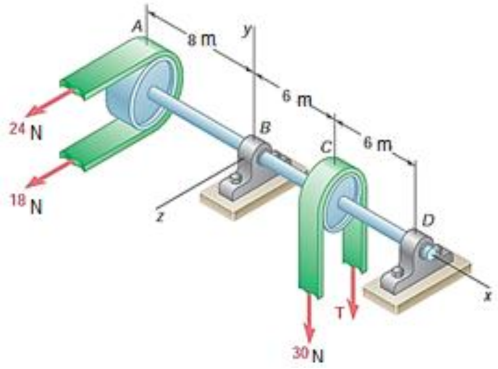
COURSE OUTCOME 2 (CO2):

1. The ramp ABCD is supported by cables at corners C and D. The tension in each of the cables is 810 N. Determine the moment about A of the force exerted by (a) the cable at D, (b) the cable at C.

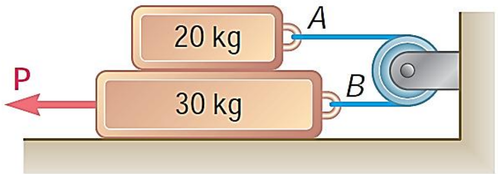


2. Two transmission belts pass over sheaves welded to an axle supported by bearings at B and D. The sheave at A has a radius of 2.5 m. and the sheave at C has a radius of 2 m. Knowing that the system rotates at a constant rate, draw the free-body diagram

needed to determine the tension T and the reactions at B and D. Assume that the bearing at D does not exert any axial thrust and neglect the weights of the sheaves and axle.

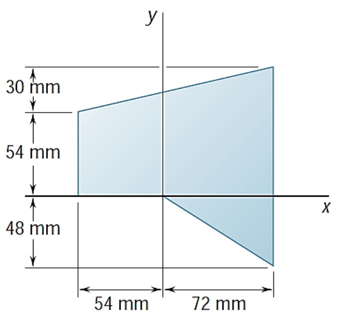


3. The coefficients of friction are m_s = 0.40 and m_k = 0.30 between all surfaces of contact. Determine the smallest force P required to start the 30-kg block moving if cable AB (a) is attached as shown, (b) is removed.

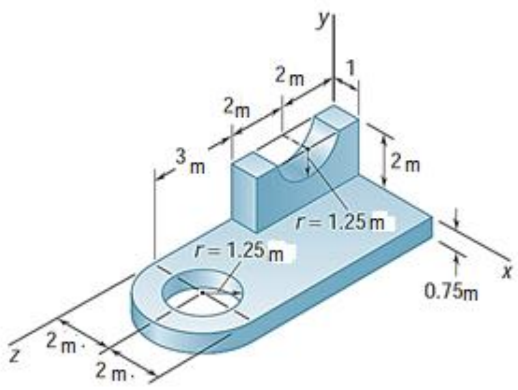


COURSE OUTCOME 3 (CO3):

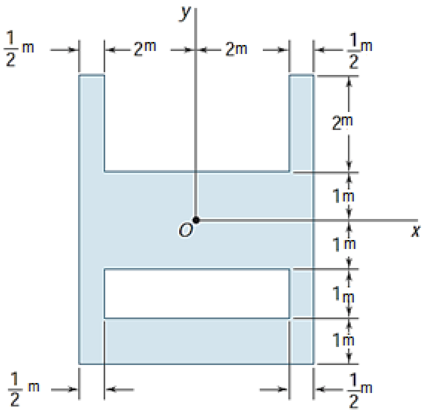
1. Locate the centroid of the plane area shown.



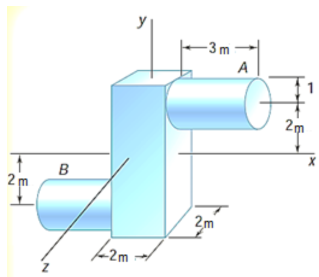
2. Locate the centre of gravity of the steel machine element shown. The diameter of each hole is 1 m.



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

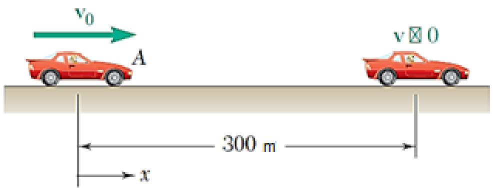


4. A steel forging consists of a 6 x 2 x 2m. rectangular prism and two cylinders of diameter 2m and length 3m. as shown. Determine the moments of inertia of the forging with respect to the coordinate axes, knowing that the specific weight of steel is 490 N/m^3.



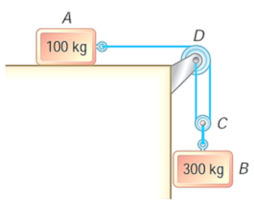
COURSE OUTCOME 4 (CO4):

1. The brakes of a car are applied, causing it to slow down at a rate of 10 m/s^2. Knowing that the car stops in 300 m, determine (a) how fast the car was traveling immediately before the brakes were applied, (b) the time required for the car to stop.



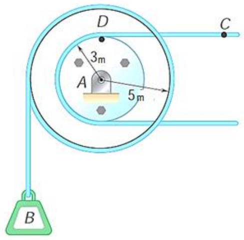
2. Starting from x = 0 with no initial velocity, a particle is given an acceleration a = 0.12 V^2 +16, where a and v are expressed in m/s^2 and m/s, respectively. Determine (a) the position of the particle when v = 5 3 m/s, (b) the speed and acceleration of the particle when x = 4 m.

3. The two blocks shown start from rest. Assume that the coefficient of kinetic friction between block A and the horizontal plane is m_k = 0.25 and the pulley is assumed to be of negligible mass. Analyse the acceleration of each block and the tension in each cord using D'Alembertz principle, Work Energy method and Impulse momentum method.

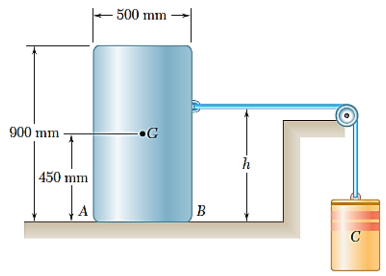


COURSE OUTCOME 5 (CO5):

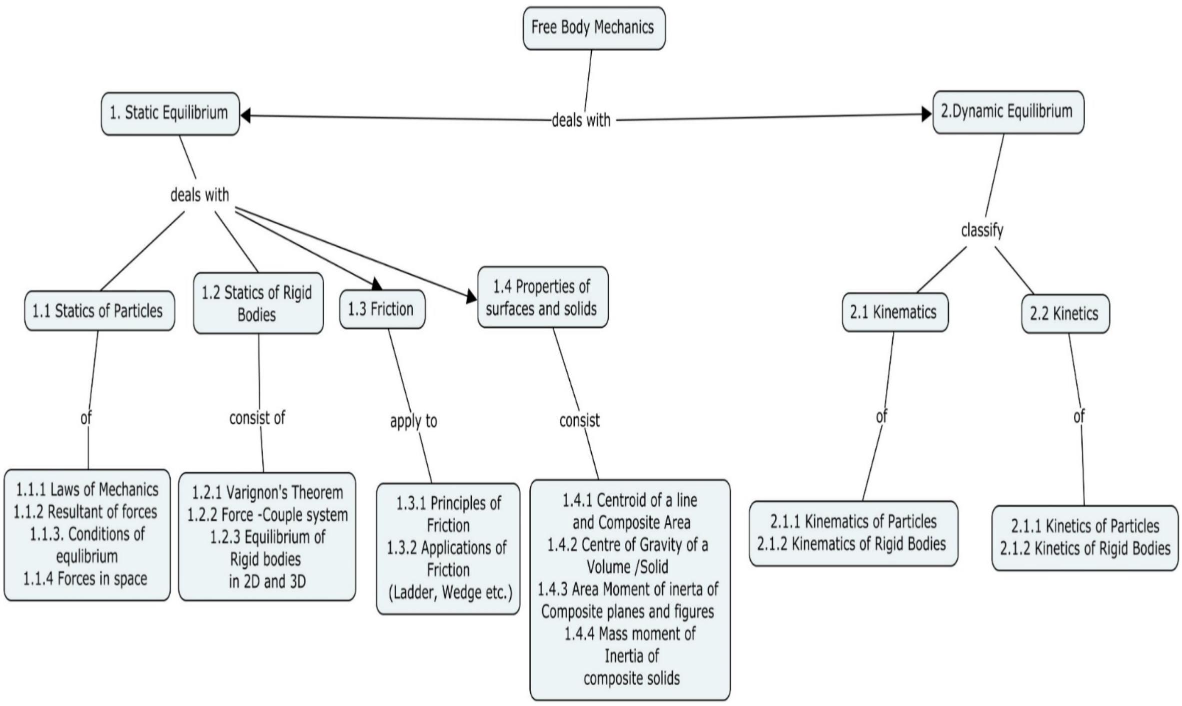
1. Load B is connected to a double pulley by one of the two inextensible cables shown. The motion of the pulley is controlled by cable C, which has a constant acceleration of 9 m/s^2 and an initial velocity of 12 m/s, both directed to the right. Determine (a) the number of revolutions executed by the pulley in 2 s, (b) the velocity and change in position of the load B after 2 s, and (c) the acceleration of point D on the rim of the inner pulley at t = 0.



2. A completely filled barrel and its contents have a combined mass of 90 kg. A cylinder C is connected to the barrel at a height h = 550 mm as shown. Knowing m_s = 0.40 and m_k = 0.35, determine the maximum mass of C so the barrel will not tip.



Concept Map



Syllabus

Statics of Particles: Fundamental principles and concepts – Laws of mechanics – Principle

of Transmissibility – Parallelogram, Triangle and Polygon law of forces – Resultant of concurrent and non-concurrent coplanar forces. Static Equilibrium – Conditions of equilibrium in statics – Lami's Theorem – Free body Diagram – Reactions. 3D Statics – Forces in space;
Statics of Rigid Bodies: Moment of a force – Varignon's theorem – Force Couple System – Reduction of system of forces into one force and couple – Equilibrium of rigid bodies in 2D and 3D.
Friction: Role of frictional force – Types of friction – Limiting friction – Coefficient of friction and angle of friction – Coulomb's law of friction – Angle of Repose – Cone of friction – Problems in wedge friction.
Distributed Forces: Centroid and Centre of Gravity – Simple and Composite plane figures and solid bodies – Pappus and Guldinus Theorem. Area Moment of Inertia – Parallel and Perpendicular Axis Theorem – Polar Moment of Inertia – Radius of gyration – Mass Moment of Inertia – Simple and Composite plane figures and solid bodies;
Dynamics of Particles: **Kinematics of Particles:** Rectilinear Motion – Uniform and Variation acceleration – Motion of particle under gravity – Relative motion. Curvilinear motion; **Kinetics of Particles:** Newton's Second Law of motion – D'Alembertz Principle. Work energy principle – Conservation of energy. Impulse-Momentum principle – Conservation of linear momentum – Motion of singular body and connected bodies. **Dynamics of Rigid Bodies**: **Kinematics of Rigid Bodies:** Linear motion & Angular motion – General plane motion. **Kinetics of Rigid Bodies:** D'Alembertz Principle – Work energy principle – Impulse-momentum principle – Conservation of Angular Momentum.

Learning Resources

1. Beer F.P. and Johnston Jr. E.R., '**Vector Mechanics for Engineers: Statics and Dynamics**', Twelfth Edition, Tata McGraw Hill, 2019.
2. Meriam J.L and Kraig L.G, '**Engineering Mechanics-Statics and Dynamics**', John Wiley & sons, New York, Eighth Edition, 2016.
1. Timoshenko, S, Young, D, Rao. J, '**Engineering Mechanics**', Fourth Edition, Tata McGraw Hill, Fifth Edition, 2017.
2. R.C. Hibbeller, **'Engineering Mechanics: Statics & Dynamics**', Prentice Hall, , Thirteen Edition, 2013.
3. Irving H. Shames, **'Engineering Mechanics - Statics and Dynamics'**, Pearson Education Asia Pvt. Ltd., 2006.
4. Palanichamy and Nagan S., '**Engineering Mechanics – Statics and Dynamics**', Third Edition, Tata McGraw Hill, 2005.
5. S. Rajasekaran and G. Sankara subramanian, '**Fundamentals of Engineering Mechanics**', Vikas Publishing House Pvt. Ltd., New Delhi, Third Edition, 2005.
6. Anthony M. Bedford and Wallace Fowler, '**Engineering Mechanics: Statics and Dynamics'**, Prentice Hall, Fifth Edition, 2007.
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8. N.H.Dubey, '**Engineering Mechanics – Statics and Dynamics**', Tata McGraw-Hill Publishing Company, New Delhi, 2017.
9. Boresi A.P. and Schmidt R.J., '**Engineering Mechanics: Statics and Dynamics**', Thomson Asia Press, Singapore, 2008.
10. Andrew Pytel and Jaan Kiusalaans, **'Engineering Mechanics – Statics and Dynamics',** Cengage Publications, USA, Third Edition, 2011.
11. Sadhu Singh, '**Engineering Mechanics; Statics and Dynamics',** Khanna publishers, New Delhi, Second Edition, 2004.
12. https://nptel.ac.in/courses/112103108/ - Engineering Mechanics - Prof. U. S. Dixit- Indian Institute of Technology, Guwahati
13. https://nptel.ac.in/courses/112106180/ - Statics and Dynamics- Dr. Mahesh V. Panchagnula, Indian Institute of Technology, Madras
14. https://www.edx.org/course/engineering-mechanics
15. https://www.coursera.org/learn/engineering-mechanics-statics

Course Contents and Lecture Schedule

Module No.	Topics	No. of hours	Course outcome
1.1	**Statics of Particles**		
1.1	Fundamental principles and concepts		
1.1.1	Laws of Mechanics	1	CO1
1.2	Resultant of concurrent and non-concurrent	1	CO1
1.3	Conditions of Static Equilibrium	1	CO1
1.3.1	Lami's theorem & its application in 2D	1	CO1
1.4	Forces in space	2	CO1
1.2	**Statics of Rigid bodies**		
1.2.1	Moment of a force & Varignon's theorem	1	CO1
1.2.2	Force couple system	1	CO1
1.2.3	Equilibrium of rigid bodies in 2D	1	CO1
1.2.4	Equilibrium of rigid bodies in 3D	2	CO1
2.	**Friction**		
2.1	Fundamentals of friction	1	CO2
2.2	Angle of repose and cone of friction	1	CO2
2.3	Problems in Wedge friction	2	CO2
3.	**Distributed Forces**		
3.1	Centroid of simple and composite plane figures	1	CO3
3.2	Centre of gravity of simple and composite solid	1	CO3
3.3	Pappus and Guldinus theorem Centroid of line	1	CO3
3.4	Moment of Inertia – Theorems	1	CO3
3.5	Area Moment of Inertia of plane figures	2	CO3
3.6	Mass Moment of Inertia of solid bodies	1	CO3
4.	**Dynamics of Particles**		
4.1	Kinematics of Particles		
4.1.1	Rectilinear motion	1	CO4
4.1.2	Curvilinear motion	1	CO4
4.2	Kinetics of Particles		CO4
4.2.1	Newton's second law of motion	1	CO4
4.2.2	D'Alembertz principle	1	CO4
4.2.3	Work Energy Principle	2	CO4
4.2.4	Impulse Momentum Principle	2	CO4
5.	**Dynamics of Rigid Bodies**		
5.1	Kinematics of Rigid Bodies	1	CO5
5.1.1	General Plane motion	1	CO5
5.2	Kinetics of Rigid Bodies		
5.2.1	D'Alembertz principle	1	CO5
5.2.2	Work Energy principle	1	CO5
5.2.3	Impulse Momentum principle	2	C05
	Total No. of Hours	**36**	

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18ME230	METAL CASTING AND FORMING PROCESSES	Category	L	T	P	Credit
		PC	3	0	0	3

Preamble

Manufacturing processes are the steps through which raw materials are transformed into a final product. Manufacturing processes can be classified as: 1. Casting Processes,
2. Forming Processes, 3. Machining Processes, 4. Joining Processes, 5. Finishing Processes.
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. Products may be discrete products like nails, piston, engine blocks or continuous products like rod, tube and pipes.
Plastic moulding is the process of shaping plastic using a rigid frame or mould. The technique allows for the creation of objects of all shapes and sizes with huge design flexibility for both simple and highly complex designs. A popular manufacturing option, plastic moulding techniques are responsible for many car parts, containers, signs and other high volume items.
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. Products such as tubes, panels, car doors, PC panels, computer casing and utensils are made by metal forming processes.
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. Many prosthetics and orthotics are constructed of resin, plastic, or metal through additive manufacturing.
The first, second, third and fourth parts of this course aim to provide knowledge on the working principles, process capabilities, process parameters, equipment advantages, limitations and applications of various metal casting, metal forming, plastic moulding and additive processes.

Prerequisite

Nil

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Explain the working principles, process capabilities, process parameters and equipment of metal casting, forming, plastic moulding and additive processes.	30
CO2	Determine the forming forces for various metal forming processes.	10
CO3	Identify defects and interpret causes for defects in product of metal casting and forming processes.	10
CO4	Select the suitable material and process for a given product or component.	50

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.2, 2.4.4, 3.3.1,4.3.2
CO2	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	S	M	L	-	-	-	-	-	-	-	L	-	S	-	L
CO2	S	M	L	-	-	-	-	-	-	-	M	-	S	-	L
CO3	S	M	L	-	-	-	M	-	-	-	M	-	S	-	L
CO4	S	M	L	-	-	-	M	-	-	-	M	-	S	-	L

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	**20**	**20**	**20**	**20**	**20**	**20**	**20**
Understand	**30**	**30**	**30**	**30**	**30**	**30**	**30**
Apply	**50**	**50**	**50**	**50**	**50**	**50**	**50**
Analyse	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Evaluate	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Create	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Assessment Pattern: Psychomotor

Psychomotor Skill	**Miniproject /Assignment/Practical Component**
Perception	**-**
Set	**-**
Guided Response	**-**
Mechanism	**Assignment**
Complex Overt Responses	**-**
Adaptation	**-**
Origination	**-**

Sample Questions for Course Outcome Assessment**

** (2 to 3 at the cognitive level of course outcome)

Course Outcome 1 (CO1):

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. Summarize the working principle of fusion deposition modelling (FDM).

Course Outcome 2(CO2):

4. 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.
5. 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.

6. 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.

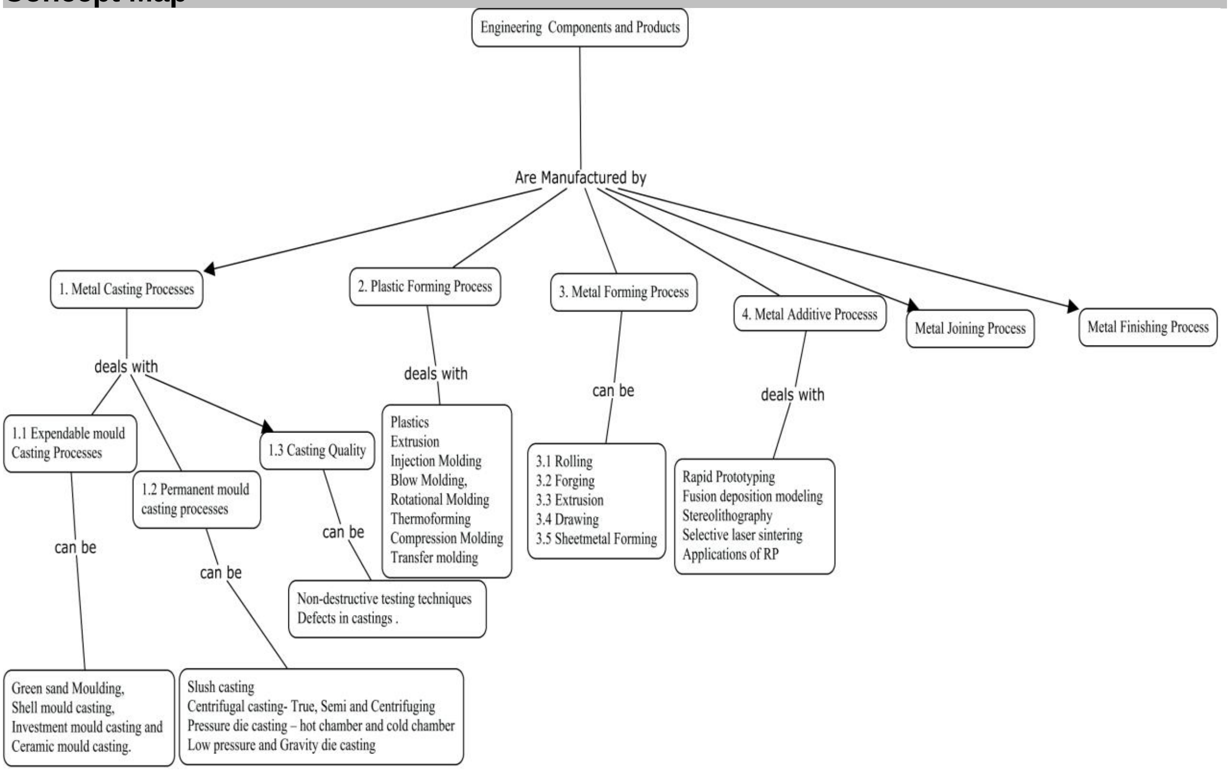
Course Outcome 3 (CO3):

7. List the defects that occur in rolled plates and sheets.
8. Suggest few techniques to minimize incomplete casting and inclusions in casting.
9. 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 4 (CO4):

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 articles produced? i) Cans and ii) Cups

Concept Map



Syllabus

Metal casting:

Expendable mould Casting Processes: Pattern - materials, types, and allowances. Moulding sand- types, ingredients, properties Core- Types, functions, chaplets, Types of sand 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, Plaster and Ceramic mould casting.

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

Casting Quality: Defects in casting and remedies 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.

Metal forming Processes:

Fundamental of Metal forming, Elastic and plastic deformation, 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 and sheets, Calculation of Rolling Force.

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, Calculation of Forging Force.

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

Extrusion Process: hot, cold, impact and hydro static extrusion, process parameter involved, Extrusion Machines-Horizontal, Vertical hydraulic presses and dies and defects in extrusion, Calculation of Extrusion Force.

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 and defects in sheet metal process, Calculation of Sheet Metal Forming Force.

Metal additive processes: Introduction to Rapid Prototyping – fusion deposition modelling - Stereolithography– Selective laser sintering – applications.

Learning Resources

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. S.K.HajraChoudhury and A.K. HajraChoudhury, “Elements of Work shop Technology”, Vol – I Manufacturing Processes, Media Promoters and Publishers Pvt. Ltd, 1986.
4. P.L.Jain, “Principles Of Foundry Technology”, Tata McGraw Hill, Fifth Edition, 2009.
5. Prabodh C. Bolur, “A Guide to Injection Moulding of Plastics”, Third edition, Sri Prema Sai Printers & Publishers, Mangalore, 2007.
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. E.Paul Degarmo, J.T.Black, and Ronald A. Konser, “Materials and Processes in Manufacturing”, 5th Edition, Prentice Hall India Ltd., 1997.
9. Philip F. Oswald, and Jairo Munoz, “Manufacturing Process and systems”, John Wiley and Sons, 1992.
10. https://nptel.ac.in/courses/112107144/13- COURSE CO-ORDINATED BY : IIT ROORKEE
11. https://nptel.ac.in/courses/112107145/17-Dr. D. B. Karunakar Mechanical and Industrial Engineering Department Indian Institute of Technology, Roorkee
12. https://nptel.ac.in/courses/112107083/-Dr. D. B. Karunakar Department of Mechanical and Industrial Engineering Indian Institute of Technology, Roorkee
13. https://www.class-central.com/course/nptel-principles-of-casting-technology-7899-Prof. Pradeep K. Jha, Department of Mechanical and Industrial Engineering, IIT Roorkee.
14. https://www.edx.org/course/fundamentals-manufacturing-processes-mitx-2-008x-0-A. John Hart, Associate Professor of Mechanical Engineering, Massachusetts Institute of Technology
15. https://www.afsinc.org/courses/introduction-metalcasting- Course Coordinated by American Foundry Society, 1695 North Penny Lane, Schaumburg, IL 60173

16. https://www.coursera.org/lecture/high-throughput/additive-manufacturing-metals-Dxsjj- Dr. Richard W. Neu, Professor, The George W. Woodruff School of Mechanical Engineering
17. https://www.mooc-list.com/course/fundamentals-manufacturing-processes-edx- A. John Hart, MIT.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Hours	Course Outcome
1	**Metal casting Processes**		
1.1	**Expendable mould Casting Processes:** Pattern - materials, types, and allowances. Moulding sand- types, ingredients, properties	2	CO1
1.1.1	Core- Types, functions, chaplets, Steps involved in making a green sand mould.	1	CO1
1.1.2	Moulding machines - Squeeze type, Jolt type, and Sand slinger.	1	CO1
1.1.3	Procedural steps and applications of Shell mould casting, Investment mould casting , Plaster and Ceramic mould casting	2	CO4
1.2	**Permanent mould casting processes:** Procedural steps and applications of Permanent mould casting processes such as Gravity die casting, Slush casting	2	CO4
1.2.1	Centrifugal casting- True, Semi and Centrifuging, Pressure die casting – hot chamber and cold chamber	2	CO4
1.3	**Casting Quality:** Defects in casting and remedies and summary of Non-destructive testing techniques.	2	CO3
2	**Plastic forming processes:** Plastics, general properties and applications of thermo plastics and thermosets.	1	CO1
2.1	Forming/shaping and applications of plastics: Extrusion, Injection Molding, Blow Molding, Rotational Molding	2	CO4
2.1.1	Thermoforming, Compression Molding, Transfer molding, Casting.	2	CO4
3.	**Metal Forming Process**		
3.1	Fundamental of Metal forming, Elastic and plastic deformation, Hot and cold working processes.	1	CO1
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	CO1, CO4
3.2.1	Calculation of Rolling Force	1	CO2
3.2.2	Defects in rolled plates and sheets.	1	CO3
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	CO1
3.3.1	Forging presses and dies and defects in forging.	1	CO1, CO3
3.3.2	Calculation of Forging Force		CO2
3.4	**Extrusion Process**: hot, cold, impact and hydro static extrusion, process parameter involved	2	CO1
3.4.1	Extrusion Machines-Horizontal, Vertical hydraulic presses and dies and defects in extrusion	1	CO1, CO3
3.4.2	Calculation of Extrusion Force	1	CO2

3.5	**Drawing Process:** Wire and tube drawing, process parameter involved, Wire Drawing equipments and dies and defects in drawing.	2	CO1, CO3
3.5.1	Calculation of Drawing Force	1	CO2
3.6	**Sheet metal forming Process**: Formability of Sheet metal, Shearing mechanism, Drawabilty, process parameter involved.	1	CO1
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	CO1
3.6.2	Tube bending, Stretch Forming, Deep Drawing and defects in sheet metal process.	1	CO1, CO3
3.6.3	Calculation of Sheet Metal Forming Force	1	CO2
4	**Metal additive processes**		
4.1	Introduction to Rapid Prototyping, Fusion deposition modelling.	2	CO4
4.2	Stereolithography, Selective laser sintering and applications.	2	CO4

Course Designers:

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18ME240	ENGINEERING THERMODYNAMICS

Category	L	T	P	Credit
PC	2	1	-	3

Preamble

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

Prerequisite

Engineering Mathematics
Physics

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Determine the change of properties and energy transfer during different thermodynamic processes in closed system using ideal gas, water or steam.	24
CO2	Determine the energy transfer and change in properties of ideal gas, steam in thermodynamically open systems during different thermodynamic processes.	18
CO3	Determine the efficiency of heat engine and COP of heat pump , refrigerator	22
CO4	Determine the entropy change and availability of open and closed system for different thermodynamic processes and II law efficiency	20
CO5	Calculate the change of properties of ideal gas mixture	16

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Apply	Value	Mechanism	1.2,2.1,3.2,4.1.1
CO2	TPS3	Apply	Value	Mechanism	1.2,2.1,3.2,4.1.1
CO3	TPS3	Apply	Value	Mechanism	1.2,2.1,3.2,4.1.1
CO4	TPS3	Apply	Value	Mechanism	1.2,2.1,3.2,4.1.1
CO5	TPS3	Apply	Value	Mechanism	1.2,2.1,3.2,4.1.1

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	M	M	L									L		M	
CO2	S	S	L									L		S	
CO3	S	S	L									L		S	
CO4	S	S	L									L		M	
CO5	S	S	L									L		L	

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	**2**	**3**	1	2	3	
Remember	**20**	**20**	**20**	-	-	-	**20**
Understand	30	30	30	-	-	-	30
Apply	50	50	50	100	100	100	50
Analyse							
Evaluate							
Create							

Assessment Pattern: Psychomotor

Psychomotor Skill	Mini project /Assignment/Practical Component
Perception	
Set	
Guided Response	
Mechanism	Assignment/ spoken tutorials.
Complex Overt Responses	
Adaptation	
Origination	

Sample Questions for Course Outcome Assessment**

Course Outcome 1(CO1):

1. Define: Thermodynamics System
2. State zeroth Law of Thermodynamics
3. Draw the phase equilibrium diagram for a pure substance on h-s plot with relavent constant property lines.
4. A gas in a piston cylinder device is compressed and as a result its temperature rises. Is this a heat or work interaction?
5. A rigid tank contains a hot fluid that is cooled while being stirred by a paddle wheel. Initially the internal energy of the fluid is 800 kJ. During the cooling process, the fluid losses 500 kJ of heat and the paddle wheel does 100kJ of work on the fluid. Determine the final internal energy of the fluid. Neglect the energy stored in the paddle wheel.
6. A mass of 1.5 kg of air is compressed in a quasi-static process from 0.1MPa to 0.7 MPa for which pv = constant. The initial density of air is 1.16kg/m^3. Find the work done by the piston to compress the air.

Course Outcome 2(CO2):

1. Derive the steady flow energy equation
2. 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.
3. Air at 100 kPa and 280 K is compressed steadily to 600 kPa and 400 K. The mass flow rate of the air is 0.02 kg/s, and a heat loss of 16kJ/kg occurs during the process. Assuming the changes in kinetic and potential energies are negligible, determine the necessary power input to the compressor.

Course Outcome 3 (CO3):

1. A refrigerator is to remove heat from the cooled space at a rate of 300 kJ/min to maintain its temperature at 28°C. If the air surrounding the refrigerator is at 25°C, determine the minimum power input required for this refrigerator

2. Bananas are to be cooled from 24 to 13°C at a rate of 215 kg/h by a refrigeration system. The power input to the refrigerator is 1.4 kW. Determine the rate of cooling, in kJ/min, and the COP of the refrigerator. The specific heat of banana above freezing is 3.35 kJ/kg°C.

3. Using an engine of 30% thermal efficiency to drive a refrigerator having a COP of 5, what is the heat input into the engine for each MJ removed from the cold body by the refrigerator? If this system is used as a heat pump, how many MJ of heat would be available for heating for each MJ of heat input to the engine?

Course Outcome 4 (CO4):

1. Calculate the entropy change of the universe as a result of the following processes:
   (a) A copper block of 600 g mass and with C_p of 150 J/K at 100°C is placed in a lake at 8°C.
   (b) The same block, at 8°C, is dropped from a height of 100 m into the lake.
   (c) Two such blocks, at 100 and 0°C, are joined together.

2. Each of three identical bodies satisfies the equation U = CT, where C is the heat capacity of each of the bodies. Their initial temperatures are200 K, 250 K, and 540 K. If C = 8.4 kJ/K, what is the maximum amount of work that can be extracted in a process in which these bodies are brought sto a final common temperature?

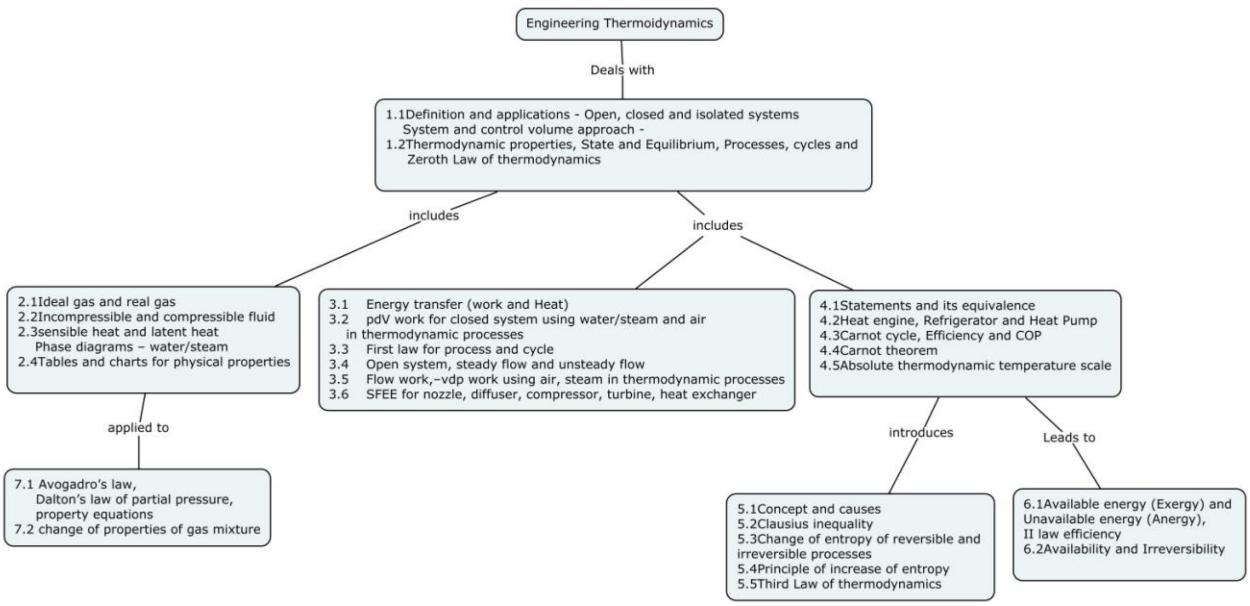
3. A pressure vessel has a volume of 1 m^3 and contains air at 1.4 MPa, 175°C. The air is cooled to 25°C by heat transfer to the surroundings at 25°C. Calculate the availability in the initial and final states and the irreversibility of this process. Take P_0 = 100 kPa.

Course Outcome 5(CO5):

1. Consider a gas mixture that consists of 3 kg of O_2, 5 kg of N_2, and 12 kg of CH_4, Determine (a) the mass fraction of each component, (b) the mole fraction of each component, and (c) the average molarmass and gas constant of the mixture.

2. 0.1m^3 of hydrogen initially at 1.2 MPa, 200°C undergoes a reversible isothermal expansion to 0.1 MPa. Find (a) the work done during the process, (b) the heat transferred, and (c) the entropy change of the gas.

Concept Map



Syllabus

Basic Concepts: Definition and applications **-** Open, closed and isolated systems – System and control volume approach - Thermodynamic properties, State and Equilibrium, Processes and cycles, - Zeroth Law of thermodynamics

Gases and water/steam: Ideal gas and real gas – compressible and incompressible fluid - Sensible heat and latent – phase diagrams of water/steam(p-v, p-T, T-v, T-s, h-s) - Tables and charts of physical properties.

First law of Thermodynamics: Forms of energy, energy transfer by heat and work, sign convention, path and point functions. 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, -v dp 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 of entropy for solids, liquids and gases in different thermodynamic processes. Principle of increase of entropy - Third law of thermodynamics.

Exergy and Anergy: Available (Exergy) and Unavailable energy (Anergy) – Availability for flow and non flow processes, Irreversibility.

Gas mixture: Avogadro's law, Dalton's law of partial pressure, property equations and change of properties of gas mixture.

Learning Resources

1. Yunus A. Cengel and Michael A. Boles, '**Thermodynamics: An Engineering Approach**', Eighth Edition, McGraw Hill, 2016.
2. Richard E. Sonntag, Claus Borgnakke, Gordon J. Vanwylen, '**Fundamental of Thermodynamics**', Wiley, 2002.

3. Nag, P.K., ‘**Engineering Thermodynamics**’, Fifth edition, 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.

On line study materials:

7. https://nptel.ac.in/courses/112105123/
8. https://www.youtube.com/watch?v=Sn_TSa7AkMU
9. https://www.youtube.com/watch?v=4RX_lpoGRBg
10. https://www.youtube.com/watch?v=SQEkhVUM_Kw

(Use of Standard and approved Steam Table, Mollier Chart is permitted)

Course Contents and Lecture Schedule

Module No.	Topic	No. of Hours	Course Outcome
1.	**Basic Concepts**		CO1
1.1	Definition and applications **-** Open, closed and isolated systems – System and control volume approach	1	
1.2	Thermodynamic properties, State and Equilibrium, Processes, cycles and Zeroth Law of thermodynamics	2	
2.	**Gases and Water/Steam**		
2.1	Ideal gas and real gas	1	
2.2	Incompressible and compressible fluid		
2.3	sensible heat and latent heat ,Phase diagrams – water/steam	2	
2.4	Tables and charts for physical properties		
3.	**First law of thermodynamics**		
3.1	Energy transfer (work and Heat), path and point functions	1	
3.2	pdV work for closed system using water/steam and air in thermodynamic processes	2	
3.3	First law for process and cycle	2	
3.4	Open system, steady flow and unsteady flow	1	CO2
3.5	Flow work, –v dp work using air, steam in thermodynamic processes	2	
3.6	SFEE for nozzle, diffuser, compressor, turbine, heat exchanger.	4	

4.	**Second Law of Thermodynamics**		CO3
4.1	Statements and its equivalence, reversible and irreversible processes	2	
4.2	Heat engine, Refrigerator and Heat Pump	2	
4.3	Carnot cycle, Efficiency and COP	3	
4.4	Carnot theorem	1	
4.5	Absolute thermodynamic temperature scale	1	
5.	**Entropy**		CO4
5.1	Concept and causes	1	
5.2	Clausius inequality		
5.3	Change of entropy for solids, liquids and gases in different thermodynamic processes	3	
5.4	Principle of increase of entropy	1	
5.5	Third Law of thermodynamics		
6.0	**Exergy and Anergy**		
6.1	Available energy (Exergy) and Unavailable energy (Anergy) and Second law efficiency	1	
6.2	Availability for flow and non flow processes and Irreversibility	2	
7.0	**Gas mixture**		CO5
7.1	Avogadro's law, Dalton's law of partial pressure, property equations	2	
7.2	change of properties of gas mixture	3	
	TOTAL	40 hours	

Course Designers:

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2. Mr. M.S. Govardhanan govardhanans@tce.edu

18ME250	MATERIALS ENGINEERING	Category	L	T	P	Credit
		ES	3	0	0	3

Preamble

The course work aims at imparting the fundamental knowledge on classification of materials, their properties, selection criteria of materials, imperfections in materials and their strengthening mechanism, testing of materials, phase diagram for ferrous and non ferrous alloys, heat treatment and surface treatment of steel.

Prerequisite

Basic course (No prerequisite)

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage *** in %
CO1	Select suitable material on the basis of its structure and properties for specific engineering application	20
CO2	Select suitable strengthening mechanism and list its effects for a crystalline material.	20
CO3	Calculate the stress, strain, hardness, percentage elongation and reduction in area and tensile strength of materials.	20
CO4	Illustrate various phases, phase percentage, invariant reactions, micro structure development of ferrous and nonferrous alloy systems using phase diagrams	20
CO5	Select appropriate heat treatment and surface hardening process for steel.	20

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	K3	Value	Mechanism	1.1, 1.2, 2.1.1, 2.1.5, 2.4.4, 3.2.3 3.3.1, 4.4.3
CO2	TPS3	K3	Value	Mechanism	1.1, 1.2, 2.4.4, 3.2.3 3.3.1, 4.4.3
CO3	TPS3	K3	Value	Mechanism	1.1, 1.2, 2.4.4, 3.2.3, 3.2.5, 3.3.1, 4.4.3
CO4	TPS3	K3	Value	Mechanism	1.1, 1.2, 2.1.1, 2.1.5, 2.4.4, 3.2.3, 3.3.1, 4.4.3
CO5	TPS3	K3	Value	Mechanism	1.1, 1.2, 2.1.1, 2.1.5, 2.4.4, 3.2.3 3.3.1, 4.4.3

Mapping with Programme Outcomes and Programme Specific 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**	-	-	-	-	-	-	-	-	-	-	-
CO2	**M**	**M**	**M**	**L**	-	-	-	-	-	-	-	-	-	-	-
CO3	**M**	**M**	**M**	**L**	-	-	-	-	-	-	-	-	-	-	-
CO4	**M**	**M**	**M**	**L**	-	-	-	-	-	-	-	-	-	-	-
CO5	**M**	**M**	**M**	**L**	-	-	-	-	-	-	-	-	-	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	20	20	20	-	-	-	20
Understand	30	30	30	100	100	100	30
Apply	50	50	50	-	-	-	50
Analyse	-	-	-	-	-	-	-
Evaluate	-	-	-	-	-	-	-
Create	-	-	-	-	-	-	-

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	-
Set	-
Guided Response	-
Mechanism	Assignment
Complex Overt Responses	-
Adaptation	-
Origination	-

Sample Questions for Course Outcome Assessment**

Course Outcome 1(CO1):

1. In selecting the materials for surgical gloves, what factors should you consider? Identify the appropriate material and justify your answer.
2. 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.
3. 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 2(CO2):

1. An undeformed specimen of some alloy has an average grain diameter of 0.050 mm. You are asked to reduce its average grain diameterto 0.020 mm. Is this possible? If so explain the procedure you would use and name the process involved. If it is not possible explain why?
2. A solution heat treated 2014 aluminium alloy is to be precipitation hardened to have a minimum yield strength of 345 MPa and a ductility of at least 12% EL. Specify s a practical precipitation heat treatment in terms of temperature and time that would give these mechanical characteristics. Justify your answer.
3. An uncold-worked brass specimen of average grain size 0.01 mm has a yield strength of 150 MPa. Estimate the yield strength of h alloy after it has been heated to 500 ^{0}C for 1000sec, if it is known that the value of σ_0 is 25 MPa.

Course Outcome 3(CO3):

1. 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.
2. 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.

3. 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.

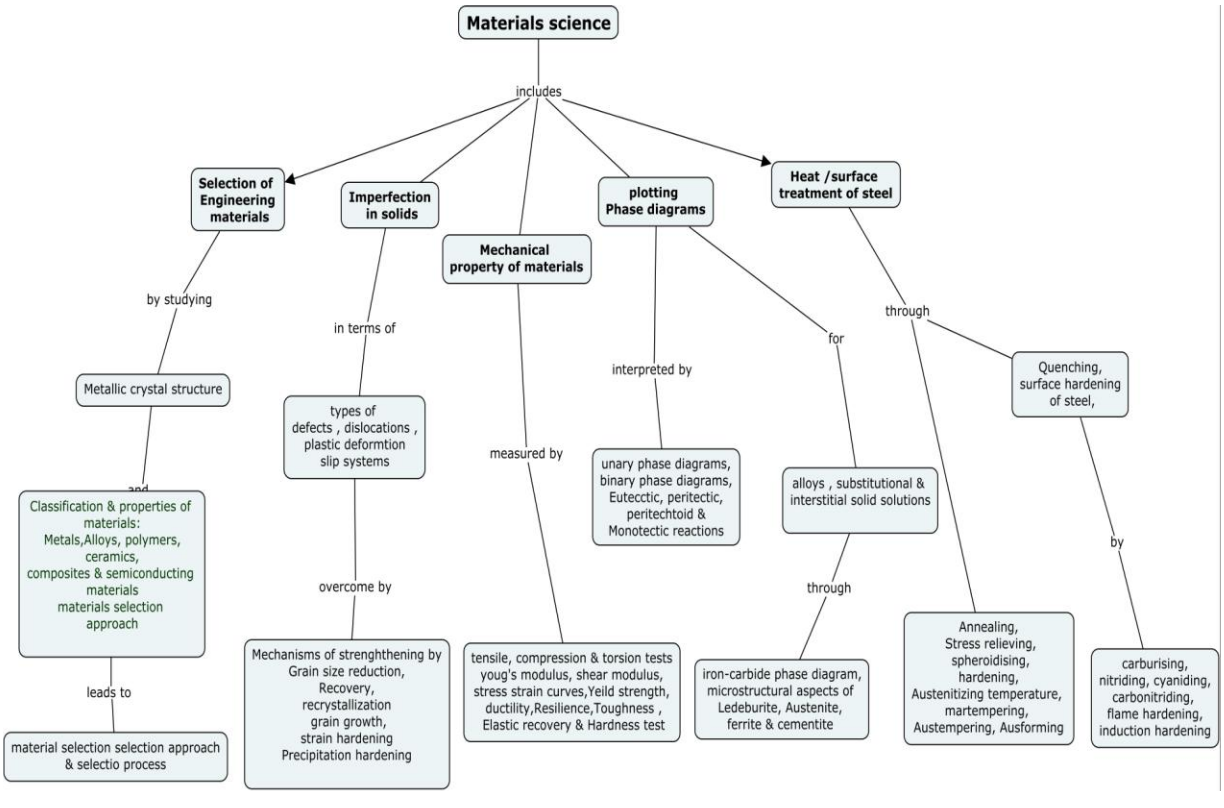
Course Outcome 4 (CO4):

1. Illustrate the development of microstructure during the equilibrium solidification of a 35 wt% Ni – 65 wt % Cu, using suitable phase diagram.
2. Compute the mass fractions of proeutectoid ferrite and pearlite that form in an iron-carbon alloy containing 0.35 wt% C.
3. For an iron-carbon alloy of composition 3 wt% C-97 wt% Fe, Make schematic sketches of the microstructure that would be observed for conditions of very slow cooling at the following temperatures: 1250 ^{0}C, 1145 ^{0}C and 700 ^{0}C. Lable the phases and indicate their composition approximately.

Course Outcome 5 (CO5):

1. Question 3 Demonstrate a suitable method to minimize the surface roughness of coarse grained steel.
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℃, b) 250-350℃ and c) 400-600℃.
3. Illustrate an isothermal transformation diagram for plain-carbon eutectoid steel and exhibit the various decomposition products in it.

Concept Map



Syllabus

Structure, properties and selection of engineering materials: Introduction to crystals, Unit cells, Metallic crystal structures, Classification and properties of Materials, Metals and Alloys, Polymers, Ceramics, Composites and Semiconductors. Selection of Engineering Materials: Material selection approach, selection process. **Imperfection in solids and strengthening mechanism:** Point, Line, Surface and Volume defects, Dislocations and plastic deformation, Slip systems, Slip in single crystals, Deformation by twinning, Mechanisms of strengthening: solid solution strengthening, Strengthening by Grain Size Reduction, Recovery, Recrystallization and Grain Growth, Strain Hardening and Precipitation Hardening. **Mechanical Property measurement:** Tensile, Compression and Torsion tests, Young's modulus, Shear modulus, True stress and strain, Engineering stress and strain, Stress-strain curves, Generalized Hooke's law, Yielding and yield strength, Ductility, Resilience, Toughness and Elastic recovery, Hardness: Rockwell, Brinell and Vickers and their relation to strength. **Phase diagrams:** Alloys, Substitutional and Interstitial solid solutions, Phase diagram fundamentals, Unary phase diagram, Interpretation of binary phase diagrams, Eutectic, Peritectic, Peritectoid and Monotectic reactions, Iron-carbide phase diagram and Microstrctural aspects of Ledeburite, Austenite, Ferrite and Cementite, Copper alloys; Brass, Bronze, Aluminium alloys, Al-Cu, Nickel and Titanium alloys. **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, Surface Hardening of steel: Carburising, Nitriding, Cyaniding, Carbonitriding, Flame hardening, Induction hardening.

Learning Resources

1. Callister W.D., Materials Science and Engineering, John Wiley & Sons, 9th Edition, 2014.
2. Sidney H. Avner, "Introduction to Physical Metallurgy", Tata McGraw Hill, New Delhi, 2nd Edition, 5th reprint, 2009.
3. William F Smith, Javad Hashemi, Ravi Prakash, Materials Science and Engineering, Tata McGraw Hill Private Limited, 5th Edition, 2013.
4. George Dieter, Mechanical Metallurgy, Tata McGraw-Hill, 3rd Edition, New Delhi, 2013.
5. Rajan.T.V., Sharma C.P., Ashok Sharma., Heat Treatment Principles And Techniques, Prentice-Hall Of India Pvt. Ltd., New Delhi, 2002.
6. https://nptel.ac.in/courses/112104203/
7. https://nptel.ac.in/couses/113107078/
8. https://nptel.ac.in/courses/113105023/
9. https://nptel.ac.in/courses/113106032/
10. https://nptel.ac.in/courses/113105024/
11. http://web.utk.edu/~prack/MSE%20300/surface%20treatments.pdf

Course Contents and Lecture Schedule

Module No.	Topic	No. of Hours	Course Outcome
1.	**Structure, properties and selection of engineering materials**		
1.1	Introduction to crystals, Unit cells, Metallic crystal structures.	2	CO1
1.2	Classification and properties of Materials, Metals and Alloys, Polymers, Ceramics, Composites and Semiconductors.	3	CO1
1.3	Selection of Engineering Materials: Material selection approach, selection process.	2	CO1
2.	**Imperfection in solids and strengthening mechanism**		
2.1	Point, Line, Surface and Volume defects.	2	CO2
2.2	Dislocations and plastic deformation, Slip systems, Slip in single crystals, Deformation by twinning.	2	CO2
2.3	Mechanisms of strengthening: solid solution strengthening, Strengthening by Grain Size Reduction, Recovery, Recrystallization and Grain Growth, Strain Hardening and Precipitation Hardening.	3	CO2
3.	**Mechanical Property measurement**		
3.1	Tensile, Compression and Torsion tests, Young's modulus, Shear modulus.	2	CO3

3.2	True stress and strain, Engineering stress and strain, Stress-strain curves, Generalized Hooke's law, Yielding and yield strength,	2	CO3
3.3	Ductility, Resilience, Toughness and Elastic recovery.	1	CO3
3.4	Hardness: Rockwell, Brinell and Vickers and their relation to strength.	2	CO3
4.	**Phase diagrams**		
4.1	Alloys, Substitutional and Interstitial solid solutions, Phase diagram fundamentals.	1	CO4
4.2	Unary phase diagram, Interpretation of binary phase diagrams, Eutectic, Peritectic, Peritectoid and Monotectic reactions.	2	CO4
4.3	Iron-carbide phase diagram and Microstrctural aspects of Ledeburite, Austenite, Ferrite and Cementite,	2	CO4
4.4	Copper alloys; Brass, Bronze, Aluminium alloys, Al-Cu, Nickel and Titanium alloys.	3	CO4
5.	**Heat Treatment and Surface treatment of Steel:**		
5.1	Annealing, Stress relieving, Process annealing, Spheroidising, Full annealing, Normalising, Hardening, Tempering.	2	CO5
5.2	TTT diagram, Continuous cooling curves, Austenitizing temperature.	1	CO5
5.3	Martempering, Austempering and Ausforming, Mechanism of heat removal during quenching, Quenching medium,	2	CO5
5.4	Surface Hardening of steel: Carburising, Nitriding, Cyaniding, Carbonitriding, Flame hardening, Induction hardening.	2	CO5
	Total Number of Hours	**36**	

Course Designers:

1.	**Dr. N. Sankara Subramanian**	**nssphy@tce.edu**
2.	**Dr. M Senthamizhselvi**	**msphy@tce.edu**

18ME270	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 and moulding sand and also able to identify the microstructure of the given material.

Prerequisite

- Nil

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Determine the mechanical properties of different materials.	70
CO2	Identify the microstructure of the given ferrous material.	20
CO3	Determination of physical properties of the moulding sand	10

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.2, 2.1.4, 3.1, 4.4.2
CO2	TPS3	Apply	Value	Mechanism	1.2, 2.1.4, 3.1, 4.4.2
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.1.4, 3.1, 4.4.2

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
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- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

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 Material Science lab)

Assessment Pattern: Psychomotor

Psychomotor Skill	Mini Project / Practical Component / Observation
Perception	
Set	
Guided Response	
Mechanism	All Exercises
Complex Overt Responses	
Adaptation	

Origination	

List of Experiments / Activities with CO Mapping

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

1. Determination of the Young's Modulus of Steel by conducting tension test in UTM.
2. Determination of the Young's Modulus of the beam (Steel, Wood, Aluminium etc.) by conducting the bending test.
3. Determination of the Young's Modulus of the beam (Steel, Wood, Aluminium etc.) by conducting the bending test using Huggen Berger Tensometer.
4. Determination of the rigidity modulus of the material by conducting torsion test.
5. Determination of the rigidity modulus of the compression and tension spring by conducting spring test.
6. Determination of the Young's Modulus of the beam (Steel, wood, Aluminium etc.) by conducting the deflection test in UTM
7. Determination of Brinell hardness and Rockwell hardness for Steel, Copper, Aluminium and Brass

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

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

Course Designers:

1. Dr. D. Brindha dbciv@tce.edu
2. Dr. M. Kathiresan umkathir@tce.edu

18ME280	WORKSHOP

Category	L	T	P	Credit
ES	0	0	2	1

Preamble

Workshop is a hands-on training practice to Mechanical and Civil 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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Construct various regular solid models with card board	10
CO2	Make different types of Mild Steel plate joints using fitting operations.	30
CO3	Fabricate sheet metal components.	30
CO4	Make different types of wooden joints.	30

*** Weightage depends on Bloom's Level, number of contact hours

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS 3	Apply	Value	Mechanism	1.2, 2.1.2, 3.1, 4.4.2
CO2	TPS 3	Apply	Value	Mechanism	1.2, 2.1.2, 3.1, 4.4.2
CO3	TPS 3	Apply	Value	Mechanism	1.2, 2.1.2, 3.1, 4.4.2
CO4	TPS 3	Apply	Value	Mechanism	1.2, 2.1.2, 3.1, 4.4.2

Mapping with Programme Outcomes and Programme Specific 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	PSO 1	PSO 2	PSO 3
CO1	S	M	L	L	L	_	_	_	S	_	_	_	L	_	L
CO2	S	M	L	L	L	_	_	_	S	_	_	_	L	_	L
CO3	S	M	L	L	L	_	_	_	S	_	_	_	L	_	L
CO4	S	M	L	L	L	_	_	_	S	_	_	_	L	_	L

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Trade	Observation/Viva	Record	Continuous Assessment	Total (Marks)
Card Board Exercises	20	10	20	50
Fitting				

Sheet Metal				
Carpentry				

NOTE:

- Terminal Examination will be conducted for Maximum of 100 Marks
- Students will be evaluated in any of the two trades. Each of $1^1/_2$ hours duration

Assessment Pattern: Psychomotor

Psychomotor Skill	Mini project / Practical Component /Observation
Perception	
Set	
Guided Response	
Mechanism	All Practical Component
Complex Overt Responses	
Adaptation	
Origination	

Syllabus with CO Mapping

CO1 Card Board Exercises **(2 Hours)**

Construction of cube/Triangular/square/Pentagonal/Hexagonal Prisms (Any ONE solid)
Construction of Triangular/square/Pentagonal/Hexagonal Pyramids (Any ONE solid)

CO2 Fitting Exercises **(6 Hours)**

Preparation of Square/V/L/Gauge/Taper/Radius/Dove Tail Fitting (Any TWO Fitting Exercises)

CO3 Sheet Metal Exercises **(8 Hours)**

Preparation of Litre Cone/Dust pan (Straight, Taper)/Tray (Straight, Taper) - (Any ONE sheet metal Exercise)

CO4 Carpentry Exercises **(6 Hours)**

Preparation of wooden parts like Door frame/Office tray (Any ONE Carpentry Exercise)
Demonstration of plumbing pipe line circuit for domestic application. **(2 Hours)**

Number of exercise is to be completed

1. Card board exercises - 2 Nos.
2. Fitting Exercises - 2 Nos.
3. Sheet metal Exercises - 1 No.
4. Carpentry Exercises - 1 No.
5. Demonstration on plumbing - 1 No.

Learning Resources

1. John K.C “Mechanical Workshop”, Practice by Prentice Hall India Learning Private Limited, Second edition, 2010.

Course Designers

1. Dr.C.Paramasivam cpmect@tce.edu
2. M.Karthic mkmect@tce.edu

18ES290	LATERAL THINKING	Category	L	T	P	Credit
		ES	0	0	2	1

Preamble

The purpose of thinking is to collect information and to make the best possible use of it. Vertical thinking is concerned with proving or developing concept patterns. Lateral thinking is concerned with restructuring such patterns (insight) and provoking new ones (creativity). Lateral and vertical thinking are complementary. Skill in both is necessary. Although the emphasis in education has always been exclusively on vertical thinking, the need for lateral thinking arises from the limitations of the behaviour of mind as a self-maximizing memory system. Lateral thinking can be learned, practised and used. It is possible to acquire skill in it just as it is possible to acquire skill in mathematics. The course provides formal opportunities to practise lateral thinking and also an explanation of the processes involved.

Prerequisite

NIL

Course Outcomes

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

CO #	Course Outcome Statement	Weightage in %
CO1	Explain the concept of lateral thinking, distinguish it from vertical thinking.	10
CO2	Use lateral thinking for problem solving	10
CO3	Generate Alternatives, challenge assumptions and suspend judgment and Practice lateral thinking in design process	20
CO4	Apply the concept of factorization and reversal method for restructuring	20
CO5	Organize brainstorming sessions	10
CO6	Use PO for innovation	10
CO7	Aware of limitation of established patterns and practice lateral thinking in small projects	20

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	-	2.3.1, 3.2.6
CO2	TPS3	Apply	Value	-	2.4.1, 2.4.2, 2.4.3
CO3	TPS3	Apply	Value	-	2.4.1, 2.4.2, 2.4.3, 2.4.5, 2.4.6
CO4	TPS3	Apply	Value	-	2.3.1, 2.4.2, 2.4.3
CO5	TPS4	Analyse	Organize	-	3.1.1, 3.1.2, 3.2.1, 3.2.2
CO6	TPS3	Apply	Value	-	2.1.4, 2.3.1, 2.4.1, 2.4.2, 2.4.3, 2.4.6
CO7	TPS5	Evaluate	Characterize	-	2.3.4, 4.5.1, 4.6.1

Mapping with Programme Outcomes and Programme Specific Outcomes

CO #	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	M	L	-	-	-	-	-	-	-	-	-	L
CO2	S	M	L	-	-	-	-	-	-	-	-	L
CO3	S	M	L	-	-	-	-	S	L	L	-	L
CO4	S	M	L	-	-	-	-	S	L	L	-	L
CO5	S	S	M	L	-	-	-	S	S	S	-	L
CO6	S	M	L	-	-	-	-					L
CO7	S	S	S	M	-	S	-	-	S	S	-	S

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Continuous Assessment

Worksheets (5)	:	20 Marks
Case Studies (3)	:	30 Marks

Terminal Examination

Ability Test	:	50 Marks
Case Study (Best) Presentation and Viva Voce	:	50 Marks

Syllabus

The way the mind works, Difference between lateral and vertical thinking, Attitudes towards lateral thinking, Basic nature of lateral thinking, The use of lateral thinking Techniques, The generation of alternatives, Challenging assumptions, Innovation, Suspended judgment, Design, Dominant ideas and crucial factors, Fractionation, The reversal method, Brainstorming, Analogies, Choice of entry point and attention area, Random stimulation, Concepts/divisions/polarization, The new word PO, Blocked by openness, Description/problem solving/design

Learning Resources

1. Edward de Bono, "Lateral Thinking: Creativity Step by Step", Happer Collins Publisher, 1990.
2. Edward de Bono, "Six Thinking Hats", Little Brown and Company Publisher, 1985.
3. Edward de Bono's Thinking Course, Video Lecture, Weblink: https://www.yputube.com/watch?v=AUq_AL2LNEw

Course Contents and Lecture Schedule

Module No.	Topic	No. of Hours	Course Outcome
1.	The way the mind works	1	CO1
1.1	Difference between lateral and vertical thinking	1	CO1
1.2	Attitudes towards lateral thinking	1	CO2
2.	Basic nature of lateral thinking	1	CO2
2.1	The use of lateral thinking techniques	1	CO2
2.2	The generation of alternatives	1	CO3
2.3	Challenging assumptions	1	CO3
2.4	Innovation	1	CO3
2.5	Suspended judgment	1	CO3
3.	Design	1	CO3
3.1	Dominant ideas and crucial factors	1	CO3
3.2	Fractionation	1	CO4
4.	The reversal method	1	CO4
4.1	Brainstorming	1	CO5
4.2	Analogies	1	CO5
4.3	Choice of entry point and attention area	1	CO5
4.4	Random stimulation	1	CO5
4.5	Concepts/divisions/polarization	1	CO5
4.6	The new word PO	2	CO6
5.	Blocked by openness	2	CO7
5.1	Description/problem solving/design	2	CO7

Course Designers:

S J. Thiruvengadam sjtece@tce.edu

18CH2A0	Environmental Sciences	Category	L	T	P	Credit
		ES	1	0	1	-

Preamble

The objective of this course is intended to make the students to understand the basic concepts of environment, ecology and pollution of the current environmental issues and to participate in various activities on conserving and protecting the environment.

Prerequisite

NIL

Course Outcomes

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

CO Number	Course Outcome	Weightage*** in %
CO1	Describe the importance and progression of ecological system	15%
CO2	Explain the significance of natural resources	10%
CO3	Demonstrate the effects of pollution on environment and human beings	15%
CO4	Practice the suitable management method during disaster episode	10%
CO5	Explain the ethics and values related to Environment	15%
CO6	Describe the Traditional values and Impact of modernization on Environment	10%
CO7	Carry out group activities	25%

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.1,2.3.1,2.3.2,2.3.4
CO2	TPS2	Understand	Respond	Guided Response	1.1,2.3.1,2.3.2,2.3.4
CO3	TPS3	Apply	Value	Mechanism	1.1,2.1.1,2.1.5,2.4.1,4.1.2
CO4	TPS3	Apply	Value	Mechanism	1.1,2.4.1,2.4.7,4.1.1,4.1.2
CO5	TPS2	Understand	Respond	Guided Response	1.1,2.5.1,2.5.2,
CO6	TPS2	Understand	Respond	Guided Response	1.1,2.4.7,2.5.4,
CO7	TPS4	Analyse	Organise	Complex Overt Responses	3.1.1,3.1.2,3.1.3,3.1.4,4.1.1,4.1.2

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	M	-	-	-	-	L	S	-	-	-	-	-
CO2	M	-	-	-	-	L	-	L	-	-	-	-
CO3	M	M	-	-	L	M	S	-	-	-	-	-
CO4	M	-	L	L	L	M	M	-	-	-	-	-
CO5	L	-	-	-	-	-	-	M	-	-	-	-
CO6	L	L	-	-	-	-	M	-	-	-	-	-
CO7	S	M	M	M	M	M	-	-	S	M	M	-

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain							
Cognitive Levels	Continuous Assessment Tests			Assignment#			Terminal Examination ***
	1	2	3	1	2	3	
Remember	0	20	0	NA	NA	NA	Presentation on Case study report
Understand	0	40	0				
Apply	0	40	0				
Analyse	0	0	0				
Evaluate	0	0	0				
Create	0	0	0				

Assignment: Marks will be given for the review I, II & III of case study presentation.

*** Case study presentation and evaluation

- Each group comprise of maximum three students
- Students will submit the case study report similar to final year project report
- Evaluation of case study presentation is based on the approved rubrics

Method of Evaluation

a)Internal assessment

S.No	Description	Max.marks	Final conversion
1	CAT -II	50	40
2	Assignment marks (from Review I,II & III)	3 X 10 =30	10
		Total	50

b) End semester examination – Case study presentation

Performance Index	Marks per Individual
Originality of the work	20
Data collected	20
Suggestion to overcome for the identified issues	20
Final Presentation	40
Total	100

Model Titles for Case Study:

1. Environmental impacts of quarry industries in Melur Taluk.
2. A study on impacts of tanneries on ground water and soil quality in Dindigul district.
3. Effect of pharmaceutical industry on groundwater quality in poikaraipatty village, Alagar Kovil.
4. Solid waste and waste water management in TCE hostel.
5. Environmental effect of Kudankulam atomic power plant.
6. Case study on effect of Sterlite industry.
7. Effect on ground water and soil quality by dyeing industries in Tiruppur.
8. Effect of textile wastes in Karur District.
9. Segregation of waste and its recycling by Madurai Municipality at Vellakkal
10. Effect of fire work waste on atmosphere in Sivakasi region

Sample Questions for Course Outcome Assessment**

Course Outcome 1(CO1):

1. Describe the Universal Energy flow model in an Ecosystem.
2. Discuss the conversion of one ecosystem into another ecosystem with example.
3. Explain the multidisciplinary nature of the environment.

Course Outcome 2 (CO2):

1. Summarize the importance of Natural resources to animals and human beings.
2. Describe the role of an individual in the conservation of Natural resources.

Course Outcome 3(CO3):

1. Demonstrate the effects and control measures of air pollution

2. Investigate the sources and management methods of e-waste.

Course Outcome 4(CO4):

1. Dramatize the mitigation methods adopted in severe cyclone affected areas.
2. Suggest the precautionary steps to prevent life from flood.

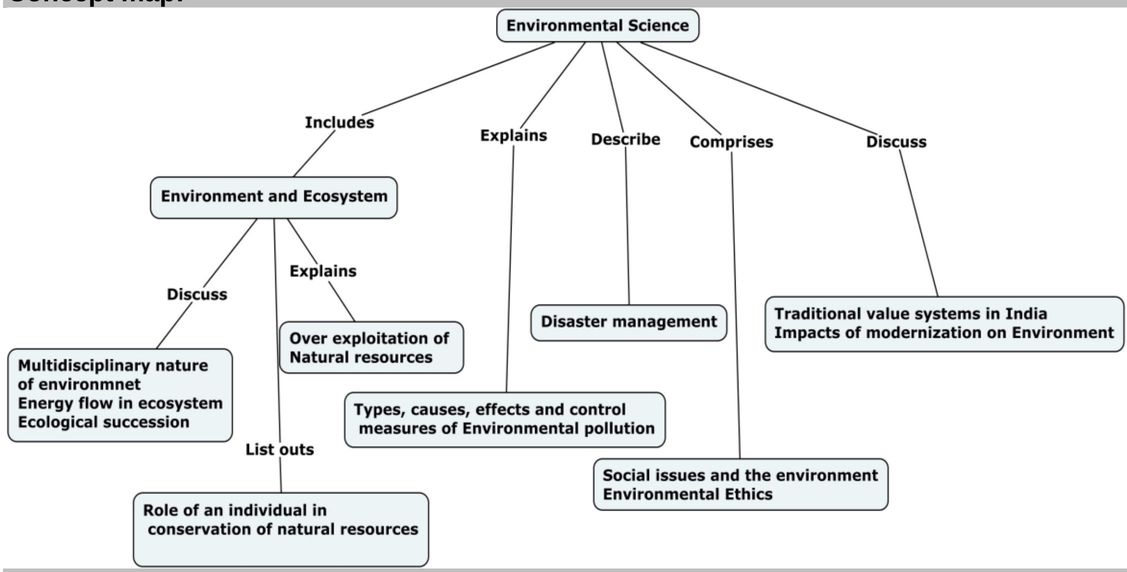
Course Outcome 5 (CO5):

1. Discuss the need for public awareness on environmental protection.
2. Identify the requirement for the equitable utilization of natural resources.

Course Outcome 6(CO6):

1. Describe the traditional value systems of India.
2. Recall the environmental related points discussed in our Indian Vedas.
3. List out the impacts of modernization on environment

Concept map:



Syllabus

Environment and Ecosystem - Multidisciplinary nature of environment- Ecosystem- Energy flow in ecosystem-Ecological succession-Over exploitation of Natural resources-Role of an individual in conservation of natural resources. **Environmental pollution and control -** Environmental pollution – types, causes, effects and control measures - Disaster management strategies. **Environmental Ethics and Values -** Social issues and the environment -need for public awareness, Environmental Ethics- need for equitable utilization of natural resources- Traditional value systems in India, Impacts of modernization on Environment

Awareness and actual activities:

- ✓ Group meeting on water management, promotion of recycle use, reduction of waste,
- ✓ Plantation
- ✓ Cleanliness drive
- ✓ Drive on segregation of waste
- ✓ Energy saving
- ✓ Lectures by Environmentalist
- ✓ Slogan and poster making event

Learning Resources

1. Kaushik,A & Kaushik.C.P, Environmental Science and Engineering, 6th Edition, New Age International, 2018.
2. Erach Bharucha, Text book of Environmental studies for Undergraduate courses, 2nd Edtion, UGC, 2013.
3. Gilbert M.Masters, Introduction to Environmental Engineering and Sciences, 2nd Edition, Pearson , 2004.
4. Garg S.K & Garg, Ecological and Environmental studies, Khanna Publishrers, 2006.
5. Wright &Nebel, Environmental science towards a sustainable future, 8th Editon,Prentice Hall of Indial Ltd, 2002.
6. Documentary titled "HOME" by Yves Bertrand, Video Link: https://www.youtube.com/watch?v=jqxENMKaeCU

Course Contents and Lecture Schedule

Module No.	Topic	No. of Hours	Course Outcome
1.0	**Environment and Ecosystem**		
1.1	Multidisciplinary nature of environment-Ecosystem	1	CO1
1.2	Energy flow in ecosystem – Universal energy flow model	1	CO1
1.3	Ecological succession	1	CO1
1.4	Over exploitation of Natural resources	1	CO2
1.5	Role of individual in conservation of natural resources	1	CO2
2.0	**Environmental pollution and control**		
2.1	Environmental pollution – types(Air, Water,soil,Marine),	2	CO3
2.2	causes (gaseous, liquid, solid, plastic, e-waste, biomedical waste and radiations),	2	CO3
2.3	**E**ffects and control measures of Pollution	2	CO3
2.4	Disaster managements during cyclone, Tsunami, flood, draught and earthquake	2	CO4
3.0	**Environmental Ethics and Values**		
3.1	Social issues and the environment -need for public awareness	1	CO5
3.2	Environmental Ethics- need for equitable utilization of natural resources	1	CO5
3.3	Traditional value systems in India,	1	CO6
3.4	Impacts of modernization on Environment	2	CO6
4.0	**Awareness and actual activities**		
4.1	Group meeting on water management, promotion of recycle use, reduction of waste	2	CO7
4.2	Plantation	1	CO7
4.3	Cleanliness drive	1	CO7
4.4	Drive on segregation of waste	1	CO7
4.5	Energy saving	1	CO7
4.6	Lectures by Environmentalist	1	CO7
4.7	Slogan and poster making event	Through online	CO7

Course Designers:

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18ME310	FOURIER SERIES AND NUMERICAL METHODS

Category	L	T	P	Credit
BS	3	0	0	3

Preamble

An engineering student needs to have some basic mathematical tools, numerical tools and techniques. This emphasizes the development of rigorous logical thinking and analytical skills of the student and appraises him the complete procedure for solving different kinds of problems that occur in engineering. Based on this the course aims at giving the adequate exposure in the theory and applications of Fourier series, PDE and Numerical methods.

Prerequisite

Basic Differentiation and Integration.

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage in %
CO1	Compute the periodic functions arising in the study of engineering problems as Fourier series of Sines and Cosines.	20%
CO2	Form a PDE and Solve linear Partial Differential Equation	10%
CO3	Solve the system of linear algebraic equations, nonlinear algebraic equations	20%
CO4	Predict the integration of functions using numerical tools	10%
CO5	Solve the IVPs in ODE using single step and multi step methods	20%
CO6	Compute the solution of BVP'S in PDE using finite difference methods	20%

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	-	1.1.1, 2.1.1, 2.1.5, 3.1.2, 4.1.1
CO2	TPS2	Understand	Respond	-	1.1.1, 2.1.1, 2.1.5, 3.1.2, 4.1.1
CO3	TPS3	Apply	Value	-	1.1.1, 2.1.1, 2.4.1, 3.1.2, 4.1.1
CO4	TPS2	Understand	Respond	-	1.1.1, 2.1.1 , 3.1.2, 4.1.1
CO5	TPS3	Apply	Value	-	1.1.1,2.1.5, 2.4.1, 3.1.2, 4.1.1
CO6	TPS3	Apply	Value	-	1.1.1 2.1.5 , 2.4.1, 3.1.2, 4.1.1

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PO12	PSO 1	PSO 2	PSO 3
CO 1	S	M	M	M	-	-	-	-	M	-	-	M			S
CO 2	S	S	S	S	-	-	-	-	M	-	-	M			S
CO 3	S	S	S	S	-	-	-	-	-	-	-	M			S
CO 4	S	S	S	S	-	-	-	-	-	-	-	M			S
CO 5	S	S	S	S	-	-	-	-	-	-	-	M			S
CO 6	S	S	S	S	-	-	-	-	-	-	-	M			S

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	**2**	**3**	1	2	3	

Remember	10	1 0	10	-	-	-	10
Understand	30	30	30	-	-	-	20
Apply	60	60	60	100	100	100	70
Analyse							
Evaluate							
Create							

Sample Questions for Course Outcome Assessment**

** (2 to 3 at the cognitive level of course outcome)

Course Outcome 1(CO1):

1. Use the Fourier series expansion of $x^2 = \frac{\pi^2}{3} + 4\sum_1^\infty (-1)^n \frac{\cos nx}{n^2}$, $-\pi < x < \pi$ to predict the value of $\sum \frac{1}{n^2}$.
2. Obtain the Half Range Fourier sine and cosine series for $f(x) = (x+1)^2$ in (-1,0).
3. Find the Fourier coefficients for the function $f(x) = \begin{cases} l - x, 0 < x < l \\ 0. \quad x > l \end{cases}$ in (0, 2l).

Course Outcome 2(CO2):

1. Discuss the two methods of forming partial differential equations.
2. Solve $(x^2 - yz)p + (y^2 - xz) q = (z^2 - xy)$
3. Solve $z = px + qy + p^2 - q^2$

Course Outcome 3(CO3):

1. Give the physical significance of Newton's method
2. Solve the following system of equations using Gauss –Seidal method: 10x +5y -2z =3, 4x +10y+3 = -3; x+6y+10z = -3
3. Solve the following system of equations using Gauss elimination method: x+2y+z = 3; 2x +3y +3z =10

Course Outcome 4 (CO4):

1. Evaluate the integral $\int_1^2 \frac{dx}{1+x^2}$ using Trapezoidal rule with two subintervals
2. Find the value of $\log 2^{\frac{1}{3}}$ from $\int_0^1 \frac{x^2 dx}{1+x^3}$ using Simpson's one –third rule with h =0.25
3. What is the general Newton-Cotes formula? How is the Trapezoidal rule its special case?

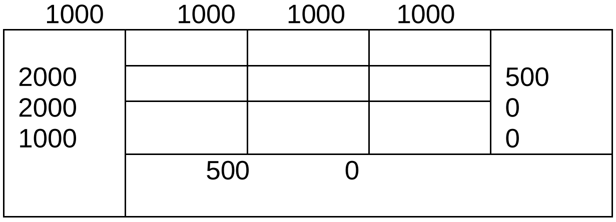
Course Outcome 5 (CO5):

1. Using Euler's method, find the solution of the initial value problem $\frac{dy}{dx} = \log(x+y)$, y(0)=2 at x = 0.2 by assuming h=0.2
2. Use Runge Kutta method to compute y for x =0.1, given $y^1 = \frac{xy}{1+x^2}$, y(0)=1, take h = 0.1
3. Using Milne's method, find y(2) if y(x) is the solution of $y^1 = \frac{1}{2}(x+y)$, given y(0)=2, y(0.5)= 2.636, y(1)= 3.595 and y(1.5)= 4.968

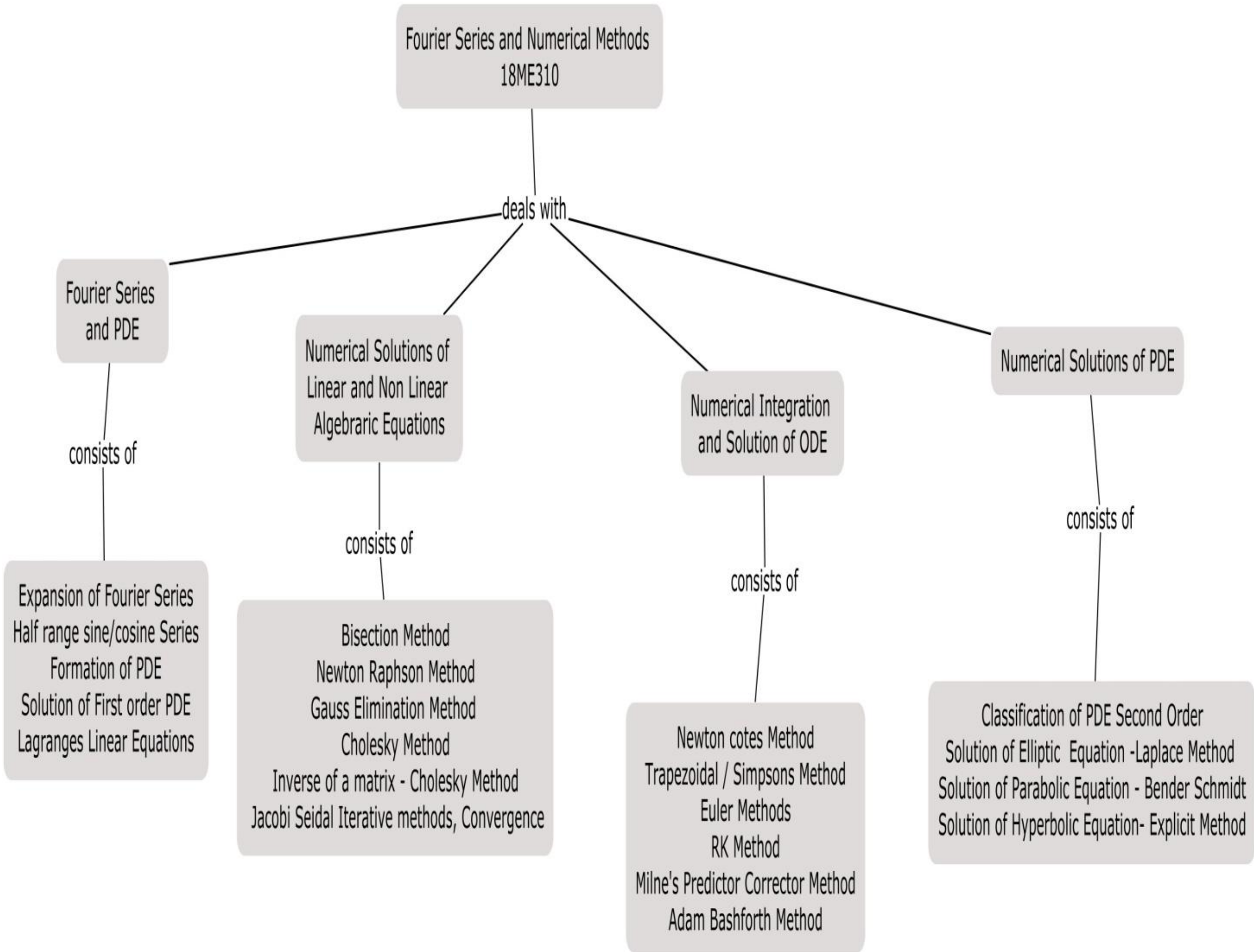
Course Outcome 6(CO6):

1. Solve $u_{xx}= 2u_t$, given u (0,t)=0, u(4,t)=0, u(x,0)= x(4-x). Assume h =1. Find the values of u upto t=5
2. Solve numerically, $4u_{xx} = u_{tt}$ with boundary conditions u (0,t)=0, u(4,t)=0 and the initial conditions $u_t(x,0)=0$ and u(x,0)= x(4-x), taking h =1. (for 4 time steps)

3. Solve $\nabla^2 u = 0,$ the boundary conditions are given below. (give only three iteration)



Concept Map



Syllabus

Fourier Series & *Partial Differential Equations*:: Expansion of full range Fourier series - Half range Fourier Sine and Cosine Series - Formation of PDE- Solution of first order PDE- Lagrange's linear equations. **Numerical Methods:** Numerical solutions of linear and nonlinear algebraic equations: Bisection method, Newton- Raphson method, Convergence- Gauss Elimination method, Cholesky decomposition method , method of inverse of a matrix using Cholesky method – Jacobi, seidal iterative methods, convergence **Numerical integration**: Newton Cote's methods of iteration , trapezoidal and Simpson's rules . **Numerical Solution of ODE**: Single Step methods: Euler method , improved & modified Euler method –Runge Kutta method of fourth order. Multi step methods: Milne's Predictor and corrector method and Adam's Bashforth predictor and corrector method **. Numerical solution of PDE** : Classification of PDE of second order , Solution of elliptic equation (Laplace equation only) , solution of Parabolic equation by Bender Schmidt method, Solution of Hyperbolic equation by Explicit method.

Learning Resources

1. P. Kandasamy, K.Thilagavathy and K. Gunavathi, Engineering Mathematics, Volume-III, S.Chand & Company Ltd, Fourth Edition, 2008 (Fourier series & PDE)

2. B.S.Grewal, Higher Engineering Mathematics, Khanna Publishers, 42th Edition,2012
3. S. R. K. Iyengar, R. K. Jain, Mahinder Kumar Jain, "Numerical methods for Scientific and Engineering Computations", New Age International publishers, 6th Edition,2012.
4. P. Kandasamy, K. Thilagavathy, K. Gunavathi, Numerical methods, S.Chand & Company Ltd, New Delhi , 8th Edition, 2013
5. https://nptel.ac.in/syllabus/syllabus_pdf/111107062.pdf

Course Contents and Lecture Schedule

Module No.	Topic	No. of Hours	Course Outcome
1.	**Fourier Series** & ***Partial Differential Equations***		
1.1	Expansion of Fourier Series (Full range)	2	CO1
1.2	Half range Fourier Sine and Cosine Series	2	C01
1.3.	Formation of PDE	2	C02
1.4	Solution of first order PDE	2	C02
1.5	Lagrange's linear equations	1	CO2
2	**Numerical Methods**		
2.1	Numerical solutions of linear and nonlinear algebraic equations: Bisection method	1	C03
2.2	Newton- Raphson method, Convergence	2	CO3
2.3	Gauss Elimination method	1	CO3
2.4	Cholesky decomposition method	2	CO3
2.5	Method of inverse of a matrix using Cholesky method	1	CO3
2.6	Jacobi, seidal iterative methods, convergence	2	CO3
3	**Numerical Integration & Numerical Solution of ODE**		
3.1	Newton Cote's methods of iteration	2	C04
3.2	Trapezoidal and Simpson's rules	2	C04
3.3	Single Step methods : Euler method	1	CO5
3.4	Runge Kutta method of fourth order	2	CO5
3.5	Multi step methods: Milne's Predictor and corrector method	2	CO5
3.6	Adam's Bashforth predictor and corrector method	2	C05
4	**Numerical solution of PDE**		
4.1	Classification of PDE of second order	1	CO6
4.2	Solution of elliptic equation (Laplace equation)	2	CO6
4.3	Solution of Parabolic equation by Bender Schmidt method	2	C06
4.4	Solution of Hyperbolic equation by Explicit method	2	CO6

Course Designers:

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18ME320	MECHANICS OF MATERIALS

Category	L	T	P	Credit
PC	2	1	0	3

Preamble

Mechanics of materials is the study of mechanical behaviour of solid objects subjected to stresses and strains. It often refers to various methods of calculating the stress in beams, columns, pressure vessels and shafts. This course is concerned with the stability of mechanical components under different static loading conditions.

Prerequisite

Nil

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Compute the stresses, strains, principal stresses, elastic constants and their relations of a structural member.	20
CO2	Determine the shear force and bending moment, slope, deflection on different types of beams	30
CO3	Calculate the bending and shear stresses of different beams	15
CO4	Compute the torsional shear stresses in circular shafts	10
CO5	Determine the crippling load on columns of different end conditions and the stresses in cylindrical and spherical vessels	25

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.5, 3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3
CO2	TPS3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.5, 3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.5, 3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.5, 3.2.3, 4.3.1, 4.3.2, 4.3.3
CO5	TPS3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.5, 3.2.3, 4.3.1, 4.3.2, 4.3.3

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	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	_	_

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	10	10	10	-	-	-	10

Understand	20	20	20	-	-	-	20
Apply	70	70	70	100	100	100	70
Analyse	-	-	-	-	-	-	-
Evaluate	-	-	-	-	-	-	-
Create	-	-	-	-	-	-	-

Assessment Pattern: Psychomotor

Psychomotor Skill	**Miniproject /Assignment/Practical Component**
Perception	-
Set	-
Guided Response	-
Mechanism	**Assignment**
Complex Overt Responses	-
Adaptation	-
Origination	-

Sample Questions for Course Outcome Assessment**

** (2 to 3 at the cognitive level of course outcome)

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 $kN\text{-}m^2$

Course Outcome 4 (CO4):

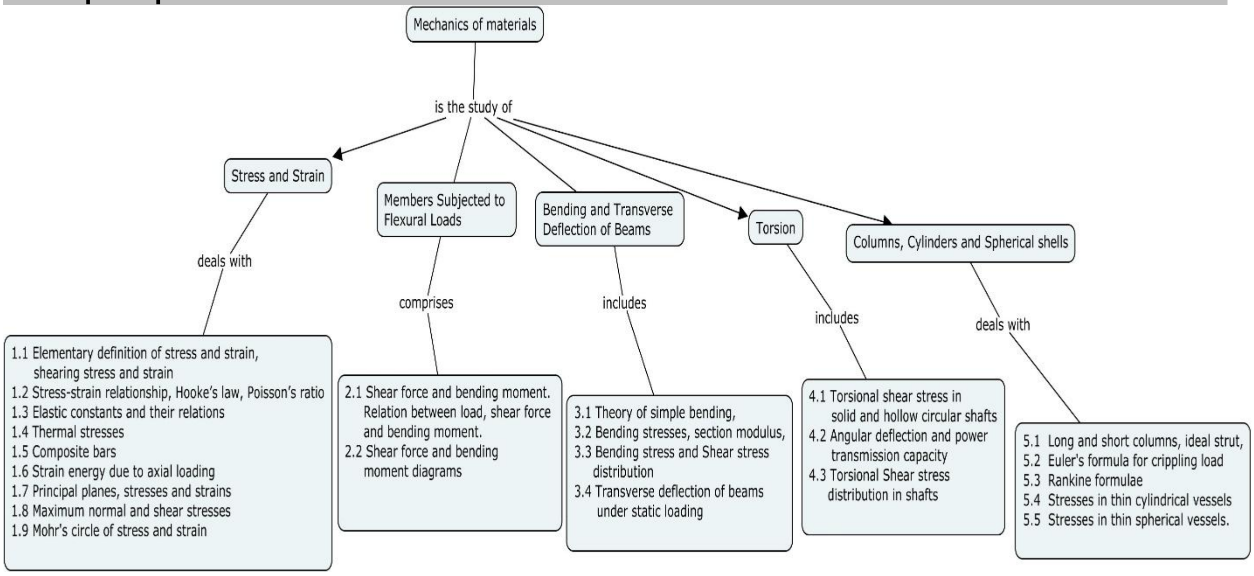
1. Explain the method of calculating angle of twist in a shaft.
2. A solid shaft has to transmit 337.5 kW at 100 rpm. If the shear stress is not to exceed 65 N/mm^2 and the internal diameter is 0.6 times external diameter, find the external and internal diameters assuming that the maximum torque is 1.3 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. 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.

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: Concept 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, stresses in composite bars, strain energy due to axial loading. Principal stresses and planes, Major and Minor principal stresses- Stress strain transformation- Mohr's circle of stress. **Members Subjected to Flexural Loads:** Relation between load, shear force and bending moment. Construction of Shear force diagrams and bending moment diagrams for different types of static loading - Cantilever, simply supported and overhanging beams. Slope and deflection of beams under static loading. **Bending and Shear stresses in Beams:** Theory of simple bending - section modulus – Determination and distribution of bending and shear stress in different beams **Torsion of shafts:** Torsional shear stress in solid and hollow circular shafts, torsional rigidity of shafts - Power transmission. **Columns, Cylinders and Spherical shells:** Long and short columns, Euler's formula for crippling load with different end conditions, eccentric loading, Rankine formulae. Stresses in thin, thick cylinders and spherical shells.

Learning Resources

1. Ferdinand P. Beer and E. Russell Johnston Jr., "**Mechanics of Materials**", McGraw Hill Book Company, 2014.
1. R.C.Hibbeler , Mechanics of materials , (SI Edition) , Pearson Education Ltd, 2018.
2. Egor P. Popov, "**Engineering Mechanics of Solids**", Second Edition, Pearson Education Ltd, 2015.
3. James M. Gere and Stephen P. Timoshenko, "Mechanics of Materials", 3rd edition, McGraw Hill Book Company, 2002.
4. Timoshenko, S.P. and D.H. Young, "**Elements of Strength of Materials**", 5th edition. East-West Press, 2011.
5. Bansal, R.K., "**A Text Book of Strength of Materials**", Laxmi Publications (P) Ltd. New Delhi, 2011.
6. Rajput, R.K., "**Strength of Materials**", S. Chand Publications, 2015.
7. 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	CO
1.0	**Stress and Strain:**		

1.1	Elementary definition of stress and strain, tension, compression, shearing stress and strain	1	CO1
1.2	Stress-strain relationship, Hooke's law, Poisson's ratio	1	CO1
1.3	Elastic constants and their relations	1	CO1
1.4	Thermal stresses	2	CO1
1.5	Composite bars		
1.6	Strain energy due to axial loading	1	CO1
1.7	Principal planes, stresses and strains	2	CO1
1.8	Stress strain transformation	1	CO1
1.9	Mohr's circle of stress and strain	2	CO1
2.0	**Members Subjected to Flexural Loads:**		
2.1	Shear force and bending moment. Relation between load, shear force and bending moment.	2	CO2
2.2	Shear force and bending moment diagram		
2.2.1	Shear force and bending moment diagrams for cantilever subjected to various types of loading	2	CO2
2.2.2	Shear force and bending moment diagrams for simply supported beam subjected to various types of loading	2	CO2
2.2.3	Shear force and bending moment diagrams for overhanging beam subjected to various types of loading	2	CO2
3.0	**Bending and Transverse Deflection of Beams:**		
3.1	Theory of simple bending,	2	CO3
3.2	Bending stresses, section modulus,	1	CO3
3.3	Bending stress and Shear stress distribution	1	CO3
3.4	Transverse deflection of beams under static loading	1	CO3
4.0	**Torsion:**		
4.1	Torsional shear stress in solid and hollow circular shafts	2	CO4
4.2	Angular deflection and power transmission capacity	1	CO4
4.3	Torsional Shear stress distribution in shafts	1	CO4
5.0	**Columns, Cylinders and Spherical shells**		
5.1	Long and short columns, ideal strut,	1	CO5
5.2	Euler's formula for crippling load for columns of different ends, concept of equivalent length, eccentric loading	2	CO5
5.3	Rankine formulae and other empirical relations	2	CO5
5.4	Stresses in thin cylindrical vessels	2	CO5
5.5	Stresses in thin spherical vessels.	1	CO5
	Total	**36**	

Course Designers:

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18ME331	METAL JOININING 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 (18ME230), and Metal joining processes (18ME330).

Prerequisite

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Explain the working principles, process capabilities, process parameters and equipment of metal joining processes.	20
CO2	Identify defects and interpret causes for defects in product of metal joining processes.	10
CO3	Select the suitable material and metal joining process for a given product or component.	40
CO4	Conduct exercises in metal casting, forming and joining processes.	30

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.2, 2.4.4, 3.3.1,4.3.2
CO2	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PO1 2	PSO 1	PSO 2	PSO 3
CO 1	S	M	L	-	-	-	-	-	-	-	L	-	S	-	L
CO 2	S	M	L	-	-	-	-	-	-	-	M	-	S	-	L
CO 3	S	M	L	-	-	-	M	-	-	-	M	-	S	-	L
CO 4	S	M	L	-	-	-	M	-	-	-	M	-	S	-	L

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Theory (70 marks)				Practical (30 marks)		
Cognitive Levels	**Continuous Assessment Tests (20)**	**Terminal Examination (50)**		**Valuation category**	**Continuous Assessment (10)**	**Continuous Assessment**

	1	2				Test 3 (20)
Remember	**20**	**20**	**20**	**Class work/ Exercise**	**90**	**90**
Understand	**40**	**40**	**40**	**Record / Viva-voce**	**10**	**10**
Apply	**40**	**40**	**40**			
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.

Assessment Pattern: Psychomotor

Psychomotor Skill	**Miniproject /Assignment/Practical Component**
Perception	**-**
Set	**-**
Guided Response	**-**
Mechanism	**Practical**
Complex Overt Responses	**-**
Adaptation	**-**
Origination	**-**

Sample Questions for Course Outcome Assessment**

** (2 to 3 at the cognitive level of course outcome)

Course Outcome 1 (CO1):

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.

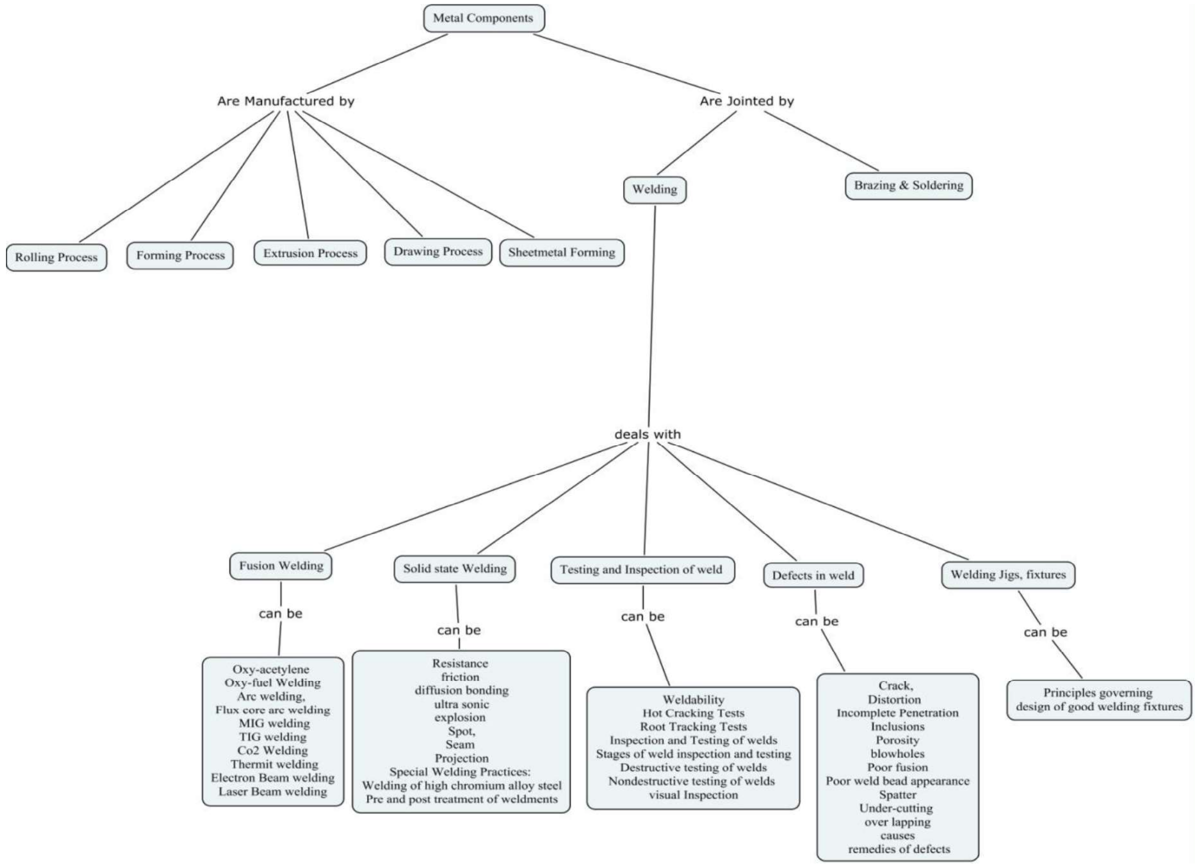
Course Outcome 2 (CO2):

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 3 (CO3):

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, SMAW, Flux core arc welding, SAW ,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, friction stir welding, diffusion bonding, ultra sonic welding, explosion welding.

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.

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

Learning Resources

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, 9th Edition, Reprint 2008.
5. Richard.L,Little, “**Welding and Welding Technology**” - McGraw Hill Education (India) Private Limited , New Delhi, 42nd Reprint 2013.

6. Parmer R.S, "**Welding Engineering and Technology**", 2nd Edition, Khanna publishers, Delhi, 2010.
7. 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.
8. P.N.Rao, "**Manufacturing Technology**", Volume-1, Tata McGraw Hill, New Delhi, Third Edition, 2011.
9. P.C. Sharma, "**A Text Book of Production Technology (Manufacturing Processes)**", S. Chand & Company Ltd., New Delhi, Seventh Reprint, 2012.
10. AWS Welding Handbook, Volume 1, Welding Science & Technology, American Welding Society, 2001.
11. AWS Welding Handbook, Volume 2, Welding Processes, Part 1, American Welding Society, 2004.
12. AWS Welding Handbook, Volume 3, Welding Processes, Part 2, American Welding Society, 2004.
13. https://nptel.ac.in/courses/113106067/Week1/Overview.pdf- Dr. G. Phanikumar Professor, Dept. of MME, IIT Madras.
14. https://nptel.ac.in/courses/112107090/- COURSE CO-ORDINATED BY : IIT ROORKEE
15. http://textofvideo.nptel.ac.in/112107089/lec3.pdf- Prof. Dr. D. K. Dwivedi Department of Mechanical and Industrial Engineering Indian Institute of Technology, Roorkee
16. https://ocw.mit.edu/courses/materials-science-and-engineering/3-37-welding-and-joining-processes-fall-2002/lecture-notes/ - COURSE CO-ORDINATED BY MIT.

Practical Component:

List of Experiments

1. Preparation of green sand mould using single piece pattern.
2. Preparation of green sand mould using split pattern.
3. Melting, pouring and casting.
4. Preparation of component using plastic injection moulding machine.
5. Exercises on Arc Welding with appropriate current and voltage settings.
6. Exercises on MIG Welding with appropriate current and voltage settings.
7. Exercises on Spot Welding with appropriate current and voltage settings.
8. Exercises on Brazing / soldering on the sheet metal part.
9. Conversion of round rod in to square rod
10. Preparation of tool for shaping machine / chisel.
11. Preparation of Z – Clamp / S – Hook. .
12. Preparation of square headed bolt.
13. Inspection of castings and weldment (surface cracks) using dye penetrant test method.
14. Demonstration of inspection of castings and weldment (Internal cracks) using ultrasonic flaw detector.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Hours	Course Outcome
1	Metal Joining Process- Introduction, Solidification of the weld metal, base metal, heat affected zone, weld metal, shielding gases, filler metal, fluxes.	1	CO1
2	Fusion welding		
2.1	Oxy-fuel gas Welding, Arc welding, SMAW	1	CO1, CO3
2.2	GTAW, GMAW and SAW, Thermit welding, Co_2 Welding	1	CO1, CO3
2.3	Plasma arc welding, Electron Beam welding, Laser Beam welding	1	CO1, CO3
3	Solid State welding		CO1, CO3
3.1	Resistance Welding-spot, seam, projection welding, friction welding	1	CO1, CO3

3.2	Friction stir welding, diffusion bonding, ultra sonic welding, explosive welding	1	CO1, CO3
4	Defects in welding		CO2
4.1	Cold and hot cracks, hydrogen induced cracking, Lamellar tearing, Incomplete Penetration, Inclusions / Porosity and blowholes	1	CO2
4.2	Improper fusion, Poor weld bead appearance, Spatter, Under-cutting and over lapping, causes and remedies of defects	1	CO2
5	Testing and Inspection of welding		CO2
5.1	Weldability, Stages of weld inspection and testing, Hot Cracking Tests	2	CO2
5.2	Destructive and Non-destructive testing of welds and visual Inspection.	1	CO2
6	Brazing- Principle of Operation, advantages, Limitations and application	1	CO1
7	Soldering- Principle of Operation, advantages, Limitations and application		CO1
	Total	**12**	

Practical Component:

Ex. No	List of Experiments	No of Hrs.
	Moulding and Casting Practices	
1.	Preparation of green sand mould using single piece pattern.	2
2.	Preparation of green sand mould using split pattern.	2
3.	Melting, pouring and casting.	2
4.	Preparation of component using plastic injection moulding machine.	2
	Metal Joining Practices	
5.	Exercises on Arc Welding with appropriate current and voltage settings.	2
6.	Exercises on MIG and TIG Welding with appropriate current and voltage settings.	2
7.	Exercises on Spot Welding with appropriate current and voltage settings.	2
8.	Exercises on Brazing / soldering on the sheet metal part.	2
	Smith Forging Practices	
9.	Conversion of round rod in to square rod	2
10.	Preparation of tool for shaping machine / chisel.	2
	Preparation of Z – Clamp / S – Hook. .	2
11.	Preparation of square headed bolt.	2
12.	**Non Destructive Inspection of Castings and Weldments**	
13.	Inspection of castings and weldment (surface cracks) using dye penetrant test method.	2
14.	Demonstration of inspection of castings and weldment (Internal cracks) using ultrasonic flaw detector.	
15.	**CAT-III**	3
	Total	29

NOTE:

- Minimum 12 Exercises are to be conducted.
- Students will be evaluated in any of the two trades in CAT-III, each of a 1 ½ hour's duration.

Course Designers:

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18ME340	THERMAL ENGINEERING	Category	L	T	P	Credit
		PC	2	1	-	3

Preamble

Thermal Engineering is the branch of mechanical engineering which deals with the applications of engineering thermodynamics in power cycles, refrigeration cycles, and engineering devices such as steam turbines, compressors, refrigerators and air conditioners. A mechanical engineer needs to know the basic construction, working principle and performance analysis of power and refrigeration cycles and thermal systems.

Prerequisite

Engineering Thermodynamics

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Analyze the performance of various gas power cycles using P-V and T-s diagrams	23
CO2	Analyze the performance of vapour power cycles using steam tables and Mollier chart.	23
CO3	Determine the performance parameters of vapour compression refrigeration systems using refrigeration tables and charts	18
CO4	Determine the performance parameters of steam turbines using velocity triangles, steam tables and Mollier chart and reciprocating air compressors using thermodynamic relations.	18
CO5	Determine the psychrometric properties of air undergoing various psychrometric processes using thermodynamic relations and psychrometric chart.	18

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS4	Analyse	Organise	Complex Overt Responses	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO2	TPS4	Analyse	Organise	Complex Overt Responses	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO5	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	S	S	S	S	_	_	_	S	M	M	_	_	_	S	_
CO2	S	S	S	S	_	_	_	S	M	M	_	_	_	S	_
CO3	S	M	S	M	_	_	_	S	M	M	_	_	_	M	_
CO4	S	M	S	M	_	_	_	S	M	M	_	_	_	M	_
CO5	S	M	S	M	_	_	_	S	M	M	_	_	_	M	_

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	20	20	20	-	-	-	10
Understand	20	20	20	-	-	-	30
Apply	30	60	60	-	100	100	30
Analyse	30	0	0	100			30
Evaluate							
Create							

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	
Set	
Guided Response	
Mechanism	Assignment
Complex Overt Responses	Assignment
Adaptation	
Origination	

Sample Questions for Course Outcome Assessment**

** (2 to 3 at the cognitive level of course outcome)

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. Determine the turbine output from a single stage impulse turbine having smooth blades, steamflow rate of 20 kg/s, steam velocity of 600 m/s, blade speed of 250 m/s, nozzle angle of 20° and blade outlet angle of 25°. Also calculate axial thrust.
2. 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°.
3. 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.
4. 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.

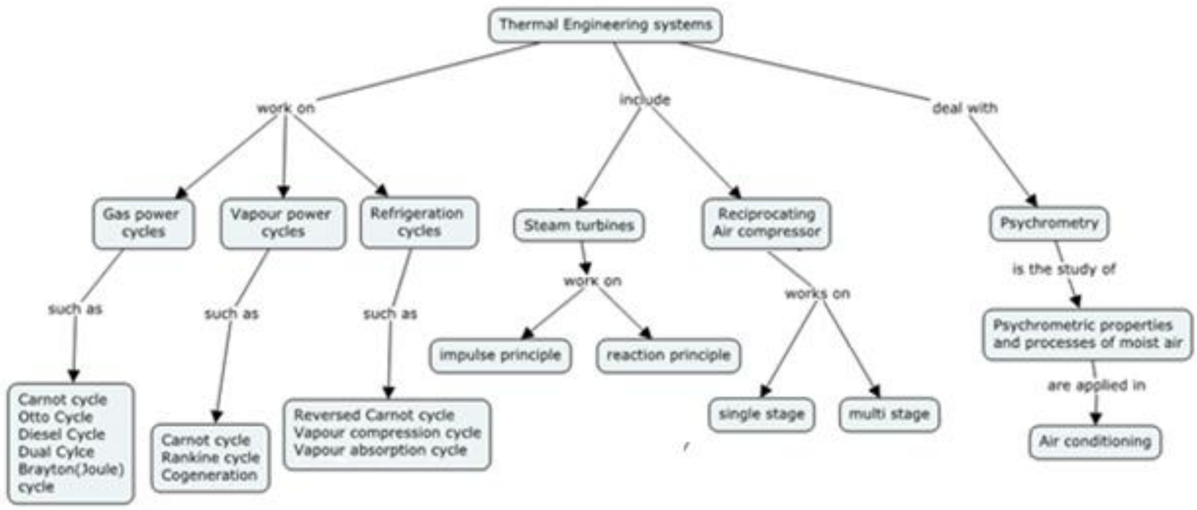
Course Outcome 5 (CO5):

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.
   Dry bulb temperature, Wet bulb temperature, Dew point temperature, Relative humidity and 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



Syllabus

Introduction to Power cycles: Diesel, Gas turbine and Steam power cycles.

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, Brayton (Joule) cycle- Air standard efficiency and mean effective pressure calculations.

Vapour power cycles: Carnot cycle, Rankine cycle, Reheat Rankine cycle, – Performance calculations, Regenerative Rankine Cycle with one open or closed feed water heater (Qualitative treatment), Concept of cogeneration.

Refrigeration cycles: Reversed Carnot cycle, Vapour Compression Refrigeration cycle with superheating and sub-cooling, Performance calculations and applications. Working principle of Vapour Absorption Refrigeration System.

Steam turbines: Impulse and Reaction Types, Components – steam nozzle, Working principle, Velocity diagrams and Performance calculations for single stage turbine, Compounding (Qualitative treatment).

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, Performance calculations.

Psychrometric properties and processes: Psychrometric properties, Psychrometric processes- heating, cooling, humidification dehumidification, adiabatic mixing,, Applications in air-conditioning.

Learning Resources

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**"- second edition, McGraw Hill Education (India) Private Limited, 2017.
4. T.D.Eastop and McConkey, "**Applied Thermodynamics for Engineering Technologists**" Fifth Edition, Pearson Education Ltd, 2009.
5. Gordon Rogers and Yon Mayhew "**Engineering Thermodynamics: Work and Heat Transfer**", 4th edition, Pearson Education Ltd, 2009.
6. Michael J. Moran, Howard N. Shapiro, Daisie D. Boettner P, Margaret B. Bailey, "**Fundamentals of Engineering Thermodynamics**", Seventh Edition, John Wiley & Sons Inc., 2011.
7. R.K. Rajput, "**Thermal Engineering**", Laxmi Publications, Ninth Edition, 2013.
8. http://nptel.ac.in/courses/IIT-MADRAS/Applied_Thermodynamics/
9. http://ocw.mit.edu/courses/aeronautics-and-astronautics/16-050-thermal-energy-fall-2002/lecture-notes/

Tables and Charts

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.
3. Psychrometric Chart

Course Contents and Lecture Schedule

Module No.	Topic	No. of Hours	Course Outcome
1	**Power Cycles**		
1.1	**Gas power cycles**		CO1
1.1.1	Carnot cycle - Air standard efficiency and mean effective pressure calculations	1	CO1
1.1.2	Otto cycle - Air standard efficiency and mean effective pressure calculations	1	CO1
1.1.3	Diesel cycle- Air standard efficiency and mean effective pressure calculations	1	CO1
1.1.4	Comparison of Otto and Diesel cycles	1	CO1
1.1.5	Dual cycle- Air standard efficiency and mean effective pressure calculations.	1	CO1
1.1.6	Brayton (Joule)cycle- Air standard efficiency and mean effective pressure calculations.	1	CO1
	Tutorial	**2**	CO1
1.2	**Vapour power cycles**		CO2
1.2.1	Carnot cycle	1	CO2
1.2.2	Rankine cycle- Performance calculations	1	CO2
	Tutorial	**1**	CO2
1.2.3	Reheat Rankine cycle - Performance calculations	2	CO2
1.2.4	Regenerative Rankine cycle	1	CO2
1.2.5	Cogeneration- Definition and Types	1	CO2
2	**Refrigeration cycles**		CO3
2.1	Reversed Carnot cycle	1	CO3
2.2	Vapour Compression Refrigeration cycle with super heating and sub-cooling, Performance calculations and applications.	1	CO3
	Tutorial	**1**	CO3
2.3	Working principle of Vapour Absorption Refrigeration System	1	CO3

3	**Steam turbines**		CO4
3.1.1	Impulse and reaction types- Components- steam nozzle	1	CO4
3.1.2	Working principle, Velocity diagrams	1	CO4
3.1.3	Performance calculations for single stage turbine	1	CO4
	Tutorial	**1**	CO4
3.1.4	Compounding - Types	1	CO4
4	**Reciprocating air compressors**		CO5
4.1	Working principle, Work of compression in single stage with and without clearance volume, Free Air Delivery	2	CO5
4.2	Isothermal efficiency, Volumetric efficiency	1	CO5
4.3	Multi stage compression, Intercooling	1	CO5
4.4	Condition for minimum work, Performance calculations	1	CO5
	Tutorial	**1**	CO5
5	**Psychrometric properties and processes**		CO6
5.1	Psychrometric properties	1	CO6
5.2	Psychrometric processes- heating, cooling, humidification dehumidification, adiabatic mixing	2	CO6
	Tutorial	**2**	CO6
5.3	Applications in air-conditioning	1	CO6
	Total	**36**	

Course Designers:

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2. Dr. B.Karthikeyan bkmech@tce.edu

18ME350	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 science and technology, 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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Explain the characteristics, standards and errors of measuring instruments	20
CO2	Select suitable instruments for measuring motion, force, torque, strain, temperature, flow, pressure and level.	30
CO3	Identify methods and devices for measurement of length, angle, gear & thread parameters, surface roughness and geometric features of parts and design GO-NOGO gauges.	35
CO4	Discuss the significance and working of various types of comparators and advanced metrological machines.	15

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.2, 2.4.4, 3.2.3, 4.3.2
CO2	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.2.3, 4.3.2
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.2.3, 4.3.2
CO4	TPS2	Understand	Respond	Guided Response	1.2, 2.4.4, 3.2.3, 4.3.2

Mapping with Programme Outcomes and Programme Specific Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
CO1	S	L	-	-	-	M	-	M	-	-	-	-	-	-	S
CO2	S	S	M	L	-	-	-	-	-	-	-	-	S	-	S
CO3	S	S	S	M	-	-	-	-	-	-	-	-	S	-	S
CO4	S	L	L	-	-	-	-	-	-	-	-	-	-	-	S

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	20	20	20	-	-	-	20
Understand	40	40	40	50	50	50	40
Apply	40	40	40	50	50	50	40
Analyse	-	-	-	-	-	-	-
Evaluate	-	-	-	-	-	-	-
Create	-	-	-	-	-	-	-

Assessment Pattern: Psychomotor

Psychomotor Skill	Mini-project /Assignment/Practical Component
Perception	-
Set	-
Guided Response	Assignment
Mechanism	-
Complex Overt Responses	-
Adaptation	-
Origination	-

Sample Questions for Course Outcome Assessment**

** (2 to 3 at the cognitive level of course outcome)

Course Outcome 1(CO1):

1. Define international standard for length.
2. Distinguish between precision and accuracy.
3. Describe the causes of errors in a measuring instrument.

Course Outcome 2(CO2):

1. Explain construction, working, merits and demerits of turbine meters.
2. Describe the working of Bourdon-tube pressure gauge with a neat sketch.
3. Explain Hall Effect displacement sensor with neat diagram.

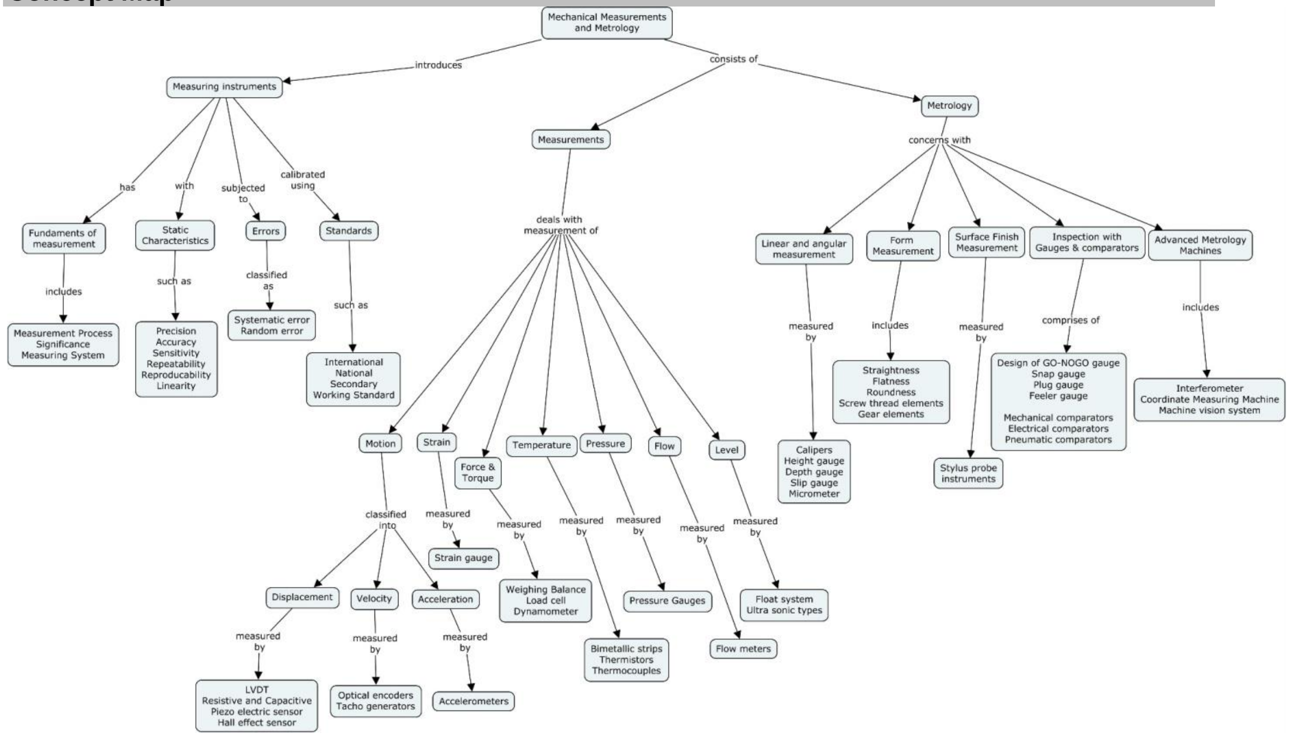
Course Outcome 3(CO3):

1. With suitable figures, illustrate how Vernier calipers shall be used to measure the inner and outer diameter of a hollow cylinder.
2. Suggest an appropriate instrument to measure the minor diameter of an external thread and explain the same.
3. Design a GO-NO GO gauge for a component having 25 H/f8 fit.

Course Outcome 4 (CO4):

1. List the various light sources for laser interferometry.
2. Explain the working of co-ordinate measuring machine and mention its merits and demerits.
3. Describe the basic elements of a machine vision system.

Concept Map



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, Force and Torque: Strain gauge factor, mechanical strain gauge, electrical strain gauge, platform balance, load cell, cantilever beams, torsion bar dynamometer, servo controller dynamometer, absorption dynamometer
Measurement of Temperature: Bimetallic strip, liquid in glass thermometer, Resistance Temperature Detectors, Thermistor, Thermocouples, Pyrometers.
Measurement of Flow: Differential Pressure Meters, Rotameters, Turbine Meters, Electromagnetic Flowmeters, Ultrasonic Flowmeters
Measurement of Pressure: Dead-Weight Tester, Bourdon-tube pressure gauges, Diaphragm and Bellows Gages
Measurement of Level: Float system, Hydrostatic systems, capacitive and ultra-sonic type.

Linear and Angular Measurements: Internal/ External calipers, Vernier caliper, Vernier Height gauge, Depth gauge, Gear tooth Vernier, plunger dials, Slip gauges, Inside / Outside Micrometer, Sine Bar, Bevel protractor, Sprit level.
Form Measurement: Straightness measurement, flatness measurement – N.P.L flatness interferometer, roundness measurement, measurement of screw thread elements – major diameter, minor diameter, effective diameter, pitch, use of thread gauges, measurement of gear elements – runout, pitch, profile, lead, backlash
Surface Finish Measurement: Concepts, terminology and methods of measuring surface finish, 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, Electrical comparator, Optical comparators, Pneumatic Air gauge.
Advanced Metrological Machines: Auto collimator, Laser interferometer, Coordinate measuring machine (CMM), Machine vision for metrology

Learning Resources

1. N.V. Raghavendra and L. Krishnamurthy, “**Engineering Metrology and Measurements**”, Oxford University Press, 2013
2. Thomas G. Beckwith, Roy D. Marangoni, John H. Lienhard V, “**Mechanical Measurements**”, Pearson Learning Solution, 2011
3. R. K. Jain, “**Engineering Metrology**”, Khanna Publishers, 2009
4. J P Holman, “**Experimental Methods for Engineers**”, Tata McGraw Hill, 2012
5. Anand K Bewoor and Vinay A Kulkarni, “**Metrology and Measurement**”, Tata McGraw Hill, 2009.
6. Rajput R.K., “**Mechanical Measurements and Instrumentation**”, Kataris & sons Publishers, 2009.
7. Galyer.J.F.W. Shotbolt, C.R., “**Metrology for Engineers**”, ELBS with Casell Ltd., UK, Fifth Edition, 1990.
8. Alan S Morris, Reza Langari, “**Measurement and Instrumentation**”, Academic Press, 2012
9. K J Hume, “**Engineering Metrology**”, Macdonald & Co Publishers, 1962
10. NPTEL – Metrology.
    Link: https://nptel.ac.in/courses/112106179/
11. NPTEL – Mechanical Measurements and Metrology.
    Link: https://nptel.ac.in/courses/112106138/
12. NPTEL – Engineering Metrology (includes Lab demonstration)
    Link: https://nptel.ac.in/courses/112104250/

Course Contents and Lecture Schedule

Module No.	Topic	No. of Hours	Course Outcome
1.	**Measurement Fundamentals:** The process of measurement- significance, generalized measuring system	1	CO1
1.1	**Characteristics of measuring instruments:** Static characteristics - Precision, Accuracy, Sensitivity, Repeatability, Reproducibility, Linearity	1	CO1
1.2	**Errors**- Systematic and Random, Uncertainty of Measurement	2	CO1
1.3	**Standards** - National, Reference, Secondary, and Working Standards, interchangeability, Bias, Calibration, calibration of machine tools Traceability, Confidence level.	2	CO1
2.1	**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	3	CO2
2.2	**Measurement of Strain, Force and Torque:** Strain gauge factor, mechanical strain gauge, electrical strain gauge, platform balance, load cell, cantilever beams, torsion bar dynamometer, servo controller	3	CO2

	dynamometer, absorption dynamometer		
2.3	**Measurement of Temperature:** Bimetallic strip, liquid in glass thermometer, Resistance Temperature Detectors, Thermistor, Thermocouples, Pyrometers.	2	CO2
2.4	**Measurement of Flow**: Differential Pressure Meters, Rotameters, Turbine Meters, Electromagnetic Flowmeters, Ultrasonic Flowmeters	2	CO2
2.5	**Measurement of Pressure:** Dead-Weight Tester, Bourdon-tube pressure gauges, Diaphragm and Bellows Gages	2	CO2
2.6	**Measurement of Level:** Float system, Hydrostatic systems, capacitive and ultra-sonic type.	2	CO2
3.1	**Linear and Angular Measurements:** Internal/ External calipers, Vernier caliper, Vernier Height gauge, Depth gauge, Gear tooth Vernier, plunger dials, Slip gauges, Inside / Outside Micrometer, Sine Bar, Bevel protractor, Sprit level.	3	CO3
3.2	**Form Measurement**: Straightness measurement, flatness measurement – N.P.L flatness interferometer, roundness measurement, measurement of screw thread elements – major diameter, minor diameter, effective diameter, pitch, use of thread gauges, measurement of gear elements – runout, pitch, profile, lead, backlash	4	CO3
3.3	**Surface Finish Measurement**: Concepts, terminology and methods of measuring surface finish, Principle and operation of stylus probe instruments	2	CO3
3.4	**Inspection using gauges:** Types- limit gauges, Snap gauge, Plain plug gauge, ring gauges, Radius gauges, Feeler gauges - Gauge design	3	CO3
3.5	**Comparator** - Mechanical comparator, Electrical comparator, Optical comparators, Pneumatic Air gauge	1	CO3
3.6	**Advanced Metrological Machines:** Auto collimator, Laser interferometer, Coordinate measuring machine (CMM), Machine vision for metrology	3	CO4

Course Designers:

1. Prof. A. Manoharan manotce@tce.edu
2. Prof. C. Selva Kumar cskmech@tce.edu

18ME360	PROBLEM SOLVING USING COMPUTERS

Category	L	T	P	Credit
ES	2	0	2	3

Preamble

This course is intended for the candidate who desires to learn problem-solving techniques and the design of computer solutions in a precise manner. The course emphasizes problem-solving methodologies, algorithm design, algorithm development and computer-programming skills.

Prerequisite

Nil

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage in %
CO1	Explain the solution for a given problem using program design concepts and build flowchart for modelling the solution.	10
CO2	Develop and implement algorithms for simple mathematical and engineering problems using appropriate control structures.	20
CO3	Build algorithms and programs for solving problems related to matrix manipulations using array processing techniques.	20
CO4	Solve string manipulation and numeric problems using modularization or recursion concepts as applicable.	15
CO5	Construct algorithms for searching and sorting problems and implement them using procedural language.	15
CO6	Develop programs for storing, retrieving and processing data using structures and files.	20

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.2,2.1.1,2.1.2,4.5.3
CO2	TPS3	Apply	Value	Mechanism	1.2 ,2.1.5, 2.5.1, 4.5.3
CO3	TPS3	Apply	Value	Mechanism	1.2,2.1.5, 2.5.1, 4.5.3
CO4	TPS3	Apply	Value	Mechanism	1.2,2.1.5,2.5.1, 4.5.3
CO5	TPS3	Apply	Value	Mechanism	1.2, 2.1.5,2.4.7, 2.5.1, 4.5.3
CO6	TPS3	Apply	Value	Mechanism	1.2, 2.1.5, 2.5.1, 4.5.3

Mapping with Programme Outcomes and Programme Specific Outcome

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	M	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

CO6	S	M	L		L				L			L			L

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Practical Component			Terminal Examination
	1	2	3	1	2	3	
Remember	20	10	10	-	-	-	10
Understand	30	30	30	20	20	20	30
Apply	50	60	60	80	80	80	60
Analyse	-	-	-	-	-	-	-
Evaluate	-	-	-	-	-	-	-
Create	-	-	-	-	-	-	-

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject/Assignment/**Practical Component**
Perception	-
Set	-
Guided Response	20
Mechanism	80
Complex Overt Responses	-
Adaptation	-
Origination	-

Sample Questions for Course Outcome Assessment

Course Outcome 1(CO1):
1. Draw the flowchart to find the highest among three numbers (Understand)
2. Explain the pseudo code to exchange the value of variables(Understand)
3. Give the pseudo code for calculating the interest.(Understand)

Course Outcome 2(CO2):
1. Write a pseudo code to print the grade of the students based on the marks. (Apply)
2. Write a C program to print the following pattern.
```
*
**
***
****
*****
```
3. Develop an algorithm to find Sum of Digits of a Number. (Apply)

Course Outcome 3(CO3):
1. Write a C program to find product of two m* n matrices(Apply)
2. Give an algorithm that gets the maximum and minimum value in anarray. (Apply)
3. Develop an algorithm to print the Multiplication Table of any number(Apply)

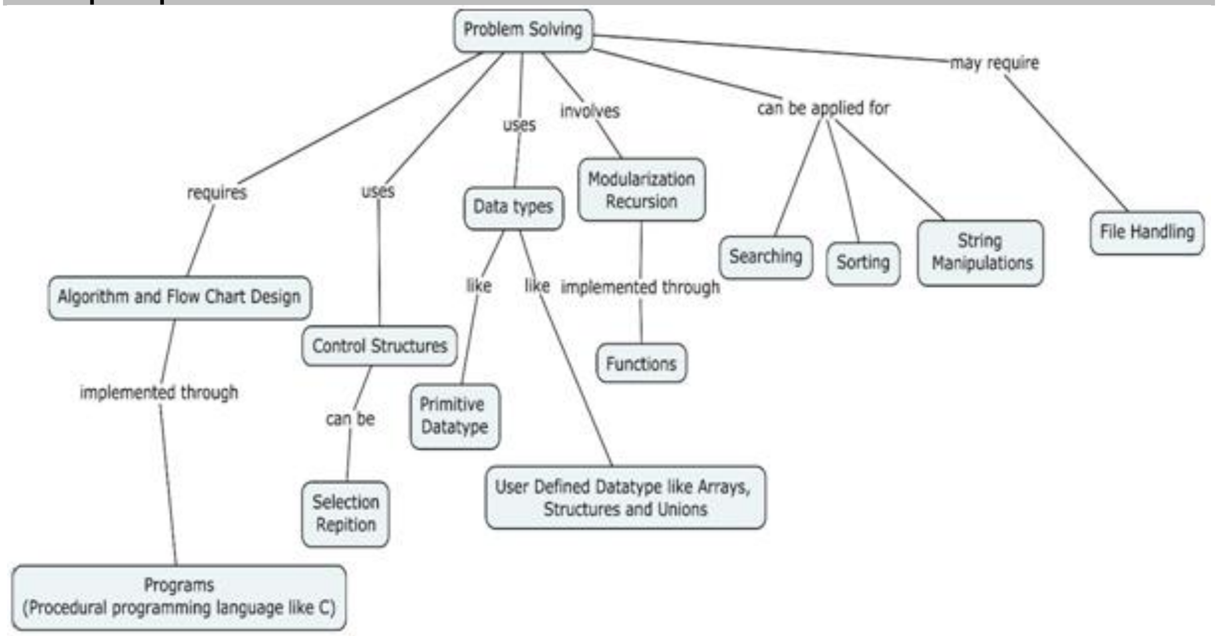
Course Outcome 4 (CO4):
1. Develop an algorithm to compare two strings. (Apply)
2. Design an algorithm to find whether a Number is Prime or Composite using Recursion. (Apply)
3. Develop an algorithm to find LCM of two Numbers using function(Apply)

Course Outcome 5 (CO5):
1. Given an array arr = {4, 6, 72, 81, 91} and key = 81; How many iterations are done until the element is found in Binary Search? (Apply)

2. Demonstrate the working of insertion sort on the following set of numbers : {30, 43, 8, 6, 12, 1, 7,10} (Apply).
3. Write a C program to sort the numbers using selection sort. (Apply).

Course Outcome 6(CO6):
1. Develop an algorithm to copy the content of a file to another file (Apply).
2. Develop an algorithm to maintain a student database using structures (Apply).
3. Write a C program to search for a given word in the file. (Apply)

Concept Map



Syllabus

Theory Component:

Introduction to Computer Problem Solving – Problem solving aspect - Program Design - Developing an Algorithm – Flowcharts - Fundamentals Algorithms - Exchanging values of variables, Counting.

Control structures - Selection Control Structures - Repetition Control Structures - Summation of set of numbers - - Sine function computation - - Reversing the digits of an Integer, Factoring Methods - Finding square root of a number -The smallest divisor of an integer, Generating Prime numbers.

Array Processing and Techniques - Array technique - Finding the maximum number in a set - Finding k^{th} smallest number - Matrix manipulations,

Modularization and Recursion- Factorial computation, Fibonacci sequence generation, String Manipulations – comparison between strings, copying of strings, searching for substring,

Sorting and Searching Algorithms – Bubble sort, sorting by selection, Insertion Sort, Linear Search, Binary search.

File Handling-– Structures – storing and accessing elements – Union – Union of Structures, Files – Read and Write operations on text files.

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 forloops)

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

Problem solving using strings

Problem solving using sorting and searching techniques

Problem solving using structures, files

Learning Resources

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.
3. Yashavant Kanetkar , Let Us C, 16th Edition, BPB Publications, 2017.
4. Yashavant kanetkar, COMPUTER SYSTEM AND PROGRAMMING IN C, First Edition, BPB Publications 2018.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures	Course Outcome
1	**Introduction to Computer Problem Solving**		
1.1	Problem Solving aspect, Program Design, Developing an Algorithm	1	CO1
1.2	Flowcharts	1	CO1
1.3	Problem Solving using Fundamental Algorithms - Exchanging the values of two variables, Counting	1	CO1
2	**Control Structures and Factoring Methods**		
2.1	Selection Control Structures, Repetition Control Structures	2	CO2
2.2	Summation of a set of numbers, Sine function computation, Reversing the digits of an Integer.	1	CO2
2.3	Factoring Methods - Finding square root of a number -The smallest divisor of an integer	1	CO2
2.4	Generating Prime numbers	1	CO2
3	**Array Processing and Techniques**		
3.1	Finding maximum and the minimum value in a set	1	CO3
3.2	Finding kth smallest number	1	CO3
3.3	Matrix manipulations – Addition, Multiplication and Transpose of matrices	2	CO3
4	**Modularization and recursion**		
4.1	Factorial Computation	1	CO4
4.2	Fibonacci sequence generation	1	CO4
4.3	String manipulations – Comparison between	1	CO4

Module No.	Topic	No. of Lectures	Course Outcome
	strings, Copying of strings, Searching for substring		
5	**Sorting and Searching Algorithms**		
5.1	Bubble Sort, Sorting by selection, Insertion Sort	2	CO5
5.2	Linear Search, Binary Search	2	CO5
6	**File Handling**		
6.1	Structures - storing and accessing elements, array of structures	2	CO6
6.2	Union – Union of Structures	1	CO6
6.3	Files – Read and Write operations on text files	2	CO6
	Total	**24**	

Course Contents and Lecture Schedule for Laboratory

Module No.	Topic	No. of Lectures	Course Outcome
1.	Write simple C programs using fundamental algorithms	2	CO1
2.	Write C programs using selection control structures.	2	CO2
3.	Write C programs using repetition control structures.	2	CO2
4.	Design C programs for array handling	2	CO3
5.	Write C programs for matrix manipulations	3	CO3
6.	Develop C programs using functions	2	CO4
7.	Write C programs using recursion technique	1	CO4
8.	Develop C programs for string manipulations	2	CO4
9.	Write C programs to implement different sorting methods	2	CO5
10.	Write C programs to implement different searching methods	2	CO5
11.	Develop C programs using structures and union	2	CO6
12.	Develop C programs for various file operations on text files	2	CO6
	Total Hours	**24**	

Course Designers:

1. Mrs.B.Subbulakshmi bscse@tce.edu
2. Dr.M.Vijayalakshmi mviji@tce.edu

18ME370	MECHANICAL MEASUREMENTS & METROLOGY LAB

Category	L	T	P	Credit
PC	0	0	2	1

Preamble

This course exposes the students 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 calipers, comparators, gauges and measuring machines.

Prerequisite

Nil

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Measure and compare the speed, torque, strain and Displacement	20
CO2	Determine the moment of inertial of the given object	10
CO3	Determine of whirling speed of shaft and Gyroscopic couple, and acceleration of the cam	20
CO4	Measure the various linear, angular and form measurements of the given component.	20
CO5	Determine the surface roughness of the given components	10
CO6	Calibrate linear measurement devices using slip gauges	20

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.2, 2.2.3, 3.2.5, 3.3.1, 4.6.2
CO2	TPS3	Apply	Value	Mechanism	1.2, 2.2.3, 3.2.5, 3.3.1, 4.6.2
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.2.3, 3.2.5, 3.3.1, 4.6.2
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.2.3, 3.2.5, 3.3.1, 4.6.2
CO5	TPS3	Apply	Value	Mechanism	1.2, 2.2.3, 3.2.5, 3.3.1, 4.6.2
CO6	TPS3	Apply	Value	Mechanism	1.2, 2.2.3, 3.2.5, 3.3.1, 4.6.2

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	S	S	M	M	L	-	-	-	M	-	-	-	M	-	S
CO2	S	S	M	M	L	-	-	-	M	-	-	-	M	-	S
CO3	S	S	M	M	L	-	-	-	M	-	-	-	M	-	S
CO4	S	S	M	M	L	-	-	-	M	-	-	-	M	-	S
CO5	S	S	M	M	L	-	-	-	M	-	-	-	M	-	S
CO6	S	S	M	M	L	-	-	-	M	-	-	-	M	-	S

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

1. Students are examined for 50 marks in instrumentation and dynamics lab and 50 marks in Metrology lab for terminal examination.
2. Duration:3 Hours (1 Hour 30 minutes for instrumentation and dynamics lab and 1 Hour 30 minutes for Metrology lab)

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Practical Component/Observation
Perception	-
Set	-
Guided Response	-
Mechanism	**Practical Component/Observation**

Complex Overt Responses	-
Adaptation	-
Origination	-

List of Experiments/Activities with CO Mapping

MEASUREMENTS LAB

List of experiments

S. No	**Title of the experiment (**Any six experiments are to be conducted)	**CO #**
1	Measurement of the plane strain in the beam using strain gauge and its comparison	CO1
2	Measurement of speed using different device and its comparison	CO1
3	Measurement of torque using torque sensor and its comparison	CO1
4	Determination of displacement using LVDT and its calibration	CO1
5	Determination of moment of inertial of the given object	CO2
6	Determination of whirling speed of shaft	CO3
7	Determination of Gyroscopic couple	CO3
8	Determination of displacement , velocity , acceleration of the given cam	CO3

METROLOGY LAB

List of experiments

S. No	**Title of the experiment (**Any six experiments are to be conducted)	**CO #**
1	Profile measurement of linear, angular and thread elements using Tool Makers Microscope	CO 4
2	Profile measurement of linear, angular and thread elements using Profile Projector	CO 4
3	2D & 3D measurements using Coordinate Measuring Machine.	CO 4
4	Measurement of Surface Roughness using portable surface roughness tester.	CO 5
5	Checking of OD and ID using comparators– Pneumatic, electronic and mechanical.	CO 6
6	Calibration of micrometer / Vernier caliper using Standard slip gauge.	CO 6
7	Straightness / Flatness Testing using Autocollimator	CO 4

Learning Resources

1. NPTEL – Mechanical measurement and metrology https://nptel.ac.in/courses/112106138/46
2. NPTEL – Engineering Metrology https://nptel.ac.in/courses/112104250/

Course Designers:

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18ES390	DESIGN THINKING	Category	L	T	P	Credit
		ES	1	-	2	2

Preamble

Design has been defined as a "systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints". Human-centered design is defined as a process and a set of techniques used to create new solutions for the world. Solutions include products, services, environments, organizations, and modes of interaction. The reason this process is called "human-centered" is because it starts with the people we are designing for. This course facilitates the development of students' professional skills through their team engagement in developing conceptual design for a local community problem.

Prerequisite

Nil

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage in %
CO1	Identify a specific social need to be addressed	20
CO2	Identify stakeholder's requirements for the societal project	20
CO3	Develop measurable criteria in which design concepts can be evaluated	10
CO4	Develop prototypes of multiple concepts using user's feedback	30
CO5	Select the best design solution among the potential solutions with its functional decomposition	20

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1.1, 3.1.2, 3.2.3, 3.2.6, 4.1.2
CO2	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1.2, 2.5.1, 2.5.2, 3.1.2, 3.2.3, 3.2.6, 4.1.2
CO3	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1.3, 3.1.2, 3.2.3, 3.2.6, 4.1.2, 4.3.1
CO4	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1.4, 3.1.2, 3.2.3, 3.2.6, 4.1.2, 4.4.1
CO5	TPS5	Evaluate	Organise	Adaptation	1.1, 1.2, 2.1.5, 3.1.2, 3.2.3, 3.2.6, 4.1.2, 4.4.1

Mapping with Programme Outcomes and Programme Specific Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	M	L	-	-	M	M	M	L	M	M	S
CO2	S	M	L	-	-	M	M	M	L	M	M	S
CO3	S	M	L	-	-	M	M	M	L	M	M	S
CO4	S	M	L	-	M	M	M	M	L	M	M	S
CO5	S	S	M	L	M	M	M	M	L	M	M	S

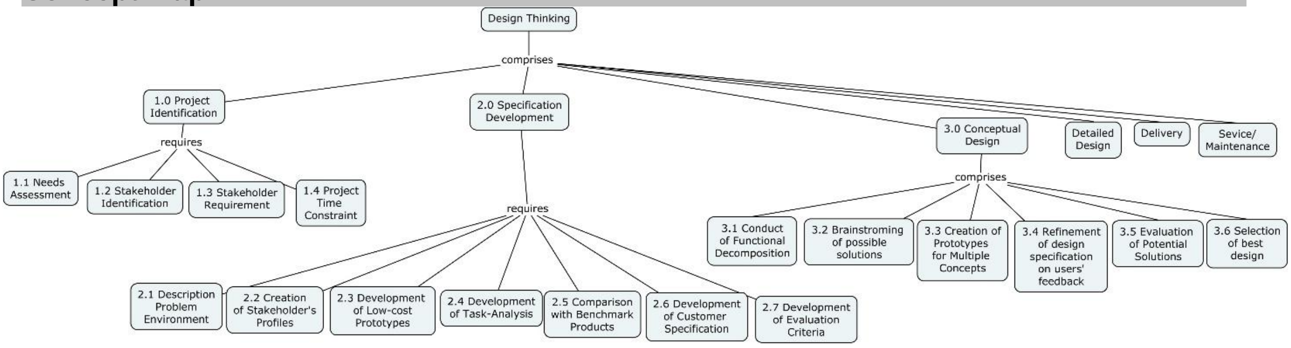
S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Phases	Deliverables	Marks	Course Outcomes
Continuous Assessment			
Review 1 – Problem Identification	Technical Report	10	CO1 and CO2
Review 2 – Specification Development	Technical Report	20	CO3
Review 3 -Conceptual Design	Technical Report	20	CO4 and CO5
End-Semester Examination			
Demonstration	Prototype	60	CO1, CO2, CO3, CO4 and CO5
Poster Presentation	Poster	40	

- Reports are to be submitted at each review. The report and presentation will be evaluated based on Rubrics
- Demonstration and Poster presentation will be evaluated by two faculty members nominated by their respective Head of the Department.

Concept Map



Syllabus

1.0 Project Identification: Needs Assessment, Stakeholder Identification, Stakeholder Requirement Project Time Constraint.

2.0 Specification Development: Description Problem Environment, Creation of Stakeholder's Profiles Development of Low-cost Prototypes, Development of Task-Analysis, Comparison with Benchmark Products, Development of Customer Specification, Development of Evaluation Criteria,

3.0 Conceptual Design: Conduct of Functional Decomposition, Brainstroming of possible solutions, Creation of Prototypes for Multiple Concepts, Refinement of Design Specification on users' feedback, Evaluation of Potential Solutions, Selection of best design

Learning Resources

1. Learning Material prepared by TCE faculty members
2. https://www.ideo.com/
3. https://engineering.purdue.edu/EPICS

Course Contents and Lecture Schedule

Module No.	Topic	No. of Hours		Course Outcome
		In-Class	Hands-on	
1.	**Project Identification**: Introduction to Human-Centered Design	1	-	CO1
1.1	Needs Assessment	1	2	CO1
1.2	Identification of Stakeholders	1	2	CO2
1.3	Identification of Stakeholder Requirements		2	CO2
1.4	Project Time Constraint	1	2	CO2
2.	**Specification Development**			
2.1	Description Problem Environment	1	2	CO3
2.2	Creation of Stakeholder's Profiles		2	CO3
2.3	Development of Low-cost Prototypes	1	2	CO3
2.4	Development of Task-Analysis	1	2	CO3
2.5	Comparison with Benchmark Products	1	2	CO3
2.6	Development of Customer Specification		2	CO3
2.7	Development of Evaluation Criteria	1	2	CO3
3.	**Conceptual Design**			
3.1	Conduct of Functional Decomposition	1	2	CO4
3.2	Brainstroming of possible solutions	1	2	CO5
3.3	Creation of Prototypes for Multiple Concepts	1	2	CO5
3.4	Refinement of design Specification on users' feedback		2	CO6
3.5	Evaluation of Potential Solutions	1	2	CO6
3.6	Selection of best design		2	CO6
	Total	12	34	

Course Designers:

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18ME410	OPERATIONS RESEARCH	Category	L	T	P	Credit
		BS	3	0	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. 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

CO Number	Course Outcome Statement	Weightage in %
CO1	Formulate the LPP and solve by Graphical method	10%
CO2	**Solve** Linear Programming Problems (LPP) by appropriate techniques (Simplex methods & dual simplex method)	20%
CO3	Examine the performance characteristics such as time and cost in solving shortest route, transportation problems with an appropriate model	20%
CO4	Solve the given assignment problem with an appropriate method	10%
CO5	Determine the solutions to single and multi channel Queuing problems	20%
CO6	Solve deterministic inventory problems	20%

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	-	1.1.1, 2.1.1, 2.1.5, 3.1.2, 4.4.3
CO2	TPS3	Apply	Value	-	1.1.1, 2.1.2, 2.3.4, 3.1.5, 4.4.3
CO3	TPS3	Apply	Value	-	1.1.1, 2.1.5, 2.1.5, 3.1.5, 4.6.1
CO4	TPS2	Understand	Respond	-	1.1.1, 2.1.2, 2.1.5, 3.1.2, 4.4.3
CO5	TPS3	Apply	Value	-	1.1.1, 2.1.1, 2.1.5, 3.1.5, 4.6.1
CO6	TPS3	Apply	Value	-	1.1.1, 2.1.1, 2.1.5, 3.1.2, 4.4.3

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PO12	PSO 1	PSO 2	PSO 3
CO 1	S	S	S	S	-	-	-	-	M	-	-	M			S
CO 2	S	S	S	S	-	-	-	-	M	-	-	M			S
CO 3	S	S	S	S	-	-	-	-	-	-	-	M			S
CO 4	S	S	S	S	-	-	-	-	-	-	-	M			S
CO 5	S	S	S	S	-	-	-	-	-	-	-	M			S

CO 6	S	S	S	S	-	-	-	-	-	-	-	M			S
CO 7	S	S	S	S	-	-	-	-	-	-	-	M			S

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	**2**	**3**	1	2	3	
Remember	10	10	10	-	-	-	10
Understand	30	30	30	-	-	-	20
Apply	60	60	60	100	100	100	70
Analyse							
Evaluate							
Create							

Sample Questions for Course Outcome Assessment**

** (2 to 3 at the cognitive level of course outcome)

Course Outcome 1(CO1):

1. Define Feasible Solution.

2. Identify the optimal solution of the following LPP using Graphical method
Max Z= $3x_1 + 2x_2$ Subject to $x_1 - x_2 \geq 1$; $x_1 + x_2 \geq 3$; $x_1, x_2 \geq 0$

3. . A farm is engaged in breeding pigs. The pigs are fed on various products grown on the farm. In view of the need to ensure certain nutrient constituents (call them X, Y and Z), it is necessary to buy two additional products say, A and B. One unit of product A contains 36 units of X, 3 units of Y and 20 units of Z. One unit of product B contains 6 units of X, 12 units of Y and 10 units of Z. The minimum requirement of X, Y and Z is 108 units, 36 units and 100 units respectively. Product A costs Rs. 20 per unit and Product B costs Rs. 40 per unit. Formulate the above as a linear programming problem to minimize the total cost. Identify the optimal number of units of products of A and B that minimizes the total cost using graphical method.

Course Outcome 2(CO2):

1. Solve the following Linear Programming Problem by the dual simplex method
Min Z =$5x_1 + 6x_2$ subject to $x_1+x_2 \geq 2$; $4x_1+x_2 \geq 4$;
$X_1, x_2 \geq 0$

2. Use dual simplex method to solve the following LPP
Max $Z = 3x_1 - x_2$ Subject to $x_1 + x_2 \geq 1$;
$x_1 + 3x_2 \geq 2$; $x_1, x_2 \geq 0$

3. Using Simplex method, Solve the following LPP
Minimize Z = $x_1 - 3x_2 + 2x_3$
Subject to $3x_1 - x_2 + 2x_3 \leq 7$; ; $-2x_1 + 4x_2 \leq 12$, $- 4x_1 + 3x_2 + 8x_3 \leq 10$
$x_1, x_2, x_3 \geq 0$

Course Outcome 3(CO3):

1. Solve the following transportation problem to maximize the profit

Destination						
		A	B	C	D	Supply
Source	1	15	51	42	33	23
	2	80	42	26	81	44
	3	90	40	66	60	33
	Demand	23	31	16	30	100

2. Solve the transportation problem

Factory	Warehouses						Availability
	A	B	C	D	E	F	
1	9	12	9	6	9	10	5
2	7	3	7	7	5	5	6
3	6	5	9	11	3	11	2
4	6	8	11	2	2	10	9
Requirement	4	4	6	2	4	2	

3. Use Vogel's Approximation method to obtain an initial basic feasible solution of the transportation problem.

	Available				
Demand	11	13	17	14	250
	16	18	14	10	300
	21	24	13	10	400
	200	225	275	250	950

Course Outcome 4 (CO4):

1. The owner of a small machine shop has a four mechanics available to assign jobs for the day. Five jobs are offered with expected profit for each mechanic on each jobs, which are as follows

Job

Mechanic
$$\begin{bmatrix} 62 & 78 & 50 & 111 & 82 \\ 71 & 84 & 61 & 73 & 59 \\ 87 & 92 & 111 & 71 & 81 \\ 48 & 64 & 87 & 77 & 80 \end{bmatrix}$$

By using the assignment method, Produce the assignment of mechanics to the job that will result in maximum profit. Which job should be declined?

2. A company has five jobs V, W, X, Y and Z and five machines A, B, C, D and E. The given matrix shows the return in Rs. of assigning a job to a machine. Assign the jobs to machines using Hungarian Method so as to maximize the total returns.

Machines. Returns in Rs.

Jobs	*A*	*B*	*C*	*D*	*E*	*F*
V	5	11	10	12	12	4
W	2	4	6	3	3	5
X	3	12	5	14	14	6
Y	6	14	4	11	11	7
Z	7	9	8	12	12	5

3. Briefly explain the process of solving a maximization type Assignment Problem

Course Outcome 5 (CO5):

1 The railway marshalling yard is sufficient only for trains (there being 11 lines, one of which is earmarked for the shunting engine to reverse itself from the crest of the hump to the rear of the train.)n Trains arrive at the rate of 25 trains per day , inter-arrival time and service time follow exponential with an average of 30 minutes. Determine (i) the probability that the yard is empty. (ii) the average queue length.

2. A petrol pump station has 2pumps. The service times follow the exponential distribution with a mean of 4 minutes and cars arrive for service in a Poisson process at the rate of 10 cars per hour.

Find the probability that a customer has to wait for service. What proposition of time the pumps remain idle?

3. Suppose people arrive to purchase tickets for a basket ball game at the average rate of 4 minutes. It takes an average of 10 seconds to purchase a ticket. If a sports fan arrives 2 min before the game starts and if it takes exactly 11/2 min to reach the correct seat after the fan purchase a ticket, then (i) Can the sports fan expect to be seated for the start of the game?
(ii) What is the probability that the sports fan will be seated for the start of the game? (iii) How early must the fan arrive inorder to be 99% sure of being seated for the start of the game?

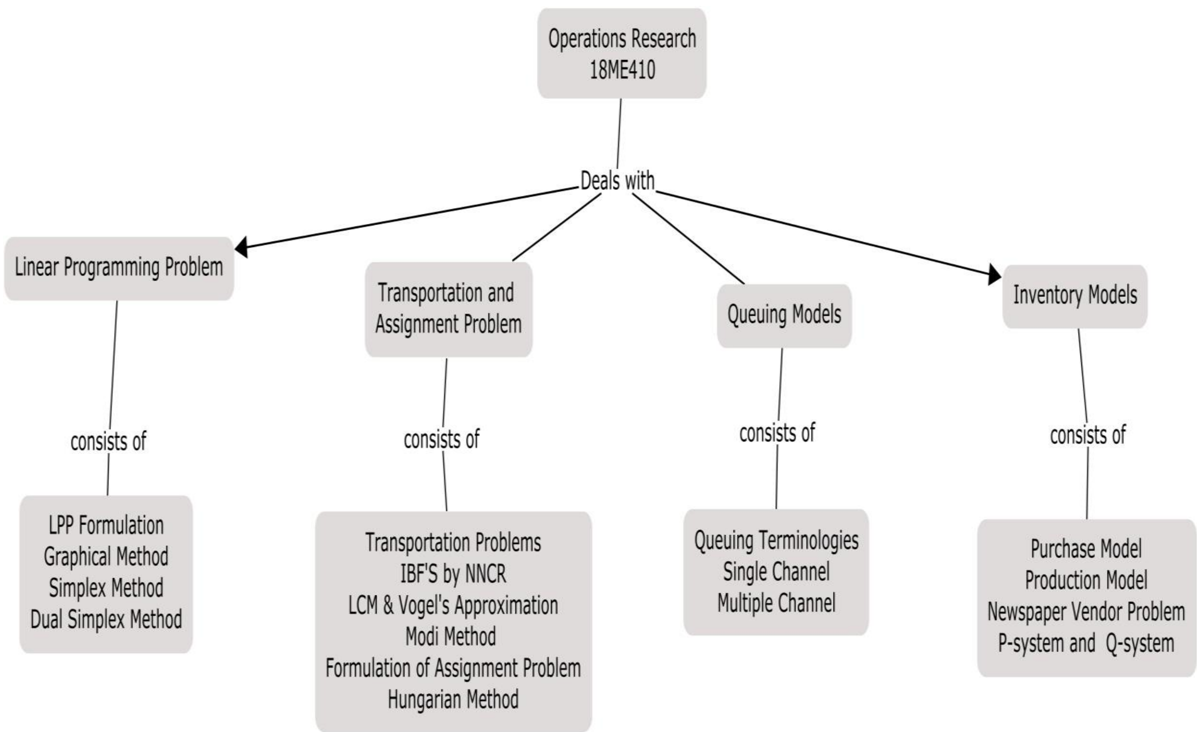
Course Outcome 6(CO6):

1. A commodity is to be supplied at a constant rate of 200 units per day. Supplies of any amount can be obtained at any required time, but each ordering costs Rs.50; cost of holding the commodity in inventory is Rs 2 per unit per day while the delay in the supply of the item induces a penalty of Rs. 10 per unit per day. Find the optimal policy (Q,t), where t is the reorder cycle period and Q is the inventory after reorder. What would be the best policy to adopt if the penalty cost becomes infinite?

2. The production department of a company requires 3,600 kg of raw material for manufacturing a particular item in the year. It has been estimated that the cost of placing an order is Rs.36 and the cost of carrying inventory is 25 per cent of the investment in the inventories. The price is Rs 10 per kg. Help the purchase manager to determine an ordering policy for raw material.

3. How does a fixed order quantities system (Q-system) and periodic review system (P-system) differ in placing an order?

Concept Map



Syllabus

Linear Programming: Introduction - LPP formulation - Graphical method , Simplex method , Dual simplex method. **Transportation and Assignment Problems**: Transportation problems, IBFs by NWCR, LCM and Vogel's approximation method, optimal solution for a TP using MODI method - Formulation of Assignment Problem – Hungarian method for Assignment problem - Travelling Salesman Problem.. **Queuing Models** (Poisson arrival and Exponential service Pattern): Queuing terminologies and applications, Single Channel- Finite & infinite population Queue, Multiple Channel- Infinite population Queue. **Inventory models:** Purchase model with and without shortages, Production model with and without shortages, quantity discount model, Newspaper vendor problem, p-system and Q-system

Learning Resources

1. G.Srinivasan, "Operations Research: Principles and Applications", PHI Ltd., 2010
2. Ravindran Philips Solberg, "Operations Research Principles and Practice" 2nd Edition, John Wiley & Sons, 1987
3. Hamdy A.Taha "Operations Research – An Introduction", MacMillan India Ltd., Seventh Edition ,2003.
3. Hira.D Gupta.P.K, "Operations Research",S.Chand Publications, First Edition, Reprint 2001 4. Kanti swarup Gupta.P.K, Man Muhan" 'Operations Research: Sultan Chand & Sons India Ltd., Twelth Edition,New Delhi 2004.

5. https://nptel.ac.in/syllabus/syllabus_pdf/110106062.pdf

Course Contents and Lecture Schedule

Module No.	Topic	No. of Hours	Course Outcome
1.	**Linear Programming**		
1.1	Introduction & LPP formulation	1	CO1
1.2	Graphical method	2	CO1
1.3	Simplex method	3	CO2
1.4	Dual simplex method	3	CO2
2	**Transportation and Assignment Problems**		
2.1	Transportation problems	2	CO3
2.2	IBFs by NWCR	1	CO3
2.3	LCM and Vogel's approximation method	3	CO3
2.4	Optimal solution for a TP using MODI method	1	CO3
2.5	Assignment Problem – Formulation	1	CO4
2.6	Hungarian method for Assignment problem, Travelling Salesman Problem	1	CO4
3.	**Queuing Models (Poisson arrival and Exponential service Pattern)**		
3.1	Queuing terminologies and applications	1	CO5
3.2	Single Channel- Finite & infinite population Queue	4	CO5
3.3	Multiple Channel- Infinite population Queue.	4	CO5
4.	**Inventory models**		
4.1	Purchase model	3	CO6
4.2	Production model, quantity discount model	3	CO6
4.3	Newspaper Vendor problem	1	CO6
4.4	P-system and Q-system	2	CO6

Course Designers:

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3. Dr.A.P.Pushpalatha appmat@tce.edu

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18ME420	DESIGN OF MACHINE ELEMENTS	Category	L	T	P	Credit
		PC	2	1	0	3

Preamble

Machine Design is the creation of new and better machines that works safely, reliably and well. Mechanical design is a complex process, requiring many skills. Extensive relationships need to be subdivided into a series of simple tasks. The complexity of the process requires a sequence in which ideas are introduced and iterated. Design is an iterative process with many interactive phases. Many resources exist to support the designer, including many sources of information about the materials, loading conditions and computational design equations and tools. The survival of a mechanical machine element is often related through their stress and strength. Thus, Machine Design is defined as the use of scientific principles, technical information and imagination in the description of a machine or a mechanical system to perform specific functions with maximum economy and efficiency.

Prerequisite

- Engineering Mechanics
- Mechanics of Materials

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage In %
CO1	Design of simple machine elements subjected to static and fatigue loading.	15
CO2	Design of shafts, keys and couplings under different loading conditions for mechanical applications.	20
CO3	Design of welded joints, riveted joints and threaded joints subjected to different loading conditions	25
CO4	Design of helical coil springs, leaf springs and flywheels for mechanical applications	15
CO5	Design of piston, connecting rod and crank shaft for an automobile engine and sliding contact bearings and anti-friction bearings	25

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.4.4, 3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6
CO2	TPS3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.4.4, 3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.4.4, 3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.4.4, 3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6
CO5	TPS3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.4.4, 3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6

Mapping with Programme Outcomes and Programme Specific 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	PSO 1	PSO 2	PSO 3
CO1.	S	S	S	L	-	-	-	M	L	-	-	-	S	-	M
CO2.	S	S	S	M	-	-	-	M	L	L	-	-	S	-	M
CO3.	S	S	S	M	-	-	-	M	L	L	-	-	S	-	M
CO4.	S	S	S	M	-	-	-	M	L	L	-	-	S	-	M
CO5.	S	S	S	M	-	-	-	M	L	L	-	-	S	-	M

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests (30 marks)			Design Project (20 marks)	Terminal Examination (50 marks)
	1	2	3		
Remember	10	10	10	0	10
Understand	10	10	10	0	10
Apply	80	80	80	0	80
Analyse	0	0	0	100	0
Evaluate	0	0	0	0	0
Create	0	0	0	0	0

Design Project: The students will do a Design project in which the students should identify the real-life application of the machine element and gather the input information for loads, materials etc., from the identified real-life application. The student has to follow the procedure for designing that machine element and compare it with that of the actual value. A final technical report has to be submitted. The total mark for evaluation is 100 and has to be converted to 20.

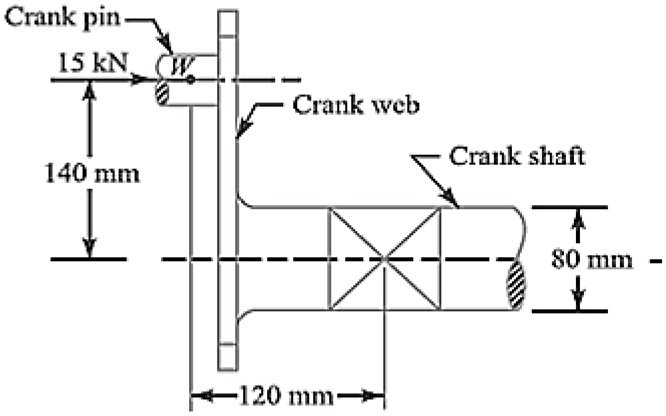
Assessment Pattern: Psychomotor

Psychomotor Skill	Mini Project/ Assignment/ Practical
Perception, Set	-
Guided Response	-
Mechanism	-
Complex Overt Responses	Design Project
Adaptation	-
Origination	-

Sample Questions for Course Outcome Assessment

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 transverse Shear force of 5 kN. Find the diameter of bolt required according to,
   - Maximum principal stress theory.
   - Maximum shear stress theory.
   - Maximum principal strain theory.
   - Maximum strain energy theory.
   - 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 W_{min} = – 300 × 10^3 N to W_{max} = 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 solid steel shaft is supported on two bearings 1.8 m apart and rotates at 250 r.p.m. A 20° involute gear D, 300 mm diameter is keyed to the shaft at a distance of 150 mm to the left on the right-hand bearing. Two pulleys B and C are located on the shaft at distances of 600 mm and 1350 mm respectively to the right of the left-hand bearing. The diameters of the pulleys B and C are 750 mm and 600 mm respectively. 30 kW is supplied to the gear, out of which 18.75 kW is taken off at the pulley C and 11.25 kW from pulley B. The drive from B is vertically downward while from C the drive is downward at an angle of 60° to the horizontal. In both cases the belt tension ratio is 2 and the angle of lap is 180°. The combined fatigue and shock factors for torsion and bending may be taken as 1.5 and 2 respectively. Design a suitable shaft taking working stress to be 42 MPa in shear and 84 MPa in tension.

2. A hollow shaft of 0.5 m outside diameter and 0.3 m inside diameter is used to drive a propeller of a marine vessel. The shaft is mounted on bearings 6 metre apart and it transmits 5600 kW at 150 r.p.m. The maximum axial propeller thrust is 500 kN and the shaft weighs 70 kN. Determine: The maximum shear stress developed in the shaft, and the angular twist between the bearings.

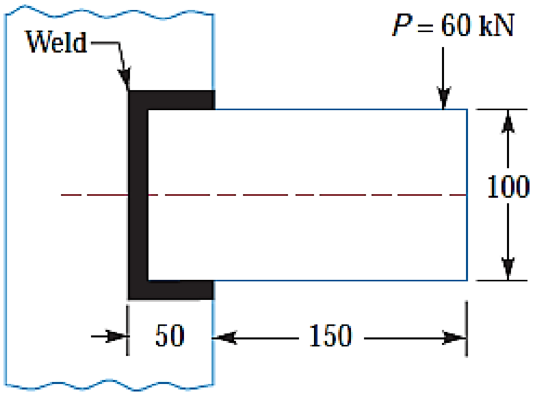
3. Design a bushed-pin type flexible coupling for connecting a motor shaft to a pump shaft for the following service conditions: Power to be transmitted = 40 kW; speed of the motor shaft = 1000 r.p.m.; diameter of the motor shaft = 50 mm; diameter of the pump shaft = 45 mm. The bearing pressure in the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

4. Design a shaft and flange for a Diesel engine in which protected type of flange coupling is to be adopted for power transmission. The following data is available for design: Power of engine = 75 kW; speed of engine = 200 r.p.m.; maximum permissible stress in shaft = 40 MPa; maximum permissible twist in shaft = 1° in length of shaft equal to 30 times the diameter of shaft; maximum torque = 1.25 × mean torque; pitch circle diameter of bolts = 3 × diameter of shaft; maximum permissible stress in bolts = 20 MPa. Find out: 1. Diameter of shaft, 2.

number of bolts, and 3. diameter of bolts.

Course Outcome 3 (CO3):

1. A rectangular steel plate is welded as a cantilever to a vertical column and supports a single concentrated load P, as shown in Figure. Determine the weld size if shear stress in the same is not to exceed 140 MPa.



2. A steam engine cylinder of size 300 mm × 400 mm operates at 1.5 N/mm^2 pressure. The cylinder head is connected by means of 8 bolts having yield point stress of 350 MPa and endurance limit of 240 MPa. The bolts are tightened with an initial preload of 1.8 times the steam lead. The joint is made leak-proof by using soft copper gasket which renders the effect of external load to be half. Determine the size of bolts, if factor of safety is 2 and stress concentration factor is 3

3. A pressure vessel has an internal diameter of 1 m and is to be subjected to an internal pressure of 2.75 N/mm^2 above the atmospheric pressure. Considering it as a thin cylinder and assuming efficiency of its riveted joint to be 79%, calculate the plate thickness if the tensile stress in the material is not to exceed 88 MPa. Design a longitudinal double riveted double strap butt joint with equal straps for this vessel. The pitch of the rivets in the outer row is to be double the pitch in the inner row and zig-zag riveting is proposed. The maximum allowable shear stress in the rivets is 64 MPa. You may assume that the rivets in double shear are 1.8 times stronger than in single shear and the joint does not fail by crushing. Make a sketch of the joint showing all calculated values. Calculate the efficiency of the joint.

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 is 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.

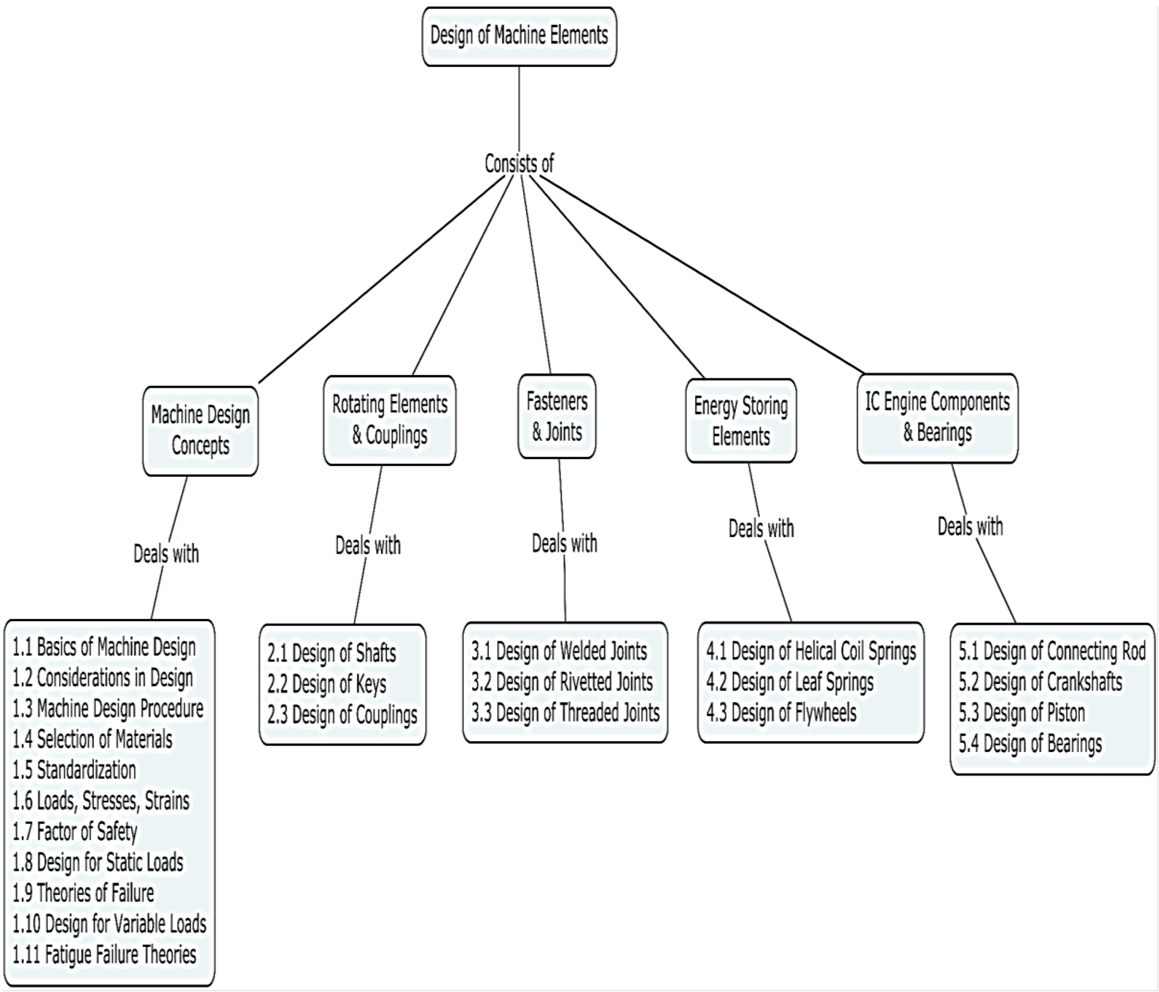
2. Design a side crankshaft for a 500 mm × 600 mm gas engine. The weight of the flywheel is 80 kN and the explosion pressure is 2.5 N/mm^2. The gas pressure at maximum torque is 0.9 N/mm^2 when the crank angle is 30º. The connecting rod is 4.5 times the crank radius.

3. Design a cast iron piston for a single acting four stroke engine for the following data: Cylinder bore = 100 mm; Stroke = 125 mm ; Maximum gas pressure = 5 N/mm^2; Indicated mean effective pressure = 0.75 N/mm^2 ; Mechanical efficiency = 80% ; Fuel consumption = 0.15 kg per brake power per hour ; Higher calorific value of fuel = 42 × 103 kJ/kg ; Speed = 2000 r.p.m. Any other data required for the design may be assumed.

4. Design a suitable journal bearing for a centrifugal pump from the following available data: Load on the bearing = 13.5 kN; Diameter of the journal = 80 mm; Speed = 1440 r.p.m.; Bearing characteristic number at the working temperature (75°C) = 30 ; Permissible bearing pressure intensity = 0.7 N/mm^2 to 1.4 N/mm^2; Average atmospheric temperature = 30°C. Calculate the cooling requirements, if any.

5. A ball bearing subjected to a radial load of 4000 N is expected to have a satisfactory life of 12 000 hours at 720 r.p.m. with a reliability of 95%. Calculate the dynamic load carrying capacity of the bearing, so that it can be selected from manufacturer's catalogue based on 90% reliability. If there are four such bearings each with a reliability of 95% in a system, what is the reliability of the complete system?

Concept Map



Syllabus

Machine Design Concepts: Introduction to Machine Design – General Considerations in Machine elements Design – Machine Design Process/Procedure. Engineering Materials & its properties – Selection of Materials – Standardization – Preferred Numbers. Determination of Loads, Types of Stresses, Strain & Deflection in simple machine parts – Factor of safety. Design for Static Load – Theories of Failure. Design for Fluctuating loads – Fatigue failure theories – Goodman equation – Soderberg equation.
Shafts and Couplings: Design of Shafts – combined twisting moment and bending moment - combined twisting moment, bending moment and axial loads. Design of Keys. Design of Couplings – Rigid and Flexible Couplings.
Design of Joints: Design of Welded joints – Lap and Butt joints – Welded joints subjected to transverse and eccentric loads. Riveted Joints – Design of different types of riveted joints – Pressure vessels – Structural Joints – Riveted joints subjected to eccentric loads. Design of Threaded Joints – Bolted Joints in simple Tension and Shear – Eccentrically Loaded Bolted Joints.
Energy Storing Elements: Design of Helical Coil Springs – Tension and Compression springs subjected to axial loads and eccentric loads. Design of parallel and concentric springs subjected to axial loads - Design of Leaf Springs. Design of Flywheels for IC engines and Punching presses.
IC Engine Components & Bearings: Design of Piston, Connecting Rod & Crank shafts – Side and Centre Crank. Design of Sliding Contact and Rolling Contact Bearings.

Learning Resources

1. Richard G Budynas and J Keith Nisbett **"Shigley's Mechanical Engineering Design"**, Tenth Edition, Tata McGraw Hill, 2015.
2. Robert L. Norton, **"Machine Design: An Integrated Approach"**, Fifth Edition, Pearson, 2018.
3. V.B. Bhandari, **"Design of Machine Elements"**, Fourth Edition, McGraw Hill Education India Pvt. Ltd., 2017.
4. Alfred Hall, Alfred Holowenko, Herman Laughlin and S Somani, **"Schaum's Outline - Machine Design"**, McGraw Hill Education India Pvt. Ltd., 2017
5. Robert C. Juvinall and Kurt M. Marshek, **"Machine Component Design"**, Wiley India Edition, 2016.
6. Ansel C. Ugural, **"Mechanical Design of Machine Components"**, Second Edition, CRC Press, 2015
7. Anup Goel, "**Design of Machine Elements**", First Edition, Technical Publications, 2016.
8. PSG College, **"Design Data: Data Book of Engineers"**, Kalaikathir Achchagam, 2019
9. Joseph E Shigley and Charles R Mischke, **"Standard Handbook of Machine Design",** Third Edition, McGraw Hill Pvt. Ltd., 2004
10. K. Lingaiah, **"Machine Design Data Handbook"**, Second Edition, McGraw Hill Pvt. Ltd., 2010.
11. Prof. B. Maiti, Prof. S.K. Roychowdhury, Prof. G. Chakraborty, **"Design of Machine Elements 1"**, NPTEL, IIT Kharagpur - https://nptel.ac.in/courses/112105125/
12. Dr. Kathryn Wingate, **"Machine Design Part 1",** Coursera, Georgia Institute of Technology - https://www.coursera.org/learn/machine-design1
13. Prof. Martin Culpepper, **"Elements of Mechanical Design",** MITOCW, Massachusetts Institute of Technology - https://ocw.mit.edu/courses/mechanical-engineering/2-72-elements-of-mechanical-design-spring-2009/index.htm

Course Contents and Lecture Schedule

Module No.	Topics	No. of Lectures
1.	**Machine Design Concepts**	
1.1	Introduction to Machine Design	1
1.1.1	General Considerations in Machine Elements Design	
1.1.2	Machine Design Process/Procedure	
1.1.3	Engineering Materials & its Properties	1

1.1.4	Selection of Materials	
1.2	Standardization	
1.2.1	Preferred Numbers	
1.3	Determination of Loads, Types of Stresses, Strain & Deflection in Simple Machine Parts	1
1.3.1	Factor of Safety	
1.4	Design for Static Loads	1
1.4.1	Theories of Failure	
1.5	Design for Variable or Fluctuating Loads	1
1.5.1	Fatigue Failure Theories – Goodman & Soderberg Equation	
2.	**Shafts and Couplings**	
2.1	Design of Shafts subjected to combined twisting & bending	1
2.1.1	Design of Shafts subjected to combined twisting, bending & axial loads	2
2.3	Design of Keys	1
2.4	Design of Couplings – Rigid Couplings	2
2.4.1	Design of Couplings – Flexible Couplings	1
3.	**Design of Joints**	
3.1	Design of Welded Joints – Lap and Butt Joints	2
3.1.1	Welded Joints subjected to Torsion and Bending moment	2
3.2	Design of Riveted Joints and its Types	1
3.2.1	Design of Riveted Joints for Pressure Vessels & Structural Joints	2
3.3	Design of Threaded Joints in Tension & Shear	1
3.3.1	Bolted Joints subjected to Eccentrical Loading	1
4.	**Energy Storing Elements**	
4.1	Design of Helical Coil Springs – Axial Loads & Eccentric Loads	2
4.1.1	Springs in Parallel and Concentric or Composite Springs	1
4.2	Design of Leaf Springs	1
4.3	Design of Flywheels	2
5.	**Automobile Components and Bearings**	
5.1	Design of Connecting Rod	2
5.2	Design of Crankshafts	2
5.3	Design of Piston	1
5.4	Design of Sliding Contact Bearings	2
5.5	Design of Rolling Contact Bearings	2
	Total No. of Hours	**36**

Course Designers:

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18ME430	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

Nil

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Explain the fundamentals of metal cutting, cutting tools, tool life, tool wear and cutting fluids	10
CO2	Explain the working principle, work holding devices and machining parameters of machine tools.	30
CO3	Determine the cutting parameters in orthogonal cutting process.	10
CO4	Determine the cutting parameters like metal removal rate, machining time for turning, drilling, boring, shaping, planning, milling, grinding and broaching processes.	30
CO5	Select the suitable material and machining processes for a given product or component.	20

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.2, 2.4.4, 3.3.1,4.3.2
CO2	TPS2	Understand	Respond	Guided Response	1.2, 2.4.4, 3.3.1,4.3.2
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO5	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	S	M	L	-	-	-	-	-	-	-	L	-	S	-	L
CO2	S	M	L	-	-	-	-	-	-	-	M	-	S	-	L

CO 3	S	M	L	-	-	-	M	-	-	-	M	-	S	-	L
CO 4	S	M	L	-	-	-	M	-	-	-	M	-	S	-	L
CO 5	S	M	L	-	-	-	M	-	-	-	M	-	S	-	L

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	**20**	**20**	**20**	**20**	**20**	**20**	**20**
Understand	**60**	**20**	**20**	**60**	**20**	**20**	**20**
Apply	**20**	**60**	**60**	**20**	**60**	**60**	**60**
Analyse	-	-	-	-	-	-	-
Evaluate	-	-	-	-	-	-	-
Create	-	-	-	-	-	-	-

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	-
Set	-
Guided Response	-
Mechanism	**Assignment**
Complex Overt Responses	-
Adaptation	-
Origination	-

Sample Questions for Course Outcome Assessment**

** (2 to 3 at the cognitive level of course outcome)

Course Outcome 1 (CO1):

1. Define chip thickness ratio.
2. List the functions of apron in shaper tool head.
3. Compare up milling with down milling

Course Outcome 2 (CO2):

1. Name any four work holding devices used in planning machine.
2. Describe the drill nomenclature with neat sketches.
3. Why balancing is needed for the grinding wheel.

Course Outcome 3 (CO3):

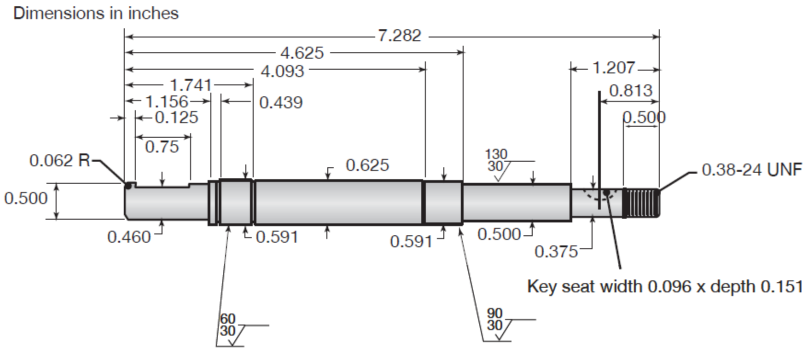
1. In an orthogonal cutting on a M.S tube of size 150mm diameter and 2.1mm thickness, conducted at 90 m/min and 0.21mm/rev feed, the following data are recorded: Cutting force = 1250N. Feed force = 300N, Chip thickness =0.3mm, contact length = 0.75mm and power = 2 KW, rake angle 10°. Compute shear strain, shear energy per unit volume.
2. While doing orthogonal machining of a mild steel part, a depth of cut of 0.8 mm is used at 55 rpm. If the chip thickness is 1.6 mm and it is of continuous type. Determine the chip thickness ratio. Also calculate the length of chip removed in one minute if work diameter is 50 mm before the cut is taken.
3. Following data relate to an orthogonal cutting process:
Chip thickness obtained =0.85 mm, breadth of cut = 25 mm, rake angle used = 10°, Depth of cut = 0.3 mm, Tangential force = 900 N, Feed force = 450 N. Determine (i) Coefficient of friction between the tool and the chip, (ii) Ultimate shear stress of the work material.

Course Outcome 4 (CO4):

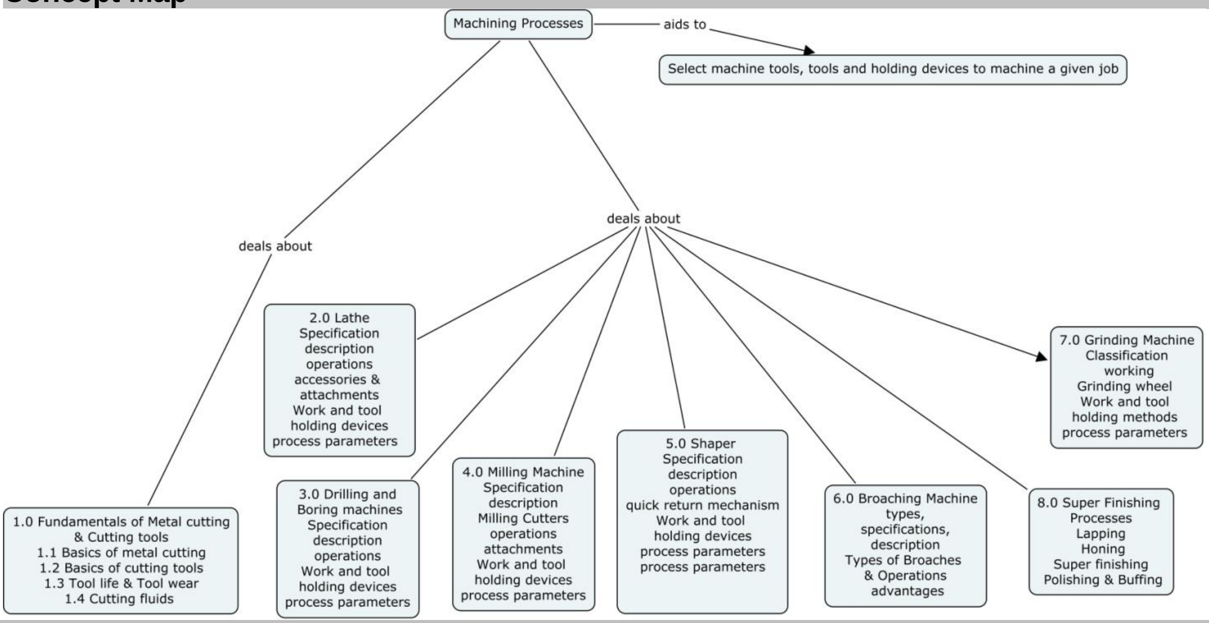
1. Find the correct number of strokes per minute to use on a shaper cutting a mild steel piece of 250mm long and 150mm wide. The cutting speed is 20m/min for HSS tool. If a feed of 1mm is used then how much time will be taken for machining one surface of job.
2. A steel workpiece is to be milled. Metal removal rate is 30 cm^3/ min. Depth of cut is 5mm and width of cut is 100mmm. Find the table feed.
3. A taper pin of length 80 mm has a taper length of 48 mm. The larger diameter of taper is 83 mm and the smaller diameter is 73 mm. Determine: i). Taper in mm/m and in degree. ii). the angle to which the compound rest should be set up. iii). the tail stock setting over.

Course Outcome 5 (CO5):

2. How do you select a grinding wheel for the following materials?
a. (i).Aluminium
b. (ii). Copper
c. (iii) Steels
3. Select and describe type of milling operation used for machining slender and intricate parts.
4. 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 cutting model) , Chip thickness ratio, Velocity ratio, Merchant circle diagram, Cutting forces , 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 & Tool wear: Taylor's equation, Variables affecting tool life, Machinability- Definition.

Cutting fluids: Function, and types.

Lathe: Centre lathe and Capstan & Turret Lathe, semiautomatic – single spindle , automatic screw type – multi spindle- cycle time reduction- 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, DOC & machining time.

Drilling and Boring machines: Introduction 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: Introduction, 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.

Learning Resources

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.
2. Serope Kalpakjian and Steven R.Schmid, “**Manufacturing Engineering and Technology**”, Sixth Edition, PHI, 2010.
3. Mikell P.Groover, ”**Fundamental of Modern Manufacturing**”, Wiley India Edition, Third Edition, Reprint, 2012.
4. E. Paul DeGarmo, J.T. Black and Ronald A. Kohser, “**Degarmo's Materials and Processes in Manufacturing** ”, John Wiley & Sons, 11th Edition 2011.
5. Philip F. Oswald, and Jairo Munoz, “**Manufacturing Process and Systems**”, John Wiley India Edition, 9th Edition, Reprint 2008.
6. P.N.Rao, “**Manufacturing Technology**”, Volume-2, 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. https://nptel.ac.in/downloads/112105127/ - COURSE CO-ORDINATED BY : IIT KHARAGPUR.
9. https://nptel.ac.in/courses/112105126/2- COURSE CO-ORDINATED BY : IIT KHARAGPUR.
10. https://nptel.ac.in/syllabus/112105127/-Prof. A.K. Chattopadhyay, Prof. A.B. Chattopadhyay, Prof. S. Paul, IIT Kharagpur.
11. https://www.coursera.org/courses?query=manufacturing%20process
12. http://web.mit.edu/2.810/www/files/lectures/lec5-machining-2018.pdf - T. Gutowski- MIT

Module No.	Topic	No. of Hours	Course Outcome
1	Fundamentals of Metal cutting & Cutting tools		
1.1	Basics of metal cutting: Mechanism of chip formation (orthogonal cutting model) , Chip thickness ratio, Velocity ratio	2	CO1
1.1.1	Merchant circle diagram, Cutting forces , measurement of cutting forces	1	CO1, CO3
1.1.2	Types of chips - continuous, discontinuous & continuous with built up edge, Chip breakers.	1	CO1
1.2	Basics of cutting tools: Characteristics, Cutting tool materials, properties and applications.	1	CO1
1.3	Tool life & Tool wear- Taylor's equation, Variables affecting tool life, Machinability-Definition.	1	CO1, CO3

1.4	Cutting fluids - Function, and types	1	CO1

Course Designers:

2.0	Lathe		
2.1	Centre lathe, Capstan & Turret Lathe, specifications, description	1	CO2
2.2	Semiautomatic – single spindle, automatic screw type – multi spindle- cycle time reduction	1	CO2
2.3	Nomenclature of single point cutting tool, Operations performed on lathe.	1	CO2
2.4	Lathe accessories & attachments, Work and tool holding methods / devices	1	CO2
2.5	Definition of process parameters – cutting speed, feed, DOC & machining time	1	CO2, CO4, CO5
3.0	Drilling and Boring machines		CO2
3.1	Introduction, Radial drilling machine and Horizontal boring machine, specifications, description,	2	CO2
3.2	Nomenclature of drill, Operations performed on drilling machine.	1	CO2
3.3	Work and tool holding methods / devices	1	CO2
3.4	Definition of process parameters – cutting speed, feed, DOC & machining time	1	CO2, CO4,CO5
4.0	Milling Machine		CO2
4.1	Introduction, Column and Knee type milling machine, specifications	1	CO2
4.2	Description, attachments	1	CO2
4.3	Milling cutters, Nomenclature of plain milling cutter & operations performed	1	CO2
4.4	Work and tool holding methods / devices	1	CO2
4.5	Definition of process parameters – cutting speed, feed, DOC & machining time	1	CO2, CO4,CO5
5.0	Shaper		CO2
5.1	Introduction, specifications, description, Quick return mechanism	1	CO2
5.2	Definition of process parameters - cutting speed, feed, DOC & machining time	1	CO2
6.0	Broaching Machine		CO2
6.1	Introduction, types, specifications, description	1	CO2
6.2	Types of Broaches & Operations, advantages	1	CO2
7.0	Grinding Machine		CO2
7.1	Introduction, Classification, working of grinding machines.	1	CO2
7.2	Grinding wheel (Abrasives & Bond), Selection of Grinding wheel, mounting, glazing & loading, dressing, balancing.	2	CO2
7.3	Work and tool holding methods / devices	1	CO2
7.3	Definition of process parameters – cutting speed, feed, DOC & machining time	1	CO2, CO4 CO5
8.0	Super Finishing Processes		CO2
8.1	Lapping, Honing	1	CO2
8.2	Super finishing, Polishing & Buffing	1	CO2
Total		**36**	

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18ME440	FLUID MECHANICS

Category	L	T	P	Credit
PC	2	1	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

Nil

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO 1.	Explain the effect of fluid properties on a flow system and concept of fluid statics.	22
CO 2.	Apply the kinematic concepts and dynamic concepts which relates to the conservation principles of mass and energy.	26
CO 3.	Determine the major and minor losses associated with pipes.	18
CO 4.	Compute the compressible flow properties and its application.	18
CO 5.	Determine the property variation in variable area flow and effect off-design condition.	16

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.4.5, 4.6.5
CO2	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.4.5, 4.6.5
CO3	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.4.5, 4.6.5
CO4	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.4.5, 4.6.5
CO5	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.4.5, 4.6.5

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	S	M	-	-	M	-	L	-	L	-	L	M	-	S	-
CO2	S	S	-	-	M	-	L	-	L	-	L	M	-	S	-
CO3	S	M	-	-	M	-	L	-	L	-	L	M	-	S	-
CO4	S	M	-	-	M	-	L	-	L	-	L	M	-	S	-
CO5	S	S	-	-	M	-	L	-	L	-	L	M	-	S	-

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	**20**	**20**	**20**	**--**	**--**	**--**	**20**
Understand	**30**	**30**	**30**	**--**	**--**	**--**	**30**
Apply	**50**	**50**	**50**	100	100	100	**50**
Analyse	**--**	**-**	**-**	**--**	**--**	**--**	**-**
Evaluate	**--**	**--**	**--**	**--**	**--**	**--**	**--**
Create	**--**	**--**	**--**	**--**	**--**	**--**	**--**

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	-
Set	-
Guided Response	-
Mechanism	Assignment/Spoken Tutorial
Complex Overt Responses	-
Adaptation	-
Origination	-

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):

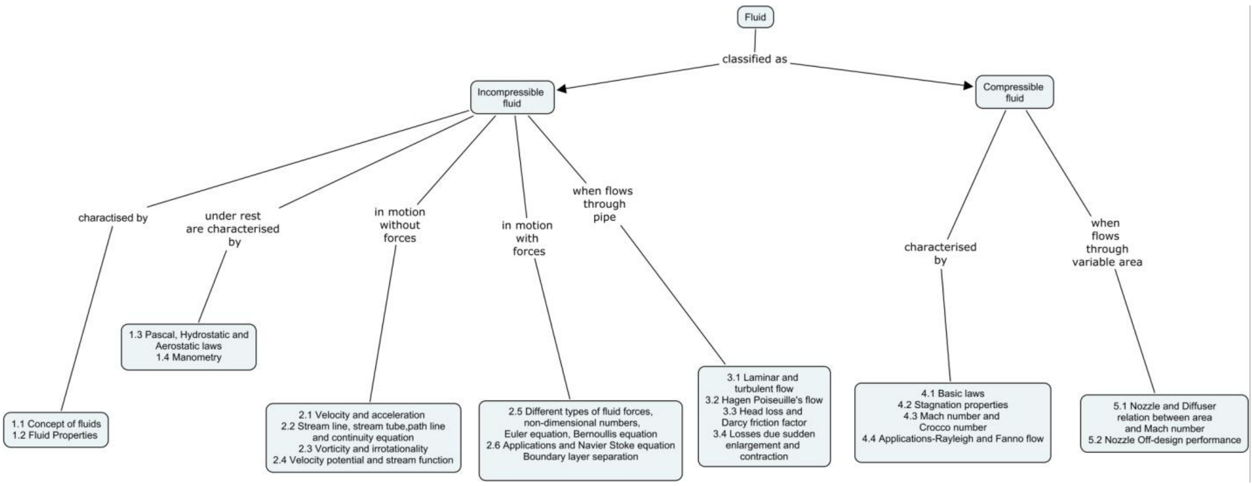
1. A sonic velocity air jet has a temperature of 280 K. Determine (i) Velocity of sound in the jet, (ii) Stagnation temperature and stagnation enthalpy of the jet, (iii) stagnation velocity of sound, (iv) Critical speed of sound, (v) Stagnation to static pressure ratio, (vi) maximum isentropic speed and (vii) Crocco number.
2. Derive an expression for Mach number in terms of stagnation to static temperature ratio.

Course Outcome 5 (CO5):

1. 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.
2. 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?

Concept Map



Syllabus

Basic Concepts: Concept of fluid: Liquid and gases, Ideal and real fluids, Newtonian and non-Newtonian fluid - 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: 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 - 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, Turbulent Flow in Pipes: 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 –Various regimes of flow- Critical Mach number - Crocco number-Applications gas flow dynamics: Rayleigh and Fanno flow. **Isentropic Flow with variable area:** Nozzle and Diffuser -relation between area and mach number- Nozzle Off-design performance.

Learning Resources

1. Bruce R. Munson, Theodore H. Okiishi, Wade W. Huebsch, Rothmayer, **"Fluid Mechanics**", Seventh Edition, Wiley India Pvt. Ltd, 2013.
2. S.M. Yahya, **"Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion"**, Sixth Edition, New Age International (P) Ltd, 2018.
3. S. K. Som, G. Biswas, Suman Chakraborty, **"Introduction to Fluid Mechanics and Fluid Machines"**, Third Edition, Tata McGraw - Hill Publishing Company Limited - New Delhi, 2017.
4. Yunus A. Cengel, John M. Cimbala, "**Fluid Mechanics: Fundamental and Applications**", Third Edition, McGraw-Hill Education (India) Pvt. Ltd, 2014**.**
5. Frank White, "**Fluid Mechanics**", Eighth Edition, McGraw Hill Education (India) Pvt. Ltd, 2017.
6. R.K. Bansal, "**A Text Book of Fluid Mechanics and Hydraulic Machines**", Tenth Edition, Laxmi Publications (P) Ltd., 2018.
7. R.K. Rajput, "**Fluid Mechanics and Hydraulic machines**", S.Chand & Company Ltd, 2016.
8. S.M. Yahya, **"Gas tables for Compressible Flow Calculations"**, Eighth Edition, New Age International (P) Ltd, 2018.
9. NPTEL Video Lectures – Introduction to Fluid Mechanics and Fluid Engineering, Prof.S.Chakraborty, IIT Kharagpur. URL: www.nptel.ac.in/courses/112105183
10. 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/
11. NPTEL Video Lectures – Gas Dynamics and Propulsion, Prof. V. Babu, IIT Madras. URL: www.nptel.ac.in/courses/112106166

12. 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	COs
1.	**Basic Concepts**		
1.1	Concept of fluid: Liquid and gases, Ideal and real fluids, Newtonian and non-Newtonian fluid.	1	CO1
1.2	Properties of Fluids, Pressure, Density, Specific Gravity, Viscosity, Surface Tension and Capillarity, Compressibility and Bulk Modulus	1	
	Tutorials	2	
	Fluid Statics		
1.3	Pressure at a Point: Pascal's Law - Pressure force on a fluid element: Hydrostatic law and aerostatic law	1	
1.4	Manometry	1	
	Tutorials	2	
2.	**Fluid Kinematics**		CO2
2.1	Velocity and Acceleration of a fluid particle	1	
2.2	Stream line, stream tubes and path line, Continuity Equation in Cartesian Co-ordinates	1	
2.3	Vorticity and irrotationality	1	
2.4	Velocity Potential and Stream Function	1	
	Tutorials	2	
	Fluid Dynamics		
2.5	Different types of fluid forces- non-dimensional number, Reynolds number, Froude number, Euler number, Weber number and Mach number - Euler's equation of motion, Bernoulli's equation	1	
2.6	Applications of Bernoulli's Equation, Venturimeter and Orifice meter -Navier Stokes Equation, Boundary Layer separation	1	
	Tutorials	2	
3.	**Pipe Flow**		CO3
3.1	Laminar and turbulent flow, Reynolds Experiment and Significance of Reynolds Number	1	
3.2	Laminar Flow in Pipes: Hagen Poiseuille's flow,	2	
3.3	Turbulent Flow in Pipes: Darcy-Weisbach equation	1	
3.4	Losses due sudden enlargement and contraction.	1	
	Tutorials	2	
4.	**Gas Dynamics**		CO4
4.1	Definition - Basic laws and Governing equations	1	
4.2	Stagnation state and properties - Velocity of sound	1	
4.3	Mach number –Various Regimes of flow- Critical Mach number – Crocco number	2	
4.4	Applications gas flow dynamics: Rayleigh and Fanno flow.	1	
	Tutorials	2	
5	**Isentropic Flow with variable area**		
5.1	Nozzle and Diffuser -Relation between area and Mach number	2	CO5
5.2	Nozzle Off-design performance	2	
	Tutorials	2	
	Total	**38**	

Course Designers:

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18ME450	PRODUCTION DRAWING

Category	L	T	P	Credit
PC	1	0	4	3

Preamble

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 material, surface and tolerance along with fits as per Bureau of Indian Standard for drawing practices.

Prerequisite

Basics of Engineering Graphics

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Explain the Indian standards for the preparation of production drawing and blue print reading.	30%
CO2	Draw the assembled view of the mechanical products from the given part drawing	20%
CO3	Draw the part drawing of the mechanical products from the given assembly drawing	20%
CO4	Prepare detailed drawing of parts (or) an assembly	30%

*** Weightage depends on Bloom's Level, number of contact hours

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.2, 2.5.1, 4.1.1
CO2	TPS3	Apply	Value	Mechanism	2.1.1, 2.3.1, 2.4.6, 2.4.7, 3.2.5
CO3	TPS3	Apply	Value	Mechanism	2.1.1, 2.3.1, 2.4.6, 2.4.7, 3.2.5
CO4	TPS3	Apply	Value	Mechanism	2.1.1, 2.3.1, 2.4.6, 2.4.7, 3.2.5

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	S	S	-	-	-	-	-	-	-	-	L	-	S	-	-
CO2	S	L	S	L	-	-	-	-	-	-	L	-	S	-	-
CO3	S	L	-	L	-	-	-	-	-	-	M	-	S	-	-
CO4	S	M	L	-	-	-	-	-	-	-	M	-	S	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	-	-	0	-	-	-	0
Understand	-	-	30	10	10	10	30
Apply	-	-	70	-	-	-	70
Analyse	-	-	-	-	-	-	
Evaluate	-	-	-	-	-	-	
Create	-	-	-	-	-	-	

Assessment Pattern: Psychomotor

Psychomotor Skill	**Miniproject /Assignment/Practical Component**
Perception	
Set	
Guided Response	Assignment
Mechanism	Drawing Plate preparation
Complex Overt Responses	
Adaptation	
Origination	

Question pattern for Terminal Examination: 100 Marks

1. **Manual Drawing (PART – A) : 5 x 6 = 30 Marks [Theory part]**
2. **Manual Drawing (PART – B)**
   - **Part to Assembly : 1 x 20 = 20 Marks [either / or Type]**
   - **Assembly to Part : 1 x 20 = 20 Marks [either / or Type]**
3. **Manual Drawing (PART – C)**
   Detailed Drawing : 1 x 30 = 30 Marks [either / or Type]

Pattern for Continuous Assessment: 50 Marks

1. **ASSIGNMENTS : 10 MARKS**
2. **DRAWING PLATE SUBMISSION : 20 MARKS**
3. **MODEL TEST : 20 MARKS**

Sample Questions for Course Outcome Assessment**

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, and 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 figure5.
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 figure6.

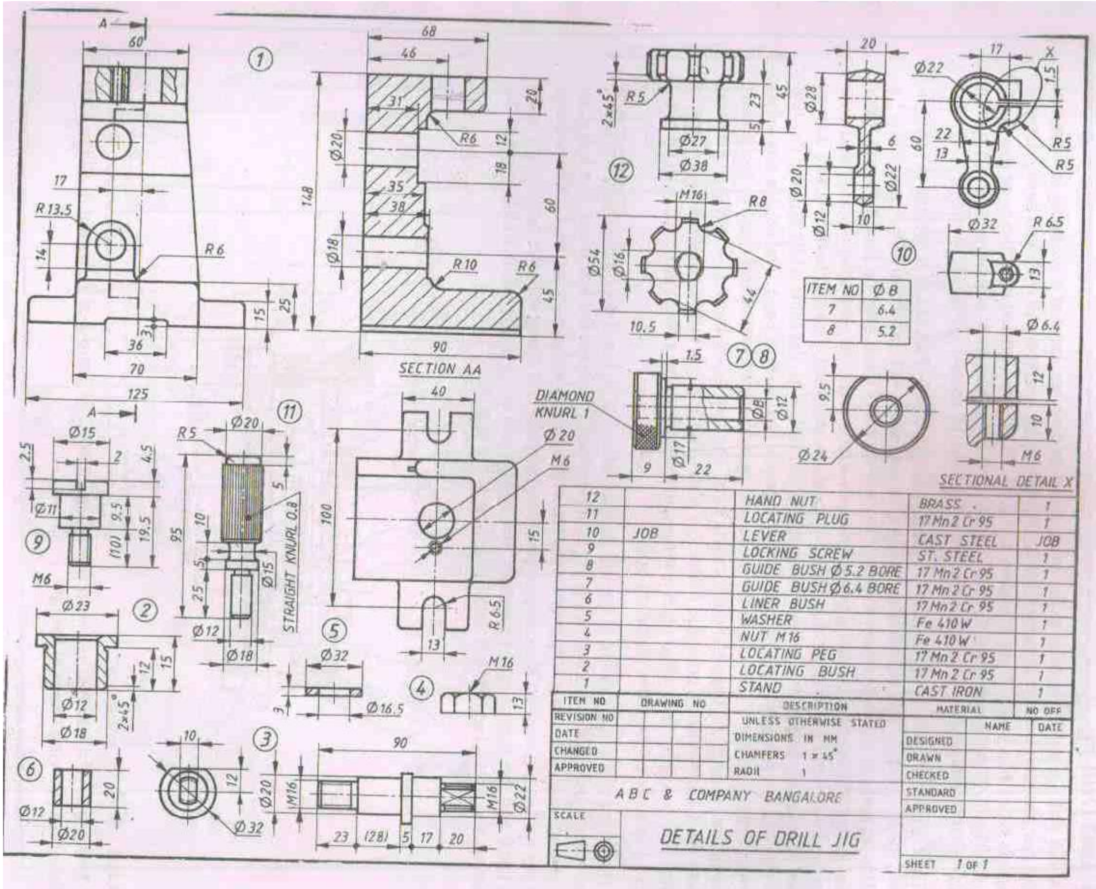


Figure 1 Component details of a drill jig

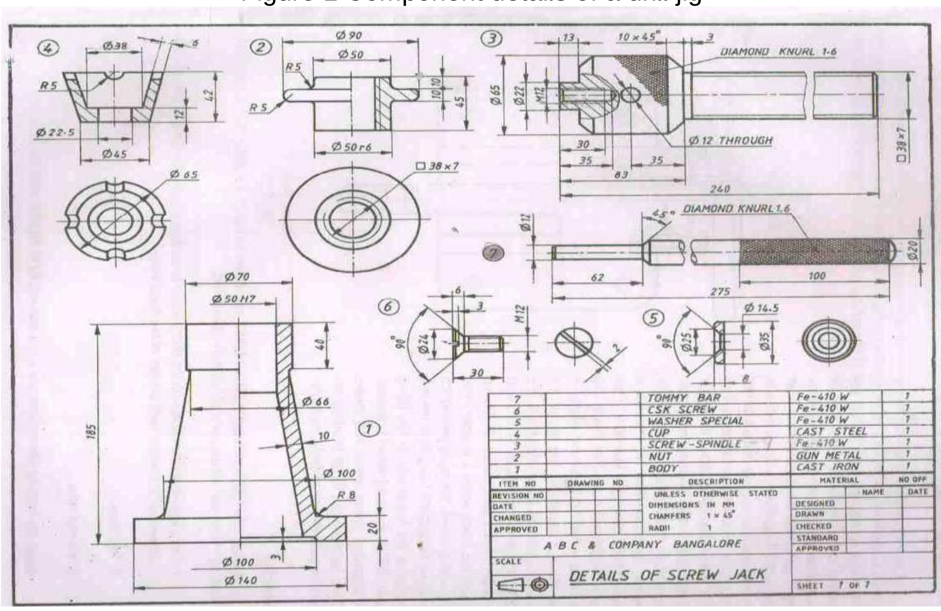
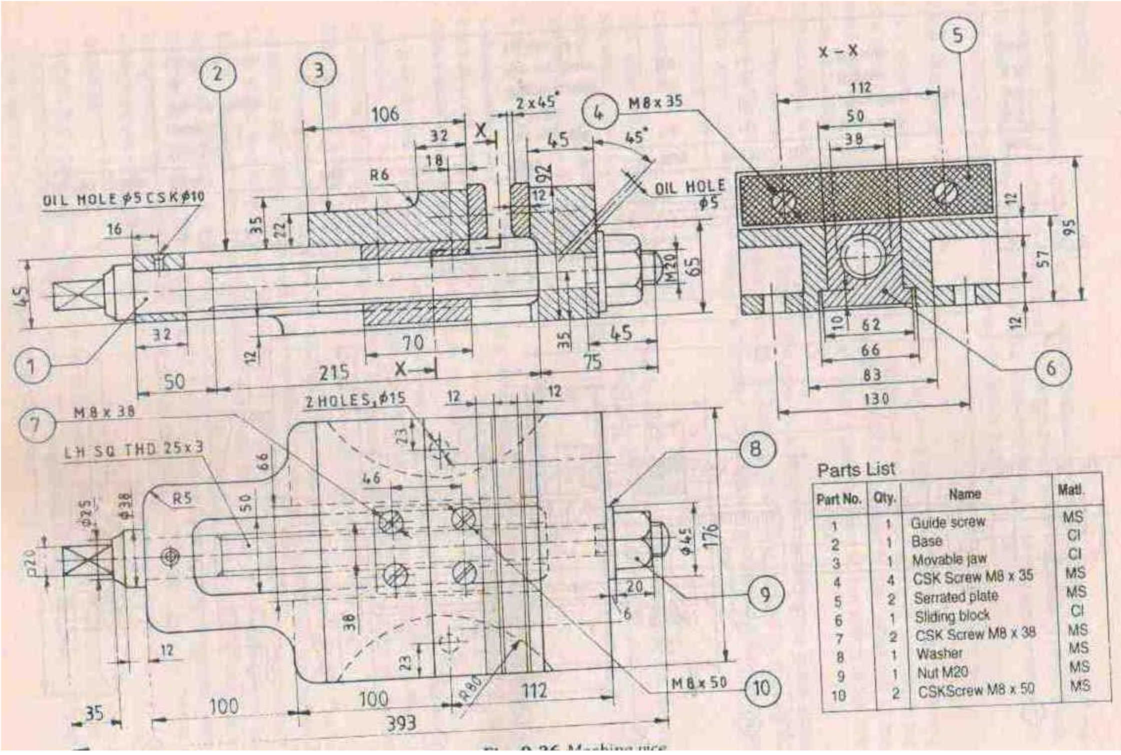


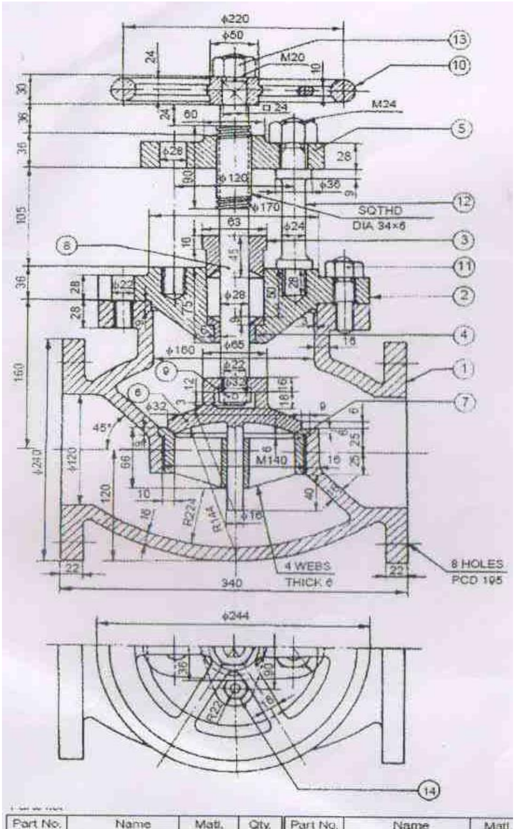
Figure 2 Component details of screw jack



Parts List

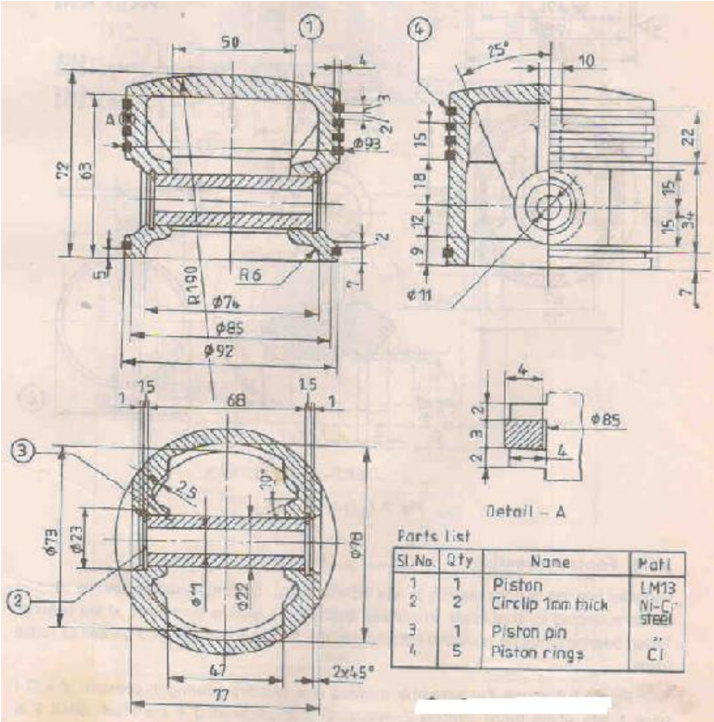
Part No.	Qty.	Name	Matl.
1	1	Guide screw	MS
2	1	Base	CI
3	1	Movable jaw	CI
4	4	CSK Screw M8 x 35	MS
5	2	Serrated plate	MS
6	1	Sliding block	CI
7	2	CSK Screw M8 x 38	MS
8	1	Washer	MS
9	1	Nut M20	MS
10	2	CSKScrew M8 x 50	MS

Figure 3 Assembly details of machine vice



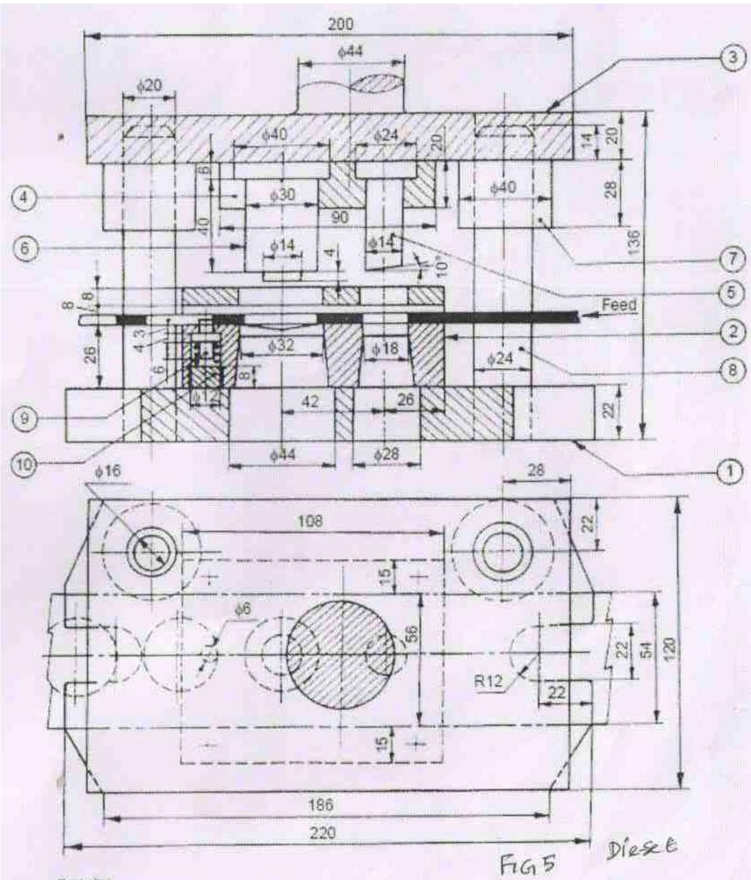
Part No.	Name	Matl.	Qty.	Part No.	Name	Matl.
1	Body	CI	1	8	Spindle	GM
2	Cover	CI	1	9	Collar	GM
3	Gland	GM	1	10	Hand wheel	CI
4	Neck bush	GM	1	11	Stud with nut	MS
5	Bridge	MS	1	12	Stud with collar	MS
6	Valve	GM	1	13	Nut	MS
7	Valve seat	GM	1	14	Stud with nut	MS

Figure 4 Assembly details of stop valve



Sl.No.	Qty	Name	Matl
1	1	Piston	LM13
2	2	Circlip 1mm thick	Ni-Cr steel
3	1	Piston pin	"
4	5	Piston rings	CI

Figure 5 Component details of a piston

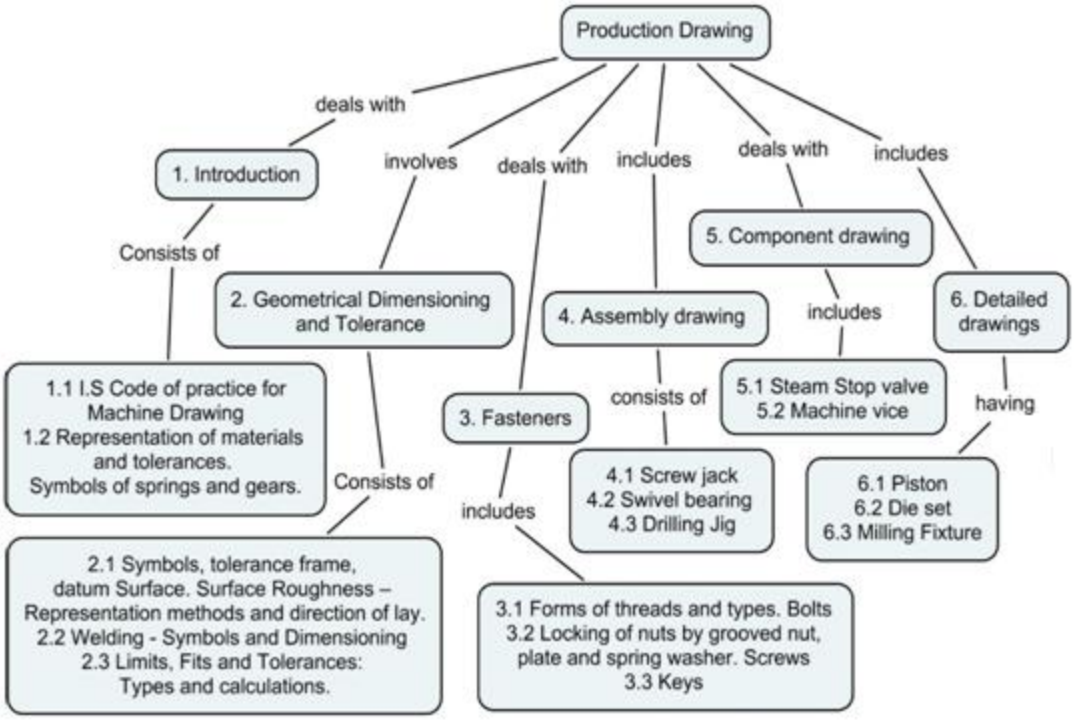


Parts list

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

Concept Map



Syllabus

Introduction:Bureau of Indian Standards (BIS) for drawing practice–drawing sheets, drawing sheet layout, scales, types of lines, uses of different grades of pencils, sectional views, revolved, removed sections and hatching of sections. **Symbols and conventional representation** –Different materials, springs, gears and other machine elements, surface roughness, weld symbols and its dimensioning, thread, bolt, nuts, screws, keys. **Dimensioning and tolerancing**- Elements, system and arrangement of dimensioning, Indication of dimensional and geometrical tolerances, Indication of lay.

Tolerance, Fundamental deviation and Fits: Tolerance grade number of different manufacturing process, selection of tolerance grade, standard tolerance grade, computation of IT tolerance, positioning of tolerance, computation of fundamental deviations, **Fits -**Hole and Shaft basis system of fits, classifications and calculation.**Blue print reading** – Interpretation of information from the given production drawing.

Assembly drawing: Preparation of assembly drawing from the given part drawings of Screw jack, Swivel bearing and Drilling Jig. **Component drawing:** Preparation of part drawing from the given assembly drawings of Steam Stop valve and Machine vice.**Detailed drawings:** Preparation of detailed drawings of assembly or part drawing of IC engine piston, Die set and milling fixture.

Learning Resources

1. K.R.Gopalakrishna, "**Machine Drawing**", Eighteenth Edition, Subhas Stores, Bangalore, 2004.
2. K.L. Narayana, P.Kannaiah and K. Venkata Reddy, "**Machine Drawing**", Third Edition, New Age International Publishers, New Delhi, 2019.
3. K.L. Narayana, P.Kannaiah and K. Venkata Reddy, "**Production Drawing**", Third Edition, New Age International Ltd., New Delhi, 2014.
4. Thamos P.Olivo and Dr.C.Thamos Olivo, "**Basic Blueprint Reading and Sketching**", 9th edition, Industrial Press Inc, New York, 2003.
5. Walter W Sturtevant, "Practical Problems in Mechanical Drawing and Blue-Print Reading", Wentworth Press, 2016.
6. PS. Gill, "**A Text Book of Machine Drawing**", Seventh edition Reprint, S. K. Kataria & Sons. New Delhi. 2004.
7. RK. Dhawan, "**A Text book of Machine Drawing**", First Edition, Sultan Chand and Sons, New Delhi, 2015.
8. BIS recommendation for school practices: SP46:2003.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Introduction**	
1.1	**Bureau of Indian Standards (BIS) for drawing practice** – drawing sheets, drawing sheet layout, scales, types of lines, uses of different grades of pencils	2
1.2	Sectional views, revolved, removed sections and hatching of sections.	2
1.3	**Symbols and conventional representation** – Different materials, springs, gears and other machine elements, surface roughness, weld symbols and its dimensioning,	2
1.4	Thread, bolt, nuts, screws, keys. **Dimensioning and tolerancing**- Elements, system and arrangement of dimensioning, Indication of dimensional and geometrical tolerances, Indication of lay.	2
1.5	**Tolerance, Fundamental deviation and Fits:** Tolerance grade number of different manufacturing process, selection of tolerance grade, standard tolerance grade,	2
1.6	Computation of IT tolerance, positioning of tolerance, computation of fundamental deviations,	3
1.7	**Fits** -Hole and Shaft basis system of fits, classifications and calculation.	2
1.8	**Blue print reading** – Interpretation of information from the given production drawing.	3
2	**Assembly drawing**	
2.1	Preparation of assembly drawing from the given part drawings of Screw jack	4
2.2	Preparation of assembly drawing from the given part drawings of Swivel bearing	4
2.3	Preparation of assembly drawing from the given part drawings of Drill Jig	4
3	**Component drawing**	
3.1	Preparation of part drawing from the given assembly drawings of Steam Stop valve	6
3.2	Preparation of part drawing from the given assembly drawings of Machine vice.	6
4	**Detailed drawings**	
4.1	Preparation of detailed drawings of assembly or part drawing of IC engine piston	6
4.2	Preparation of detailed drawings of assembly or part drawing of Die set	6
4.3	Preparation of detailed drawings of assembly or part drawing of milling fixture	6
		60

Course Designers

1. Dr. K. Chockalingam kcmech@tce.edu
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3. Dr.C. Paramasivam cpmech@tce.edu

18ME470	THERMAL ENGINEERING LAB

Category	L	T	P	Credit
PC	0	0	2	1

Preamble

Mechanical engineering students are required to understand the construction, working and performance of thermal systems. This course enables the students to determine experimentally, the performance characteristics of I.C.Engines, gas turbine, steam boiler and turbine, air compressor, refrigerator and air conditioner.

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Prerequisite

18ME340: Thermal Engineering

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	determine various performance characteristics of I.C. and Gas turbine Engines and air compressor	40
CO2	determine the performance of Refrigerator and Air-conditioning units	25
CO3	determine dryness fraction of steam and thermal efficiency of steam generator and steam turbine	25
CO4	draw valve timing of 4-stroke engine and port timing of 2-stroke engine and determine the properties of fuel	10

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.2, 2.2.3, 3.1.2, 3.2.3 4.3.3
CO2	TPS3	Apply	Value	Mechanism	1.2, 2.2.3, 3.1.2, 3.2.3 4.3.3
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.2.3, 3.1.2, 3.2.3 4.3.3
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.2.3, 3.1.2, 3.2.3 4.3.3

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	S	M	S	M	_	_	_	S	S	S	M	_	_	M	_
CO2	S	M	S	M	_	_	_	S	S	S	M	_	_	M	_
CO3	S	M	S	M	_	_	_	S	S	S	M	_	_	M	_
CO4	M	L	M	L	_	_	_	S	S	S	M	_	_	L	_

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	**Model Examination**	**Terminal Examination**
Remember		
Understand		
Apply	50**	100
Analyse		
Evaluate		
Create		

** Observation and Record – 30 marks and Model Test - 20 marks

Assessment Pattern: Psychomotor

Psychomotor Skill	**Miniproject /Practical Component/Observation**

Perception	-
Set	-
Guided Response	-
Mechanism	Observation and Calculation
Complex Overt Responses	-
Adaptation	-
Origination	-

List of Experiments/Activities with CO Mapping

1. Performance test on 4-stroke Petrol / Diesel / Gas turbine engine – CO1
2. Energy balance test on Diesel engine by calorimeter method / air flow measurement – CO1
3. Retardation test on Diesel engine – CO1
4. Volumetric efficiency test on Diesel engine / Reciprocating air compressor – CO1
5. Performance test on vapour compression /absorption Refrigeration test rig – CO2
6. Performance test on Air conditioning test rig – CO2
7. Performance test on steam Boiler and Turbine – CO3
8. Steam dryness fraction test using separating and throttling calorimeter – CO3
9. Determination of valve timing of 4-stroke and port timing of 2-stroke engines – CO4
10. Evaluation of physical properties such as flash point, fire point and viscosity of fuel – CO4.

Learning Resources

1. https://nptel.ac.in/courses/112103262/1 by Dr. Pranab K. Mondal and Dr. Vinayak N. Kulkarni, IITG.

Course Designers:

1.	Dr. A.Valan Arasu	avamech@tce.edu
2.	Dr. B.Karthikeyan	bkmech@tce.edu

18ME490	PROJECT MANAGEMENT

Category	L	T	P	Credit
HSS	2	1	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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Explain project, project management, life cycle and project formulation	8
CO2	Analyze and Manage time in projects through Gantt charts, CPM and PERT techniques, update and monitor projects	27
CO3	Manage resources of project using resource smoothing and levelling techniques	23
CO4	Optimize resources of projects using scheduling, fast tracking and re-estimation techniques with CPM Cost Model.	25
CO5	Identify the need for communication and risk management in projects with emerging trends in project management. Analyze Project worthiness using Earned Value Management	17

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.1, 3.1.1, 3.2.1, 3.3.1, 4.3.1
CO2	TPS 3	Apply	Value	Mechanism	1.1.1, 1.2, 2.1, 2.4.7, 4.3.4
CO3	TPS 3	Apply	Value	Mechanism	1.1.1, 2.1, 2.4.7, 4.3.4
CO4	TPS 3	Apply	Value	Mechanism	1.1.1, 2.1, 2.4.7, 4.3.4
CO5	TPS 3	Apply	Value	Mechanism	1.1.1, 2.1, 2.4.7, 4.3.4

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	-	-	L	L	-	-	L	L	L	L	-	S	-	-	-
CO2	S	S	-	M	L	-	M	-	L	M	L	S	-	-	-
CO3	S	S	-	M	-	-	M	S	L	M	M	S	-	-	M
CO4	S	S	-	M	-	-	L	S	L	M	M	S	-	-	M
CO5	-	L	L	L	L	L	M	L	S	M	M	S	-	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	20	10	10	-	-	-	10
Understand	20	30	10	-	-	-	15
Apply	60	60	80	20	30	50	75
Analyse	-	-	-	-	-	-	-

Evaluate	-	-	-	-	-	-	-
Create	-	-	-	-	-	-	-

Assessment Pattern: Psychomotor

Psychomotor Skill	Assignment
Perception	-
Set	20
Guided Response	30
Mechanism	50
Complex Overt Responses	-
Adaptation	-
Origination	-

Sample Questions for Course Outcome Assessment

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

3. Find the status of the project on the 10th day of its commencement.

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 are 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

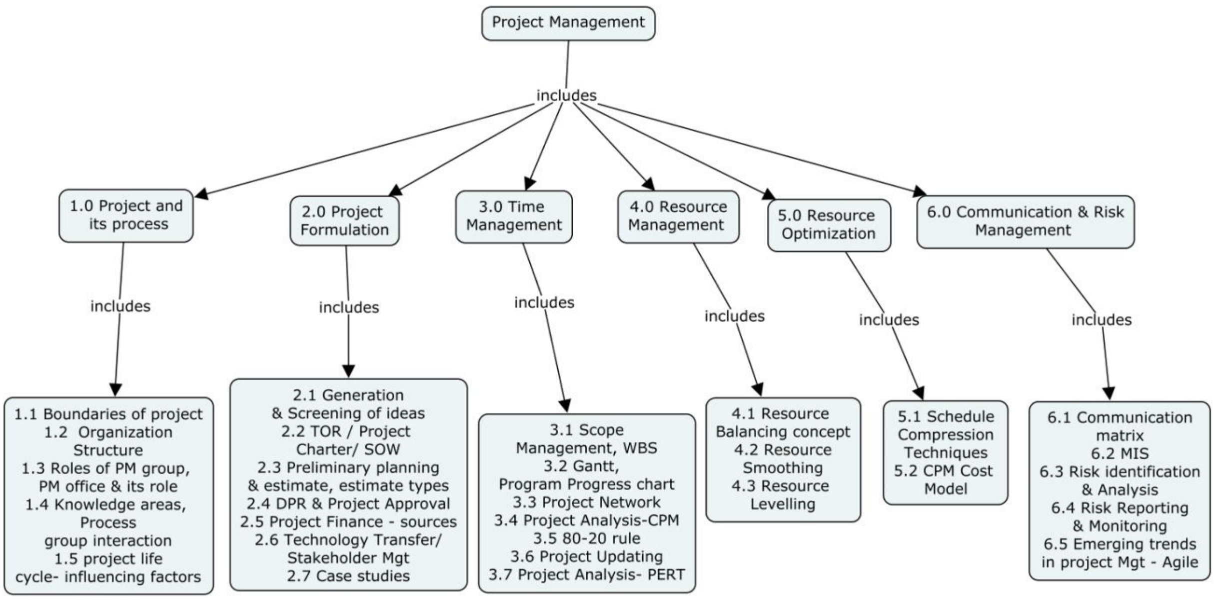
3. A project consists of 7 activities with costs and times gives as shown in table. Crash the project and determine the optimum time and minimum cost relationship for the project. Assume the indirect cost to vary at Rs.500/- per day.

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. Conduct EVA for a project having a Budget at Completion as Rs. 100 lakhs and estimated duration of completion as 5 years. The status of the project by the end of 2.5 years is as follows: PV = Rs. 60 lakhs, EV = Rs. 52.5 lakhs and CV = Rs. 70 lakhs. Determine CV, SV, CPI, SPI, EAC, ETC, Final Cost, Final Schedule and TCPI for the project
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 Case study, 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, Earned Value Management Agile Project management - Case study

Learning Resources

1. Punmia B. C. and Khandelwal K.K., “Project Planning and Control with PERT/CPM”, Laxmi publications, New Delhi, 1989.
2. "A Guide to the Project Management Body of Knowledge (PMBOK Guide)” - Fifth Edition, An American National Standard, ANSI/PMI 990001-2008.
3. Jerome D. Wiest and Ferdinand K. Levy, “A Management Guide to PERT/CPM”, Prentice Hall of India Publishers Ltd., New Delhi, 1994.
4. Srinath L.S., “PERT & CPM- Principles and Applications”, Affiliated East West Press Pvt., Ltd., New Delhi, 2008
5. A Risk Management Standard, AIRMIC Publishers, ALARM, IRM: 2002
6. Gene Dixon, “Service Learning and Integrated Collaborative Project Management”, Project Management Journal, DOI:10.1002/pmi, February 2011, pp.42-58
7. Nptel videos at *https://nptel.ac.in/courses/112102107/* by Prof. Arun Kanda, Dept of Mechanical Engineering, IIT, Delhi.
8. Nptel videos at *https://nptel.ac.in/courses/105106149/* by Dr. Koshy Varghese, Dept of Civil Engineering, IIT, Madras.

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	
1.5	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, Parametric and Bottom up estimates	1
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	
3.0 Time Management		
3.1	Project Scope Management, Work break down structure -Activity/ Task- Events- Case study. Project planning tools- Rolling wave planning-Tutorial	2
3.2	Gantt Charts, Milestone chart, Program Progress chart- Creating milestone plan	1
3.3	Project Network- Fulkerson’s rules – A-O-A and A-O-N networks Introduction to software-Tutorial	2
3.4	Analyze project time- Critical path method (deterministic approach- activity oriented network analysis- Square network diagram-Tutorial	2

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- PERT (Probabilistic Approach)- Event oriented network analysis- Optimistic, Pessimistic & Most likely time, Degree of variability in average time, Probabilistic estimate, % utilization of resources- Tutorial	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-Tutorial	2
4.3	Resource levelling technique- Resource constraint	1
	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- Tutorials	2
5.2	Optimize project cost for time and resource- CPM Cost model- Case study	1
	Tutorials	2
6.0 Communication & Risk Management		
6.1	Communication Management- meaning and process, communication matrix	1
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	1
6.4	Risk reporting and monitoring- Case study	
6.5	Emerging trends in project management: (Brief concept only)- Theory of Constraints, Agile Project Management, Earned Value Management	1
	Total Periods	36

Course Designers:

1. Dr. G. Chitra gcciv@tce.edu
2. Ms. T. Karthigaipriya karthigaipriya@tce.edu

18EG460	PROFESSIONAL COMMUNICATION

Category	L	T	P	Credit
HSS	0	1	2	2

Preamble

This course helps the students to achieve effective language proficiency for their professional, social and interpersonal communication skills, hence increasing their employability and career skills.

Prerequisite

Basic English Knowledge

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Listen, watch, understand and respond to talks, conversations, etc by native and neutral speakers on science, general context, and from ETS test samples with confidence.	22%
CO2	Present ideas, express opinions/comments, practice presentation, and converse in discussions on a variety of technical and non-technical domains without fear	39%
CO3	Read and comprehend passages/texts from various topics – general and reasoning, to respond precisely through reading techniques, besides getting awareness on competitive exam lexicon/verbal exercises for career prospects	17%
CO4	Write journal abstracts/projects and business correspondences with clarity, accuracy, intelligibility, and precision.	22%

*** Weightage depends on Bloom's Level, number of contact hours

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	2.4.2, 2.4.6, 3.2.1, 3.2.2,
CO2	TPS3	Apply	Value	Mechanism	3.1.3, 3.1.2, 3.2.4, 3.2.5,3.2.6
CO3	TPS2	Understand	Respond	Guided Response	2.4.6, 2.4.5, 3.2.1,
CO4	TPS3	Apply	Value	Mechanism	2.4.3, 3.2.1, 3.2.3, 3.2.5

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1									L	S		M			
CO2									S	S		M			
CO3									M	S		M			
CO4									M	S		M			

S- Strong; M-Medium; L-Low

Assessment Pattern:

Internal: No Continuous Assessment Test(CAT) will be conducted. Students' performance will be continuously assessed in various classroom activities in Listening, Speaking, Reading and Writing for 50 marks as detailed below:

Listening Test - 10
Speaking Test (Group Discussion and Technical Presentation) - 20
Written Test(Objective/Descriptive to be tested for 40 marks and converted to 20 marks)- 20

External (Practical):

Group Discussion - 20
Personal Interview / Situational Conversation (BEC speaking based) - 20
Listening Test - 20
Reading / Writing – Computerised or Paper-based Test / General Aptitude Test – Objective type - 40

List of Experiments/Activities with CO Mapping

S.No	Activities	Hours		CO Mapping			
		T	P				
1	Listening, Reading and Writing based on Extensive Reading	2		CO1		**CO3**	CO4
2	Listening exercises at lab - online resources		2	**CO1**			
3	Developing Listening skills (BEC / IELTS / TOEIC / TOEFL)		2	**CO1**			
4	GD/Mock interview/Presentation Intro at lab through online		2	**CO1**			
5	GD Practice at classroom in groups		4	CO1	**CO2**		
6	Presentation on Technical / general topics – from dailies &	1	4		**CO2**		
7	Mock interview practice at classroom	1	4	CO1	**CO2**		
8	Comprehension Descriptive and Reasoning	2	2			**CO3**	
9	General Aptitude Practice – Vocabulary Development / Sentence completion / Error spotting /Analogy / Reasoning	3	2			CO3	**CO4**
10	Business Correspondence - BEC Writing Task II	2					**CO4**
11	Basics of Technical Writing/ Project Reports		2		**CO2**		
12	Preparation of Resume	1					**CO4**

Learning Resources

Reference Books:

1. Cappel, Annette and Sharp, Wendy, Cambridge English: Objective First, 4th Ed., CUP, New Delhi, 2013.
2. Cusack, Barry. Improve Your IELTS Listening and Speaking Skills (With CD) Paperback, Mcmillan, 2007.
3. Bates, Susan TOEFL iBT Exam Paperback – Oxford, 2012.
4. Hart, Guy Brook. Cambridge English Business Benchmark: 2 Ed., CUP 2014

Websites:

1. https://ielts-up.com (IELTS – LSRW – Practice Tests)
2. www.cambridgeenglish.org (BEC - LSRW)
3. www.etsglobal.org (TOEIC Preparation)
4. www.examenglish.com (Online Exams for international ESL Exams)
5. www.testpreppractice.net (GRE Tests -Vocabulary /Analogy / Sentence Completion / Reading)
6. https://www.freshersworld.com (Placement Papers)

Extensive Reading:

Coelho, Paulo. The Alchemist, Harper Publication, 2018.

Course Designers:

1. Dr.A.Tamilselvi , Convenor
2. Dr S.Rajaram
3. Mr.Vinoth.R
4. Dr.G.Jeya Jeevakani
5. Ms.R.Manibala

18CHAB0	CONSTITUTION OF INDIA	Category	L	T	P	Credit
		AC	2	0	0	0

Preamble

On the successful completion of the course, the students will be able to explain the basic features and fundamental principles of Constitution of India. The Constitution of India is the supreme law of India. Parliament of India cannot make any law which violates the Fundamental Rights enumerated under the Part III of the Constitution. The Parliament of India has been empowered to amend the Constitution under Article 368, however, it cannot use this power to change the “basic structure” of the constitution, which has been ruled and explained by the Supreme Court of India in its historical judgments. The Constitution of India reflects the idea of “Constitutionalism” – a modern and progressive concept historically developed by the thinkers of “liberalism” – an ideology which has been recognized as one of the most popular political ideology and result of historical struggles against arbitrary use of sovereign power by state. The historic revolutions in France, England, America and particularly European Renaissance and Reformation movement have resulted into progressive legal reforms in the form of “constitutionalism” in many countries. The Constitution of India was made by borrowing models and principles from many countries including United Kingdom and America.

The Constitution of India is not only a legal document but it also reflects social, political and economic perspectives of the Indian Society. It reflects India’s legacy of “diversity”. It has been said that Indian constitution reflects ideals of its freedom movement; however, few critics have argued that it does not truly incorporate our own AICTE Model Curriculum for Mandatory Courses & Activities (Non-Credit) for Undergraduate Degree in Engineering & Technology ancient legal heritage and cultural values. No law can be “static” and therefore the Constitution of India has also been amended more than one hundred times. These amendments reflect political, social and economic developments since the year 1950. The Indian judiciary and particularly the Supreme Court of India has played an historic role as the guardian of people. It has been protecting not only basic ideals of the Constitution but also strengthened the same through progressive interpretations of the text of the Constitution. The judicial activism of the Supreme Court of India and its historic contributions has been recognized throughout the world and it gradually made it “as one of the strongest court in the world”

Course Outcome:

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

CO1	Explain the meaning of the constitution law and constitutionalism and Historical perspective of the Constitution of India	Understand
CO2	Explain the salient features and characteristics of the Constitution of India, scheme of the fundamental rights and the scheme of the Fundamental Duties and its legal status	Understand
CO3	Explain the Directive Principles of State Policy, Federal structure and distribution of legislative and financial powers between the Union and the States, and Parliamentary Form of Government in India	Understand
CO4	Explain the amendment of the Constitutional Powers and Procedure, the historical perspectives of the constitutional amendments in India, and Emergency Provisions.	Understand
CO5	Explain the Local Self Government – Constitutional Scheme in India, Scheme of the Fundamental Right to Equality,	Understand
CO6	Explain the scheme of the Fundamental Right to certain Freedom under Article 19, and Scope of the Right to Life and Personal Liberty under Article 21	Understand

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	M	L	-	-	-	M	-	M	-	L	-	-
CO2	M	L	-	-	-	M	-	M	-	L	-	-
CO3	M	L	-	-	-	M	-	M	-	L	-	-
CO4	M	L	-	-	-	M	-	M	-	L	-	-
CO5	M	L	-	-	-	M	-	M	-	L	-	-
CO6	M	L	-	-	-	M	-	M	-	L	-	-

S- Strong; M-Medium; L-Low

Syllabus

1. Meaning of the constitution law and constitutionalism
2. Historical perspective of the Constitution of India
3. Salient features and characteristics of the Constitution of India
4. Scheme of the fundamental rights
5. The scheme of the Fundamental Duties and its legal status
6. The Directive Principles of State Policy – Its importance and implementation
7. Federal structure and distribution of legislative and financial powers between the Union and the States
8. Parliamentary Form of Government in India – The constitution powers and status of the President of India
9. Amendment of the Constitutional Powers and Procedure
10. The historical perspectives of the constitutional amendments in India
11. Emergency Provisions : National Emergency, President Rule, Financial Emergency
12. Local Self Government – Constitutional Scheme in India
13. Scheme of the Fundamental Right to Equality
14. Scheme of the Fundamental Right to certain Freedom under Article 19
15. Scope of the Right to Life and Personal Liberty under Article 21

Assessment Pattern

Bloom's category	**Continuous Assessment Tests**		**Seminar**
	1	**2**	**-**
Remember	40	40	0
Understand	60	60	100
Apply	0	0	0
Analyze	0	0	0
Evaluate	0	0	0
Create	0	0	0

References

1. Durga Das Basu, 'Introduction to The Constitution of India', LexisNexis Butterworths Wadhwa, 20th Edition, Reprint 2011.
2. Constitution of India, National Portal of India, Web link: https://www.india.gov.in/my-government/constitution-india

Course Designers:

1. Adapted from AICTE Model Curriculum for Undergraduate Degree Courses in Engineering & Technology, Volume-II, January 2018.

18ME510	KINEMATICS AND DYNAMICS OF MACHINERY

Category	L	T	P	Credit
PC	2	1	-	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 thedetermination of the motion and interaction of machine elements, as well as forces acting onmachines and mechanisms. Specific applications will be made to mechanisms such as rotating machinery, cams, gears, flywheels, and balancing.

Prerequisite

Nil

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Explain the working of different mechanism.	10
CO2	Explain the inversions of mechanisms	10
CO3	Determine the velocity and acceleration of simple mechanisms	20
CO4	Develop the cam profile for various type of motion.	15
CO5	Determine the contact ratio of gear pair and speed ratio of gear trains.	15
CO6	Perform balancing of rotating and reciprocating components.	15
CO7	Determine the gyroscopic couple on the two-wheeler, four wheeler, ship and airplane.	15

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

COs	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS 2	Understand	Respond	Guided response	1.2, 2.1.1, 2.1.2, 2.1.4,2.1.5, 2.4.4,3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3,4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6
CO2	TPS 2	Understand	Respond	Guided response	1.2, 2.1.1, 2.1.2, 2.1.4,2.1.5, 2.4.4,3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3,4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6
CO3	TPS 3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.4.4,3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3,4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6
CO4	TPS 3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.4.4,3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3,4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6
CO5	TPS 3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.4,2.1.5, 2.4.4,3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3,4.4.1, 4.4.2,

					4.4.3, 4.4.4, 4.4.5, 4.4.6
CO6	TPS 3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.4.4,3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3,4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6
CO7	TPS 3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.4,2.1.5, 2.4.4,3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3,4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6

Mapping with Programme Outcomesand Programme Specific Outcomes

Cos	PO1	PO2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PO1 2	PSO 1	PSO 2	PSO 3
CO1	M	L	L	L	_	_	_	_	_	_	_	_	M	_	_
CO2	M	L	L	L	_	_	_	_	_	_	_	_	M	_	_
CO3	S	M	S	L	_	_	_	_	_	_	_	_	M	_	M
CO4	S	M	M	L	_	_	_	_	_	_	_	_	M	_	M
CO5	S	M	M	L	_	_	_	_	_	_	_	_	M	_	M
CO6	S	M	M	L	_	_	_	_	_	_	_	_	M	_	M
CO7	S	M	M	L	_	_	_	_	_	_	_	_	M	_	M

S- Strong; M-Medium; L-Low

AssessmentPattern: Cognitive Domain

Cognitive Levels	ContinuousAssessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	10	10	10	-	-	-	10
Understand	30	10	10	-	-	-	15
Apply	60	80	80	100	100	100	75
Analyse	-	-	-	-	-	-	-
Evaluate	-	-	-	-	-	-	-
Create	-	-	-	-	-	-	-

AssessmentPattern: Psychomotor

Psychomotor Skill	Miniproject/Assignment/Practical Component
Perception	-
Set	-
Guided Response	-
Mechanism	Assignment 1 : Making of mechanism prototype Assignment 2 : Simulation of four bar and slider crank mechanism using Matlab or C
Complex Overt Responses	-
Adaptation	-
Origination	-

Sample Questions for Course Outcome Assessment**

** (2 to 3 at the cognitive level of course outcome)

Course Outcome 1(CO1):

1. Define Kinematic Link. Give examples for Kinematiclinks.
2. Define kinematicpair
3. Define degrees of freedom.

Course Outcome 2(CO2):

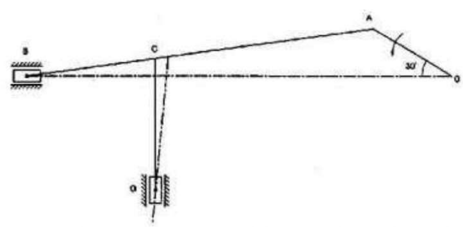
1. Explain the working principles of slider crank mechanism inversions with neat sketch.
2. Explain the working principles of double slider crank mechanism inversions with neat sketch.
3. Explain the working principles of four bar mechanism inversions with neat sketch

Course Outcome 3 (CO3):

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 45° from the inner dead centreposition.

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 linkBC.

3. The dimensions of the various links of a mechanism, as shown in fig. are as follows: OA=300mm;AB=1200;BC=450mmandCD=450mm.ifthecrankOArotatesat20 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 4 (CO4):

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° of cam rotation Follower to move dwell for next 60 ° of cam rotation Follower to return to its starting position during next 90° 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 1000r.p.m.

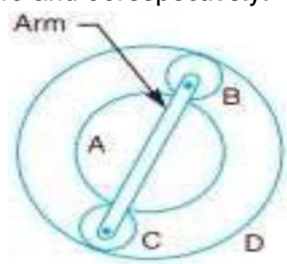
2. A cam is rotating clockwise at a uniform speed is required to give a roller follower the motion defined below: Follower to move outwards through 30 mm during 120° of cam rotation, Follower to move dwell for next 60° of cam rotation,
Follower to return to its starting position during next 90° of cam 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 1500r.p.m.

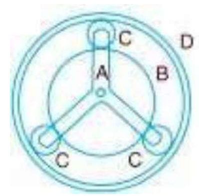
3. Design a cam for operating the exhaust valve of an oil engine. It is required to give equal uniform acceleration and retardation during opening and closing of the valve each of which corresponds to 60° of cam rotation. The valve must remain in the fully open position for 20° of cam rotation.The lift 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 5 (CO5):

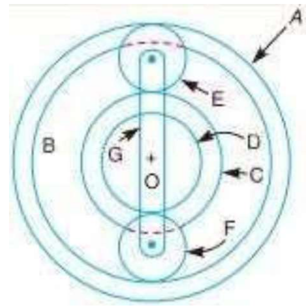
1. An epicyclic train of gears is arranged as shown in Fig. How many revolutions does the arm, to which the pinions B and C are attached,make:
   a) When A makes one revolution clockwise and D makes half a revolutionanticlockwise,
   b) When A makes one revolution clockwise and D is stationary? The number of teeth on the gears A and D are 40 and 90respectively.



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 thewheels.



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 thearrangement;
2. Find the number of teeth on A andB;
3. If the arm G makes 100 r.p.m. clockwise and A is fixed, find the speed ofB
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 wheelB.



Course Outcome 6 (CO6):

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 verticalaxis.

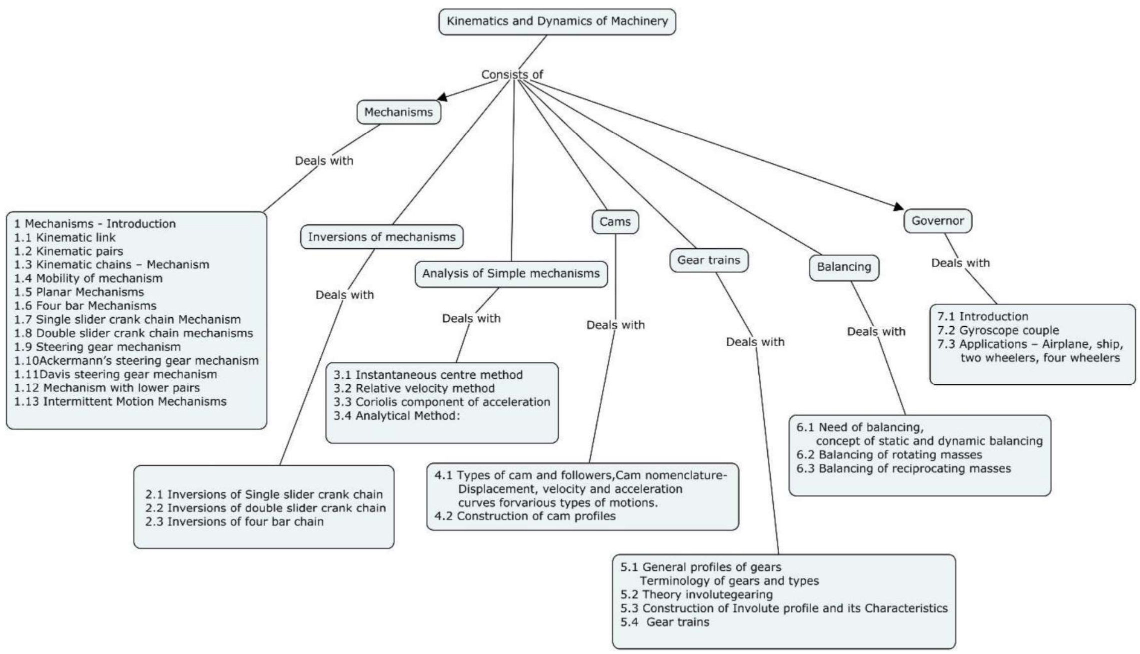
Course Outcome 7 (CO7):

1. An aeroplane makes a complete half circle of 50 metres radius, towards left, when flying at 200 km per hr. The rotary engine and the propeller of the plane has a mass of 400 kg and a radius of gyration of 0.3 m. The engine rotates at 2400 r.p.m. clockwise when viewed from the rear. Find the gyroscopic couple on the aircraft and state its effect on it.
2. The heavy turbine rotor of a sea vessel rotates at 1500 r.p.m. clockwise looking from the stern, its mass being 750 kg. The vessel pitches with an angular velocity of 1 rad/s. Determine the gyroscopic couple transmitted to the hull when bow is rising, if the radius

of gyration for the rotor is 250 mm. Also show in what direction the couple acts on the hull?

3. The turbine rotor of a ship has a mass of 8 tonnes and a radius of gyration 0.6 m. It rotates at 1800 r.p.m. clockwise, when looking from the stern. Determine the gyroscopic couple, if the ship travels at 100 km/hr and steer to the left in a curve of 75 m radius.

Concept Map



Syllabus

Mechanisms: Kinematics, Mechanisms and machines –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,Steering gear mechanism, Mechanism with lower pairs -Intermittent Motion Mechanisms, compound Mechanisms. Inversions of Four bar, Single slider crank chain and Double slider crank chain mechanism**. Velocity and acceleration 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 different mechanisms -Coriolis component of acceleration in Quick return motion mechanisms. Analytical Method: Angular velocity and angular acceleration of connecting rod in Single slider crank chain & four bar Mechanisms. **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 – spherical faced follower - Uniform Velocity Motion- simple harmonic motion- Cycloidal Motion- Uniform Acceleration and Retardation Motion. **Gears and Gear trains**: General profiles of gears- Theory of involute gearing -Contact ratio –Interference and undercuttingGear trains: speed ratio - 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. Primary and Secondary Unbalanced Forces of Reciprocating Masses - Partial Balancing of Unbalanced Primary Force in a Reciprocating engine - Effect of partial balancing of reciprocating parts of two cylinder locomotives **Gyroscope** – Introduction –gyroscope couple – applications – airplane, ship, two wheelers, four wheelers

Learning Resources

1. John Joseph Uicker, Gordon Pennock, JoselphE.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.
4. Thomas Bevan, **"Theory of Machines",** CBS – Third Edition,2010.
5. Singh, V.P., **"Theory of Machines",** Dhanpat Rai & Co., (P) Ltd., New Delhi,2011.
6. Sadhu Singh, "**Theory of Machines**". Pearson Education, New Delhi,2009.
7. Ashok G.Ambekar," **Mechanism and Machine theory**",Prentice Hall of India, New Delhi,2011.
8. **Kinematics of Mechanisms and Machines** https://nptel.ac.in/courses/112/105/112105268/ Prof. Anirvan Das Gupta, Indian Institute of Technology, Kharagpur
9. **Kinematics of Machines** https://nptel.ac.in/courses/112/104/112104121/# Prof. A. K. Malik ,Indian Institute of Technology, Kanpur
10. **Dynamics of Machines**, https://nptel.ac.in/courses/112/104/112104114/ Prof. Amithbha Ghosh Indian Institute of Technology, Kanpur

Course Contents and Lecture Schedule

S.No	Topic	No. of Lectures	Course outcome
1	**Mechanisms - Introduction**		
1.1	Kinematic link	1	CO1
1.2	Kinematic pairs		CO1

1.3	Kinematic chains – Mechanism		CO1
1.4	Mobility of mechanism		CO1
1.5	Planar Mechanisms		CO1
1.6	Four bar Mechanisms	1	CO1
1.7	Single slider crank chain Mechanism		CO1
1.8	Double slider crank chain mechanisms		CO1
1.9	Steering gear mechanism		CO1
1.10	Ackermann's steering gear mechanism	2	CO1
1.11	Davis steering gear mechanism		CO1
1.12	Mechanism with lower pairs	1	CO1
1.13	Intermittent Motion Mechanisms		CO1
2	**Inversions of mechanism**	1	
2.1	Inversions of Single slider crank chain mechanisms		CO2
2.2	Inversions of double slider crank chain mechanisms		CO2
2.3	Inversions of four bar chain mechanisms		CO2
3	Analysis of Simple mechanisms		
3.1	Instantaneous centre method		
	Properties of Instantaneous Centre and Arnold-Kennedy's theorem	3	CO3
	Velocity calculation of four bar mechanisms and Single slider crank chain Mechanisms		CO3
3.2	Relative velocity method		
	Vector Position Analysis -Velocity and acceleration of different mechanisms	3	CO3
3.3	Coriolis component of acceleration in Quick return motion mechanisms.	2	CO3
	Velocity and acceleration of Single slider crank Mechanisms		CO3
3.4	Analytical Method:		
	Angular velocity and angular acceleration of connecting rod in Single slider crank chain	2	CO3
	Angular velocity and angular acceleration of four bar chain		CO3

4	**Cams**		
4.1	Types of cams and followers - Cam nomenclature- Displacement, velocity and acceleration curves forvarious types of motions.	2	CO4
4.2	Construction of cam profiles	3	CO4
5	**Gear trains**		

5.1	General profiles of gears-Terminology of gears and types	1	CO5
5.2	Theory involutegearing	2	CO5
5.3	Construction of Involute profile and its Characteristics		CO5
5.4	Gear trains		CO5
	Simple, Compound and Reverted gear trains	1	CO5
	Epicyclic gear trains	1	CO5
6	**Balancing**		
6.1	Need of balancing, concept of static and dynamic balancing	1	CO6
6.2	Balancing of rotating masses	2	CO6
6.3	Balancing of reciprocating masses	4	CO6
7	**Gyroscope**		
7.1	Introduction	1	CO7
7.2	Gyroscope couple	1	CO7
7.3	Applications – Airplane, ship, two wheelers, four wheelers	3	CO7
	Total number of hours	**38**	

Course Designers:

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18ME520	HEAT AND MASS TRANSFER	Category	L	T	P	Credit
		PC	2	1	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

- 18ME340 - Thermal Engineering
- 18ME440 - Fluid Mechanics

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Calculate the temperature and rate of conduction heat transfer under steady state	18
CO2	Compute the temperature and rate of conduction heat transfer under transient state	12
CO3	Determine the rate of convection heat transfer under natural and forced modes	18
CO4	Compute the rate of radiation heat exchange between surfaces	18
CO5	Determine the size and heat transfer rate of heat exchangers using LMTD and NTU method	18
CO6	Calculate the rate of mass diffusion and mass transfer coefficient	16

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO2	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO5	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO6	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PO1 2	PSO 1	PSO 2	PSO 3
CO1	S	M	L	-	_	_	_	S	M	M	_	_	_	M	_
CO2	S	M	L	-	_	_	_	S	M	M	_	_	_	M	_
CO3	S	M	L	-	_	_	_	S	M	M	_	_	_	M	_
CO4	S	M	L	-	_	_	_	S	M	M	_	_	_	M	_
CO5	S	M	L	-	_	_	_	S	M	M	_	_	_	M	_
CO6	S	M	L	-	_	_	_	S	M	M	_	_	_	M	_

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	**2**	**3**	1	2	3	
Remember	10	10	10	-	-	-	10
Understand	30	30	30	-	-	-	30
Apply	60	60	60	100	100	100	60
Analyse							
Evaluate							
Create							

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	
Set	
Guided Response	
Mechanism	Assignment
Complex Overt Responses	
Adaptation	
Origination	

Sample Questions for Course Outcome Assessment**

** (2 to 3 at the cognitive level of course outcome)

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 ^{o}C. 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?

Course Outcome 2 (CO2):

1. Prove that the temperature distribution in a transient heat conduction Lumped parameter system is

$$\frac{T - T\infty}{T_i - T_\infty} = \exp\left[-\frac{h A_s}{C V \rho}\tau\right]$$

2. A long cylinder of radius 150 mm and at an initial uniform temperature of 5300 C is suddenly exposed to an environment at 300 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 m2/s respectively. Determine the temperature at a radius of 120 mm after the time duration of 265 seconds.
3. 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 2650 C and 1500 C respectively. If the convection coefficient is 35 W/m2 K, when exposed to air at 250 C, determine the conductivity of the material.

Course Outcome 3 (CO3):

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 250 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 m2. Take the property values at free stream temperature of 250 C.

Course Outcome 4 (CO4):

1. What is a black body?
2. Obtain the expression for heat exchange between two parallel non black bodies.
3. 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.

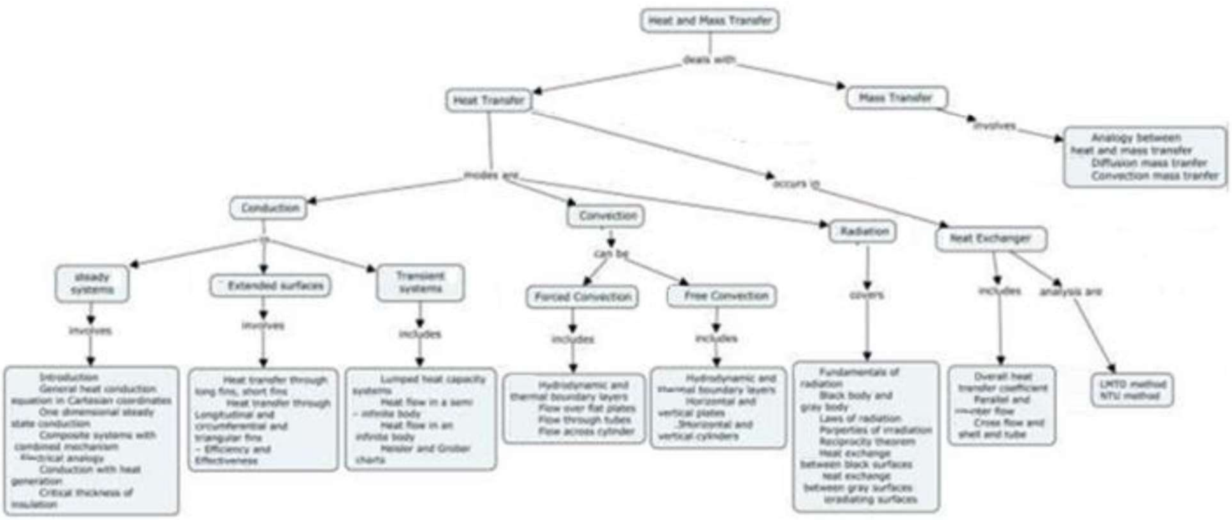
Course Outcome 5 (CO5):

1. Obtain an expression for LMTD of a parallel flow heat exchanger.
2. Water at 68 ^oC is cooled using air in a cross flow heat exchanger, the air entering at 300^oC. 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.
3. A counter flow heat exchanger is employed to cool 0.55 kg/s (C_p = 2.45 kJ/kg K) of oil from 1150 ^oC to 400 ^oC by the use of water. The inlet and outlet temperatures of cooling water are 150 ^oC and 750 ^pC 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.

Course Outcome 6 (CO6):

1. State Fick's law of mass diffusion.
2. 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°C.
3. Dry air at 27 °C and 1 atm flows over a wet flat plate 50 cm long at a velocity of 50 m/s. Calculate the mass transfer coefficient of water vapour in air at the end of the plate.

Concept Map



Syllabus

Conduction

Steady State Conduction
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. 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 Conduction
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

Forced convection - Introduction-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-** Introduction-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.

Heat exchangers
Classification- overall heat transfer co-efficient- fouling factor- LMTD method, numerical problems -NTU method, numerical problems.

Mass transfer
Introduction to mass transfer - Fick's law of diffusion, Analogy between heat, mass and momentum transfer, Diffusion mass transfer- diffusion coefficient of water vapour in air, numerical problems, Mass transfer in convection- non-dimensional numbers, mass transfer coefficient, numerical problems.

Learning Resources

1. Yunus A.Cengel and Afshin Ghajar, "**Heat and Mass Transfer: fundamentals and applications**", 5 th Edition, Mc Graw Hill, 2015.
2. Holman, J.P., **"Heat Transfer"**, 10th Edition, McGraw Hill., 2010.
3. Frank P. Incropera, David P. DeWitt, Theodore L. Bergman, and Adrienne S. Lavine, "**Introduction to Heat Transfer**", John Wiley and Sons, 2011.
4. Mahesh M. Rathore, "**Engineering Heat and Mass Transfer**", Laxmi Publication , 2015.
5. Necati Ozisik, "**Heat Transfer – a Basic Approach**", McGraw Hill, 1994.
6. Rajput, R.K., "**A Text Book of Heat and Mass Transfer**", 7th Edition, S.Chand & Company Ltd, 2018.
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, 2017.
10. Kothandaraman, C.P., **"Fundamentals of Heat and Mass Transfer",** 4th Edition, New Age International, 2012.
11. https://nptel.ac.in/courses/112108149/ - Lecture Notes
12. https://nptel.ac.in/courses/112101097/ - Video Lectures by Prof.S.P.Sukhatme, Mechanical Engineering, IIT Bombay.

Data Book

1. Kothandaraman, C. P., **"Heat and Mass Transfer Data Book",** New Age International Publisher, 2018.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures	Course Outcome
	Conduction		
1	**Steady State Conduction**		

1.1	Introduction, Modes of heat transfer	1	CO1
1.2	Fourier law of conduction, general heat conduction equation in Cartesian co-ordinates	1	CO1
1.3	One dimensional steady state conduction- plane wall, hollow cylinder and sphere, numerical problems.	2	CO1
1.4	Composite systems with combined mechanism – electrical analogy, Critical thickness of insulation, numerical problems.	1	CO1
1.5	Conduction with inner heat sources – plane wall and solid cylinders, spheres, numerical problems.	2	CO1
1.6	Introduction, Heat transfer through long fins, short fins with negligible heat loss from the fin tip (insulated fin tip).	2	CO1
1.7	Heat transfer through extended surfaces – short fins with convection from fin tip Longitudinal and circumferential and triangular fins – efficiency and effectiveness, numerical problems.	2	CO1
2	**Transient Conduction**		
2.1	Introduction, Lumped heat capacity systems, numerical problems.	1	CO2
2.2	Heat flow in a semi – infinite body: initial temperature with suddenly immersed in liquid and convection boundary conditions, numerical problems.	1	CO2
2.3	Heat flow in an infinite body	1	CO2
2.3.1	Heisler and Grober charts, numerical problems.	1	CO2
3	**Convection**		
3.1	**Forced convection**		
3.1.1	Introduction, Hydrodynamic and thermal boundary layers	1	CO3
3.1.2	Flow over flat plates: Laminar boundary layer thickness in terms of Reynolds number, Nusselt equation numerical	1	CO3
3.1.3	Flow through tubes - Nusselt equation, numerical problems.	1	CO3
3.1.4	Flow across cylinder- Nusselt equation, numerical problems.	1	CO3
3.2	**Free convection**		
3.2.1	Introduction, Hydrodynamic and thermal boundary layers	1	CO3
3.2.2	Horizontal and vertical plates – horizontal and vertical cylinders – Nusselt equation, numerical problems.	1	CO3
3.2.3	Horizontal and vertical cylinders – Nusselt equation, numerical problems.	1	CO3
4	**Radiation**		
4.1	Introduction, Wave theory and quantum theory	1	CO4
4.2	Concepts of black body and gray body	1	CO4
4.3	Stefan – Boltzman law – emissive power – monochromatic emissive power – Weins law –Kirchoff's law, numerical problems.	1	CO4
4.4	Radiative properties, emissivity, absorptivity, reflectivity, transmissivity, radiosity	1	CO4
4.5	Radiation shape factor – Reciprocity theorem	1	CO4
4.6	Heat exchange between black surfaces, numerical problems.	1	CO4
4.7	Reradiating surfaces, Heat exchange between gray surfaces, numerical problems.	1	CO4
5	**Heat exchangers**		
5.1	Classification- overall heat transfer co-efficient- fouling factor	2	CO5
5.2	LMTD method, numerical problems	2	CO5
5.3	NTU method, numerical problems	1	CO5
6	**Mass transfer**		

6.1	Introduction to mass transfer - Analogy between heat, mass and momentum transfer, Fick's law of diffusion	2	CO6
6.2	Diffusion mass transfer – diffusion coefficient of water vapour in air, numerical problems	1	CO6
6.3	Mass transfer in convection- Non-dimensional numbers, mass transfer coefficient, numerical problems	1	CO6
	Total	**38**	

Course Designers:

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18ME530	STATISTICAL QUALITY CONTROL

Category	L	T	P	Credit
ES	2	1	-	3

Preamble

This course provides the essentiality of SQC, sampling and reliability engineering. Study on various types of control charts, six sigma and process capability to help the students understand various quality control techniques. Quality control 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

- NIL

Course Outcomes

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

Sl. No	Course Outcomes	Weightage*** in %
CO1	Select an appropriate probability distribution to determine probability mass function for solving engineering problem.	20
CO 2.	Interpret the results of hypothesis on mean, variance, proportion of small and large samples, for goodness-of-fit and independence of attributes.	20
CO 3.	Explain the basic Concepts of Quality and its tools.	10
CO 4.	Construct the X bar, R & σ charts from the available data	15
CO 5.	Construct the p, np, c & u charts from the available data	15
CO 6.	Measure the performance of the sampling plans	20

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	2.1.1, 2.1.2, 2.1.3, 2.1.4, 2.1.5, 2.3.1, 2.3.3, 2.4.1, 2.4.2 2.5.1, 2.5.4 3.1.1,3.1.2,3.1.4, 3.2.3,3.2.4
CO2	TPS4	Analyse	Organise	Complex Overt Responses	1.2.1, 2.1.1, 2.1.2, 2.1.3, 2.5.1
CO3	TPS2	Understand	Respond	Guided Response	1.1.1, 2.1.1,2.1.2
CO4	TPS3	Apply	Value	Mechanism	2.1.1, 2.1.2, 2.1.3, 2.1.4, 2.1.5, 2.3.1, 2.3.3, 2.4.1, 2.4.2 2.5.1, 2.5.4 3.1.1,3.1.2,3.1.4, 3.2.3,3.2.4
CO5	TPS3	Apply	Value	Mechanism	2.1.1, 2.1.2, 2.1.3, 2.1.4, 2.1.5, 2.3.1, 2.3.3, 2.4.1, 2.4.2 3.1.1,3.1.2,3.1.4, 3.2.3,3.2.4
CO6	TPS3	Apply	Value	Mechanism	2.1.1, 2.1.2, 2.1.3, 2.1.4, 2.1.5, 2.3.1, 2.3.3, 2.4.1, 2.4.2 3.1.1,3.1.2,3.1.4, 3.2.3,3.2.4

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	M	_	_	L	_	_	_	_	_	_	_
CO2.	S	M	M	L	M	_	_	L	_	_	L	L	_	_	S
CO3.	L	L	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
CO6.	M	M	M	M	M	_	_	L	_	_	L	L	_	_	S

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	20						
Understand	20	20	20	100			20
Apply	40	80	80		60	100	60
Analyse	20						20
Evaluate							
Create							

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component		
	Assignment 1	Assignment 2	Assignment 3
Perception			
Set			
Guided Response			
Mechanism		40	
Complex Overt Responses			
Adaptation			
Origination			

Sample Questions for Course Outcome Assessment**

** (2 to 3 at the cognitive level of course outcome)

Course Outcome 1 (CO1):

1. State and Explain 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 2 (CO2):

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 1.79 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 3(CO3):

1. Describe the basic concept of Quality?
2. Explain the different Causes of variation.
3. Explain the 7QC tools?

Course Outcome 4(CO4):

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

a. Compute the trial control limits for X and R charts.

b. Construct X bar and R chart

2. Control charts for *X* bar and *R* are maintained on a certain dimension of a

manufactured part measured in cm. The subgroup size is 5. The values of *X bar* and *R* are computed for each subgroup. After 25 subgroups ΣX bar = 41.283 and ΣR = 0.339, compute the values of 3σ limits for *X bar* and *R* chart and estimate the value of sigma on the assumption that the process is in statistical control also determine the process capability.

3. An automatic lathe machines a specified spindle with diameter 15.00±0.04mm. Control chart for X bar and R charts are maintained for this process. The sub group size is 5. The values for above are computed for each subgroup. After 20 subgroups ΣX bar = 627.48 & ΣR = 125.0. Compute the values of 3 sigma limits for above charts. Estimate the values of sigma on the assumption that the process is in control.

Course Outcome 5 (CO5):

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.

3. In plastic moulding process, the results of the inspection of 10 lots of 125 items each are given in the following table.

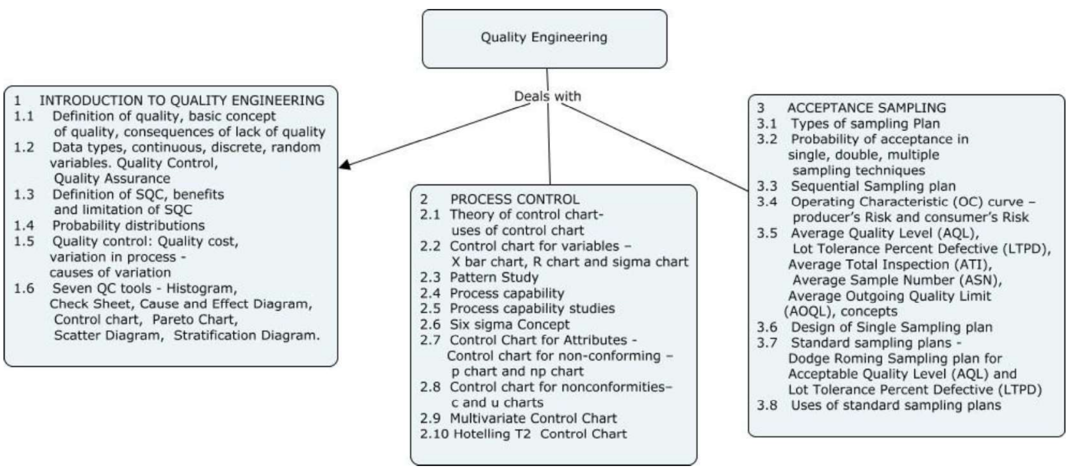
Lot No.	1	2	3	4	5	6	7	8	9	10
No. of defectives	4	8	9	2	12	6	7	5	4	7

(i) Compute trial control limits
(ii) Plot the appropriate chart
(iii) Draw the conclusion

Course Outcome 6 (CO6):

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

Concept Map



Syllabus

Introduction to Statistical: Fundamentals of SQC, Data and Types of Data, benefits and limitation of SQC, 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 and Measurement system Analysis.

Introduction to Quality Control: Definition of quality, basic concept of quality, consequences of lack of quality–Data types, continuous, discrete, random variables. Quality Control, Quality Assurance –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..
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.
Introduction about statistical software – (One assignment will be based on statistical software)

Learning Resources

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.
3. Besterfield D.H., **"Quality Control"**, Prentice Hall, Seventh Edition, 2001.
4. Grant, Eugene .L, **"Statistical Quality Control"**, McGraw-Hill, Tenth reprint, 2008
5. Monohar Mahajan, **"Statistical Quality Control"**, Dhanpat Rai & Sons, 2001.
6. https://www.youtube.com/watch?v=qb3mvJ1gb9g - Session 49 - SQC
7. https://www.youtube.com/watch?v=TbPUiJKyxqw - Module 2 SPC Part 1
8. https://www.youtube.com/watch?v=NP71-G8UMQM - SQC

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures	Course Outcome
1	**Introduction to Statistical**		
1.1	Fundamentals of SQC, data and types of data, benefits and limitation of SQC	2	**CO1**
1.2	Probability distributions – The Binomial probability distribution - hyper geometric	2	
1.3	Negative Binomial distribution - the Poisson probability distribution	1	
1.4	The normal distribution - the exponential distribution gamma distribution.	1	

2	**Tests of Hypotheses**		
2.1	hypotheses and test procedures - tests concerning a population mean	2	**CO2**
2.2	tests concerning a population proportion	1	
2.3	*z* tests and confidence intervals for a difference between two Population means	2	
2.4	The two-sample *t* Test and confidence interval	1	
2.5	Inferences concerning a difference between population proportion - inferences concerning two population variances, measurement system analysis	2	
3	**INTRODUCTION TO QUALITY ENGINEERING**		
3.1	Definition of quality, basic concept of quality, consequences of lack of quality	1	**CO3**
3.2	Data types, continuous, discrete, random variables. Quality Control, Quality Assurance	1	
3.3	Definition of SQC, benefits and limitation of SQC	1	
3.4	Probability distributions	1	
3.5	Quality control: Quality cost, variation in process - causes of variation	1	
3.6	Seven QC tools - Histogram, Check Sheet, Cause and Effect Diagram, Control chart, Pareto Chart, Scatter Diagram, Stratification Diagram.	1	
4	**PROCESS CONTROL**		
4.1	Theory of control chart- uses of control chart	1	
4.2	Control chart for variables – X bar chart, R chart and sigma chart	2	**CO4**
4.3	Pattern Study, Process capability studies, Six sigma Concept	1	
4.4	Control Chart for Attributes - Control chart for non-conforming – p chart and np chart	3	**CO5**
4.5	Control chart for nonconformities– c and u charts	2	
5	**ACCEPTANCE SAMPLING**		
5.1	Types of sampling Plan	1	**CO6**
5.2	Probability of acceptance in single, double, multiple sampling techniques	1	
5.3	Sequential Sampling plan	1	

5.4	Operating Characteristic (OC) curve – producer's Risk and consumer's Risk	1	
5.5	Average Quality Level (AQL), Lot Tolerance Percent Defective (LTPD), Average Total Inspection (ATI), Average Sample Number (ASN), Average Outgoing Quality Limit (AOQL), concepts	3	
	TOTAL	**36**	

Course Designers:

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2. S. Karthikeyan skarthikeyanlme@tce.edu

18ME560	ACCOUNTING AND FINANCE	Category	L	T	P	Credit
		HSS	3	-	-	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 -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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Explain the basic concepts and process of accounting	10
CO2	Prepare the financial statements, comparative statements and common size statements	15
CO3	Prepare cost sheet and various types of budgets.	20
CO4	Analyse the reasons for material cost and labour cost variances.	15
CO5	Calculate the working capital requirement and Capital budgeting.	20
CO6	Suggest the appropriate sources of finance.	20

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Value	Guided response	1.1, 2.3.4, 2.4.6, 2.4.7, 2.5.1
CO2	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1.3, 2.1.4, 2.1.5, 2.3, 2.4.3, 2.4.6, 2.4.7
CO3	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1, 2.3.2, 2.4.6, 2.4.7, 3.2.3, 4.1.1, 4.1.6, 4.6
CO4	TPS4	Analyse	Value	Complex Overt Responses	1.1, 1.2, 2.1, 2.4.3, 2.4.4, 2.5.4, 4.1.1, 4.2.1, 4.2.4, 4.3.2, 4.4.6, 4.5.5, 4.6.1
CO5	TPS3	Apply	Value	Mechanism	1.1, 2.1.3, 2.1.4, 2.1.5, 2.3.4, 2.4.3, 2.4.5, 2.5.1, 3.1.5, 4.6.1
CO6	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1.5, 2.3.1, 2.3.3, 2.3.4, 2.4.3, 2.4.6, 2.4.7

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3

CO 1	M	L	-	-	-	-	-	M	-	M	S	S	-	-	-
CO 2	M	M	L	-	-	-	-	M	S	M	S	S	-	-	-
CO 3	S	L	L	-	-	-	-	S	S	S	S	S	-	-	L
CO 4	S	M	L	L	L	M	M	S	S	M	S	M	-	-	-
CO 5	S	M	L	-	S	M	M	S	S	M	M	M	-	-	-
CO 6	M	M	L	-	-	M	M	S	M	M	M	S		-	M

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	**2**	**3**	1	2	3	
Remember	20	20	20	-	-	-	20
Understand	50	30	30	-	-	-	30
Apply	30	25	50	100	50	100	40
Analyse	-	25	-	-	50	-	10
Evaluate	-	-	-	-	-	-	-
Create	-	-	-	-	-	-	-

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject/Assignment/Practical Component
Perception	
Set	
Guided Response	
Mechanism	Assignment
Complex Overt Responses	
Adaptation	
Origination	

Sample Questions for Course Outcome Assessment**

** (2 to 3 at the cognitive level of course outcome)

Course Outcome 1(CO1):

1. Define accounting.
2. Explain the accounting concepts and conventions
3. Explain the process of accounting cycle.

Course Outcome 2(CO2):

1. Prepare Trading, Profit and Loss Account and Balance Sheet from the following

S.NO	PARTICULARS	Debit balances (in Rs)	Credit balances(in Rs)
1	Capital		300000
2	Bank	15000	
3	Plant and machinery	40000	
4	Land and building	60000	

5	Debtors	20000	
6	Creditors		40000
7	Cash	70000	
8	Purchases and sales	35000	50000
9	Purchase returns and sales returns	7000	4000
10	Bills receivable	3000	
11	Bills payable		5000
12	Wages	40000	
13	Salaries	30000	
14	Discount		4000
15	Stock on Jan 2017	10000	
16	Furniture	7000	
17	Carriage inwards	5000	
18	Carriage outwards	6000	
19	Advertising	10000	
20	Travelling expense	3000	
21	Loans		60000
22	Vans	100000	
23	Telephone	2000	
	Total	**463000**	**463000**

2.From the following particulars, prepare comparative balance sheet of Malar Ltd as on 31st March 2017 and 31st March 2018.

Particulars	31st March 2017	31st March 2018
I EQUITY AND LIABILITIES 1. Shareholders' fund a) Share capital b) Reserves and surplus 2. Non-current liabilities Long-term borrowings 3. Current liabilities Trade payables	2,00,000 50,000 30,000 20,000	2,50,000 50,000 60,000 60,000
Total	**3,00,000**	**4,20,000**
II ASSETS 1. Non-current assets a) Fixed assets b) Non - current investments 2. Current assets a)Inventories b) Cash and cash equivalents	1,00,000 50,000 75,000 75,000	1,50,000 75,000 1,50,000 45,000
Total	**3,00,000**	**4,20,000**

3. Make a statement of Trend Analysis (2019 as base) from the comparative financial statements. Income Statement of Logesh (P) Ltd.

Income Statement

Particulars	2016	2017	2018	2019
Sales	300	310	350	450
Cost of Goods Sold	150	170	180	190
Gross Profit	150	140	170	260

Operating Expenses	70	75	75	80
Operating Profit	80	65	95	180

Balance sheet

Particulars	2016	2017	2018	2019
Current Assets	70	80	90	90
Fixed Assets	150	70	180	170
Total Assets	220	250	270	260
Current Liabilities	50	55	60	60
Long Term Liabilities & Capital	170	195	210	200
Total Liabilities	220	250	270	260

Course Outcome 3(CO3):

1. Prepare cost sheet in the book of Vimi from the following particulars.

Opening stock: -	Raw material	=	Rs 5,000
	Finished goods	=	Rs 4,000
Closing stock: -	Raw material	=	Rs 4,000
	Finished goods	=	Rs 5,000

Raw material purchased	=	Rs 50,000
Wages paid to laboures	=	Rs 20,000
Chargeable expenses	=	Rs 2,000
Rent and Taxes	=	Rs 7,400
Power	=	Rs 3,000
Experimental expenses	=	Rs 600
Sale of wastage of material	=	Rs 200
Office management salary	=	Rs 4,000
Office printing & stationery	=	Rs 200
Salaries to salesman	=	Rs 2,000
Commission to traveling agents	=	Rs 1,000
Sales	=	Rs 1, 00,000

2. Calculate the cost sheet from the following details given below for the month of October 2019.Total production during the period was 786 units. Identify the sales value and the cost per unit of the product.

Particulars	Rs
Raw materials on 1.10.2019	3200
Raw materials on 30.10.2019	1800
Work in Progress on 1.10.2019	2800
Work in Progress on 30.10.2019	2500
Finished goods on 1.10.2019 (Rs 3600)	120 units
Finished goods on 30.10.2019	145 units
Materials Purchased	5000
Direct wages	3000
Direct expenses	2000
Factory expenses	1500
Office and administrative expenses	1800
Selling and distribution expenses	1500

Charge profit 15% on sales

3. From the forecast of income and expenditure prepare a cash budget for the months from April to June 2019.

Month	Sales Rs	Purchases Rs	Wages Rs	Office expenses Rs	Selling expenses Rs
Feb	70,000	45,000	4,500	2,700	1,800
Mar	72,000	43,000	4,700	3,000	2,000
Apr	75,000	44,000	4,900	2,900	2,200
May	71,000	40,000	5,000	3,000	2,100
Jun	70,000	42,000	5,000	2,800	1,900

- Plant worth Rs25, 000 purchased in June. 40% payable immediately and the remaining in two equal installments in subsequent months.
- Advance tax payable in April Rs 4500
- Period of credit allowed
  - By suppliers 2 months
  - To customer 1 month
- Dividend payable Rs 7000 in June
- Delay in payment of wages and office expenses 1 month and selling expenses 1 month. Expected cash balance on 1st April Rs 30,000

Machinery expected to sell on May is Rs 20,000

Course Outcome 4 (CO4):

1. The standard mix of product is

Product X 600 units at Rs 15 per unit
Product Y 800 units at Rs 20 per unit
Product Z 1000 units at Rs 25 per unit

The consumption was:
X 640 units at Rs 20 per unit
Y 960 units at Rs 15 per unit
Z 840 units at Rs 30 per unit
Calculate the Material l variances.

2. Determine and verify the labour variances for the following circumstances:

Standard hours per unit Rs11hrs
Standard rate per hour Rs 6
Actual Production 1000 units
Actual time takes 10210 hrs
Actual rate paid Rs 4.90 per hour

Course Outcome 5 (CO5):

1. From the following information extracted from the books of a manufacturing company, compute the operating cycle in days and the amount of working capital required:

Period Covered	365 days
Average period of credit allowed by suppliers	16 days
Average Total of Debtors Outstanding	480

Raw Material Consumption	4,400
Total Production Cost	10,000
Total Cost of Sales	10,500
Sales for the year	16,000
Value of Average Stock maintained:	
Raw Material	320
Work-in-progress	350
Finished Goods	260

2. From the following information prepare an estimation of working capital requirements.
    - Expected level of production 1300000 units per annum
    - Cost per unit: Raw materials Rs.90/-, Labour Rs.40/-, Overheads Rs.70/-
    - Selling price Rs.250/- per unit
    - Raw materials to remain in stock for two weeks.
    - Materials are in process for three weeks.
    - Finished goods to remain in stock for half a month
    - Credit allowed by suppliers one month
    - Lag in payment from Debtors two months – 30% cash sales.
    - Lag in payment of wages 1 ½ weeks, overheads one month
    - Minimum expected cash and bank balance to be maintained Rs.50000/-

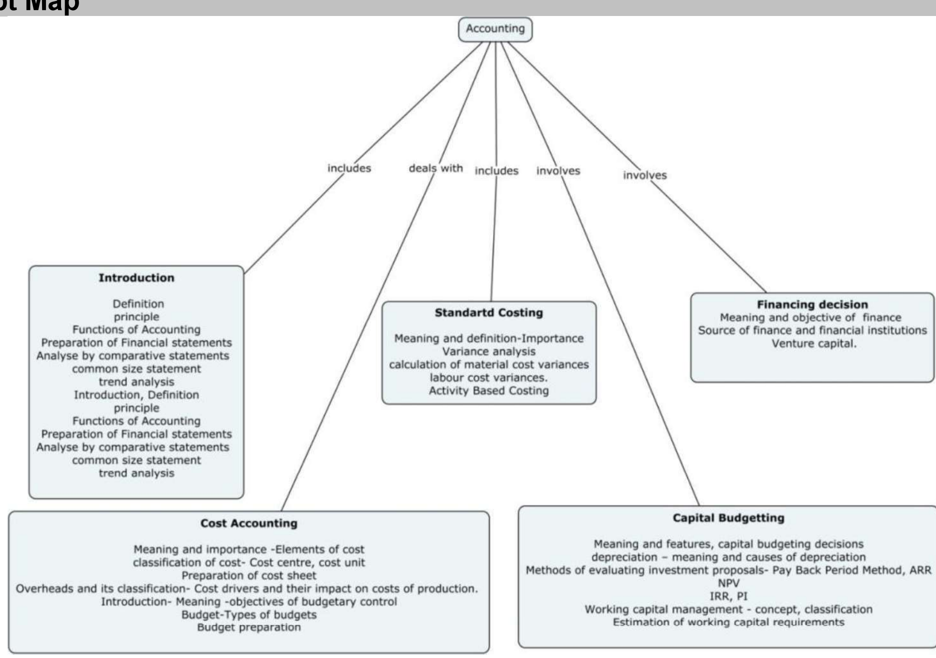
3 .From the following data of a project, Calculate IRR and suggest whether the project is to be undertaken or not if the cut off rate is 9%.

Cash Out flow (Rs.)		1,50,000
Cash Inflow(Rs.)	Year 1	41,000
	Year 2	50,000
	Year 3	50,000
	Year 4	42,000

Course Outcome 6 (CO6):

1. Identify the source of finance to start small scale industry.
2. Suggest suitable sources of finance to start a business with a capital of 60 crores.
3. Suggest the suitable sources of finance to start a business with an idea without the involvement of owner's capital

Concept Map



Syllabus

Accounting – Introduction, Definition and principle -Functions of accounting - Preparation of Financial statements and analyse them by comparative statement, common size statement and trend analysis. **Cost Accounting -** Meaning and importance -Elements of cost-classification of cost- Cost centre, cost unit-Preparation of cost sheet-Overheads and its classification- Cost drivers and their impact on costs of production. **Budget and Budgetary control**- Introduction- Meaning -objectives of budgetary control -Budget-Types of budgets and their preparation. **Standard costing**-Meaning and definition-Importance -Variance analysis-calculation of material cost, and labour cost variances, Activity based Costing. **Capital budgeting**- Meaning and features, capital budgeting decisions, depreciation – meaning and causes of depreciation. Methods of evaluating investment proposals- Pay Back Period Method, ARR, NPV, IRR, PI. **Working capital management -**concept, classification, Estimation of working capital requirements. **Finance:** objective, Source of finance and financial institutions and Venture capital.

Learning Resources

1. M.C.Shukla,T.S.Grewal,"AdvancedAccounts-Volume-I,2010 Reprint, S. Chand & company Ltd.,2010.
2. Prasanna Chandra, "Financial Management-Theory and practice" seventh Reprint,Tata McGraw-Hill publishing company Limited,2010.
3. P.S.BoopathiManickam "Financial and Management Accounting" PSG publications 2009.
4. Thomas R.Ittelson "Financial statements" Career Press, 2009
5. Michael C . Ehrhardt and Eugene F . Brigham, "Financial Management: Theory and Practice -thirteenth edition" South-Western cengage learning, 2011
6. Paramasivan.C, Subramanian.T, "Financial management" New Age international Publishers, 2014.
7. https://nptel.ac.in/courses/110/106/110106135/: Decision making using financial accounting, Prof. G Arun Kumar, IIT Madras
8. https://nptel.ac.in/courses/110/101/110101131/ : Financial Accounting, Dr. Varadraj Bapat, IIT Bombay.
9. https://nptel.ac.in/courses/110/101/110101132/: Cost Accounting, Dr. Varadraj Bapat, IIT Bombay.
10. https://nptel.ac.in/courses/110/107/110107127/: Management Accounting, Prof. Anil K. Sharma, IIT Roorkee.
11. https://www.youtube.com/watch?v=P9JIBbZas3w: Introduction to accounting, Dr.S.Vaidhyasubramanian, Adjunct professor, Sastra University.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Hours	Course Outcome
1.	**Accounting**		
1.1	Introduction, Definition	1	CO1
1.2	principle	1	
1.3	Functions of Accounting	1	
2.1	Preparation of Financial statements	2	CO2
2.2.	Analyse by comparative statements	1	
2.3	common size statement	1	
2.4	trend analysis	1	
3	**Cost Accounting**		
3.1	Meaning and importance -Elements of cost	1	
3.2	classification of cost- Cost centre, cost unit	1	

3.3	Preparation of cost sheet	2	CO3
3.4	Overheads and its classification- Cost drivers and their impact on costs of production.	2	
3.5	Introduction- Meaning -objectives of budgetary control	1	
3.6	Budget-Types of budgets	1	
3.7	Budget preparation	3	
4	**Standard costing**		
4.1	Meaning and definition-Importance	1	CO4
4.2	Variance analysis	1	
4.3	calculation of material cost variances	2	
4.4	labour cost variances.	2	
4.5	Activity based costing	2	
5	**Capital budgeting**		
5.1	Meaning and features, capital budgeting decisions	1	CO5
5.2	depreciation – meaning and causes of depreciation	1	
5.3	Methods of evaluating investment proposals- Pay Back Period Method, ARR	1	
5.4	NPV	1	
5.5	IRR, PI	1	
5.6	Working capital management - concept, classification	1	
5.7	Estimation of working capital requirements	1	
6	**Finance**		
6.1	Meaning and objective of finance	1	CO6
6.2	Source of finance and financial institutions	2	
6.3	Venture capital.	1	
	Total	**38 hrs**	

Course Designers:

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18ME570	FLUID MECHANICS AND CFD LAB	Category	L	T	P	Credit
		PC	0	0	2	1

Preamble

This practical course provides hands on experiment and the numerical simulation of different fluid system flowing internally and externally in different engineering systems using experimental set up in Fluid Mechanics Laboratory and simulation software based on finite volume method in CFD (Computational Fluid Dynamics) Laboratory.

Prerequisite

Engineering Mathematics and Physics

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Determine experimentally the rate of flow of liquids and its losses in closed conduits.	25
CO2	Determine experimentally the diameter of pipe carrying fluid using Bernoulli's theorem.	8
CO3	Determine experimentally the performance of hydraulic machines such as turbines and pumps.	17
CO4	Compute numerically the properties of compressible /incompressible fluid flowing through a pipe / venture / between two parallel plates using finite volume based simulation software	25
CO5	Compute numerically the properties of fluid flowing over a streamlined / bluff body using finite volume based simulation software	8
CO6	Determine numerically the temperature distribution in a fluid flowing through a nozzle / in a solid block at steady state / transient condition using finite volume based simulation software	17

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.1.1, 1.1.2, 1.2, 2.1.5, 2.2.3, 2.5.1, 3.2.3,
CO2	TPS3	Apply	Value	Mechanism	1.1.1, 1.1.2, 1.2, 2.1.5, 2.2.3, 2.5.1, 3.2.3
CO3	TPS3	Apply	Value	Mechanism	1.1.1, 1.1.2, 1.2, 2.1.5, 2.2.3, 2.5.1, 3.2.3
CO4	TPS3	Apply	Value	Mechanism	1.1.1, 1.1.2, 1.2, 2.1.5, 2.2.3, 2.5.1, 3.2.3, 4.1.1, 4.1.2 4.3.2, 4.3.3
CO5	TPS3	Apply	Value	Mechanism	1.1.1, 1.1.2, 1.2, 2.1.5, 2.2.3, 2.5.1, 3.2.3, 4.1.1, 4.1.2 4.3.2, 4.3.3
CO6	TPS3	Apply	Value	Mechanism	1.1.1, 1.1.2, 1.2, 2.1.5, 2.2.3,

					2.5.1, 3.2.3, 4.1.1, 4.1.2 4.3.2, 4.3.3

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	S	M	L			L		S		M		L		M	
CO2	S	M	L			L		S		M		L		M	
CO3	S	M	L			L		S		M		L		M	
CO4	S	M	L		S	L		S		M		L	L	M	
CO5	S	M	L		S	L		S		M		L	L	M	
CO6	S	M	L		S	L		S		M		L	L	M	

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Model Examination	Terminal Examination
Remember	--	--
Understand	--	10
Apply	100	90
Analyse	--	--
Evaluate	--	--
Create	--	--

Assessment Pattern: Psychomotor

Psychomotor Skill	Mini-project /Practical Component/Observation
Perception	--
Set	--
Guided Response	**Observation**
Mechanism	**Practical Component**
Complex Overt Responses	--
Adaptation	--
Origination	--

List of Experiments/Activities with CO Mapping

S.No	Description	No of Hours	Course Outcome
	Fluid Mechanics Lab		
1.	Determination of flow rate of fluid in a pipe using Venturimeter.	2	CO1
2.	Determination of flow rate of fluid in a pipe using Orificemeter.	2	
3.	Determination of frictional loss in pipes.	2	
4.	Determination of diameter of pipe carrying water using Bernoulli's theorem.	2	CO2
5.	Performance test on turbines (Pelton wheel/Francis turbine).	2	CO3
6.	Performance test on pumps (Centrifugal pump/Reciprocating	2	

	pump).		
	CFD Lab		
7.	Determination of pressure, velocity distribution and losses in laminar/turbulent flow of fluid through a circular pipe using numerical simulation software.	2	CO4
8.	Determination of pressure, velocity distribution and losses in laminar flow over a flat plate or between two parallel plates using numerical simulation software	2	CO4
9.	Determination of pressure, velocity distribution, and losses in incompressible fluid flow through a venturimeter using numerical simulation software.	2	CO4
10.	Determination of behaviour of fluid flowing over a flat plate/ cylinder / air foil bladeusing numerical simulationsoftware.	2	CO5
11.	Determination of pressure, velocity, temperature and Mach number distribution in a compressible fluid flow through a convergent-divergent nozzle using numerical simulation software.	2	CO6
12.	Determine temperature distribution in a solid wall under steady state / transient condition using numerical simulation software.	2	CO6
	Total Hours	**24**	

Learning Resources

https://nptel.ac.in/courses/112105045/ -Computational Fluid Dynamics by Professor Suman Chakravarty, IIT Kharagpur
https://nptel.ac.in/courses/112107079/ - Computational Fluid Dynamics by Professor Krishna M. Singh, IIT Madras

Course Designers:

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3. Dr. P. Maran pmmech@tce.edu

18ME580	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 Machining Processes.

Prerequisite

- Machining Processes

Course Outcomes

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

CO	Course Outcome Statement	**Weightage*** in %**
CO1	Prepare the process plan for the given parts.	20
CO2	Perform various operations like facing, turning, taper turning, threading etc. in lathe machine.	10
CO3	Conduct various operations like face milling, plain milling, key way milling, form milling etc. in milling machine.	10
CO4	Perform various operations like deep hole, pilot hole etc. in drilling machine.	10
CO5	Conduct machining of the horizontal, vertical, angular surface etc. using shaping machine.	10
CO6	Perform various operations like surface grinding, internal grinding etc. in grinding machine.	10
CO7	Perform the various operations in horizontal injection moulding machines.	10
CO8	Assemble the machined parts for final assembly.	20

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO2	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO5	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO6	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO7	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO8	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2

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	M	S						M		
CO2	M	L			L								M		
CO3	S	M	L		M	M	S						M		
CO4	S	M	L				M						M		
CO5	S	M	L		L	L							M		

CO6	S	M	L			M	M						M		
CO7	S	M	L										M		
CO8	S	M	L										M		

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Model Examination	Terminal Examination
Remember		
Understand		
Apply	50*	100
Analyse		
Evaluate		
Create		

* Observation and Record – 30 marks and Model Test - 20 marks

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Practical Component/Observation
Perception	
Set	
Guided Response	
Mechanism	Practical Component / Observation
Complex Overt Responses	
Adaptation	
Origination	

Syllabus

The following sample parts/assemblies and the various machines used for machining these parts are given below:

S. No.	Parts/ Assembly	Machine
1.	Tail Stock Spindle Binding Lever	Lathe and horizontal injection molding machine
2	Quick Change Tool Post	Lathe, Milling ad Drilling machine
3.	Catch Plate	Lathe, Milling and Surface Grinding machine
4.	Face Plate	Lathe, Milling and Surface Grinding machine
5.	Drilling vice	Lathe, Milling and Drilling machine
6.	Four Way Tool Post	Lathe, Milling, shaping Tapping and Drilling machine
7	Flange Coupling	Lathe, Milling and Drilling machine

Note:

1. Students shall be given hands-on practice on above mentioned machines for 4 weeks duration.
2. Students should complete minimum of 2 assigned assemblies within next 5 weeks duration.
3. Also, he/she encouraged to complete their assigned work after the regular class hour.

Assessment Pattern

- Terminal practical examination will be conducted as per the COE norms, to evaluate any 2 trades like turning, milling, drilling, grinding, shaping & plastic moulding etc. with 1½ hours duration each.
- If he/she got less than 50 marks in terminal examination, he/she has to undergo the supplementary examination.

Course Designers:

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18ES590	SYSTEM THINKING

Category	L	T	P	Credit
ES	1	-	2	2

Preamble

Systems thinking is the integrated paradigm for systems science and system approaches to practice. It is concerned with understanding or intervening in problem situations, based on the principles and concepts of the system model. It can help to provide a common language and an intellectual foundation and make practical system concepts, principles, patterns and tools accessible to systems engineering. System thinking considers the similarities between systems from different domains in terms of a set of common systems concepts, principles, and patterns. The scope of systems thinking is a starting point for dealing with real-world situations using a set of related systems concept. The system thinking is viewed as both a set of founding ideas for the development of systems theories and practices and also as a pervasive way of thinking need by those developing and applying them. This systems approach is a way of tackling real-world problems and making use of the concepts, principle, patterns of systems thinking to enable the systems to be engineered and used.

Prerequisite

Nil

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage in %
CO1	Explain the concepts of systems thinking, System engineering and Systems Life Cycle	10
CO2	Identify system elements, interactions, boundary and environment for the given system descriptions	10
CO3	Develop a functional architecture with appropriate primary function(s) and sub-functions of the identified system	15
CO4	Develop a physical architecture with appropriate sub-systems and components of the identified system	15
CO5	Prepare a system requirement specification review documents for the various stages of acquisition phase of the identified system	20
CO6	Develop a system model with logical and physical architecture using system modelling tool like SysML	30

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	-	1.1, 2.3.1, 2.3.2
CO2	TPS3	Apply	Value	-	1.1, 2.1.1, 2.3.1,2.3.2, 2.3.3, 2.3.4, 2.4.4, 4.3.1,
CO3	TPS3	Apply	Value	Mechanism	1.1, 2.1.1, 2.3.1,2.3.2, 2.3.3, 2.3.4, 2.4.4, 3.1.2, 3.2.3, 3.2.4, 3.2.5, 3.2.6, 4.3.1, 4.3.2, 4.3.3, 4.4.5, 4.5.1
CO4	TPS3	Apply	Value	Mechanism	1.1, 2.1.1, 2.3.1,2.3.2, 2.3.3, 2.3.4, 2.4.4, 3.1.2, 3.2.3, 3.2.4, 3.2.5, 3.2.6, 4.3.1, 4.3.2, 4.3.3, 4.4.5, 4.5.1
CO5	TPS3	Apply	Value	Mechanism	1.1, 2.1.1, 2.3.1,2.3.2, 2.3.3,

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
					2.3.4, 2.4.4, 3.1.2, 3.2.3, 3.2.4, 3.2.5, 3.2.6, 4.3.1, 4.3.2, 4.3.3, 4.4.5, 4.5.1
CO6	TPS3	Apply	Value	Mechanism	1.1, 2.1.1, 2.3.1,2.3.2, 2.3.3, 2.3.4, 2.4.4, 3.1.2, 3.2.3, 3.2.4, 3.2.5, 3.2.6, 4.3.1, 4.3.2, 4.3.3, 4.4.5, 4.5.1

Mapping with Programme Outcomes and Programme Specific Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	M	L	-	-	-	-	-	-	-	-	-	-
CO2	S	M	L	-	-	L	L	L	L	L	-	M
CO3	S	M	L	-	-	M	M	M	L	M	M	S
CO4	S	M	L	-	-	M	M	M	L	M	M	S
CO5	S	M	L	-	-	M	M	M	L	M	M	S
CO6	S	M	L	-	S	M	M	M	L	M	M	S

S- Strong; M-Medium; L-Low

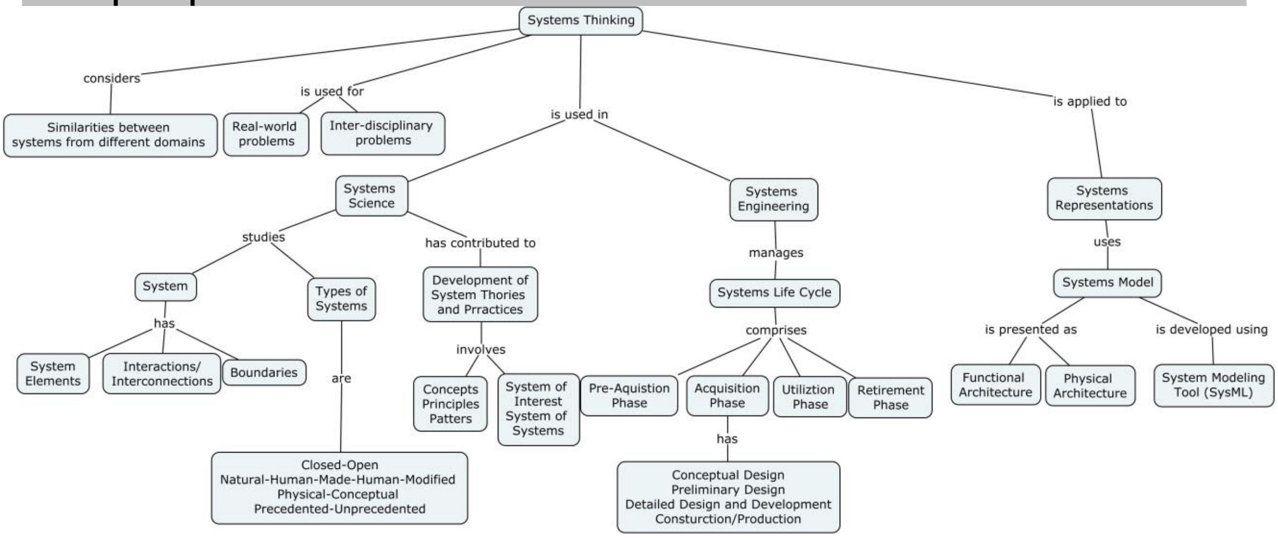
Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Test -2
Remember	20
Understand	40
Apply	40
Analyse	-
Evaluate	-
Create	-

Phases	Deliverables	Marks	Course Outcomes
Continuous Assessment			
Continuous Assessment Test-1		10	CO1 and CO2
Review 1 – Functional & Physical Architecture and System Requirement Specification	Technical Report	25	CO3, CO4 and CO5
Review 2 – Systems Modeling	Technical Report	15	CO6
End-Semester Examination			
Demonstration	Virtual Prototype with simulation	60	CO1, CO2, CO3, CO4 CO5 and CO6
Poster Presentation	Poster	40	

- Reports are to be submitted at each review. The report and presentation will be evaluated based on Rubrics.
- Demonstration of Virtual Prototype with simulation and Poster presentation will be evaluated by two faculty members nominated by their respective Head of the Department.

Concept Map



Syllabus

1.0 Systems Fundamentals: System - Definition, System Elements, Interactions, System Boundary, - Types of Systems: Closed-Open, Natural-Human-Made-Human-Modified, Physical-Conceptual and Precedented-Unprecedented. Systems science - Systems approaches. Systems Thinking: Concepts, principles and pattens. System of Interest - Systems of System. Systems Engineering: Product, Service, Enterprise. System Life Cycle: Pre-acquisition phase, Acquisition Phase, Utilization Phase and Retirement Phase.
2.0 Acquisition Phase: Conceptual Design: Business needs and requirements, Stakeholder needs and requirements, System Requirement Specification, Functional Base Line, System Requirement Review – Functional Architecture. Preliminary Design: Configuration items, Allocated Baseline, Preliminary Design Review – Physical Architecture. Detailed Design and Development: System Modeling, Product Base Line, Critical Design Review. Construction/Production: Formal Qualification Review, Acceptance Test and Evaluation.
3.0 Systems Modeling: System Model - Types of models – System Modeling Concepts – Modeling Standards. System Architecture: Logical Architecture Model – Physical Architecture Model. Systems Life Cycle Process Model: Vee model.

Learning Resources

1. A Guide to Guide to the Systems Engineering Body of Knowledge (SEBoK), version 2.2, INCOSE Systems Engineering Research Center and IEEE Computer Society, Released 31 October 2019 – https://www.sebokwiki.org/w/images/sebokwiki-farm!w/8/8b/SEBoK_v2.1.pdf
2. Systems Engineering Handbook, A Guide for Systems Life Cycle Processes and Activities, 4th Edition, INCOSE-TP-2003-002-04, 2015.
3. R. Ian Faulconbridge, Michael Ryan, “Systems Engineering Practice”, Argos Argos Press, 2014.
4. Jon Holt and Simon Perry, “SysML for Systems Engineering”, The Institution of Engineering and Technology, London, United Kingdom, 2008.
5. Sanford Friedenthal, Alan Moore and Rick Steiner, “A Practical Guide To SysML: The Systems Modeling Language, Third edition, Morgan Kaufmann, an imprint of Elsevier, 2015
6. Coursera course on Introduction to Systems Engineering - R. Ian Faulconbridge, Michael Ryan of The University of New South Wales, Sydney.
7. NPTEL Course: Systems Engineering Theory and Practice – IIT Kanpur – Prof. Deepu Philip (Last offered in 2019) - https://nptel.ac.in/courses/110/104/110104074/

Course Contents and Lecture Schedule

Module No.	Topic	No. of Hours		Course Outcome
		In-Class	Hands-on	
1.	**Systems Fundamentals:** System - Definition, System Elements, Interactions, System Boundary	1	-	CO1
1.1	Types of Systems: Closed-Open, Natural-Human-Made-Human-Modified, Physical-Conceptual and Precedented-Unprecedented.	1	2	CO1
1.2	Systems science - Systems approaches.	1	-	CO1
1.3	Systems Thinking: Concepts, principles and pattens.	1	-	CO1
1.4	System of Interest - Systems of System. Systems Engineering: Product, Service, Enterprise System Life Cycle: Pre-acquisition phase, Acquisition Phase, Utilization Phase and Retirement Phase.	2	2	CO2
2.	**Acquisition Phase**			
2.1	Conceptual Design: Business needs and requirements, Stakeholder needs and requirements, System Requirement Specification, Functional Base Line, System Requirement Review – Functional Architecture.	1	4	CO3
2.2	Preliminary Design: Configuration items, Allocated Baseline, Preliminary Design Review – Physical Architecture.	1	4	CO3
2.3	Detailed Design and Development: System Modeling, Product Base Line, Critical Design Review.	1	4	CO4
2.4	Construction/Production: Formal Qualification Review, Acceptance Test and Evaluation.	1	4	CO5
3.	**Systems Modeling**			
3.1	System Model - Types of models – System Modeling Concepts – Modeling Standards.	1	2	CO6
3.2	System Architecture: Logical Architecture Model – Physical Architecture Model.	1	4	CO6
3.3	Systems Life Cycle Process Model: Vee model.	1	2	CO6
	Total	14	28	

Course Designers:

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18CHAC0	ESSENCE OF INDIAN KNOWLEDGE	Category	L	T	P	Credit
		AC	2	0	0	0

Preamble

On the successful completion of the course, the students will be able to explain the concept of Indian Traditional Knowledge along with Indian Modern Knowledge. Traditional Knowledge Systems or Indigenous Knowledge Systems are a body of knowledge, which is very ancient and deep rooted. They have their origins in the remote past. Their systematisation and canonisation gave rise to the elite (the Greater Tradition) science. The nature of Traditional Knowledge System is diverse. It covers, among other things, literary, artistic and scientific works; songs, dances, medical treatments and practices; manufacturing and industry; and agricultural technologies and techniques. There is a dramatically growing national and international interest in incorporating Traditional Knowledge Systems, including Traditional Ecological Knowledge, into truly participatory approaches to development.

Course Outcome:

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

CO1	Explain the concept of Traditional Knowledge and Modern knowledge of India.	Understand
CO2	Explain the need and importance of protecting Traditional Knowledge, Knowledge sharing, and Intellectual property rights over Traditional Knowledge.	Understand
CO3	Explain about the use of Traditional Knowledge to meet the basic needs of human being.	Understand
CO4	Explain the rich biodiversity materials and knowledge preserved for practicing traditional lifestyle.	Understand
CO5	Explain the use of Traditional Knowledge in Manufacturing and Industry.	Understand
CO6	Explain about the cultural expression and modern applications of Traditional Knowledge	Understand

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	M	L	-	-	-	S	M	M	M	M	-	L	M	-	M
CO2	M	L	-	-	-	S	M	M	M	M	-	L	M	-	M
CO3	M	L	-	-	-	S	M	M	M	M	-	L	M	-	M
CO4	M	L	-	-	-	S	M	M	M	M	-	L	M	-	M
CO5	M	L	-	-	-	S	M	M	M	M	-	L	M	-	M
CO6	M	L	-	-	-	S	M	M	M	M	-	L	M	-	M

S- Strong; M-Medium; L-Low

Syllabus

Traditional and Modern Knowledge: Two Worlds of Knowledge - Phase of Explorers, Sir Arthur Cotton and Irrigation, Smallpox Vaccination, Late Nineteenth Century, Voelcker, Howard and Agriculture, Havell and Indian Art; Indians at the Encounter - Gaekwad of Baroda and Technical Education, Science Education and Modern Industries, Hakim Ajmal Khan and Ayurveda, R. N. Chopra and Indigenous Drugs, Gauhar Jaan and Indian Classical Music; Linking Science and the Rural - Tagore's Sriniketan Experiment, Marthandam, the YMCA Model, Gandhi's Thoughts on Development, Nehru's View of Growth; Post-Independence Era - Modernization and Traditional Knowledge, Social Roots of Traditional Knowledge Activism, Global Recognition for Traditional Knowledge. **Global Mechanisms of Protection and Sharing:** For Recognition and Protection - United Nations Educational, Scientific and Cultural Organization (UNESCO), World Health Organization (WHO), International Labour Organization (ILO), UN Working Group on Indigenous Populations, Evolution of Other Organizations; Norms of Sharing - United Nations Environment Programme (UNEP), World Intellectual Property Organization (WIPO), World Trade

Organization (WTO); IPR and Traditional Knowledge - Theoretical Background, Positive Protections of TK, Defensive Strategies, IPR Facilitation for TK. **Traditional Knowledge for Basic Needs:** Indian Midwifery Tradition—The Dai System, Surface Flow Irrigation Tanks, Housing - A Human Right, Changing Priorities—Niyamgiri. **Biodiversity and Genetic Resources:** Jeevani - The Wonder Herb of Kanis, A Holistic Approach - FRLHT, Basmati - In the New Millennium, AYUSH-Based Cosmetics. **Traditional Knowledge in Manufacturing and Industry:** Drug Discovery, A Sweetener of Bengal, The Sacred Ring of Payyanur, Channapatna Toys. **Traditional Cultural Expressions:** Banarasi Saree, Music, Built and Tangible Heritage, Modern Yoga, Sanskrit and Artificial Intelligence, Climate Change and Traditional Knowledge.

Assessment Pattern

Bloom's category	Continuous Assessment Tests		Seminar
	1	2	-
Remember	40	40	0
Understand	60	60	100
Apply	0	0	0
Analyze	0	0	0
Evaluate	0	0	0
Create	0	0	0

Learning Resources:

1. Nirmal Sengupta "Traditional Knowledge in Modern India Preservation, Promotion, Ethical Access and Benefit Sharing Mechanisms" Springer, 2019.
2. Amit Jha,"Traditional Knowledge System in India", Atlantic Publishers and Distributors Pvt Ltd, 2009.
3. Basanta Kumar Mohanta, Vipin Kumar Singh "Traditional Knowledge System and Technology in India", Pratibha Prakashan, 2012.
4. Kapil Kapoor, Michel Danino "Knowledge Traditions and Practices of India", Central Board of Secondary Education, 2012.
5. NPTEL video lecture on "Ayurvedic Inheritance of India", Video link: https://nptel.ac.in/courses/121/106/121106003/#.
6. Youtube video on "Introduction to Indian Knowledge Systems", Video link: https://www.youtube.com/watch?v=LZP1StpYEPM.
7. Youtube video on "12 Great achievements of Indian Civilization", Video link: https://www.youtube.com/watch?v=xmogKGCmclE.

Course Designers:

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18ME610	MANUFACTURING SYSTEMS AND AUTOMATION

Category	L	T	P	Credit
PC	2	-	-	2

Preamble

This course deals with different manufacturing systems and programming methods practiced in industries. It 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 techniques to build manufacturing environment.

Prerequisite

- NIL

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage *** in %
CO1	Identify the different manufacturing system, programming techniques and interfacing methods	20
CO2	Balance of assembly line using appropriate algorithm	20
CO3	Explain the different transportation and storage system for material handling	10
CO4	Explain the principle of part identification and inspection system	10
CO5	Construct ladder logic diagram for given manufacturing process	20
CO6	Develop suitable manufacturing plan for MRP/CAPP/Data collection system for a given manufacturing scenario	20

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.1, 1.2, 1.3, 2.1.1, 2.4.5, 2.4.6, 2.5.1, 2.5.4, 3.1, 3.1.5, 4.1.1, 4.5.3, 4.6.1, 4.6.2
CO2	TPS3	Apply	Value	Mechanism	1.1, 1.3, 2.1.1, 2.1.4,2.2.3, 2.4.5, 2.4.6, 2.5.1, 3.1.5, 4.3.1, 4.5.5
CO3	TPS2	Understand	Respond	Guided Response	1.1, 1.2, 1.3, 2.1.1, 2.1.4, 2.4.5, 2.4.6, 2.5.1, 3.1.1, 3.1.2, 3.2.4, 4.1.1, 4.2.2, 4.5.1, 4.5.3, 4.6.1, 4.6.2
CO4	TPS2	Understand	Respond	Guided Response	1.1, 1.2, 1.3,2.1.3, 2.1.4, 2.4.3, 2.4.4, 2.4.6, 2.5.1, 2.5.6, 2.5.1, 3.1, 3.2, 4.2.2, 4.3.2, 4.5.4, 4.6.2, 4.6.6
CO5	TPS3	Apply	Value	Mechanism	1.1, 1.3, 2.1.1, 2.1.4, 2.4.3, 2.4.6, 2.5.1, 3.2.4, 3.2.5, 4.4.1, 4.6.1, 4.6.6
CO6	TPS3	Apply	Value	Mechanism	1.1, 1.2, 1.3, 2.1.1, 2.1.4, 2.1.5, 2.4.5, 2.5.1, 3.1, 4.1.1, 4.2.2, 4.5.3, 4.5.4, 4.6.6

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	S	M	L		M		M	S	S	S	S	S			S
CO2	S	M	L				S	M	S	M	M	S			S
CO3	M	L				S	S	S	S	M	S	M			M
CO4	M	L				M	M	S	S	S	S	S			M
CO5	S	M	L						M		M	M			M
CO6	S	M	L		M			M	M	S	M	M			S

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	**2**	**3**	1	2	3	
Remember	10	40	10				10
Understand	20	60	40		100		40
Apply	70	-	50	100	-	100	50
Analyse	-	-	-	-	-		-
Evaluate	-	-	-	-	-	-	-
Create	-	-	-	-	-	-	-

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	
Set	
Guided Response	
Mechanism	Assignment
Complex Overt Responses	
Adaptation	
Origination	

Sample Questions for Course Outcome Assessment**

** (2 to 3 at the cognitive level of course outcome)

Course Outcome 1(CO1):

1. Prepare a CNC program for turning the part made up of aluminium material which has step and curvature features with all necessary calculations.
2. Identify the planning and implementation issues for FMS.
3. Suggest the data framing technique of 8 bit data along with different possible data communication errors.

Course Outcome 2 (CO2):

1. Prepare minimum rational work element for the given assembly operation.

2. Illustrate the principle of line balancing using Kilbridge and Wester method with at least 8 minimum rational work elements.
3. Identify the advantages and limitations of computerized line balancing technique.

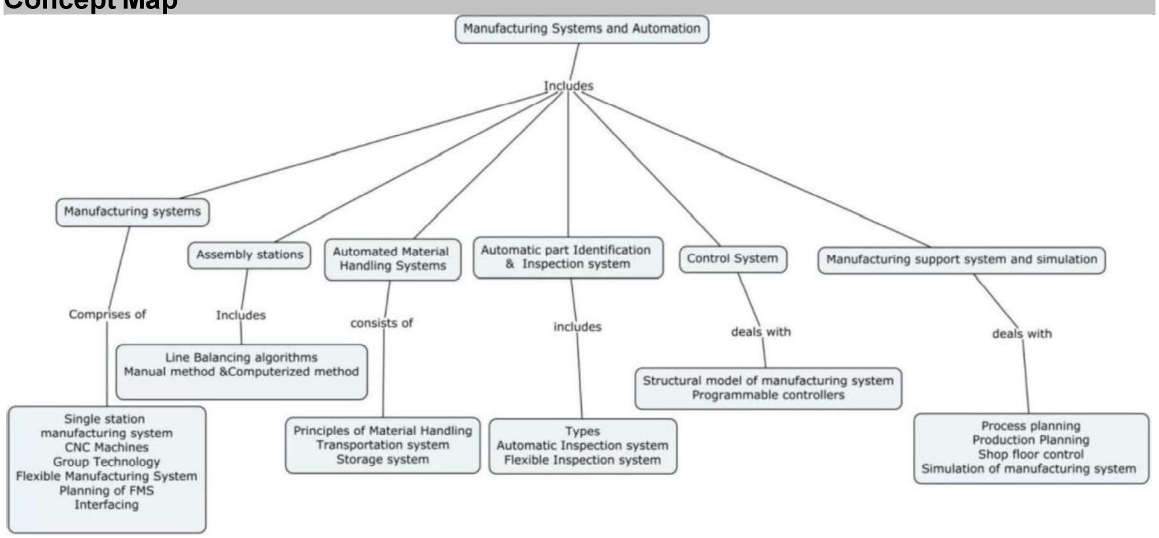
Course Outcome 3 (CO3):
1. Explain the important factor that influences the design or selection of material handling system?
2. Summarize the different features of material handling systems?
3. Describe AS/RS with its importance?

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

Course Outcome 5 (CO5):
1. Identify the Structural model of manufacturing system.
2. Identify the Sequence and programmable controllers.
3. Prepare 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. Identify the retrieval type CAPP and compare it with generative type CAPP. Also, give your comments.

Concept Map



Syllabus

Manufacturing systems: Single station manufacturing system, Single Station Manned cell, Single station automated cell. **CNC machines**: classification and programming. **Group technology**: Part classification, coding and production flow analysis. **Flexible manufacturing system:** Types, Functions, FMS layout, computer control and planning of FMS. **Assembly systems**: Classification, line balancing algorithms- manual and computerized method. **Transportation system**: Automated guided vehicle, conveyor and analysis of transportation system. **Storage system**: Automated Storage and Retrieval system and Carousel storage system. **Automatic part Identification:** Types, Bar code technique, RF identification system, Magnetic stripes and Optical character recognition.

Automatic Inspection system: Contact Vs Non-contact Inspection techniques, coordinate measuring machine and machine vision. **Programmable Logic controllers:** logic control elements, sequencing elements and ladder logic diagrams. **Manufacturing support system:** Manual and Computer Aided Process planning. **Production Planning**: Master production schedule, bill of material, inventory record, working of Material Requirements Planning and outputs. **Shop floor control**: Phases of shop floor control and factory data collection system.

Learning Resources

1. Mikell P.Groover, "Automation, Production systems and Computer Integrated Manufacturing" PHI Learning Pvt. Ltd., 3rd Edition, 2009.
2. Vajpayee S. Kant, "Principles of Computer Integrated Manufacturing", Prentice Hall of India Learning, 2009.
3. P.M. Agarwal and V.J.Patel, "CNC Fundamentals and Programming", Charotar Publishing House Pvt. Ltd., Second Edition, 2014.
4. Hindustan Machine Tool Ltd., "Mechatronics", Tata McGraw Hill, 2000.
5. Jerry Banks and Barry L. Nelson, "Discrete Event System Stimulation", Pearson Education, Fifth edition 2006.
6. H.K.Shivanand and M.M. Benal, "Flexible Manufacturing System", New Age International Pvt Ltd Publishers, 2006.
7. https://nptel.ac.in/courses/112/104/112104288/
8. https://nptel.ac.in/courses/112102011/
9. https://freevideolectures.com/course/3068/manufacturing-systems-management/5
10. https://www.btechguru.com/GATE--mechanical-engineering--production-planning-and-control--material-requirement-planning--material-requirements-planning-video-lecture--13140--23--203.html

Course Contents and Lecture Schedule

Module No.	Topic	No. of Hours	Course Outcome
1.	**Manufacturing systems:**		
1.1	Single station manufacturing system, Single Station Manned cell, Single station automated cell.	1	CO1
1.2	**CNC machines**: classification and programming.	3	
1.3	**Group technology**: Part classification, coding and production flow analysis.	3	
1.4	**Flexible manufacturing system:** Types, Functions, FMS layout, computer control and planning of FMS.	2	
2.	**Assembly systems**:		
2.1	Classification, line balancing algorithms – manual and computerized method.	2	CO2
3.	**Transportation system**:		
3.1	Automated guided vehicle, conveyor and analysis of transportation system.	2	CO3
3.2	**Storage system**: Automated Storage and Retrieval system and Carousel storage system.	2	
4.	**Automatic part Identification:**		
4.1	Types, Bar code technique, RF identification system, Magnetic stripes and Optical character recognition.	1	CO4
4.2	**Automatic Inspection system:** Contact Vs Non-contact Inspection techniques, coordinate measuring machine and machine vision.	2	
5.	**Programmable Logic controllers:**		

5.1	logic control elements, sequencing elements and ladder logic diagrams.	2	CO5
6.	**Manufacturing support system:**		
6.1	Manual and Computer Aided Process planning	2	CO6
6.2	**Production Planning**: Master production schedule, bill of material, inventory record, working of Material Requirements Planning and outputs.	3	
6.3	**Shop floor control**: Phases of shop floor control and factory data collection system.	2	
	Total	**27 Hrs**	

Course Designers:

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18ME620	DESIGN OF TRANSMISSION SYSTEMS	Category	L	T	P	Credit
		PC	2	0	0	2

Preamble

A transmission is a machine in a power transmission system, which provides controlled application of the power. Transmissions are also used in agricultural, industrial, construction, mining and automotive equipment. The transmission system used in motor vehicles used, to transfer the power from an engine to the drive wheels. The transmission system in engines reduces the higher speed to the lower speed, increasing torque in the process. Transmission systems are also used on various industrial applications where different rotational speeds and torques are required. A transmission has multiple gear ratios with the ability to switch between them as speed varies. This course is concerned with designing the basic mechanical power transmission elements such as flexible drives, Gears, Gear boxes, Clutches and Brakes for varied applications.

Prerequisite

- Mechanics of Materials
- Design of Machine Elements

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage In %
CO1	Design Flat Belts, V- Belts and Chain drives for given engineering application.	20
CO2	Design Parallel axis gears such as Spur gears and Helical Gears based on strength and wear considerations.	20
CO3	Design Inclined axis gears such as Bevel gears, Worm Gears and Crossed Helical Gears under static loading conditions.	20
CO4	Design a Gear box for machine tool and automotive applications.	20
CO5	Design a Clutch for automotive applications and material handling equipment.	10
CO6	Design of Suitable Mechanical Radial Brakes for given engineering applications.	10

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.4.4, 3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6
CO2	TPS3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.4.4, 3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.4.4, 3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.4.4, 3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6
CO5	TPS3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.4.4, 3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6
CO6	TPS3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.4.4, 3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6

Mapping with Programme Outcomes and Programme Specific 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	PSO 1	PSO 2	PSO 3
CO1.	S	M	L	M	-	-	-	M	L	L	-	-	S	-	M
CO2.	S	M	L	M	-	-	-	M	L	L	-	-	S	-	M
CO3.	S	M	L	M	-	-	-	M	L	L	-	-	S	-	M
CO4.	S	M	L	M	-	-	-	M	L	L	-	-	S	-	M

CO5.	**S**	**M**	**L**	**M**	**-**	**-**	**-**	**M**	**L**	**L**	**-**	**-**	**S**	**-**	**M**
CO6.	**S**	**M**	**L**	**M**	**-**	**-**	**-**	**M**	**L**	**L**	**-**	**-**	**S**	**-**	**M**

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests (30 marks)			Integrated System Design Project (20 marks)	Terminal Examination (50 marks)
	1	2	3		
Remember	0	0	0	0	0
Understand	10	10	10	0	10
Apply	90	90	90	0	90
Analyse	0	0	0	100	0
Evaluate	0	0	0	0	0
Create	0	0	0	0	0

Integrated System Design Project: This is a team project and each team may consist of 3 or 4 students. The students will do an Integrated System Design project wherein the students are expected to,

- Identify an application which consists of various machine elements and transmission systems and gather the input information for load, power etc.
- Design the various machine elements and transmission systems for their application by following the design procedure.
- Create a Part & Assembly model of the various designed components and draft them using any of the computer aided parametric modelling software packages.
- A final technical report has to be submitted summarizing all the work done. The total mark for evaluation is 100 and has to be converted to 30.

Assessment Pattern: Psychomotor

Psychomotor Skill	Mini Project/ Assignment/ Practical
Perception, Set	-
Guided Response	-
Mechanism	-
Complex Overt Responses	Integrated System Design Project
Adaptation	-

Origination	-

Sample Questions for Course Outcome Assessment

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, centre 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 begins 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. Design a spur gear drive required to transmit 45 kW at a pinion speed of 800 r.p.m. The velocity ratio is 3.5: 1. The teeth are 20° full-depth involute with 18 teeth on the pinion. Both the pinion and gear are made of steel with a maximum safe static stress of 180 MPa. Assume a safe stress of 40 MPa for the material of the shaft and key.

3. Design a pair of herringbone gears required to transmit 40 kW at a pinion speed of 900 r.p.m. The velocity ratio is 5: 1. The teeth are 20° full-depth involute with 26 teeth on the pinion.

COURSE OUTCOME 3 (CO3):

1. 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.

2. A double threaded worm drive has an axial pitch of 25 mm and a pitch circle diameter of 70 mm. The torque on the worm gear shaft is 1400 N-m. The pitch circle diameter of the worm gear is 250 mm and the tooth pressure angle are 25°. Find: 1. tangential force on the worm gear, 2. torque on the worm shaft, 3. separating force on the worm, 4. velocity ratio, and 5. efficiency of the drive, if the coefficient of friction between the worm thread and gear teeth is 0.04.

3. Design a pair of bevel gears to transmit 10 kW at 1440 rpm of the pinion. The velocity ratio should be about 4. Material for gear is15 Ni 2 Cr 1Mo 15 Steel. The tooth profiles of the gears are of 20^{o} composite form.

COURSE OUTCOME 4 (CO4):

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 5 (CO5):

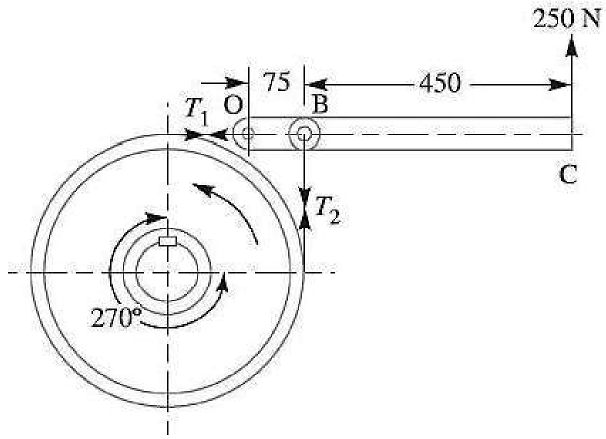
1. A single plate sketch, effective on both sides, is required to transmit 25KW at 3000 rpm. Determine the outer and inner diameter of frictional surfaces if the coefficient of friction is 0.25, ratio of diameter is 1.25 and the maximum pressure is not to exceed 0.1 N/mm2. Determine (i) the face width required and (ii) the axial spring force necessary to engage the clutch.

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.

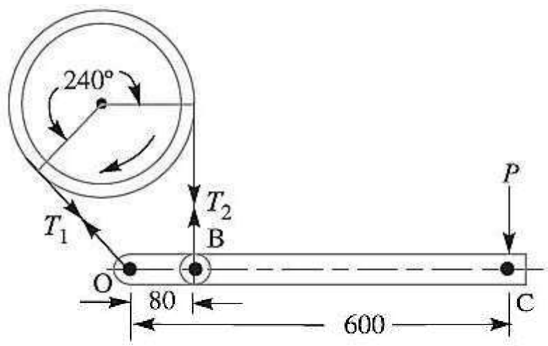
3. A plate clutch has three discs on the driving shaft and two discs on the driven shaft, providing four pairs of contact surfaces. The outside diameter of the contact surfaces is 240 mm and inside diameter 120 mm. Assuming uniform pressure and μ = 0.3, find the total spring load pressing the plates 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 6 (CO6):

1. The drum of a simple band brake is 450 mm. The band embraces 3/4th of the circumference of the drum. One end of the band is attached to the fulcrum pin and the other end is attached to a pin B as shown in Figure. The band is to be lined with asbestos fabric having a coefficient of friction 0.3. The allowable bearing pressure for the brake lining is 0.21 N/mm^2. Design the band shaft, key, lever and fulcrum pin. The material of these parts is mild steel having permissible stresses as follows: σ_t = σ_c= 70 MPa, and τ = 56 MPa

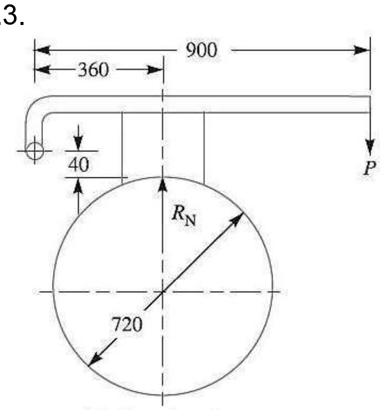


2. A band brake as shown in Figure, is required to balance a torque of 980 N-m at the drum shaft. The drum is to be made of 400 mm diameter and is keyed to the shaft. The band is to be lined with ferodo lining having a coefficient of friction 0.25. The maximum pressure between the lining and drum is0.5 N/mm^2. Design the steel band, shaft, key on the shaft, brake lever and fulcrum pin. The permissible stresses for the steel to be used for the shaft, key, band lever and pin are 70 MPa in tension and compression and 56 MPa in shear.



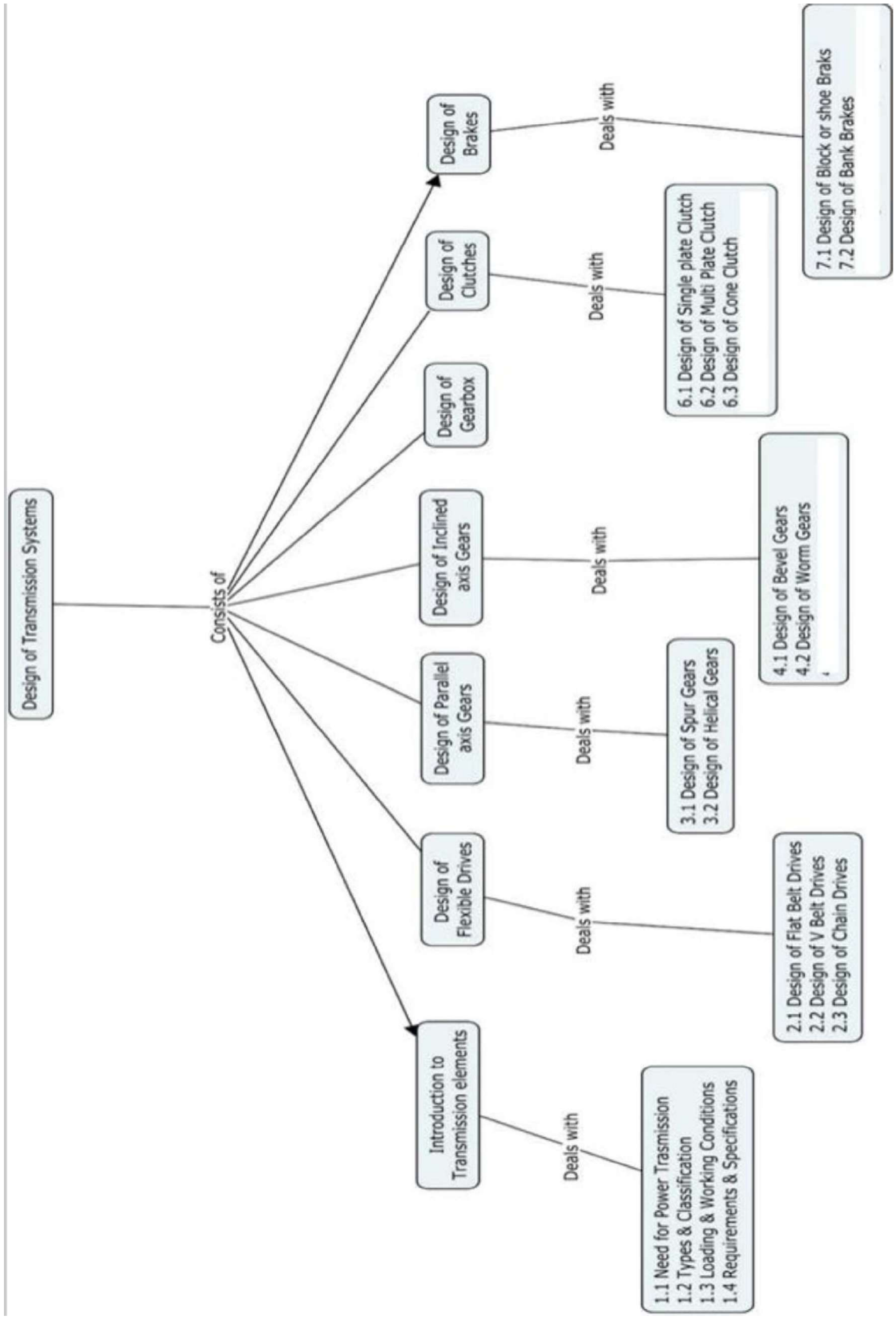
All dimensions in mm.

3. A single block brake, as shown in Figure, has a drum diameter of 720 mm. If the brake sustains225 N-m torque at 500 r.p.m.; find:(a) the required force (P) to apply the brake for clockwise rotation of the drum;(b) the required force (P) to apply the brake for counter clockwise rotation of the drum;(c) the location of the fulcrum to make the brake self-locking for clockwise rotation of the drum; and The coefficient of friction may be taken as 0.3.



All dimensions in mm.

Concept Map


Design of Transmission Systems
Consists of
Introduction to Transmission elements
Deals with
1.1 Need for Power Trasmission
1.2 Types & Classification
1.3 Loading & Working Conditions
1.4 Requirements & Specifications
Design of Flexible Drives
Deals with
2.1 Design of Flat Belt Drives
2.2 Design of V Belt Drives
2.3 Design of Chain Drives
Design of Parallel axis Gears
Deals with
3.1 Design of Spur Gears
3.2 Design of Helical Gears
Design of Inclined axis Gears
Deals with
4.1 Design of Bevel Gears
4.2 Design of Worm Gears
Design of Gearbox
Design of Clutches
Deals with
6.1 Design of Single plate Clutch
6.2 Design of Multi Plate Clutch
6.3 Design of Cone Clutch
Design of Brakes
Deals with
7.1 Design of Block or shoe Braks
7.2 Design of Bank Brakes

Syllabus

Introduction: Review on Friction, Metallurgy and Materials – Need for Power Transmission – Requirements of a Transmission System – Types and Classification of Transmission Systems –Loading Conditions – Working Conditions – Specifications of a Transmission Element.

Flexible Drives: Belt Drives – Types, Materials and Construction– Design of Flat Belts and Pulleys–Design of V Belt drives - Types of Chain drives–Design of Transmission Chain and Sprockets.

Parallel Axis Gears: Tooth terminology–Speed ratios and number of teeth- Factor of safety -Gear materials Design of spur and helical gears based on strength and wear considerations – Pressure angle in the normal and transverse plane – Equivalent number of teeth for helical gears.

Inclined Axis Gears: Design of Straight/Spiral bevel gear: Tooth terminology–equivalent number of teeth – Estimating the dimensions of pair of straight bevel gears. Worm Gear – Terminology – Thermal capacity, materials – Efficiency – Design of Worm Gear drives.

Gear box: Geometric progression – Standard step ratio – Ray diagram – Kinematics layout -Design of gear box –Design of multi speed gear box for machine tool & automobile applications–Gear Shifting mechanism.

Clutches: Design of Plate clutches: Single plate and Multi Plate clutches

Brakes: Design of Brakes: Block or Shoe brakes–Single, Pivoted and Double Block or Shoe brakes -Band Brakes Simple and Differential Band Brakes

Learning Resources

1. Richard G Budynas and J Keith Nisbett **"Shigley's Mechanical Engineering Design"**,Tenth Edition, Tata McGraw Hill, 2015.
2. Robert L. Norton, "**Machine Design: An Integrated Approach** ", Fifth Edition, Pearson, 2018.
3. V.B. Bhandari, **"Design of Machine Elements"**, Fourth Edition, McGraw Hill Education India Pvt. Ltd., 2017.
4. Alfred Hall, Alfred Holowenko, Herman Laughlin and S Somani, **"Schaum's Outline - Machine Design"**, McGraw Hill Education India Pvt. Ltd., 2017
5. Robert C. Juvinall and Kurt M. Marshek, **"Machine Component Design"**, Wiley India Edition, 2016.
6. Ansel C. Ugural, **"Mechanical Design of Machine Components"**, Second Edition, CRC Press, 2015
7. B. J. Hamrock, B. Jacobson and S. R. Schmid, **"Fundamentals of Machine Elements"**, Third Edition, Tata McGraw Hill Publishing Company Pvt. Ltd., New Delhi, 2014.
8. Orthwein W, "**Machine Component Design**", Jaico Publishing Co, 2010.
9. PSG College, **"Design Data: Data Book of Engineers"**, KalaikathirAchchagam, 2019
10. Joseph E Shigley and Charles R Mischke, **"Standard Handbook of Machine Design",** Third Edition, McGraw Hill Pvt. Ltd., 2004
11. K. Lingaiah, **"Machine Design Data Handbook"**, Second Edition, McGraw Hill Pvt. Ltd., 2010.
12. P Prof. K.Gopinath & Prof. M.M.Mayuram, **"Machine Design II"**, NPTEL, IIT Madras - https://nptel.ac.in/courses/112106137/
13. Prof. Martin Culpepper, **"Elements of Mechanical Design",** MITOCW, Massachusetts Institute of Technology - https://ocw.mit.edu/courses/mechanical-engineering/2-72-elements-of-mechanical-design-spring-2009/index.htm

Course Contents and Lecture Schedule

Module No.	Topics	No. of Lectures	Course Outcome
1.	**Introduction**		
1.1	Review on Friction, Metallurgy & Materials.	1	CO1
1.2	Need for Power Transmission		CO1
1.3	Types and Classification of Transmission Systems		CO1
1.4	Requirement of a Transmission Systems		CO1
1.5	Loading & Working Conditions	1	CO1
1.6	Specifications of a Transmission Element.		CO1
2.	**Flexible Elements**		
2.1	Design of Belt Drives	2	CO1
2.1.1	Types, Material and Construction		CO1
2.2	Design of Flat Belts and Pulleys		CO1
2.3	Selection of V Belts and Pulleys	1	CO1
2.4	Types of Chain Drives	1	CO1
2.5	Design of Transmission Chain and Sprockets		CO1
3.	**Parallel Axis Transmission Elements**		
3.1	Speed ratios and Number of teeth - Dynamic Effects – Fatigue Strength & Factor of Safety - Gear Materials	1	CO2
3.2	Design of Straight tooth spur gears	2	CO2
3.3	Design of Helical Gears Pressure angle in the normal and transverse plane - Equivalent number of teeth for helical gears	1	CO2
4.	**Inclined Axis Transmission Elements**		
4.1	Bevel Gears -Tooth terminology & equivalent number of teeth	1	CO3
4.2	Design of straight/spiral bevel gears	1	CO3
4.3	Worm Gears - Terminology, Thermal capacity, Materials & Efficiency	1	CO3
4.4	Design of worm gears	1	CO3
5.	**Gear Box**		
5.1	Gear Shifting Mechanism & Geometric progression	1	CO4
5.2	Standard step ratio		CO4
5.3	Ray diagram	1	CO4
5.4	Kinematics layout		CO4
5.5	Design of gear box	1	CO4
5.6	Design of Multi speed gear box for machine tool & automobile applications	2	CO4
6.	**Clutches**		
6.1	Design of Single Plate Clutch	1	CO5

6.2	Design of Multi-Plate Clutch	1	CO5
7.	**Brakes**		
7.1	Design of Block or Shoe Brakes – Single, Pivoted & Double	2	CO6
7.2	Design of Band Brakes – Simple & Differential	1	CO6
	Total No. of Hours	**24**	

Course Designers:

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2. B. Sankar bsmech@tce.edu

18ME670	HEAT TRANSFER LAB	Category	L	T	P	Credit
		PC	0	0	2	1

Preamble

The aim of practical course is to supplement theoretical knowledge of the mechanisms of heat transfer, gained from the theory course on heat and mass transfer, by conducting experiments, calculating heat transfer parameters and verifying the experimental results with the corresponding theoretical values.

Prerequisite

18ME520 – Heat and Mass Transfer

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Determine the thermal conductivity of metal rod and insulating material and specific heat capacity of air	20
CO2	Compute heat transfer through fins and its efficiency under natural and forced convection modes	15
CO3	Calculate the Biot number and heat transfer coefficient under transient heat transfer mode	15
CO4	Determine the natural and forced convection heat transfer coefficients	20
CO5	Find out the Stefan-Boltzmann constant and emissivity of a test surface.	20
CO6	Calculate the overall heat transfer coefficient and effectiveness of heat exchanger	10

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.2, 2.2.3, 3.1.2, 3.2.3 4.3.3
CO2	TPS3	Apply	Value	Mechanism	1.2, 2.2.3, 3.1.2, 3.2.3 4.3.3
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.2.3, 3.1.2, 3.2.3 4.3.3
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.2.3, 3.1.2, 3.2.3 4.3.3
CO5	TPS3	Apply	Value	Mechanism	1.2, 2.2.3, 3.1.2, 3.2.3 4.3.3
CO6	TPS3	Apply	Value	Mechanism	1.2, 2.2.3, 3.1.2, 3.2.3 4.3.3

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	S	M	L	-	_	_	_	S	S	S	M	_	_	M	_
CO2	S	M	L	-	_	_	_	S	S	S	M	_	_	M	_
CO3	S	M	L	-	_	_	_	S	S	S	M	_	_	M	_
CO4	S	M	L	-	_	_	_	S	S	S	M	_	_	M	_
CO5	S	M	L	-	_	_	_	S	S	S	M	_	_	M	_
CO6	S	M	L	-	_	_	_	S	S	S	M	_	_	M	_

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Model Examination	Terminal Examination
Remember		
Understand		
Apply	50**	100
Analyse		
Evaluate		
Create		

** Observation and Record – 30 marks and Model Test - 20 marks

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Practical Component/Observation
Perception	
Set	
Guided Response	
Mechanism	Observation and Calculation
Complex Overt Responses	
Adaptation	
Origination	

List of Experiments/Activities with CO Mapping

(Any 12 experiments is mandatory)

Sl. No.	Experiment	Course Outcome
1.	Conduction heat transfer test on metal bar apparatus	CO1
2.	Heat transfer analysis in a lagged pipe	CO1
3.	Determination of specific heat capacity of air	CO1
4.	Heat transfer performance of pin-fin in natural convection	CO2
5.	Heat transfer performance of pin-fin in forced convection	CO2
6.	Determination of Biot number for a lumped thermal capacity system	CO3
7.	Experiment on Transient heat transfer analysis	CO3
8.	Experimental study of heat transfer in fluidized bed	CO3
9.	Determination of heat transfer co-efficient in natural convection	CO4
10.	Determination of heat transfer co-efficient in forced convection	CO4
11.	Determination of Stefan - Boltzmann constant	CO5
12.	Determination of Emissivity of the given gray surface	CO5
13.	Determination LMTD and effectiveness of heat exchanger	CO6

Learning Resources

https://nptel.ac.in/courses/103/101/103101137/ by Prof. Ganesh A. Viswanathan, Chemical Engineering, IIT Bombay

Course Designers:

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18ME680	CAD CAM LAB	Category	L	T	P	Credit
		PC	0	0	2	1

Preamble

Computer Aided Design (CAD) 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. Computer Aided Manufacturing (CAM) is the use of computer system to control the machine tools and related machineries to produce the work pieces. CAM software uses geometrical design data to generate G codes and M codes that control the automated machinery.

This course provides the knowledge on development, manipulation and assembly of the 3D models using CAD and also aims to provide development/generation and execution of NC Codes.

Prerequisite

18ME450 - Production Drawing

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage in %
CO1	Develop 3D part model of the given component drawing using CAD packages.	18
CO2	Assemble the 3D parts with assembly constraints using CAD software.	16
CO3	Prepare detailed drawing of component and assembly, comprising of orthographic views, exploded view, bill of materials and tolerances.	16
CO4	Simulate the tool path by developing the CNC Turning and Milling program for the given component/drawing using CAM software	16
CO5	Simulate the tool path by generate CNC milling program from the given component/drawing using CAM software.	16
CO6	Develop a part program and execute the process for the given component for CNC Turning and Milling process.	18

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS 3	Apply	Value	Mechanism	1.3, 2.1.2, 3.2.5, 4.4.1,
CO2	TPS 3	Apply	Value	Mechanism	1.3, 2.1.2, 3.2.5, 4.4.1,
CO3	TPS 3	Apply	Value	Mechanism	1.3, 2.1.2, 3.2.5, 4.4.1,
CO4	TPS 3	Apply	Value	Mechanism	1.3, 2.1.2, 3.2.5, 4.4.1,
CO5	TPS 3	Apply	Value	Mechanism	1.3, 2.1.2, 3.2.5, 4.4.1,
CO6	TPS 3	Apply	Value	Mechanism	1.3, 2.1.2, 3.2.5, 4.4.1,

Mapping with Programme Outcomes and Programme Specific Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CO1	S	M	L	-	M	-	-	-	L	M	-	M	S	-	-
CO2	S	M	L	-	M	-	-	-	L	M	-	M	S	-	-
CO3	S	M	L	-	M	-	-	-	L	M	-	M	S	-	-
CO4	S	M	L	-	M	-	-	-	L	M	-	M	S	-	L
CO5	S	M	L	-	M	-	-	-	L	M	-	M	S	-	L
CO6	S	M	L	-	M	-	-	-	L	M	-	M	S	-	L

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Model Examination	Terminal Examination
Remember	-	-
Understand	-	-
Apply	50*	100

* Observation cum Record – 30 marks and Model Test - 20 marks

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Practical Component/Observation
Perception	
Set	
Guided Response	Observation and Record
Mechanism	Practical Component
Complex Overt Responses	
Adaptation	
Origination	

List of Experiments/Activities with CO Mapping

Module No.	List of Experiments	No. of Hours	Course Outcome
1	**Computer Aided Design**		
1.1	Demonstration on part modelling features such as extrude, revolve, sweep, blend, swept blend, helical sweep and assembly technique followed by detailed drawing.	2	CO1 CO2 and CO3
1.2	Develop 3D part model, assemble the model and prepare detailed drawing (orthographic views, exploded view, bill of materials and tolerances) of the given machine drawing (any 2 assembly - considered as 4 experiments) i. Engine Parts – Connecting rod/Piston, etc., ii. Machine Tool Parts – Square tool post/Machine vice/Lathe tail stock, etc., iii. Miscellaneous Parts – Coupling/Screw Jack/knuckle joint/ Plummer block/foot step bearing/Universal Joint/Plummer block, etc.,	8	CO1 CO2 and CO3
1.3	Develop 3D part model, assemble the model and prepare detailed drawing (orthographic views, exploded view, bill of	2	CO1 CO2 and

	materials and tolerances) of the given real time product. (1 real time model - considered as 2 experiments) i. Writing pen ii. Pet bottle iii. Computer monitor iv. Water bottle etc.,		CO3
2	**Computer Aided Manufacturing**		
2.1	Develop and simulate the tool path of CNC Turning programme with step, tapper turning, curvature and threading operation for the given component/drawing using CAM software. (1 experiment)	2	CO4
2.2	Develop and simulate the tool path of CNC Milling programme with profile milling, circular / rectangular pocketing and drilling operation for the given component/drawing using CAM software. (1 experiment)	2	CO4
2.3	Generate the NC Code and simulate the tool path of CNC milling programme for the given component/drawing using CAM software (2 experiments).	4	CO5
2.5	Develop a CNC Turning part program for the given component and execute the program (1 experiment).	2	CO6
2.6	Develop a CNC Milling part program for the given component and execute the program (1 experiment).	2	CO6
	Total	24	

Learning Resources

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.
3. Peter Smid, "CNC Programming Handbook", Industrial Press Inc., 2008.
4. NPTEL Course: Computer Aided Design and Manufacturing URL: https://nptel.ac.in/courses/112102102/#
5. NPTEL Course: Computer Aided Design and Manufacturing II URL: https://nptel.ac.in/courses/112102103/
6. NPTEL Course: Computer Numerical Control (CNC) of Machine tools and processes URL: https://nptel.ac.in/courses/112105211/

Course Designers

1. T. Prakash - tpmech@tce.edu
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18ES690	ENGINEERING DESIGN PROJECT	Category	L	T	P	Credit
		Project	1	0	4	3

Preamble

An engineer must understand the economic, social, political, sustainability and environmental contexts in which the need arises. Engineering solutions are always created in response to some societal/industrial need. Understanding the societal/industrial need is central to success in engineering design. Therefore, the engineering students have been assigned on the problem identification phase of engineering design. Now, they have an opportunity to reflect and realise the knowledge that have been gained through the courses such as 18ES150 Engineering Exploration, 18ES290 Lateral Thinking, 18ES390 Design Thinking, 18XX490 Project Management and 18ES590 System Thinking. This course will enable the students to integrate CDIO Skill-based courses and their domain-specific courses. More specifically, by employing the broad knowledge they gain from experiences in foundation elective, general elective and audit courses, students are better equipped to provide engineering solution societal and/or industrial needs.

Prerequisite

Nil

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage in %
CO1	Execute different phases of engineering design project including functional composition and design specification in a team.	20
CO2	Evaluate the alternate engineering design approaches as per the performance criteria with design verification and validation.	20
CO3	Evaluate a design with the use of test verification matrix / Design Failure Mode Effect Analysis (DFMEA)/ Usability testing	15
CO4	Explain the significance of Intellectual Property rights and the procedure for searching and filing a patent.	15
CO5	Exhibit team work with appropriate conflict management strategies.	10
CO6	Prepare appropriate design documents and deliver effective technical presentations	10

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1.1, 3.1.2, 3.2.3, 3.2.6, 4.1.2
CO2	TPS5	Evaluate	Organise	Adaptation	1.1, 1.2, 2.1.2, 2.5.1, 2.5.2, 3.1.2, 3.2.3, 3.2.6, 4.1.2
CO3	TPS5	Evaluate	Organise	Adaptation	1.1, 1.2, 2.1.3, 3.1.2, 3.2.3, 3.2.6, 4.1.2, 4.3.1
CO4	TPS2	Understand	Respond	Guided Response	1.1, 1.2, 2.1.4, 3.1.2, 3.2.3, 3.2.6, 4.1.2, 4.4.1
CO5	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1.5, 3.1.2, 3.2.3, 3.2.6, 4.1.2, 4.4.1
CO6	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1.4, 3.1.2, 3.2.3, 3.2.6, 4.1.2, 4.4.1

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	S	M	L	-	-	M	M	M	S	S	S	S
CO2	S	S	S	M	-	M	M	M	S	S	S	S
CO3	S	S	S	M	S	M	M	S	S	S	S	S
CO4	M	L	-	-	-	M	M	-	-	-	-	S
CO5	S	M	L	-	-	M	M	S	S	S	M	S
CO6	S	M	L	-	-	-	-	S	S	S	-	S

S- Strong; M-Medium; L-Low

Assessment Pattern:

Phases	Deliverables	Marks	Course Outcomes
Continuous Assessment			
Review 1 – Engineering Design Project Selection, functional decomposition and Specification	Technical Report	10	CO1, C06
Review 2 – Evaluation of Design Approaches	Technical Report	20	CO2, CO5, CO6
Review 3 – Design Verification and validation	Technical Report	20	CO3, CO4, CO6
End-Semester Examination			
Demonstration	Prototype	60	CO1, CO2, CO3, CO4 CO5, CO6
Design Portfolio Presentation	Portfolio Document	40	

- Reports are to be submitted at each review. The report and presentation will be evaluated based on customized Rubrics for periodic reviews.
- Demonstration and Design Portfolio presentation will be evaluated by two faculty members nominated by their respective Head of the Department.

Syllabus

Project Selection – Search Phase, Preliminary Design Review (PDR) and Critical Design Review (CDR), Project Specification, Proposal Report, Proposal Presentation

Engineering Design Process - The NASA Design Approach, Design Verification and Validation ,Design Verification Plan – DFMEA, test verification matrix, Usability testing, DRIDS-V Design Approach and Plan

Intellectual Property Rights – Trademarks, Copyrights and Patents, Types of patents, Searching patents, Filing Patents

Team formation and Communication – Types of teams, Team Conflict Management – common causes, cultural styles and conflict, Project Team Evaluation, Conducting Meetings and Making Presentations

Learning Resources

- Harvey F. Hoffman, "The Engineering Capstone Course: Fundamentals for Students and Engineers", Springer, 2014
- https://sharepoint.ecn.purdue.edu/epics/teams/Public%20Documents/EPICS_Design_Process.pdf?_ga=2.252800138.2089889711.1612784342-1089955741.1612784342

Course Contents and Lecture Schedule

Module No	Topic	No. of Lectures	Course Outcome
1	**Project Selection**		
	Search Phase, Preliminary Design Review (PDR) and Critical Design Review (CDR), Project Specification,	2	CO1, CO6

	Proposal Report, Proposal Presentation		
2	**Engineering Design Process**		
2.1	The NASA Design Approach	1	CO2
2.2	Design Verification and Validation	1	CO2
2.3	Design Verification Plan – DFMEA, test verification matrix, Usability testing,	2	CO3
2.4	DRIDS-V Design Approach and Plan	1	CO3
3	**Intellectual Property Rights**		
3.1	Trademarks, Copyrights and Patents,	1	CO4
3.2	Types of patents, Searching patents,.	1	CO4
3.3	Filing Patents	1	CO4
4	**Team formation and Communication**		
4.1	Types of teams, Team Conflict Management – common causes, cultural styles and conflict,	1	CO5
4.2	Project Team Evaluation, Conducting Meetings and Making Presentations	1	CO5, CO6
	Total	**12**	

Course Designers:

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- Dr. S.Saravana Perumaal sspmech@tce.edu
- Dr.C.Jeyamala jeyamala@tce.edu

18ME710	INDUSTRIAL ENGINEERING

Category	L	T	P	Credit
PC	3			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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Describe the theory in industrial engineering and their applications.	15
CO2	Evaluate the work methods through work measurement.	20
CO3	Develop Occupational Safety environment through Ergonomics	15
CO4	Identify the suitable forecasting techniques for given applications.	15
CO5	Prepare the charts, diagrams and production plan.	20
CO6	Explain the Industrial legislation in Indian Perspective.	15

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.1, 1.2, 2.5.1, 2.5.2, 4.1.1, 4.2.1
CO2	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.4.5, 4.6.5
CO3	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.4.5, 4.6.5
CO4	TPS4	Analyse	Organise	Complex Overt Responses	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.4.5, 4.6.5
CO5	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.4.5, 4.6.5
CO6	TPS2	Understand	Respond	Guided Response	1.1, 1.2, 2.5.1, 2.5.2, 4.1.1, 4.2.1

Mapping with Programme Outcomes and Programme Specific 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	PSO 1	PSO 2	PSO 3
CO1 (Understand)	M	L			M	M	S	M	M	M	L	M	-	-	-
CO2 (Apply)	S	M	L		S	M	M	M	M	L	M	M	-	-	M
CO3 (Apply)	S	M	L		S	S	M	M	M	M	L	M	M	-	M
CO4 (Analyze)	S	S	M	L	M	M	M	M	M	L	L	M	-	-	-
CO5 (Apply)	S	M	L		M	L	L	M	M	L	L	M	-	-	-
CO6 (Understand)	M	L			M	M	S	S	M	M	M	M	-	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels		Continuous Assessment Tests			Assignment			Terminal Examination
		1	2	3	1	2	3	
Remember		**20**	**20**	**20**				**20**
Understand		**40**	**40**	**40**	**20**	**20**	**20**	**40**
Apply		**40**	**40**	**30**	**80**	**60**	**60**	**30**
Analyse		**0**	**0**	**10**		**20**	**20**	**10**
Evaluate		**0**	**0**	**0**				**0**
Create		**0**	**0**	**0**				**0**

Assessment Pattern: Psychomotor

Psychomotor Skill	Mini-project /Assignment/Practical Component
Perception	
Set	
Guided Response	Assignment
Mechanism	Assignment
Complex Overt Responses	
Adaptation	
Origination	

Sample Questions for Course Outcome Assessment

Course Outcome 1 (CO1):

4. Describe about types of Productivity.
5. Explain about Job analysis.
6. Explain about Value stream Mapping

Course Outcome 2 (CO2):

1. 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. 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. .
3. 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 3 (CO3):

1. Compute the REBA score for the given Figure related to trolley design using the REBA Evaluation Chart
2. Compute the postural score using RUBA Analysis for the given Figure.
3. Discuss about the Biomechanics and its three orders which is required for the Ergonomic considerations

.

Course Outcome 4 (CO4):

1. Explain the choice of good forecasting technique for stated problem.
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. Plot the demand as histogram. Determine the production rate required to meet the avg. demand and plot the avg. demand forecast on the graph.

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

Course Outcome 5 (CO5):

1. The Forecast for a group of items manufactured in a firm is shown below

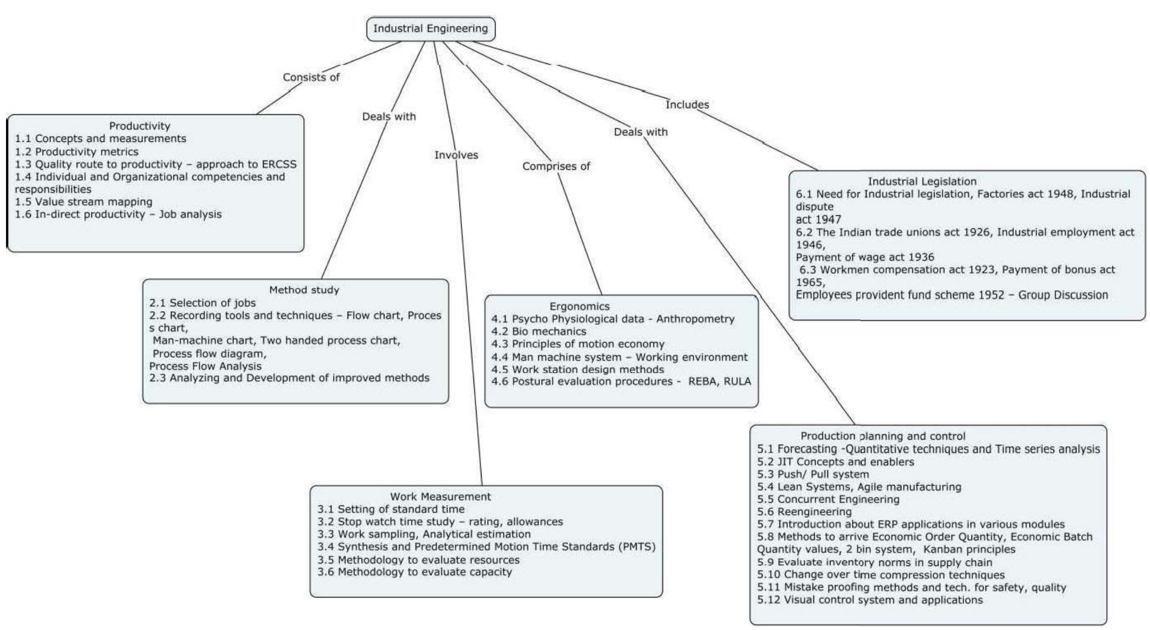
Quarter	1	2	3	4	5	6	7	8
Demand	370	320	570	670	550	370	350	480

   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 item on inventory and Rs. 125 per unit if subcontracted. Compare the cost incurred if the following pure strategies are followed: Varying the workforce size, Changing inventory levels.
2. Determine the EOQ for M/s. APJ & Co., has an annual usage of 10,000 units of materials whose cost is Rs.250 per unit. The cost of order is Rs.6 per order and the expenditure cost is Rs.4 per order. The inventory holding cost is 20% of avg. inventory. Assume that no shortage allowed. Also find the total annual cost, cycle time, no. of orders and Max. inventory
3. Determine the EOQ for M/s. XY has an annual usage of 1000 units of materials whose cost is Rs.250 per unit. The cost of order is Rs.6 per order and the expenditure cost is Rs.4 per order. The inventory holding cost is 20% of avg. inventory. Assume that no shortage allowed. Also find the total annual cost.

Course Outcome6(CO6):

1. Explain the need of Industrial legislation
2. Describe purpose of Group discussion
3. List the benefits Employees provident fund scheme

Concept Map



Syllabus

Productivity: concepts and measurements. Productivity metrics – Quality route to productivity - approach to Eliminate-Reduce-Combine-Simplify-Standardize (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.

Ergonomics: Psycho physiological data - Anthropometry, Bio mechanics - information displays - Principles of motion economy - Man machine system – Working environment – Work station design methods, Postural evaluation procedures - REBA,RULA.

Production planning and control: Forecasting - Quantitative techniques and time series analysis, JIT concepts and enablers, Push/ Pull systems. Lean Systems, Agile manufacturing, Concurrent Engineering, Reengineering, Introduction about ERP applications in various modules, Methods to arrive economic Batch Quantity ,economic order quantity values, 2 bin system, 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.

Learning Resources

1. Chase R.B, Nicholas J. Aquilano, F.and Jacobs R, "**Production and Operations Management: Manufacturing and Services**, Irwin/McGraw-Hill, 2010.
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.
4. Samuel Eilon, "**Elements of Production Planning and Control**", Universal Publishing Corporation, Bombay, 2014.
5. Panneerselvam R, "**Production and Operations Management**", PHI, New Delhi, 3rd Edition, 2012.

6. Khanna, O.P, "**Industrial Engineering and Management** ", Dhanpat Rai and Sons, 2008.
7. Ergonomics: https://nptel.ac.in/content/storage2/MP4/107103085/mod01lec01.mp4
8. Production planning: https://nptel.ac.in/courses/112102106/

Course Contents and Lecture Schedule

No.	Topics	No.of Lectures	Course Outcome
1.0	**Productivity**		CO 1
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**		CO 2
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	CO 2
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	
4.0	**Ergonomics**		
4.1	Psycho Physiological data - Anthropometry	1	CO 3
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	Postural evaluation procedures - REBA, RULA	1	
5.0	**Production planning and control**		
5.1	Forecasting -Quantitative techniques and Time series analysis	1	CO 4
5.2	JIT Concepts and enablers	1	
5.3	Push/ Pull system	1	
5.4	Lean Systems, Agile manufacturing	1	
5.5	Concurrent Engineering	1	
5.6	Reengineering	1	
5.7	Introduction about ERP applications in various modules	1	
5.8	Methods to arrive Economic Order Quantity, Economic Batch Quantity values, 2 bin system, Kanban principles	1	
5.9	Evaluate inventory norms in supply chain	1	
5.10	Change over time compression techniques	1	
5.11	Mistake proofing methods and tech. for safety, quality	1	
5.12	Visual control system and applications	1	
6.0	**Industrial Legislation**		
6.1	Need for Industrial legislation, Factories act 1948, Industrial dispute act 1947	1	CO 6
6.2	The Indian trade unions act 1926, Industrial employment act 1946, Payment of wage act 1936	1	
6.3	Workmen compensation act 1923, Payment of bonus act 1965, Employees provident fund scheme 1952 – Group Discussion	1	
	Total	**36**	

Course Designers:

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18ME770	FINITE ELEMENT ANALYSIS	Category	L	T	P	Credit
		PC	2	0	2	3

Preamble

Finite Element Analysis (FEA) is the simulation of any given physical phenomenon using the numerical technique called Finite Element Method (FEM). Engineers have used FEA to reduce the number of physical prototypes and experiments and optimize components in their design phase to develop better products. FEA gives an approximate solution of the problem and it is a numerical method used for the prediction of how a part or assembly behaves under given conditions. 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

- Engineering Mechanics
- Mechanics of Materials
- Fourier Series and Numerical Methods

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage In %
CO1	Solve the physical problem using functional approximation method like weighted residual method & Variational methods.	10
CO2	Explain the fundamental concepts of theory of Elasticity.	10
CO3	Solve for one dimensional structural and thermal problems using FEM.	20
CO4	Solve the two dimensional structural and thermal problems using FEM.	20
CO5	Formulate the shape function and stiffness matrix for two dimensional Iso Parametric and Higher Order Elements	10
CO6	Perform computer Simulation for Linear, Nonlinear static Structural, Modal, Steady state, Transient Thermal analysis using FEA Software.	30

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.2, 1.3, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.3.1, 2.3.2, 2.4.3, 2.4.4, 2.4.6, 3.2.3, 3.2.4, 3.2.5, 4.3.1, 4.3.2, 4.3.3, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6, 4.5.3, 4.5.5
CO2	TPS2	Understand	Response	Guided Response	1.2, 1.3, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.3.1, 2.3.2, 2.4.3, 2.4.4, 2.4.6, 3.2.3, 3.2.4, 3.2.5, 4.3.1, 4.3.2, 4.3.3, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6, 4.5.3, 4.5.5
CO3	TPS4	Apply	Value	Mechanism	1.2, 1.3, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.3.1, 2.3.2, 2.4.3, 2.4.4, 2.4.6, 3.2.3, 3.2.4, 3.2.5, 4.3.1, 4.3.2, 4.3.3, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6, 4.5.3, 4.5.5
CO4	TPS4	Analyse	Organise	Complex Overt Responses	1.2, 1.3, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.3.1, 2.3.2, 2.4.3, 2.4.4, 2.4.6, 3.2.3, 3.2.4, 3.2.5, 4.3.1, 4.3.2, 4.3.3, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6, 4.5.3, 4.5.5
CO5	TPS3	Apply	Value	Mechanism	1.2, 1.3, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.3.1, 2.3.2, 2.4.3, 2.4.4, 2.4.6, 3.2.3, 3.2.4, 3.2.5, 4.3.1, 4.3.2, 4.3.3, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6, 4.5.3, 4.5.5
CO6	TPS3	Analyze	Organize	Complex Overt Responses	1.2, 1.3, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.3.1, 2.3.2, 2.4.3, 2.4.4, 2.4.6, 3.2.3, 3.2.4, 3.2.5, 4.3.1, 4.3.2, 4.3.3, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6, 4.5.3, 4.5.5

Mapping with Programme Outcomes and Programme Specific 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	PSO 1	PSO 2	PSO 3
CO1.	S	M	L	L	S	M	M	M	L	L	-	-	M	-	S
CO2.	M	L	M	L	S	M	M	M	L	L	-	-	M	-	S
CO3.	S	M	L	L	S	M	M	M	L	L	-	-	M	-	S
CO4.	S	S	M	L	S	M	M	M	L	L	-	-	M	-	S

CO5.	**S**	**M**	**L**	**L**	**S**	**M**	**M**	**M**	**L**	**L**	**-**	**-**	**M**	**-**	**S**
CO6.	**S**	**S**	**M**	**L**	**S**	**M**	**M**	**M**	**L**	**L**	**-**	**-**	**M**	**-**	**S**

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain (Theory Component 70 Marks)

Cognitive Levels	Internal Examination (20 marks)				Terminal Examination (50 marks)
	Continuous Assessment Tests (15 marks)			FEA Programming Assignment (5 marks)	
	1	2	3		
Remember	0	0	0	0	0
Understand	20	10	10	0	10
Apply	80	50	40	0	70
Analyse	0	30	50	0	20
Evaluate	0	0	0	100	0
Create	0	0	0	0	0

FEA Programming Assignment: This is a group assignment and each group may consist of 2 or 3 students. The students will do a FEA programming Assignment wherein the students are expected to,

- Identify a structural, thermal and dynamic application where all the input data related to the loads, power, material are selected.
- Apply the concept of Finite Element Method to solve the problem theoretically.
- Create an executable FEA program using MATLAB or Python or C or Visual Studio or any other programming languages that the students are comfortable with.
- Analyse the problem using the developed program by varying the input data and various boundary conditions.
- Evaluate the different scenario using the program by varying the meshing and the element type.
- A final technical report has to be submitted summarizing all the work done.

Assessment Pattern: Cognitive Domain (Practical Component 30 Marks)

Cognitive Levels	Internal Examination (30 marks)	
	Continuous Assessment (10 marks)	Model Examination (20 marks)

Remember	0	0
Understand	0	0
Apply	0	0
Analyse	90	100
Evaluate	10	0
Create	0	0

Assessment Pattern: Psychomotor

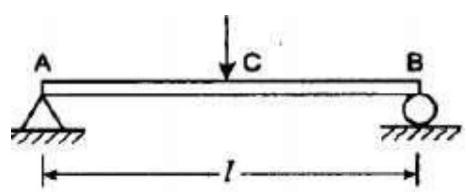
Psychomotor Skill	Mini Project/ Assignment/ Practical
Perception, Set	-
Guided Response	-
Mechanism	-
Complex Overt Responses	Practical
Adaptation	FEA Programming Assignment
Origination	-

Sample Questions for Course Outcome Assessment

COURSE OUTCOME 1 (CO1):

4. 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=a1sin(πx/l) + a2sin(3πx/l).

5. 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.



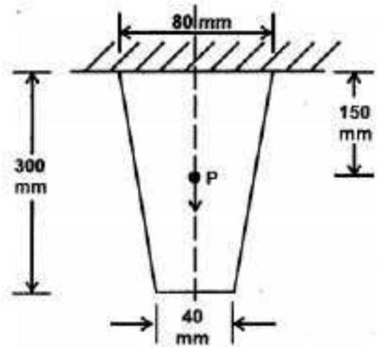
6. 3) The following differential equation is available for a physical phenomenon. d2y/dx2 + 50 = 0, 0<x<10.The trial function is, y=ax(10-x)The boundary conditions are y(0)=0 and y(10)=0,Find the value of the parameter 'a' by (i) Point collocation method (ii) Sub-domain collocation method (iii) Least squares method (iv) Galerkin's method

COURSE OUTCOME 2 (CO2):

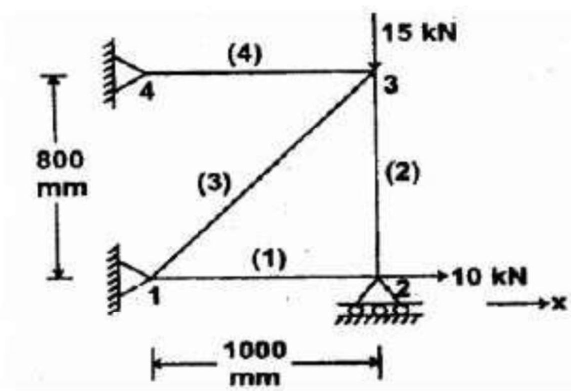
1. Distinguish between plane stress, plane strain and axisymmetric analysis in solid mechanics
2. List out the various elasticity equations.
3. Illustrate the Stress-Strain relationship matrix for an axisymmetric triangular element

COURSE OUTCOME 3 (CO3):

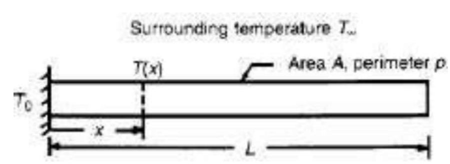
4. For a tapered bar of uniform thickness t=10mm as shown in figure. Find the displacements at the nodes by forming into two element model. The bar has a mass density ρ = 7800 Kg/m3, the young's modulus E = 2x105 MN/m2. In addition to self - weight, the bar is subjected to a point load P= 1 KN at its centre. Also determine the reaction forces at the support.



5. Consider a 4-bar truss as shown in figure. It is given that E = 200 GPa and A= 500 mm2 for the elements. Determine (a) Nodal displacements (b) Support reactions (c) Element stresses.

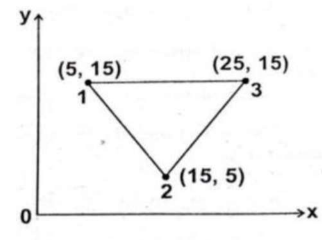


6. Find the distribution of temperature in the one-dimensional fin shown in Figure Assume the following data: h - 10 W/cm2 K, k - 70 W/cm K, T_∞. = 40°C, T_o =140 °C and L = 5 cm, and the cross section of fin is circular with a radius of 1 cm.

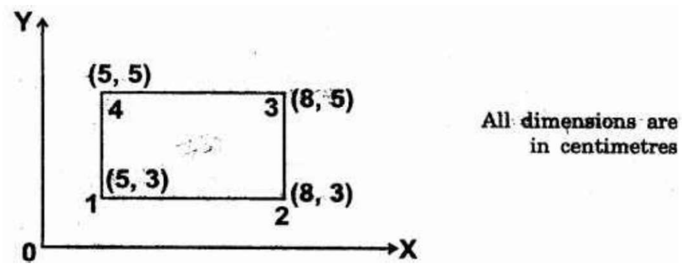


COURSE OUTCOME 4 (CO4):

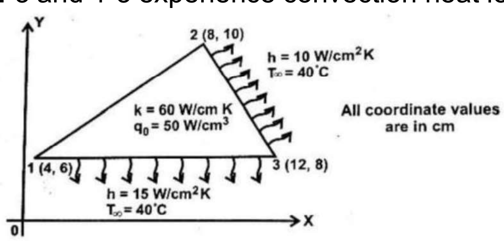
1) The plane strain elements as shown in figure. The nodal displacements are u_1=0.005mm, u_2=0.0mm,u_3=0.005mm,v_1=0.002mm,v_2=0.0mm,v_3=0.0mm. Find the element stresses σ_x,σ_y,τ_{xy}. Assume E=70GPa and μ=0.3 use unit thickness for plane strain. All dimensions are in millimetres.



2) 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°C and T_4= 46°C. Also determine the three points on the 50°C contour line.

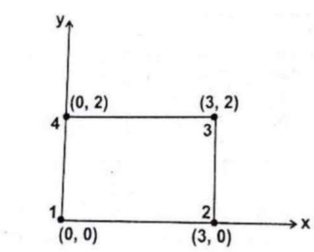


3) Compute the element matrices and vectors for the element shown in figure. When the edges 2-3 and 1-3 experience convection heat loss.



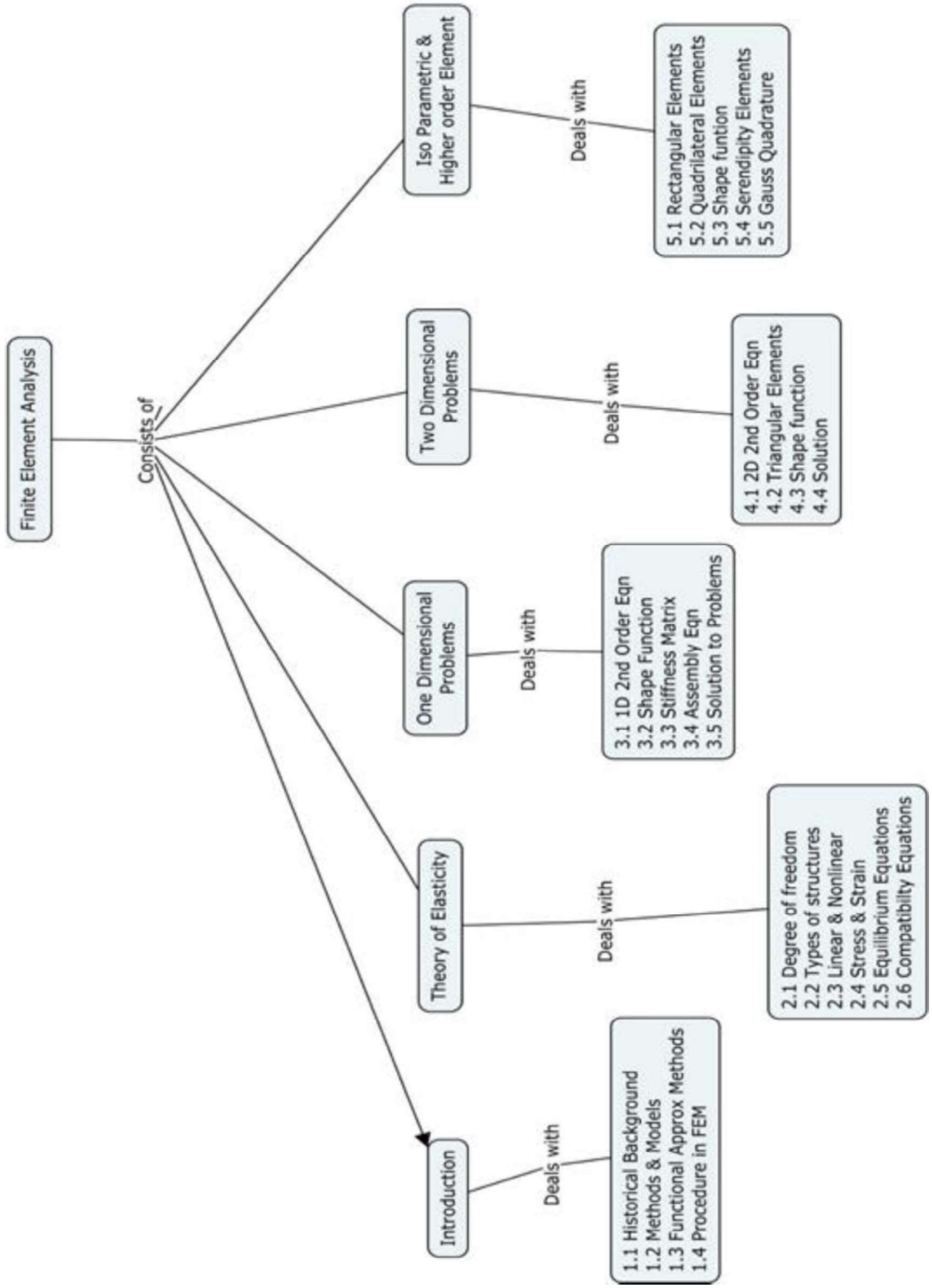
COURSE OUTCOME 5 (CO5):

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, $I = \int_{-1}^{1} \cos \pi x/2 \, dx$ by applying 3 point gaussian quadrature and compare with exact solution.

Concept Map


Finite Element Analysis
Consists of
Iso Parametric & Higher order Element
Deals with
5.1 Rectangular Elements
5.2 Quadrilateral Elements
5.3 Shape funtion
5.4 Serendipity Elements
5.5 Gauss Quadrature
Two Dimensional Problems
Deals with
4.1 2D 2nd Order Eqn
4.2 Triangular Elements
4.3 Shape function
4.4 Solution
One Dimensional Problems
Deals with
3.1 1D 2nd Order Eqn
3.2 Shape Function
3.3 Stiffness Matrix
3.4 Assembly Eqn
3.5 Solution to Problems
Theory of Elasticity
Deals with
2.1 Degree of freedom
2.2 Types of structures
2.3 Linear & Nonlinear
2.4 Stress & Strain
2.5 Equilibrium Equations
2.6 Compatibility Equations
Introduction
Deals with
1.1 Historical Background
1.2 Methods & Models
1.3 Functional Approx Methods
1.4 Procedure in FEM

Syllabus

Introduction: Historical Background – Methods for Engineering Analysis – Introduction to Numerical Methods – Mathematical Modelling of field problems in Engineering – Governing Equations – Boundary, Initial and Eigen Value problems – Functional Approximation methods Weighted Residual Methods – Variational Formulation of Boundary Value Problems – Rayleigh Ritz Technique – Procedure involved in Finite Element Method – Types – Coordinate Systems – Meshing – Error Estimates – Adaptive Refinement – Advantages & Applications of FEM.

Theory of Elasticity: Degrees of Freedom – Rigid Body Motion – Discrete and Continuum structures – Material Properties – Linear and Non-linear Analysis – Stiffness & Flexibility – Principle of Minimum Potential Energy – Stress & Strain – Notation & Components – Strain Displacement Relation – Stress Strain Relation – Plane Stress – Plane Strain - Axisymmetric – Compatibility Equations – Equilibrium Equations – Governing Differential Equations for Thermal problem.

One Dimensional Problems: One Dimensional Second Order Equations – Discretization – Element types – Derivation of Shape functions and Stiffness matrices and force vectors using FEM – Assembly of Matrices – Solution of problems from solid mechanics and heat transfer in one dimension.

Two Dimensional Problems: Second Order 2D Equations – Variational formulation – Finite Element formulation for Triangular elements (CST & LST) – Shape functions and element matrices and vectors – Plane stress, plane strain and axisymmetric problems – Body forces and temperature effects – Stress calculations – Application to Field Problems in Structural and Thermal domain using 2D triangular elements.

Iso Parametric & Higher Order Elements: Rectangular Elements – Quadrilateral Elements – Natural co-ordinate systems – Isoparametric elements – Shape functions for iso parametric elements – Formulation of stress strain & strain displacement relation for Iso parametric Elements – Jacobian Matrix – Serendipity elements – Numerical integration using Gaussian Quadrature – Matrix solution techniques.

List of Experiments/Activities with CO Mapping

S. No.	List of Experiments	Software Used	CO
1.	Introduction to Finite Element Analysis and Simulations - 6 hours	-	-
	Linear Static Structural Analysis (Any 3)	**ANSYS APDL& FEAST**	CO6
2.	• Stepped Bar		
3.	• Truss		
4.	• Different Beams with Point Load, UDL & UVL		
5.	• Discontinuities in a bar		
6.	• Buckling of Columns		
	Steady State & Transient Thermal Analysis (Any 2)	**ANSYS APDL & FEAST**	CO6
7.	• Fins subjected to Conduction & Convection		
8.	• Composite Body subjected to Conduction & Convection		

9.	• Radiation between bodies		
10.	• Heat Exchanger		
	Dynamic Analysis (Any 2)	**ANSYS APDL & FEAST**	CO6
11.	• Modal Frequency Analysis		
12.	• Harmonic Frequency Response Analysis		
13.	• Random Response Analysis		
14.	• Transient Response Analysis		
	Non-Linear Structural Analysis (Any 1)	**ANSYS Workbench**	CO6
15.	• Contact Analysis in Gears /Cam & Follower/ Bearings/ Joints & Couplings		
16.	• Analysis of bodies with material Nonlinearities		
	Transient Structural & Fatigue Analysis (Any 1)	**ANSYS Workbench**	CO6
17.	• Multibody structural Analysis of Mechanical systems		
18.	• Beams with fluctuating loads		
	Application Building, Development & Evaluation	**ANSYS Workbench & COMSOL**	CO6
19.	• Creating an Application		

Learning Resources

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.
3. Tirupathi R. Chandrupatla, Ashok D. Belagundu, “**Introduction to Finite Elements in Engineering**”, Third Edition, Reprint, Prentice Hall, 2012.
4. 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.
5. O. C. Zienkiewicz and R. L. Taylor, “**The Finite Element Method: Volume 1 The Basis**”, 5th Edition, Butterworth-Heinemann, Oxford. Reprint 2011.
6. Daryl L. Logan A, **“First Course in the Finite Element Method**”, Fourth Edition, Cengage Learning, 2007.
7. K. J. Bathe, “**Finite Element Procedures**”, Second Edition, Prentice-Hall Inc., Englewood Cliffs, New Jersey, Reprint 2012.
8. Nitin S Gokhale, Sanjay S Deshpande, Sanjeev V Bedekar, Anand N Thite, **“Practical Finite Element Analysis”**, Finite to Infinite Publications, India, 2018
9. A J Davies, **“The Finite Element Method: An Introduction with Partial Differential Equations”**, Oxford Press, Second Edition, 2011
10. George R Buchanan, **“Schaum’s outline on Finite Element Analysis”,** Schaum’s outline series, 1995.
11. G Lakshmi Narasaiah, **“Finite Element Analysis”**, BS Publications, 2008
12. I M Smith, D V Griffiths, **“Programming the Finite Element Method”,** John Wiley & Sons, Ltd, Fourth Edition, 2004.
13. David V Hutton, **“Fundamentals of Finite Element Analysis”,** McGraw Hill Publications, 2004
14. Zhuming Bi, **“Finite Element Analysis, Applications: A Systematic & Practical Approach”,** Elsevier Academic Press, 2018

Course Contents and Lecture Schedule

Module No.	Topics	No. of Lectures	Course outcome
1.	**Introduction**		
1.1	Historical Background -Methods of Engineering Analysis-Numerical Methods	1	CO1
1.2	Mathematical modelling of field problems in Engineering - Governing Equations - Boundary, Initial and Eigen Value Problems		CO1
1.3	Weighted Residual Methods -Variational Formulation of BVP.	1	CO1
1.4	Rayleigh Ritz Technique	1	CO1
1.5	Procedure Involved in FEM – Types, Coordinate Systems, Meshing	1	CO1
1.6	Error Estimates, Adaptive Refinement, Advantages & Applications of FEM		CO1
2.	**Theory of Elasticity**		
2.1	Degree of freedom, Rigid body motion, Discrete and Continuum Structures	1	CO2
2.2	Material Properties, Linear and Nonlinear Analysis		CO2
2.3	Stiffness & Flexibility		CO2
2.4	Principle of Minimum potential energy	1	CO2
2.5	Stress & Strain in 1D – Notation and Components		CO2
2.6	Strain Displacement relation		CO2
2.7	Stress Strain Relation	1	CO2
2.8	Plane Stress, Plane Strain and Axisymmetric		CO2
2.9	Compatibility and Equilibrium Equations for Structural Problems, Governing Differential Equations of Thermal Problem	1	CO2
2.	**One Dimensional Problems**		
2.1	1D Second Order Equations - Discretization, Element Types	1	CO3
2.2	Derivation of shape functions and stiffness matrices and force vectors using FEM	1	CO3
2.3	Assembly of element Matrices	1	CO3
2.4	Solution of Problems from Solid Mechanics	1	CO3
2.5	Solution of problems from heat transfer in One Dimensio1	2	CO3
4.	**Two Dimensional Problems**		
4.1	2D Second Order Equations - Variational Formulation	1	CO4
4.2	Constant triangle Triangular elements – Linear strain triangle elements	1	-
4.3	Shape function, element matrices	1	CO4
4.4	Plane stress, plane strain and axisymmetric problems	1	CO4
4.5	Body forces and temperature effects – Stress calculations		CO4
4.6	Application to Field Problems in Structural and Thermal domain using 2D triangular elements.	2	CO4

5.	**Iso Parametric & Higher Order Elements**		
5.1	Rectangular Elements -Quadrilateral Elements	1	CO5
5.2	Natural co-ordinate systems		CO5
5.3	Isoparametric elements -Shape functions for iso parametric elements	1	CO5
5.4	Formulation of stress strain & strain displacement relation for Iso parametric Elements	2	CO5
5.5	Serendipity elements	1	CO5
5.6	Numerical integration using Gaussian Quadrature -Matrix solution techniques.		CO5
	Total No. of Hours	**25**	

Course Designers:

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18MEPA0	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/Disassembly (DFA/D) provides systematic procedures and guidelines for evaluating and improving the product design for both manufacture and assembly economically. This course intends to provide a learning experience in reviewing design of components for ease of assembly, developing feasible assembly sequences and evaluating assembly systems.

Prerequisite

- Metal Joining Processes and Manufacturing Practices
- Production Drawing
- Manufacturing Systems and Automation

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage in %
CO1	Implement dimensional and geometrical tolerances for the given assembly/part to meet its specified functional requirement.	20
CO2	Recommend design modifications on the given component for ease of assembly/disassembly using design guidelines.	20
CO3	Determine feasible assembly sequences for the given set of parts using the Liaison sequence diagram and precedence constraints.	20
CO4	Determine the performance measures such as cycle time, production rate, utilization and cost involved in single-model, batch-model and mixed model manual assembly lines.	20
CO5	Determine the performance measures of single-stage and two-stage automated assembly line under the availability of buffer	20
*CO6**	*Explain the technological advancements in assembly line of future manufacturing industries*	*10**
*CO7**	*Develop CAD model of an assembly with its assembly sequence*	*10**

* COs are assessed through report preparation and practical component as assignments in continuous assessment and are not evaluated in terminal examination.

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.3, 2.1.3, 3.2.3, 3.2.5, 4.4.1
CO2	TPS3	Apply	Value	Mechanism	1.3, 2.1.3, 3.2.3, 3.2.5, 4.4.3

CO3	TPS3	Apply	Value	Mechanism	1.3, 2.1.3, 3.2.3, 3.2.5, 4.4.1
CO4	TPS3	Apply	Value	Mechanism	1.3, 2.1.3, 3.2.3, 3.2.5, 4.4.1
CO5	TPS3	Apply	Value	Mechanism	1.3, 2.1.3, 3.2.3, 3.2.5, 4.4.1
CO6	TPS2	Understand	Respond	Guided Response	1.3, 2.1.3, 3.2.3, 4.3.1
CO7	TPS3	Apply	Value	Mechanism	1.3, 2.1.2, 3.2.3, 3.2.5, 4.4.2

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	S	M	L										S		
CO2	S	M	L										S		
CO3	S	M	L										S		
CO4	S	M	L										S		
CO5	S	M	L										S		
CO6	M	L													
CO7	S	M	L		S								S		

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	10	10	10	-	-	-	-
Understand	30	30	30	-	-	-	25
Apply	60	60	60	100	100	100	75
Analyse							
Evaluate							
Create							

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	
Set	
Guided Response	
Mechanism	Assignments: • Review Report on Technological Advancement in Assembly • CAD modelling of an assembly and simulation of assembly sequences
Complex Overt Responses	
Adaptation	
Origination	

Sample Questions for Course Outcome Assessment

Course Outcome 1(CO1):

1. A 30mm diameter hole is made on a turret lathe to the limits, 30.035 and 30.00. The following two 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.

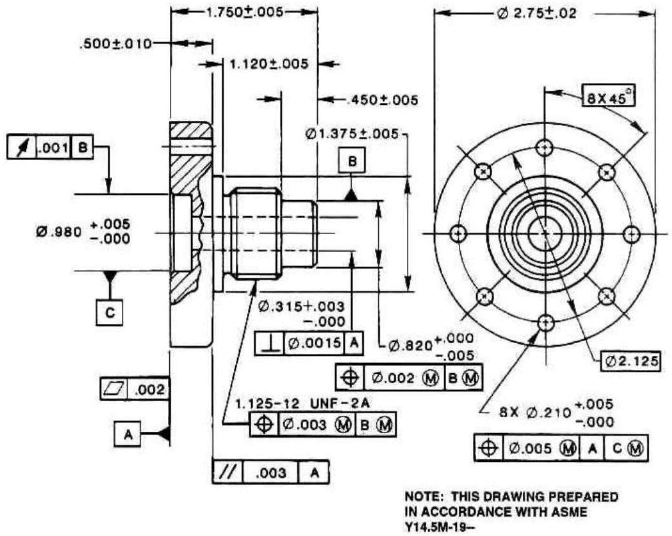


Figure 1

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.

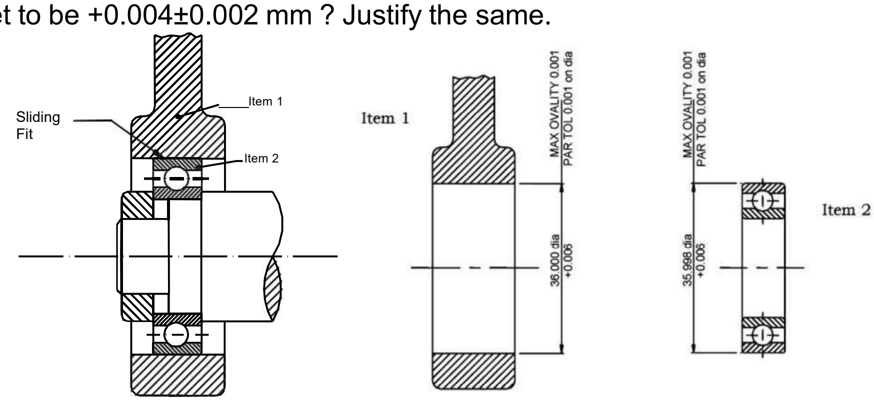


Figure 2

Course Outcome 2 (CO2):

1. Suggest and justify the suitable modifications on the design of the following components as shown in figure 3 to ensure proper assembly with minimum effort.

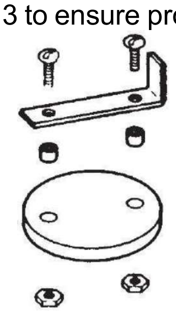


Figure 3

2. The controller assembly as in figure 4 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.

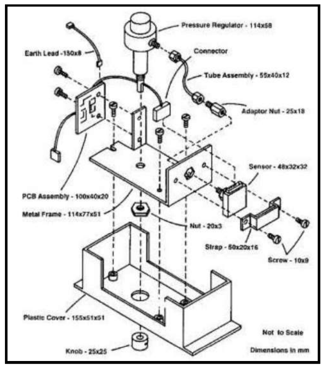


Figure 4

Course Outcome 3 (CO3):

1. Prepare an assembly sequence for the following exploded view of assembly as given in figure 3.

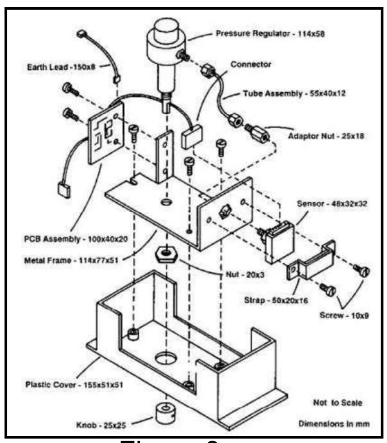
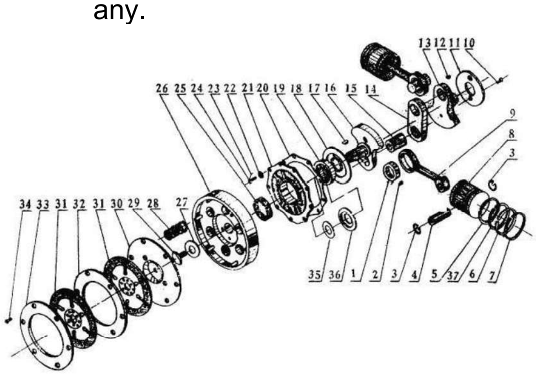


Figure 3

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
1	Retainer	2
2	CJ750 Rollers	24
3	Piston pin circlip or clasp SV	4
	Piston pin circlip OHV	
4	Piston pin SV	2
	Piston pin OHV	
5	OHV oil seal piston ring +0.00	2
	SV Oil seal piston ring +0.00	2
	SV oil seal piston ring +0.25	2
	SV Oil seal piston ring +0.50	2
	SV Oil seal piston ring +0.75	
	SV Oil seal piston ring +1.00	2
	SV Oil seal piston ring +1.25	
6	OHV air seal pistin ring +0.00	
	SV Air seal piston ring +0.00	2
	SV Air seal piston ring +0.25	1
	SV Air seal piston ring +0.50	1
	SV Air seal piston ring +0.75	1
	SV Air seal piston ring +1.0	1
	SV Air seal piston ring +1.25	2
7	OHV air seal piston ring +0.00	
	SV Air seal piston ring +0.00	
	SV Air seal piston ring +0.25	
	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	

Part #	CJ 750 Parts name	Qty
9	Link rod copper insert SV	1
	Link rod copper insert OHV	1
10	Screw	1
11	Front oil slinger	1
12	Crank shaft front part key	1
13	Crank shaft front part	1
14	Crank cheek	9
15	Crank pin	1
16	Crank shaft rear part	9
17	Crank shaft rear part key	1
18	Rear oil slinger	1
19	Bearing	1
20	Washer	6
21	Rear bearing fitting body	1
22	Washer	1
23	Fuse	
24	Screw	
25	Sealing leather cup and spring	
26	Flywheel combination	
27	Lock wafer	
28	Clutch spring	
29	Crank shaft rear screw	
30	Platen	

Part #	CJ 750 Parts name	Qty
31	Friction wafer	4
32	Drive wafer	4
33	Supporting plate	1
34	Screw	1
35	Washer	1
36	Rear oil proof disc	1
37	SV Oil seal piston ring +0.00	1
	OHV oil seal piston ring +0.00	1
	SV oil seal piston ring +0.25	
	SV oil seal piston ring +0.50	1
	SV oil seal piston ring +0.75	
	SV oil seal piston ring +1.0	
	SV oil seal piston ring +1.25	1
3-8	Piston, pins, rings and clips	
37	combination	
1-2		
9	Crank shaft combination	
13-16		
1-2		
18	Crank shaft combination w/oil	
9-11	proof key	
13-16		

Figure 4

3. Suggest 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.

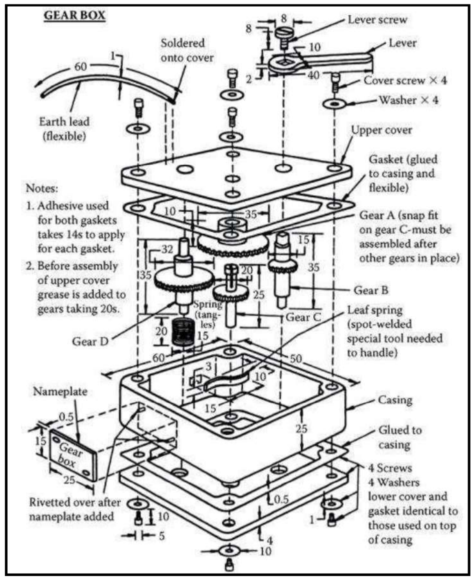


Figure 5

Course Outcome 4 (CO4):

1. 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

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.

Course Outcome 5 (CO5):

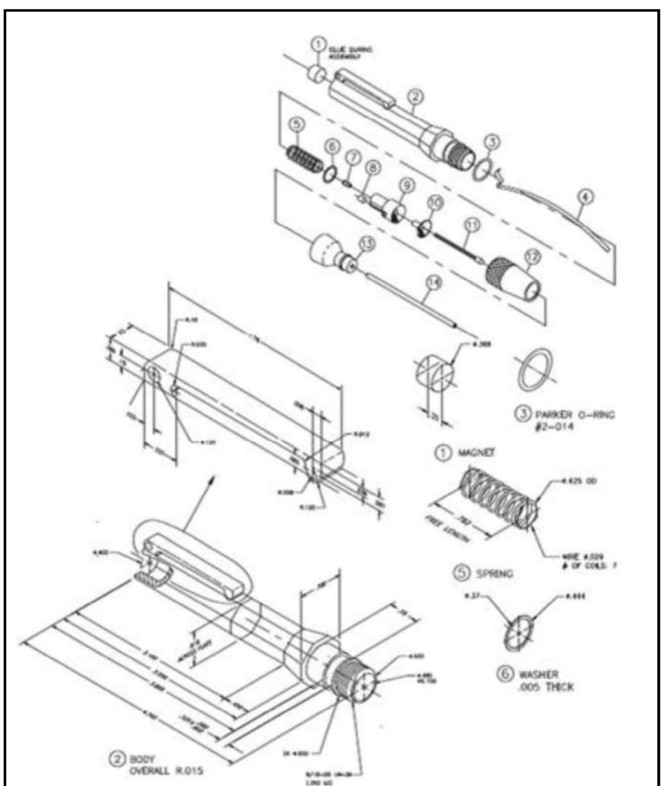
1. In the operation of a 10-station transfer line, the ideal cycle time is 1.08 min. Line stops occur due to random mechanical and electrical failures once every 28 cycles on average. When a line stop occurs, average downtime is 6.0 min. In addition to these downtimes, the tools at each workstation on the line must be changed every 100 cycles, which takes a total of 12.0 min for all ten stations. Determine (a) average hourly production rate, (b) line efficiency, and (c) proportion downtime.
2. A 30-station transfer line has an ideal cycle time of 0.75 min, an average downtime of 6.0 min per line stop occurrence, and a station failure frequency of 0.01 for all stations. A proposal has been submitted to locate a storage buffer between stations 15 and 16 to improve line efficiency. Determine (a) the current line efficiency and production rate, and (b) the maximum possible line efficiency and production rate that would result from installing the storage buffer.
3. A 20-station transfer line is divided into two stages of 10 stations each. The ideal cycle time of each stage is Tc=1.2 min. All the stations in the line have the same probability of stopping, p=0.005. The downtime is assumed constant when a breakdown occurs, Td=8.0 min. Compute the line efficiency for the following buffer capacities: (a) b=0, (b)b=∞, (c) b=10, and (d) b = 100.

Course Outcome 6(CO6):

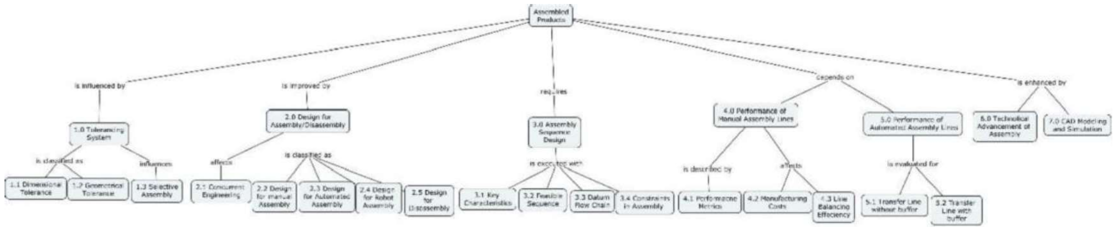
1. Write the review report on technological advancement in networked assembly systems.
2. Critique on "How technology changing assembly workstations and its workforce".

Course Outcome 6 (CO6):

1. Prepare a CAD for the assembly shown in figure 9 and simulate its sequence of assembly.



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.

Design for Assembly/Disassembly (DFA/D): Concurrent Engineering - Role of Design for Manufacture and Assembly- Need and applications - 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 Robot assembly: types of robot assembly system - design rules – Case studies.

Design for Disassembly: Guidelines – Product recovery approach – Repair, refurbishing, remanufacturing, cannibalization and recycling.

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.

Performance of manual assembly line: Cycle Time and Production Rate - Determination of production capacity and utilization, manufacturing lead time, Work-in-progress. Manufacturing Costs – fixed cost, variable cost – Cost of direct labour, material and overhead. Cost of equipment usage, cost of manufactured part.

Analysis of single-model assembly lines – Cycle time and workload analysis – Repositioning losses - Determination of line balancing efficiency – Time-distance relationship – Manning level – Considerations in assembly line design. Performance of batch-model and mixed-model assembly lines.

Performance of automated assembly line: System configurations of automated assembly lines – Storage buffers - Analysis of transfer lines – cycle time, down time, production rate, line efficiency, cost per piece, cost of material, cost per minute to operate the line. Analysis of transfer line with storage buffer - storage buffer effectiveness. Analysis of two-stage transfer line with storage buffer.

Technological Advancement in assembly:

Report Preparation on Technological Advancement in assembly for the specified topics like Industry 4.0 – The future of manufacturing: The Connected Assembly Line – Case study

(Students' engagement time is approximately 3 hours outside the class session)

Practical Component: CAD Modeling of an assembly

The students will develop CAD model of an assembly of products of daily life like fan, tubelight fittings, pen. They will prepare report on the process of development and sequencing of the same. Exploded views and simulation of part motions representing the assembly sequence using CAD packages such as Creo, Solidworks.

(Students' engagement time is approximately 6 hours outside the class session)

Learning Resources

12. Daniel E Whitney, "Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development", Oxford University Press, 2009.
13. Mikell P. Groover, "Automation, Production Systems, and Computer-Integrated Manufacturing", 4th Edition, Pearson India Education Services Pvt. Ltd., 2016.
14. Alex Krulikowski, "Fundamentals of Geometric Dimensioning and Tolerancing", Third Edition, Cengage Learning, 2012.

15. Geoffrey Boothroyd, Peter Dewhurst, Winston A Knight, "Product Design for Manufacture and Assembly", Third Edition, CRC Press, 2010.
16. 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/
17. 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 Hours	Course Outcome
1.	**Tolerancing System:**		
1.1	Importance - Dimensional and geometric tolerances - Process capability - surface finish	1	
1.2	Fit of an assembly - Cumulative effect of tolerances.	1	
1.3	Datum systems: Degrees of freedom.	1	
1.4	True position theory: Virtual size concept - Projected tolerance zone	1	CO1
1.5	Selective Assembly: Interchangeable part manufacture and selective assembly	1	
1.5.1	Deciding the number of groups - Group tolerances of mating parts equal - Total and group tolerances of shaft equal	1	
2.	**Design for Assembly/Disassembly (DFA/D):**		
2.1	Concurrent Engineering - Role of Design for Manufacture and Assembly- Need and applications	1	
2.1.1	General guidelines of Design for Assembly	2	
2.2	Design for manual assembly: guidelines for part handling, insertion and fastening		
2.2.1	Effect of symmetry, part thickness and size and weight on handling time and on grasping and manipulation -	1	
2.2.2	Effect of chamfer design on insertion operations	1	CO2
2.3	Design for automated assembly: effect of feed rate on cost – high speed automatic insertion	1	
2.4	Design for Robot assembly: types of robot assembly system - design rules	1	
2.5	Design for Disassembly: Guidelines – Product recovery approach – Repair, refurbishing, remanufacturing, cannibalization and recycling.	1	
3.	**Assembly Sequence Design**		
3.1	Key Characteristics (KC) – Flow down of KC – Ideal KC process – KC Conflicts.	1	
3.2	Assembly Sequence Design Process: Methods for finding feasible sequences	1	
3.3	Liaison diagram – Governing Rule – Generating the feasible sequences- Cutset method.	2	
3.4	Datum Flow Chain: Nominal Design – Variation Design – Assumptions – Role of assembly features.	1	CO3
3.5	Constraints in Assembly: Completely constrained assemblies – Partially constrained assemblies - Assembly precedence constraints.	1	
3.6	Design Procedure for assemblies.	1	
4.	**Performance of manual assembly lines:**		
4.1	Performance Metrics: Cycle Time and Production Rate	1	CO4
4.1.1	Determination of production capacity and utilization,	2	

Module No.	Topic	No. of Hours	Course Outcome
	manufacturing lead time, Work-in-progress.		
4.2	Manufacturing Costs – fixed cost, variable cost – Cost of direct labour, material and overhead. Cost of equipment usage, cost of the manufactured part.	2	
4.3	Analysis of single-model assembly lines – Determination of line balancing efficiency.	2	
4.3.1	Tutorial: Problems on manual assembly line	1	
5.	**Performance of automated assembly lines:**		
5.1	System configurations of automated assembly lines – Storage buffers	1	CO5
5.2	Analysis of transfer lines – cycle time, down time, production rate, line efficiency, cost per piece, cost of material, cost per minute to operate the line.	2	
5.2.1	Tutorial: Problems in transfer line without buffer	1	
5.3	Analysis of transfer line with storage buffer -storage buffer effectiveness.	2	
5.4	Analysis of two-stage transfer line with storage buffer	1	
5.4.1	Tutorial: Problems in transfer line with storage buffer	1	
6.	***Technological advancement in assembly***		
6.1	*Industry 4.0 – The future of manufacturing: The Connected Assembly Line – Case study*	*1*	CO6
7	***Practical Component: CAD Model of products of daily life***		
7.1	*CAD model of an assembly of products of daily life like pen, fan, tubelight fittings. and sequencing of the same. Exploded views and simulation of part motions representing the assembly sequence using CAD packages.*	*1*	CO7
		37	

Course Designers:

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18MEPB0	AUTOMOTIVE ENGINE SYSTEM

Category	L	T	P	Credit
PE	3	0	0	3

Preamble

This course deals with functions and features to design sub systems of an engine. It also involveswith performance and emission characteristics of different engines and fuels.

Prerequisite

18ME440 Fluid Mechanics
18ME520 Heat and Mass Transfer

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Explain the engine power train system and make conceptual layout.	10
CO2	Discuss the requirement of cooling and lubrication systems in an IC engine	10
CO3	Explore the process of air and fuel induction	25
CO4	Examine the in-cylinder fluid motion and combustion	25
CO5	Ascertain the emission trends, controlling techniques and norms for two and three wheeler application	10
CO6	Determine various engine performance and emission characteristics	20

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.2, 2.1.3, 3.2, 4.3.2
CO2	TPS2	Understand	Respond	Guided Response	1.2, 2.1.3, 3.2, 4.3.2
CO3	TPS3	Apply	Respond	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO5	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO6	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	M	L	-	-	-	-	-	S	M	M	-	-	-	S	-
CO2	M	L	-	-	-	-	-	S	M	M	-	-	-	S	-
CO3	S	M	L	-	-	-	-	S	M	M	-	-	-	M	-
CO4	S	M	L	-	-	-	-	S	M	M	-	-	-	M	-
CO5	S	S	M	L	-	-	-	S	M	M	-	-	-	M	-
CO6	S	S	S	M	-	-	-	S	M	M	-	-	-	M	-

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	10	10	10	-	-	-	10

Understand	50	30	30	-	-	-	30
Apply	40	60	60	100	100	100	60
Analyse							
Evaluate							
Create							

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	
Set	
Guided Response	
Mechanism	Assignment
Complex Overt Responses	
Adaptation	
Origination	

Sample Questions for Course Outcome Assessment**

** (2 to 3 at the cognitive level of course outcome)

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

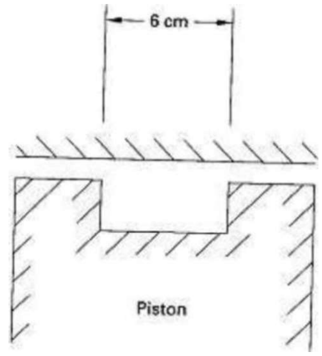
Course Outcome 3(CO3):

1. 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. 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

Course Outcome 4 (CO4):

1. 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



2. 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.
3. A 6.8- liter, in-line, eight-cylinder CI engine has a compression ratio 18.5 and a crevice volume equal to 3% of the clearance volume. During the engine cycle pressure in the crevice volume equals combustion chamber pressure while remaining at the cylinder wall temperature of 190°C. Cylinder conditions at the start of compression are 75°C and 120 kPa, and peak pressure is 11000 kPa. Cut off ratio is 2.3. Calculate: (a) Crevice volume of one cylinder (ii) percent of air fuel mixture in the crevice volume at the end of compression. (iii) Percent of air-fuel mixture in the crevice volume at the end of combustion.

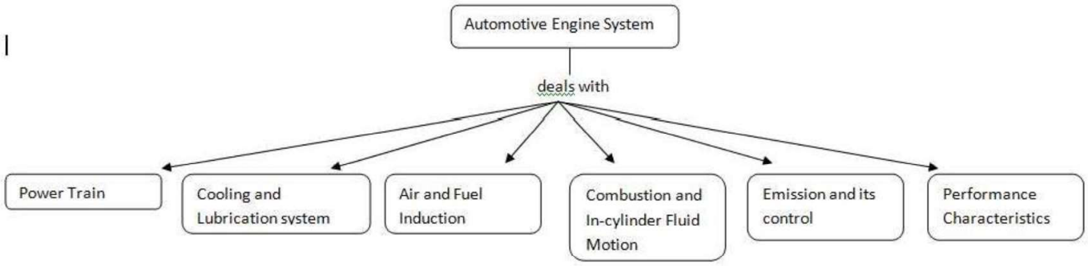
Course Outcome 5 (CO5):

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 6 (CO6):

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.
Air and Fuel Induction – Intake manifold-Volumetric efficiency-Intake valves-Fuel injectors-Carburettors-Supercharging and Turbocharging-Startified Charge Engines and Dual Fuel Engines.
In-cylinder Fluid motion and Combustion – Turbulence-Swirl-Squish and Tumble-Divided Combustion chambers-Crevice flow and blow by-Combustion in SI engines-Combustion in CI engines- Abnormal Combustion.
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, Chemical reactions involved in after treatment- Emission norms (Indian, European, US emission norms, Emission testing and certification), Fuel Norms, Environmental effects of Emissions.
Performance characteristics and Automotive sensors – Engine parameters- Work, Mean effective pressure, Torque and Power, Specific fuel consumption, performance maps Engine efficiencies, Sensors and devices used for performance and emission measurements.

Learning Resources

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.
3. Heywood J.B., **"Internal Combustion Engine Fundamentals"**, McGraw-Hill International Edition, Reprint 2012.
4. Richard Stone, **"Introduction to Combustion Engines"** 3rd Edition, Society of Automotive Engineers, Inc. 1999.
5. http://nptel.ac.in/courses/112104033/1
6. http://nptel.ac.in/courses/112104033/9
7. http://www.iitg.ernet.in/scifac/qip/public_html/cd_cell/chapters/uk_saha_internal_com bustion_engine/qip-ice-06-valve%20timing%20diagrams.pdf

Course Contents and Lecture Schedule

Module No.	Topic	No. of Hours	Course Outcome
1	**Engine power train**		
1.1	Power train and its types	1	CO1
1.2	Engine (SI and CI), Engine and its subsystems	1	CO1
1.3	Combustion chamber and its types,	1	CO1
1.4	Valve train layout & Crank train layout	1	CO1
1.5	valve timing and timing chain layout,	1	CO1
1.6	piston and piston rings, gaskets	1	CO1
1.7	importance of B/S and L/r, crank offset	1	CO1
2	**Cooling and Lubrication system**		
2.1	Energy balance and cooling load estimation, types of cooling	1	CO2

	system.		
2.2	Typical operating temperatures of engine parts, Cooling system design (Air cooled and water cooled),	1	CO2
2.3	Schematic layout of Cooling system for a two wheeler engine,.	1	CO2
2.4	Lubrication requirements of engine, Functions of Lubricating oil, Parts to be lubricated and not to be lubricated,	1	CO2
2.5	Schematic layout of lubricating system, oil filtering, Engine friction, Lubricating oils and its types and properties	1	CO2
3	**Air and Fuel Induction**		
3.1	Intake manifold, Intake valves.	1	CO3
3.2	Volumetric efficiency of SI Engines	2	CO3
3.3	Fuel injectors	1	CO3
3.4	Carburettors	1	CO3
3.5	Supercharging and Turbo charging -	1	CO3
3.6	Stratified Charge Engines and Dual Fuel Engines	1	CO3
3.7	Intake for CI engines	1	CO3
4	**In-cylinder Fluid motion and Combustion**		
4.1	Turbulence-Swirl-Squish and Tumble	1	CO4
4.2	Divided Combustion chambers	1	CO4
4.3	Crevice flow and blow by	1	CO4
4.4	Combustion in SI engines	2	CO4
4.5	Combustion in CI engines	2	CO4
4.6	Abnormal Combustion	1	CO4
5	**Emission and its Control**		
5.1	Chemistry of combustion, Stoichiometric equations of combustion.	1	CO5
5.2	Emission relation with AFR - combustion chamber design – temperature - fuel (include load /speed)	1	CO5
5.3	Alternate fuels (performance, emission and practical issues).	1	CO5
5.4	After treatment devices (include SAI, 2WC), Chemical reactions involved in after treatment-	1	CO5
5.5	Emission norms (Indian, European, US emission norms, Emission testing and certification), Fuel Norms (BS1, BS2), Environmental effects of Emissions	1	CO5
6	**Performance characteristics and Automotive sensors**		
6.1	Engine parameters- Work, Mean effective pressure	2	CO6
6.2	Torque and Power, Specific fuel consumption, Engine efficiencies	2	CO6
6.3	Sensors and devices used for performance and emission measurements	1	CO6
	Total Hours	**37**	

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18MEPCO	COMPUTATIONAL FLUID DYNAMICS	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

Computational Fluid Dynamics (CFD) course provides an introduction to the use of computational techniques to analyze the fluid flow and heat transfer in engineering problems of practical interest. The conservative laws are applied as governing equations to model and simulate problems involving diffusion, convection and convection-diffusion with different boundary conditions using finite difference method and finite volume method. The course also gives the opportunity to learn and compare various numerical models and simulation techniques for turbulent flow and combustion process.

Prerequisite

18ME340 Thermal Engineering
18ME440 Fluid Mechanics
18ME310 Fourier Series and Numerical Methods

CourseOutcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Explain the different computational techniques and solution procedures for various heat and fluid flow problems.	18
CO2	Determine the numerical solution for steady diffusion problem using finite difference method.	18
CO3	Analyse one dimensional unsteady diffusion using finite difference method.	18
CO4	Determine the numerical solution for one, two and three dimensional diffusion problems using finite volume method.	18
CO5	Analyse one dimensional convection-diffusion using finite volume method.	18
CO6	Explain the concepts, advantages and limitations of various turbulence models and combustion models.	10

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.1.1, 1.2, 2.1.1,2.1.2, 2.1.3, 3.2, 3.3.1,4.1.1, 4.1.2, 4.3.2,4.3.3
CO2	TPS3	Apply	Value	Mechanism	1.1.1, 1.2, 2.1.1,2.1.2,2.1.3, 3.2, 3.3.1, 4.1.1, 4.1.2, 4.3.2,4.3.3,4.5.5
CO3	TPS4	Analyze	Value	Mechanism	1.1.1, 1.2, 2.1, 3.2, 3.3.1, 4.1.1, 4.1.2, 4.3.2,4.3.3, 4.5.5
CO4	TPS3	Apply	Value	Mechanism	1.1.1, 1.2, 2.1.1,2.1.2,2.1.3, 3.2, 3.3.1 4.1.1, 4.1.2, 4.3.2,4.3.3, 4.5.5
CO5	TPS3	Analyse	Value	Mechanism	1.1.1, 1.2, 2.1, 3.2, 3.3.1, 4.1.1, 4.1.2, 4.3.2,4.3.3, 4.5.5
CO6	TPS2	Understand	Respond	Guided Response	1.1.1, 1.2, 2.1.1,2.1.2, 2.1.3, 3.2, 3.3.1, 4.1.1, 4.1.2, 4.3.2,4.3.3

Mapping with ProgrammeOutcomes

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			S		M				L	
CO2.	S	M	L		M			S		M				M	
CO3.	S	S	M	L	M			S		M				S	
CO4.	S	M	L		M			S		M				M	
CO5	S	S	M	L	M			S		M				S	
CO6.	M	L			M			S		M				L	

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	20	20	20	-	-	-	10
Understand	40	40	40			50	40
Apply	40	30	30	100	100	50	30
Analyse		10	10				20
Evaluate							
Create							

Assessment Pattern: Psychomotor

Psychomotor Skill	Mini project / Assignment / Practical Component
Perception	
Set	
Guided Response	Assignment
Mechanism	Assignment
Complex Overt Responses	
Adaptation	
Origination	

Course Level Assessment Questions

Course Outcome 1(CO1):

1. Derive the momentum equations for two dimensional laminar fluid flow in Cartesian co-ordinate system.
2. Write the governing equations for a heat and fluid flow problem.
3. Explain the types of partial differential equations.

Course Outcome 2 (CO2):

1. 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 ^{o}C, T_{inf}=25^{o}C. Also, calculate the relative heat transfer and fin efficiencies. Verify the numerical results with analytical solution.
2. Describe the finite difference method formulation for solving steady state diffusion problems.
3. Solve $\frac{\partial^2 u}{\partial x^2} = 0$in a computational domain of x = 0 to x=1 using five equal divisions, when u(0) = 1 and u(1) = 0.

Course Outcome 3 (CO3):

1. A large diameter steel cylindrical rod of 120 mm long having a thermal diffusivity (α) of 56.25×10^{-6} m^2/s is initially at 30° C. One end of the rod is maintained at 80° C and the other end is at 180 ° 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.
2. Analyse the effect of thermal diffusivity on cooling rate in the above problem.

3. Explain explicit and implicit scheme of solving a transient diffusion problem.

Course Outcome 4(CO4):

1. 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 °C, with the other three sides maintained at 200 °C. Use five nodes in each side of theplate.
2. Describe the finite volume method formulation for solving a steady state diffusion problem.
3. Define mass flux

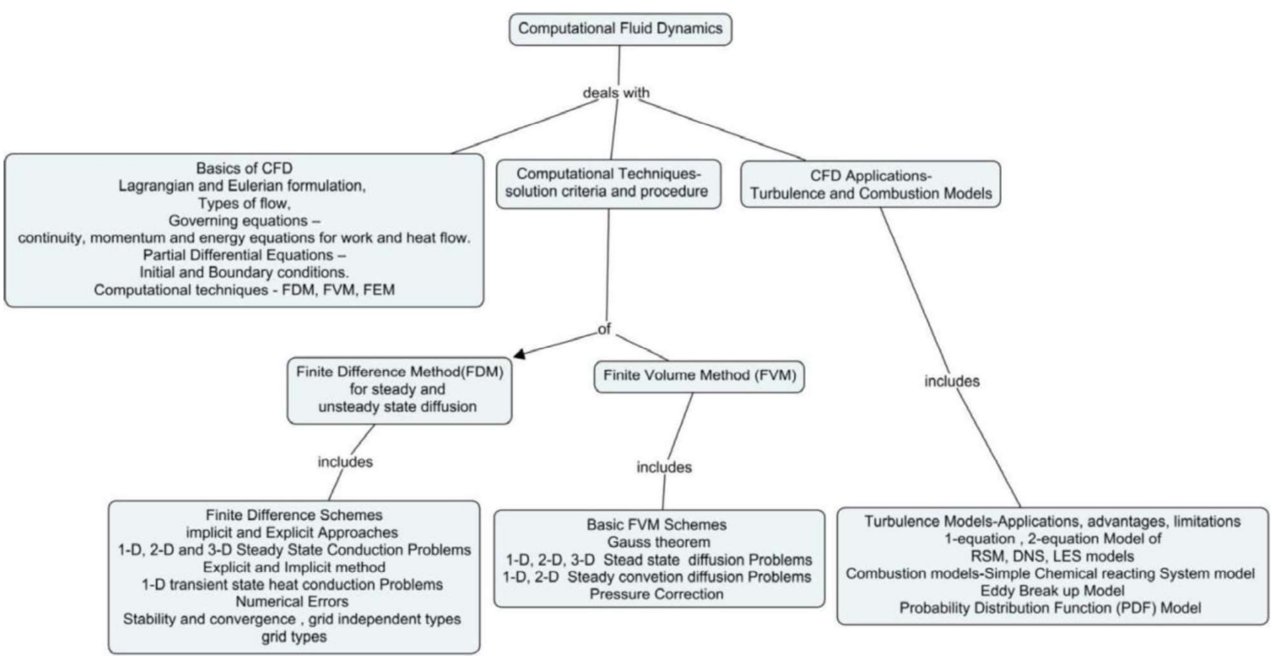
Course Outcome 5 (CO5):

1. 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 ϕ=0 at x = 1. Using five equally spaced cells and central differencing scheme, calculate the distribution of ϕ in the computationaldomain. Take u = 0.12 m/s; ρ = 1.0 kg/m3, and Γ=0.1 kg/m.s.
2. Describe the SIMPLEAlgorithm.
3. Define Peclet number

Course Outcome 6 (CO6):

1. Explain k-ε turbulencemodel.
2. Discuss the advantages and limitations of DNS model
3. Describe eddy break–up model for simulating combustionsystem

Concept Map



Syllabus

BasicsofCFD : Overview of CFD–Definition, stages, applications. Fluid Flow -Continuum hypothesis, Lagrangian and Eulerian formulation, continuity and momentum equations for fluid flow in differential and integral forms. Energy equation for work and heat flow. Partial Differential Equations -Initial and Boundary conditions. Computational Techniques: Definition and advantages Finite difference, Finite volume and Finite element.

Finite Difference Method for Steady State Diffusion Problem: Finite difference schemes-forward, central and backward difference, properties of discretization schemes. FDM for steady state diffusion - one-dimensional(1-D), two dimensional (2-D) and three dimensional (3-D) steady state conduction problems, **Finite Difference Method for Un-Steady State Diffusion Problem**: Explicit and Implicit method, FDM for 1-D transient heat conduction problems, Numerical errors - solution criteria-stability and convergence, grid independent test, types of grid.

Finite Volume Method for Steady State Diffusion Problem: Basics of Finite volume schemes -Control volume, Fluxes, Gauss-Divergence Theorem, Finite Volume formulation for 1-D, 2-D and 3-DDiffusion problems. **Finite Volume Method for Steady Convection-Diffusion Problem:** 1-D and 2-D steady convection- diffusion –Peclet number - SIMPLE Algorithm, pressure correction equation, Staggered gird.

CFD Applications: Introduction, Turbulence models– Concepts, Applications, advantages, limitations - One equation, two equations models of RSM, DNS, LES. Combustion models - Applications, advantages, limitations -Simple chemical reacting system model, Eddy break–up model and probability distribution function model.

Learning Resources

1. Muralidhar, K., and Sundararajan, T., "**Computational Fluid Flow and Heat Transfer**", Narosa Publishing House, New Delhi, 2009.
2. Versteeg H.K., "**An Introduction to Computational Fluid Dynamics, The Finite Volume Method**", Pearson; 2 edition, 2008.
3. Anderson, Jr., John D.., "**Computational fluid Mechanics the Basics with Applications**" McGraw Hill Education, 2012.
4. Oleg Zikanov, **Essential Computational Fluid Dynamics** Wiley India Pvt Ltd, 2012.
5. Fletcher, C.A.J. "**Computational Techniques for Fluid Dynamics 1 (Fundamental and General Techniques)**", Springer –Verlag, 2005.
6. Gautam Biswas and Somenath Mukherjee "**Computational FluidDynamics**" Narosa Publishing House, 2013.
7. John F Wendt **" Computational Fluid Dynamics"** Springer, 2012.
8. https://nptel.ac.in/courses/112105045/ -Computational Fluid Dynamics by Professor Suman Chakravarty, IIT Kharagpur
9. https://nptel.ac.in/courses/112107079/ - Computational Fluid Dynamics by Professor Krishna M. Singh, IIT Madras
10. https://nptel.ac.in/courses/112104272/ - Turbulent Combustion Theory and Modeling by Professor Asok De, IIT Kharagpur

Course Contents and Lecture Schedule

No.	Topic	No. hours	CO's
1.0	**Basics of CFD**		
1.1	Overview of CFD	1	CO1
1.2	Definition and stages		CO1
1.3	Applications	1	CO1
1.4	Fluid Flow		CO1
1.4.1	Continuum hypothesis	1	CO1
1.4.2	Lagrangian and Eulerian formulation	1	CO1
1.4.3	Continuity and momentum equations for fluid flow in differential and integral forms	2	CO1
1.5	Energy equation for work and heat flow	1	CO1
1.6	Partial Differential Equations	1	CO1
1.7	Initial and Boundary conditions		CO1
1.8	Computational Techniques – Definition and advantages - finite difference, finite volume, finite element Methods	1	CO1
2.0	**Finite Difference Method for Steady State Diffusion Problem**		
2.1	Finite difference schemes – forward , central and backward difference	2	CO2
2.2	Properties of discretization schemes	1	CO2
2.3	FDM for Steady state diffusion – one-dimensional (1-D),Two dimensional (2-D), Three dimensional (3-D)conduction Problems	3	CO2
No.	**Topic**	**No. hours**	**CO's**
3.0	**Finite Difference Method for Un-Steady State Diffusion Problem**		
3.1	Explicit and Implicit method	1	CO3
3.2	FDM for One dimensional transient state heat conduction problems	2	CO3
3.3	Numerical errors	1	CO3
3.4	solution criteria – stability and convergence, grid independent test, types of grid	2	CO3
4.0	**Finite Volume Method for Steady State Diffusion Problem**		
4.1	Basics of Finite volume schemes – control volume, fluxes,	1	CO4
4.2	Gauss Divergence Theorem	1	CO4
4.3	Finite Volume formulation – 1-D steady,2-D and 3-D steady state heat transfer	3	
5.0	**Finite Volume Method for Steady State Convection-Diffusion Problem**		CO4
5.1	1-D and 2-D steady Convection – Diffusion	2	CO5
5.2	Peclet number	1	CO5
5.3	SIMPLE Algorithm, pressure correction equation, Staggered gird	2	CO5
6.0	**CFD Applications**		

6.1	Introduction, Concepts of different models, Applications.	1	CO6
6.2	**Turbulence model**		CO6
6.2.1	Advantages and Limitations of One equation and two equations models of RSM	1	CO6
6.2.2	Advantages and Limitations of DNS, LES	1	CO6
6.3	**Combustion model**		CO6
6.3.1	Advantages and Limitations of Simple chemical reacting system model	1	CO6
6.3.2	Advantages and Limitations of Eddy break–up model	1	CO6
6.3.3	Advantages and Limitations of Probability Distribution Function model.		CO6
	Total	**36**	

Course Designers:

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18MEPD0	DESIGN FOR SHEET METAL MANUFACTURING	CATEGORY	L	T	P	CREDIT
		PE	2	1	0	3

Preamble

Sheet metal is one of the most versatile material in the manufacturing industry. It is made from steel, aluminium, brass, copper, tin, nickel, titanium and precious metals. And its uses expand across many different industries including transportation, aerospace, domestic appliances, consumer electronics, industrial furniture, farm equipment, body panels for modern vehicles, machinery, metal sinks, beverage cans and more. Sheet metal can be shaped in many different ways to meet many different requirements. The technology uses a variety of materials and a wide range of processes for shaping finished components and products. Sheet metal manufacturing produces parts that typically have high strength, good surface and accurate tolerances. This course covers the various sheet metal processes and provides essential basic theoretical knowledge required for designing sheet metal parts.

Prerequisite

- Nil

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage in %
C01	Explain the working principles of different presses, various sheet metal cutting operations of pressing processes, basics of shearing process and types of cutting press tools.	20
CO2	Perform design calculations for cutting force, stripping force, cutting clearance, strip layout with optimum stock utilization and selection of press for a given part.	15
CO3	Design a blanking press tool and piercing press tool with bill of materials for a given part.	20
CO4	Explain the various sheet metal non-cutting operations of pressing processes and types of non-cutting press tools.	10
CO5	Perform design calculations for bending force, blank development, drawing force, blank size, number of draws and selection of press for a given part.	15
CO6	Design a drawing press tool with bill of materials for a given part.	20

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	

CO1	TPS2	Understand	Respond	Guided Response	1.1, 1.2, 3.3.1
CO2	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1.3, 2.1.5, 3.3.1, 4.3.2, 4.4.1, 4.4.2, 4.4.3, 4.4.4
CO3	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1.3, 2.1.5, 3.3.1, 4.3.2, 4.4.1, 4.4.2, 4.4.3, 4.4.4
CO4	TPS2	Understand	Respond	Guided Response	1.1, 1.2, 3.3.1
CO5	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1.3, 2.1.5, 3.3.1, 4.3.2, 4.4.1, 4.4.2, 4.4.3, 4.4.4
CO6	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1.3, 2.1.5, 3.3.1, 4.3.2, 4.4.1, 4.4.2, 4.4.3, 4.4.4

Mapping with Programme Outcomes and Programme Specific Outcomes:

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO1 1	PO1 2	PS O1	PS O2	PS O3
CO1.	M	L	--	--	--	--	--	--	--	--	--	--	--	--	--
CO2.	S	M	L	--	--	--	--	--	L	--	--	--	S	--	--
CO3.	S	M	L	--	--	--	--	--	L	L	--	--	S	--	M
CO4.	M	L	--	--	--	--	--	--	--	--	--	--	--	--	--
CO5.	S	M	L	--	--	--	--	--	L	--	--	--	S	--	--
CO6.	S	M	L	--	--	--	--	--	L	L	--	--	S	--	M

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests (40 Marks)			Assignments (10 Marks)			Terminal Examination (50 Marks)
	1	2	3	1	2	3	
Remember	20	10	--	---	---	---	10
Understand	40	30	20	100	---	---	30
Apply	40	60	80	---	100	100	60
Analyse	---	---	---	---	---	---	---
Evaluate	---	---	---	---	---	---	---
Create	---	---	---	---	---	---	---

Assessment Pattern: Psychomotor

Psychomotor Skill	Mini Project/ Assignment/ Practical
Perception, Set	
Guided Response	
Mechanism	Assignment
Complex Overt Responses	
Adaptation	
Origination	

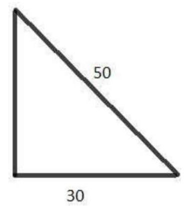
Sample Questions for Course Outcome Assessment

Course Outcome 1 (CO1):

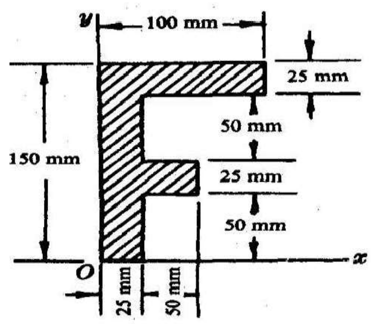
1. Explain the construction and working of an OBI press.
2. List the types of sheet metal cutting operations and explain any five.
3. Compare progressive die, combination die and compound die.

Course Outcome 2 (CO2):

1. Prepare two different layouts for making the given component from a sheet of 2 mm thickness. Find the percentage of material utilization in both the cases. Find also, the weight of the component, if it is made of brass.



2. 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.
3. Locate the centre of pressure for the component given in the figure.



Course Outcome 3 (CO3):

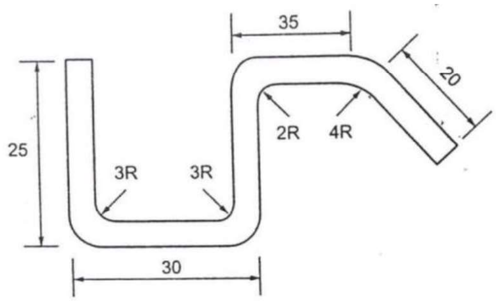
1. Design a blanking press tool for making a 50 mm copper square sheet from a 1 mm thick stock having shear strength as 130 MPa.
2. Design a compound die for making a 60 mm x 40 mm rectangular plate with a central hole of 20 mm diameter from a 2 mm thick aluminium strip having ultimate shear strength of 210 MPa.
3. Design a cutting press tool to make a plate of 50 mm x 60 mm from 2 mm thick mild steel sheet. Take shear stress as 25 kg/mm^2.

Course Outcome 4 (CO4):

1. Discuss about various types of forming dies.
2. Explain the various types of bending with neat sketches.
3. Explain the various drawing parameters.

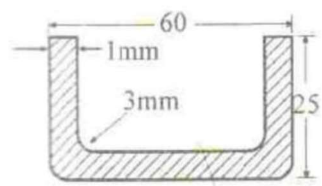
Course Outcome 5 (CO5):

1. 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.
2. 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.
3. Determine the blank length of work piece shown in figure.



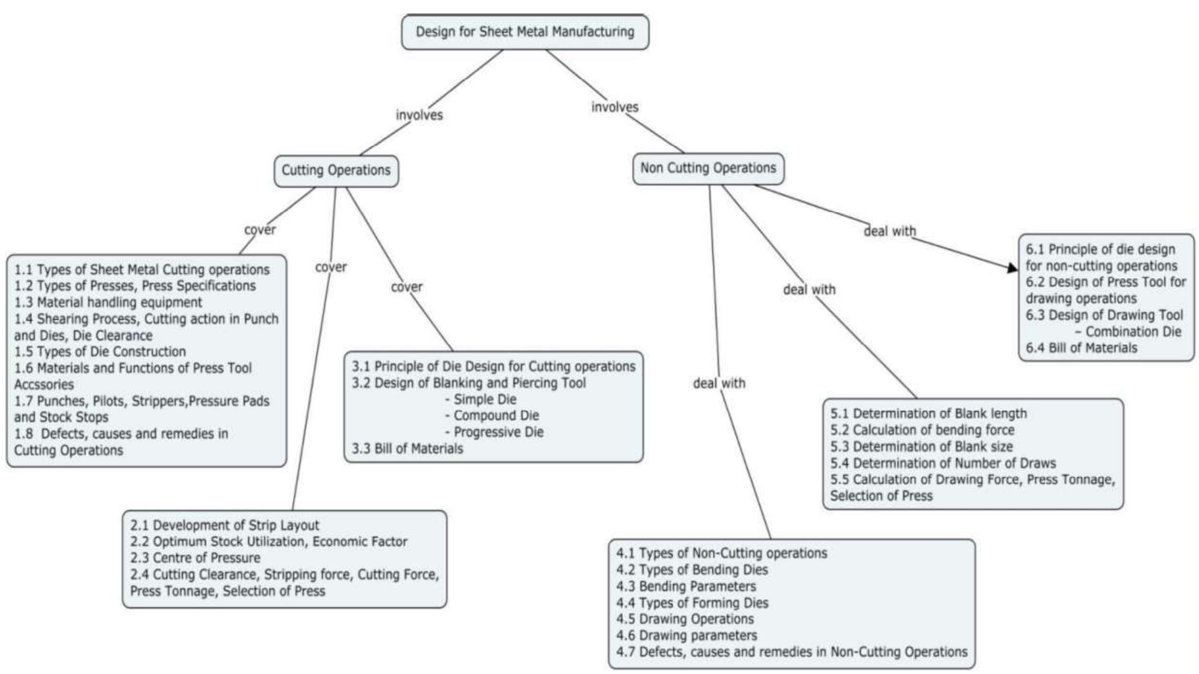
Course Outcome 6 (CO6):

1. A symmetrical cup workpiece of 54 mm diameter, 54 mm height and corner radius of 1.4 mm is to be produced from a cold rolled sheet of thickness 0.9 mm. Make the necessary calculations for designing the drawing die for this part.
2. Design a drawing press tool for the medium carbon steel component shown in the figure. Yield stress is 360 N/mm^2 and shear stress is 280 N/mm^2.



3. Sketch and design a suitable press tool for making a brass shell of 80 mm diameter, 30 mm height and corner radius of 2 mm from a I mm thick sheet. Take shear stress and yield stress for the material as 22 kgf/mm^2 and 350 N/mm^2

Concept Map



Syllabus

Sheet Metal Cutting operations:

Types of Sheet Metal Cutting operations – Blanking, Piercing, Lancing, Cutting Off, Parting, Notching, Shaving and Trimming, Types of Presses, Specifications of Press, Material handling equipment – Coil unwinding, strip straightening, strip feeding equipment, Basics of Shearing process, Cutting action in Punch and Dies, Die Clearance, Types of Die Construction – Progressive, Compound, Combination and Inverted dies, Materials and Functions of all Press Tool Accessories - Types of Punches, Pilots, Strippers, Pressure Pads and Stock Stops. Defects, causes and remedies in Cutting Operations.

Calculation of parameters for cutting operations - Development of Strip Layout, Optimum Stock Utilization, Economic Factor, Centre of Pressure - Calculation of Cutting Clearance, Stripping Forces, Cutting Forces, Press Tonnage and Selection of Press.

Principle of die design for cutting operations, Cutting Press Tools, Design of Blanking Press Tool and Piercing Press Tool –Simple Die, Compound Die and Progressive Die Bill of Materials.

Sheet Metal Non-Cutting Operations:

Types of Non-Cutting operations–Bending, Forming and Drawing, Types of Bending Dies, Bending Parameters, Types of Forming Dies, Drawing Operations, Drawing parameters, Defects, causes and remedies in non-cutting operations.

Calculation of parameters for non-cutting operations - Determination of Blank length for bending, Calculation of Bending Force - Determination of Blank size for drawing, Number of Draws, Calculation of Drawing Force, Press Tonnage and Selection of Press.

Principle of die design for non-cutting operations, Design of Drawing Press Tool – Combination Die – Bill of Materials.

Learning Resources

1. Cyril Donaldson, George H LeCain, V C Goold and Joyjeet Ghose, **"Tool Design"**, 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.
3. Nagpal, G.R, **"Tool Engineering & Design"**, Khanna Publishers, Delhi, Sixth edition, Fourth Reprint, 2011.
4. Eugene Ostergaard, **"Basic Die making"**, McGraw Hill Education Pvt. Ltd, New Delhi, 2013.
5. **"Design Data Handbook"**, PSG College of Technology, Coimbatore, 2016.
6. Semiatin, S.L, "**ASM Handbook Volume 14B: Metalworking: Sheet Forming",** 2006.
7. ASTM, **"Fundamentals of Tool Design"**, Prentice Hall of India, 2003.
8. P H JOSHI, **"Press Tools Design and Construction",** S Chand & Company, 2017.
9. **Mod-1 Lec-10 Sheet Metal Working – Presses -** https://www.youtube.com/watch?v=0z7dYQHhQUI
10. **Principle of Mechanical Press -** https://www.youtube.com/watch?v=6KsqVKGvgrg
11. **Sheet Metal Operations - Part-1** - https://www.youtube.com/watch?v=L0YgSmfwzWY
12. Prof. A. De, **"Design for sheet metal forming processes"** - https://nptel.ac.in/courses/112/101/112101005/

Course Contents and Lecture Schedule

Module No	Topic	No. of Hours	Course Outcome
1.	Sheet Metal Cutting operations		

1.1	Types of Sheet Metal Cutting operations	1	CO1
1.2	Types of Presses, Press Specifications	1	CO1
1.3	Material handling equipment	1	CO1
1.4	Basics of shearing process, Cutting action in punch and dies, Die clearance	1	CO1
1.5	Types of Die Construction	2	CO1
1.6	Materials and Functions of Press Tool Accessories - Punches, Pilots, Strippers	1	CO1
1.7	Pressure Pads, Stock Stops, Defects, causes and remedies in Cutting Operations	1	CO1
2	Calculation of parameters for cutting operations		
2.1	Development of Strip Layout	1	CO2
2.2	Optimum Stock Utilization, Economic Factor	1	CO2
2.3	Centre of Pressure	1	CO2
2.4	Calculation of Cutting Clearance, Stripping force, Cutting Force, Press Tonnage and Selection of Press	1	CO2
3	Press Tool design for cutting operations		
3.1	Principle of die design for cutting operations, Bill of Materials	1	CO3
3.2	Design of Blanking Tool and Piercing Tool – Simple Die	2	CO3
3.3	Design of Blanking and Piercing Tool – Compound Die	2	CO3
3.4	Design of Blanking and Piercing Tool – Progressive Die	2	CO3
4	Sheet Metal Non-Cutting Operations		
4.1	Types of Non-Cutting operations	1	CO4
4.2	Types of Bending Dies, Bending Parameters	1	CO4
4.3	Types of Forming Dies	1	CO4
4.4	Drawing Operations, Drawing parameters	1	CO4
4.5	Defects, causes and remedies in non-Cutting Operations	1	CO4
5	Calculation of parameters for non-cutting operations		
5.1	Determination of Blank length for bending	1	CO5
5.2	Calculation of bending force	1	CO5
5.3	Determination of Blank size for drawing	1	CO5
5.4	Determination of Number of Draws	2	CO5
5.5	Calculation of Drawing Force, Press Tonnage and Selection of Press	1	CO5
6	Press Tool design for non-cutting operations		
6.1	Principle of die design for non-cutting operations, Bill of Materials	2	CO6
6.2	Design of Press Tool for drawing operations	2	CO6
6.3	Design of Drawing Tool – Combination Die	2	CO6
	Total	36	

Course Designer:

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18MEPE0	DESIGN FOR WELDING

Category	L	T	P	Credit
PE	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

- 18ME330 Metal Joining Processes and Manufacturing Practices

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Explain the fixture inspection, validation, maintenance & calibration.	30
CO2	Explain the quality requirement for welders and processes.	10
CO3	Perform Metal Inert Gas (MIG) welding process for a given application.	15
CO4	Perform resistance welding process for a given application.	15
CO5	Design a welding fixture with reference of datum, location, orientation, resting and clamping of the part and materials used for fixture.	15
CO6	Optimize the welding process for productivity and cost.	15

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.2, 2.4.4, 3.3.1,4.3.2
CO2	TPS3	Understand	Respond	Guided Response	1.2, 2.4.4, 3.3.1,4.3.2
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO5	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO6	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	M	L			L	M	S	_	_	_	_	M	L	_	M
CO2	M	L			L	_	_	_	_	_	_	_	L	_	L
CO	S	M	L		M	M	S	_	_	_	_	M	L	_	M

3															
CO 4	S	M	L		–	–	M	–	–	–	–	–	L	–	S
CO 5	S	M	L		L	L	–	–	–	–	–	–	L	–	S
CO 6	S	M	L		–	M	M	–	–	–	–	–	L	–	S

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	**20**	**20**	**20**	**20**	**20**	**20**	**20**
Understand	**40**	**40**	**40**	**40**	**40**	**40**	**40**
Apply	**40**	**40**	**40**	**40**	**40**	**40**	**40**
Analyse	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Evaluate	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Create	**-**	**-**	**-**	**-**	**-**	**-**	**-**

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	**-**
Set	**-**
Guided Response	**-**
Mechanism	**Assignment**
Complex Overt Responses	**-**
Adaptation	**-**
Origination	**-**

Sample Questions for Course Outcome Assessment**

** (2 to 3 at the cognitive level of course outcome)

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 important process variables for Gas Metal Arc 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 Power Source required for resistance welding.
2. Discuss the major applications of resistance welding in automobile industry.
3. Explain the various types of resistance welding using suitable sketches.

Course Outcome 5 (CO5):

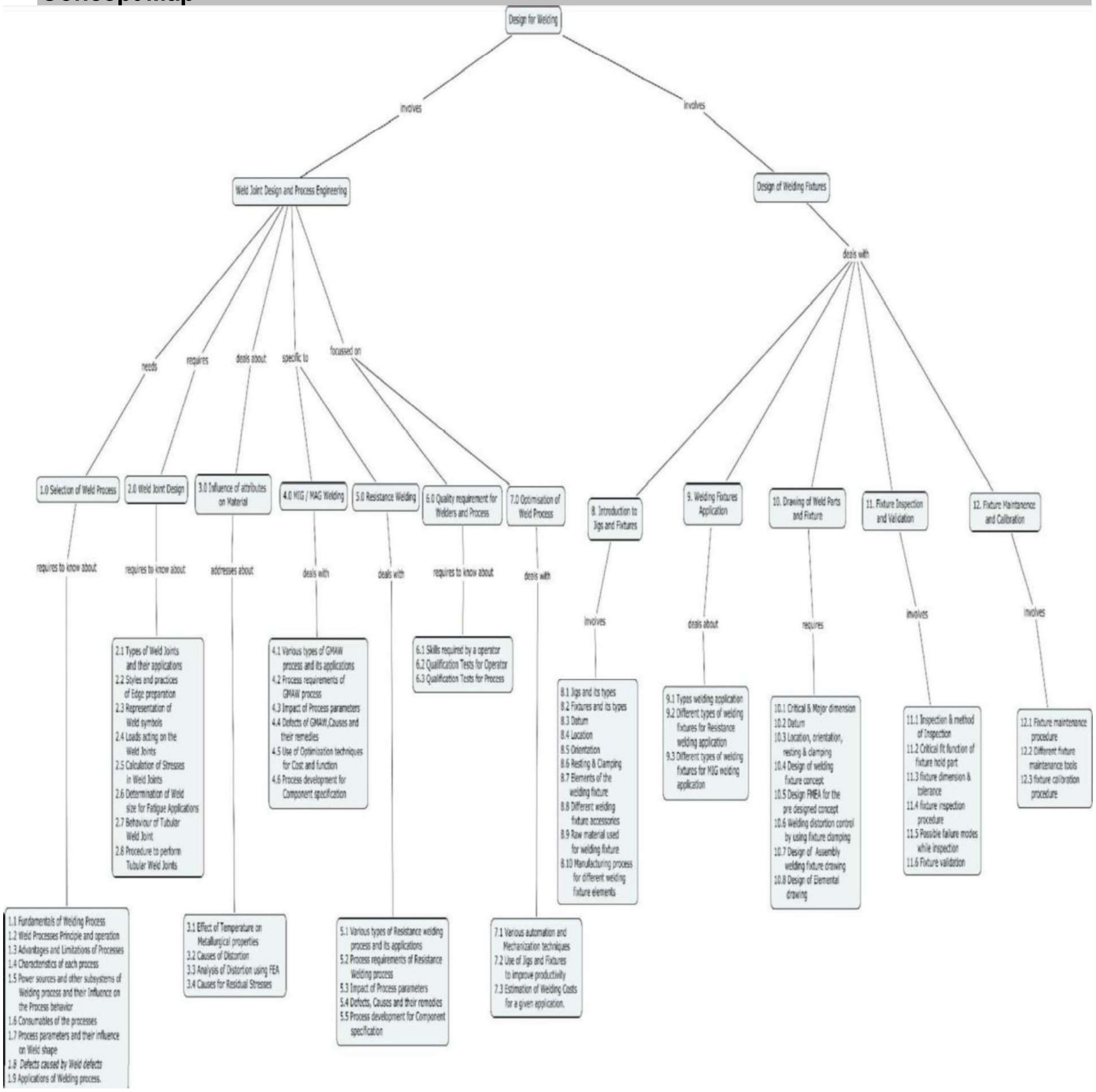
1. Mention the different elements of weld fixture.
2. Suggest the possible approaches to design the weld joints for constructing a steel bridge.

3. Construct a weld fixture for a U shaped tube welding. Justify the construction of fixture with suitable illustration.

Course Outcome 6 (CO6):

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 -** 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

Module No.	Topic	No. of Hours	Course Outcome
1.	**Selection of Weld Process**		
1.1	Fundamentals of Welding Process	1	CO1,CO5
1.2	Weld Processes Principle and operation		CO1,CO5
1.3	Advantages and Limitations of Processes	1	CO1,CO5
1.4	Characteristics of each process		CO1,CO5
1.5	Power sources and other subsystems of Welding process and their Influence on the Process behavior	1	CO1,CO5
1.6	Consumables of the processes.		CO1,CO5
1.7	Process parameters and their influence on Weld shape.	1	CO1,CO5
1.8	Defects caused by Weld defects.		CO1,CO5
1.9	Applications of Welding process.	1	CO1,CO5
2.	**Design of Weld Joints**		
2.1	Types of Weld Joints and their applications	1	CO1,CO5
2.2	Styles and practices of Edge preparation		CO1,CO5
2.3	Representation of Weld symbols	1	CO1,CO5
2.4	Loads acting on the Weld Joints		CO1,CO5
2.5	Calculation of Stresses in Weld Joints	1	CO1,CO5
2.6	Determination of Weld size for Fatigue Applications		CO1,CO5
2.7	Behaviour of Tubular Weld Joint	1	CO1,CO5
2.8	Procedure to perform Tubular Weld Joints		CO1,CO5
3.	**Influence of Attributes on Material**		
3.1	Effect of Temperature on Metallurgical properties	1	CO1,CO5
3.2	Causes of Distortion		CO1,CO5
3.3	Analysis of Distortion using FEA	2	CO1,CO5
3.4	Causes for Residual Stresses	1	CO1,CO5
4.	**MIG / MAG Welding**		
4.1	Various types of GMAW process and its applications	1	CO3
4.2	Process requirements of GMAW process	1	CO3
4.3	Impact of Process parameters	1	CO3
4.4	Defects of GMAW, Causes and their remedies	1	CO3
4.5	Use of Optimization techniques for Cost and function		CO3
4.6	Process development for Component specification	1	CO3
5.	**Resistance Welding**		
5.1	Various types of Resistance welding process and its applications	1	CO4

5.2	Process requirements of Resistance Welding process	1	CO4
5.3	Impact of Process parameters	1	CO4
5.4	Defects, Causes and their remedies		CO4
5.5	Process development for Component specification	1	CO4
6.	**Quality requirement for Welders and Process**		
6.1	Skills required by a operator	1	CO2
6.2	Qualification Tests for Operator		CO2
6.3	Qualification Tests for Process	1	CO2
7.	**Optimization of Weld Process**		
7.1	Various automation and Mechanization techniques	1	CO5
7.2	Use of Jigs and Fixtures to improve productivity	1	CO5
7.3	Estimation of Welding Costs for a given application	1	CO5
8.	**Introduction to Jigs and Fixtures**		
8.1	Jigs and its types	1	CO1
8.2	Fixtures and its types	1	CO1
8.3	Datum and its importance of the Part	1	CO1
8.4	Location and its importance of the Part		CO1
8.5	Orientation and its importance of the Part	1	CO1
8.6	Resting & Clamping and its importance of the Part		CO1
8.7	Elements of the welding fixture	1	CO1
8.8	Different welding fixture accessories used for different welding application	1	CO1
8.9	Raw material used for welding fixture	1	CO1
8.10	Manufacturing process for different welding fixture elements		CO1
9.	**Welding Fixtures Application**		CO1
9.1	Types of welding application	1	CO1
9.2	Different types of welding fixtures for Resistance welding application (Manual/Auto)	1	CO1
9.3	Different types of welding fixtures for MIG welding application (Manual/Auto)		CO1
10.	**Drawing of Weld Parts and Fixture**		
10.1	Critical & Major dimension of the part	1	CO1,CO4
10.2	Datum used in the weld part		CO1,CO4
10.3	Location, orientation, resting & clamping for the weld part	1	CO1,CO4
10.4	Design of welding fixture concept for given part.	1	CO1,CO4
10.5	Design FMEA for the pre designed concept fixture	1	CO1,CO4

10.6	Welding distortion control by using fixture clamping	1	CO1,CO4
10.7	Design of Assembly welding fixture drawing for a given part	1	CO1,CO4
10.8	Design of Elemental drawing of given welding fixture	1	CO1,CO4
11.	**Fixture Inspection and Validation**		
11.1	Inspection & method of Inspection	1	CO1,CO4
11.2	Critical fit function of fixture hold part	1	CO1,CO4
11.3	fixture dimension & tolerance	1	CO1,CO4
11.4	fixture inspection procedure	1	CO1,CO4
11.5	Possible failure modes while inspection	1	CO1,CO4
11.6	Fixture validation	1	CO1,CO4
12.	**Fixture Maintenance and Calibration**		
12.1	Fixture maintenance procedure	1	CO1,CO4
12.2	Different fixture maintenance tools	1	CO1,CO4
12.3	fixture calibration procedure	1	CO1,CO4

Course Designers:

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18MEPF0	INTEGRATED PRODUCT DEVELOPMENT

Category	L	T	P	Credit
PE	2	1	-	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

Nil

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
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	15
CO2	Perform the PESTLE Analysis and Requirement Engineering Analysis.	15
CO3	Classify the Product Development Methodologies.	10
CO4	Develop system integration, testing, certification and documentation.	15
CO5	Prepare the specific product development process for a given industry.	20
CO6	Transform customer needs into technical specification of a product.	25

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.2, 2.4.4, 3.3.1,4.3.2
CO2	TPS2	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO3	TPS3	Understand	Respond	Guided Response	1.2, 2.4.4, 3.3.1,4.3.2
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO5	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO6	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	M	L			L	M	S	–	–	–	–	M	L	–	M
CO2	S	M	L		M	M	S	–	–	–	–	M	L	–	M
CO3	M	L			L	–	–	–	–	–	–	–	L	–	L
CO4	S	M	L		–	–	M	–	–	–	–	–	L	–	S
CO5	S	M	L		L	L	–	–	–	–	–	–	L	–	S
CO6	S	M	L		–	M	M	–	–	–	–	–	L	–	S

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive	Continuous Assessment Tests	Assignment	Terminal

Levels	1	2	3	1	2	3	Examination
Remember	20	20	20				20
Understand	30	30	30				30
Apply	50	50	50	100	100	100	50
Analyse							
Evaluate							
Create							

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	
Set	
Guided Response	
Mechanism	Assignment-Case Study
Complex Overt Responses	
Adaptation	
Origination	

Sample Questions for Course Outcome Assessment**

Course Outcome 1 (CO1):

1. Define product design.
2. Define Intellectual Property.
3. Define proto typing.

Course Outcome 2 (CO2):

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 3 (CO3):

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 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.

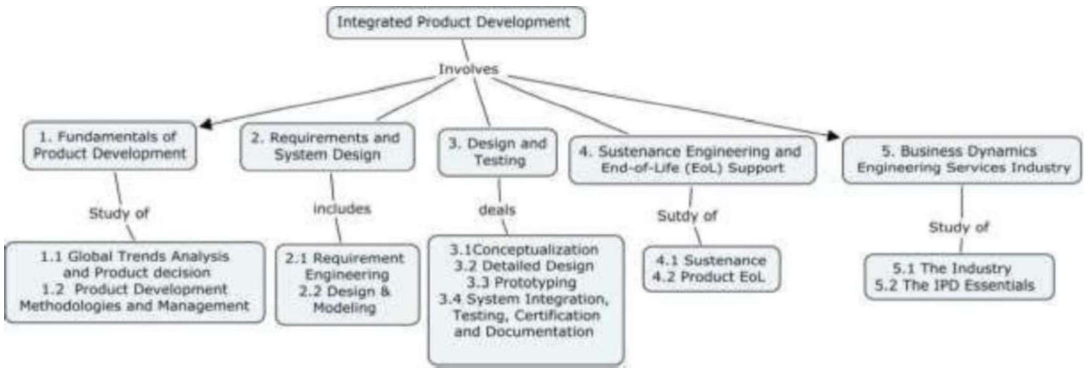
Course Outcome 5 (CO5):

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

Learning Resources

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	Co
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	Co1
1.1.2	Economical Trends(Market, Economy, Gross Domestic Product, Income Levels, Spending Pattern, target cost, Total Cost of Ownership)	1	Co2
.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	Co3
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	Co4
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, Behavioural, Technical, Stakeholder, Environmental, Industry specific, Internal-Company Specific)	1	Co5
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**		Co6
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 (Mock-ups, 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	

Course Designers:

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18MEPHO	MARKETING MANAGEMENT

Category	L	T	P	Credit
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. Marketing managers are often responsible for influencing the level, timing, and composition of customer demand. Branding aims to establish a significant and differentiated presence in the market that attracts and retains loyal customers. Digital marketing is the marketing of products or services using digital technologies, mainly on the internet , and any other digital medium.

Prerequisite

Nil

CourseOutcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Explain the Fundamentals of marketing management.	20
CO2	Develop suitable marketing research plan for various application	15
CO3	Apply various marketing development strategies to improve product life cycle.	20
CO4	Examine suitable pricing and branding methods in market place	20
CO5	Identify a suitable consumer behaviour to market a product	10
CO6	Explain Strategy for Digital marketing.	15

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.1, 1.2, 2.5.1, 2.5.2, 4.1.1, 4.2.1
CO2	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.4.5, 4.6.5
CO3	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.4.5, 4.6.5
CO4	TPS4	Analyse	Value	Complex Overt Responses	1.1, 1.2, 2.1,3. 4.1.1, 4.1.2, 4.4.5, 4.6.5
CO5	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.4.5, 4.6.5
CO6	TPS1	Understand	Value	Guided Response	1.1, 1.2, 2.5.1, 2.5.2, 4.1.1, 4.2.1

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	M	L	-	-	L	M	S	M	L	M	S	M	-	-	-
CO2	S	M	L	-	M	L	M	M	M	M	M	L	-	-	-
CO3	S	M	L	-	M	M	M	M	M	L	M	M	-	-	-
CO4	S	S	M	L	M	M	M	M	M	M	M	L	-	-	-
CO5	S	M	L	-	M	M	M	M	L	M	L	L	-	-	-
CO6	M	L	-	-	S	M	M	M	L	S	L	L	-	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	20	20	20	-	-	-	20
Understand	30	30	30	20	20	20	30
Apply	50	50	40	80	60	60	40
Analyse			10		20	20	10
Evaluate							
Create							

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	
Set	
Guided Response	Assignment
Mechanism	Assignment
Complex Overt Responses	
Adaptation	
Origination	

Sample Questions for Course Outcome Assessment**

** (2 to 3 at the cognitive level of course outcome)

Course Outcome 1(CO1):

7. Define marketing.
8. Explain the objectives of marketing management.
9. Differentiate sales management and marketing management.

Course Outcome 2(CO2):

4. Identify need of marketing research
5. Explain type of marketing research
6. Define the term marketing process

Course Outcome 3(CO3):

1. Define product life cycle.
2. Construct the marketing strategies throughout the product life cycle.
3. Build a suitable strategy to develop product life cycle.

Course Outcome 4 (CO4):

4. Define Pricing
5. Classify the Pricing methods
6. Describe the role of middle man in distribution channel

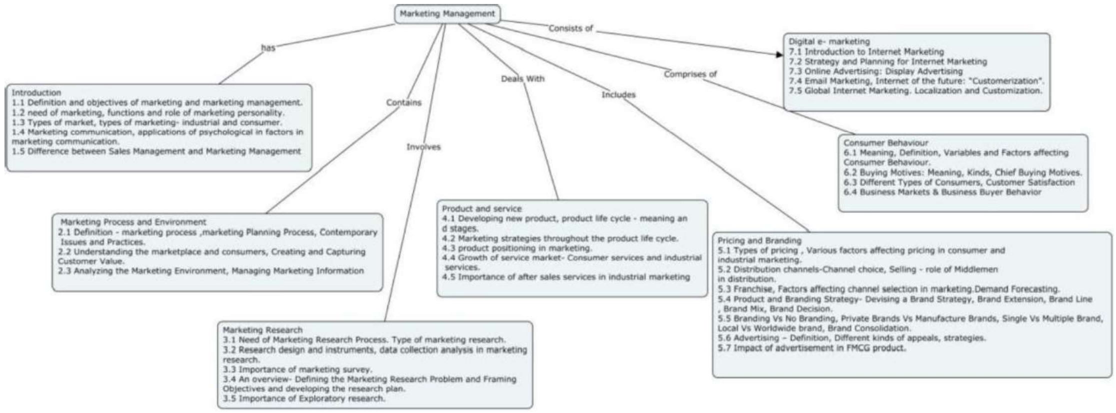
Course Outcome 5 (CO5):

4. Identify the factors affecting consumer behavior
5. Explain the different types of customers
6. Analyze the issues in marketing automobile products in a developing country like India

Course Outcome 6(CO6):

4. Summarize the advantages of internet marketing
5. Explain Customization.
6. Illustrate the current scenario of global marketing with an example

ConceptMap



Syllabus

Introduction: Definition and objectives of marketing and marketing management. need of marketing, functions and role of marketing personality. types of market, types of marketing- industrial and consumer. Marketing communication ,applications of psychological in factors in marketing communication. Difference between Sales Management and Marketing Management
Marketing Process and Environment: Definition - marketing process ,marketing Planning Process, Contemporary Issues and Practices. Understanding the marketplace and consumers, Creating and Capturing Customer Value. Analyzing the Marketing Environment, Managing Marketing Information.
Marketing Research: Need of Marketing Research Process. Type of marketing research. Research design and instruments, data collection analysis in marketing research. Importance of marketing survey. An overview- Defining the Marketing Research Problem and Framing Objectives and developing the research plan. Importance of Exploratory research.

Product and service: Developing new product , product life cycle - meaning and stages. Marketing strategies throughout the product life cycle. product positioning in marketing,
Growth of service market- Consumer services and industrial services. Importance of after sales services in industrial marketing
Pricing and Branding: Types of pricing , Various factors affecting pricing in consumer and industrial marketing. Distribution channels-Channel choice, Selling - role of Middlemen in distribution. Franchise, Factors affecting channel selection in marketing. Demand Forecasting , Product and Branding Strategy- Devising a Brand Strategy, Brand Extension, Brand Line, Brand Mix, Brand Decision. Branding Vs No Branding, Private Brands Vs Manufacture Brands, Single Vs Multiple Brand, Local Vs Worldwide brand, Brand Consolidation. Advertising – Definition, Different kinds of appeals, strategies. Impact of advertisement in FMCG product.
Consumer Behaviour: Meaning, Definition, Variables and Factors affecting Consumer Behaviour. Buying Motives: Meaning, Kinds, Chief Buying Motives. Different Types of Consumers, Customer Satisfaction. Business Markets & Business Buyer Behavior
Digital Marketing: Introduction to Internet Marketing. Strategy and Planning for Internet Marketing. Online Advertising, Display Advertising, Email Marketing, Internet of the future: "Customerization".Global Internet Marketing. Localization and Customization

Learning Resources

1. Gupta, S.L., Sales and Distribution Management, Excel Books, New Delhi, 2016.
2. Philip Kotler, **"Marketing Management",** Prentice Hall of India, New Delhi, 2015.
3. Sharma Gulnar and Singh Karan Khundia, Brand Management, Himalyan Publishing Houser, Edition 2017.
4. https://nptel.ac.in/courses/110104068/
5. https://nptel.ac.in/courses/110104070/
6. https://nptel.ac.in/courses/110107112/

Course Contents and Lecture Schedule

Module Number	Topic	No. of Lectures	Course Out Come
1	**Introduction**		
1.1	Definition and objectives of marketing and marketing management.	1	CO1

Module Number	Topic	No. of Lectures	Course Out Come
1.2	need of marketing, functions and role of marketing personality.	1	
1.3	types of market, types of marketing- industrial and consumer.	1	
1.4	Marketing communication, applications of psychological in factors in marketing communication.	1	
1.5	Difference between Sales Management and Marketing Management	1	
2	**Marketing Process and Environment**		
2.1	Definition - marketing process, marketing Planning Process, Contemporary Issues and Practices.	1	
2.2	Understanding the marketplace and consumers, Creating and Capturing Customer Value.	2	
2.3	Analyzing the Marketing Environment, Managing Marketing Information	1	
3	**Marketing Research**		
3.1	need of Marketing Research Process. Type of marketing research.	1	CO2
3.2	Research design and instruments, data collection analysis in marketing research.	1	
3.3	Importance of marketing survey.	1	
3.4	An overview- Defining the Marketing Research Problem and Framing Objectives and developing the research plan.	1	
3.5	Importance of Exploratory research.	1	
4	**Product and service**		
4.1	Developing new product, product life cycle - meaning and stages.	1	CO3
4.2	Marketing strategies throughout the product life cycle.	1	
4.3	product positioning in marketing.	1	
4.4	Growth of service market- Consumer services and industrial services.	1	
4.5	Importance of after sales services in industrial marketing	1	
5	**Pricing and Branding**		
5.1	Types of pricing , Various factors affecting pricing in consumer and industrial marketing.	1	CO4
5.2	Distribution channels-Channel choice, Selling - role of Middlemen in distribution.	1	
5.3	Franchise, Factors affecting channel selection in marketing. Demand Forecasting.	1	
5.4	Product and Branding Strategy- Devising a Brand Strategy, Brand Extension, Brand Line, Brand Mix, Brand Decision.	1	
5.5	Branding Vs No Branding, Private Brands Vs Manufacture Brands, Single Vs Multiple Brand, Local Vs Worldwide brand, Brand Consolidation.	2	
5.6	Advertising – Definition, Different kinds of appeals, strategies.	1	
5.7	Impact of advertisement in FMCG product.	1	
6	**Consumer Behaviour**		
6.1	Meaning, Definition, Variables and Factors affecting Consumer Behaviour.	1	CO5
6.2	Buying Motives: Meaning, Kinds, Chief Buying Motives.	1	
6.3	Different Types of Consumers, Customer Satisfaction	1	
6.4	Business Markets & Business Buyer Behaviour	1	

Module Number	Topic	No. of Lectures	Course Out Come
7	**Digital e- marketing**		
7.1	Introduction to Internet Marketing	1	CO6
7.2	Strategy and Planning for Internet Marketing	1	
7.3	Online Advertising: Display Advertising	1	
7.4	Email Marketing, Internet of the future: "Customerization"	1	
7.5	Global Internet Marketing. Localization and Customization.	1	
	Total	**36**	

Course Designers:

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18MEPJ0	MATERIAL HANDLING SYSTEMS ENGINEERING

Category	L	T	P	Credit
PE	3	-	-	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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Map the process and material flow. (K2)	10
CO2	Assess the potential failure modes in material storage and handling between POM/POS to POC. (K3)	20
CO3	Do posture analysis by using REBA/RULA tools and ergonomics in storage and material handling design. (K3)	20
CO4	Measures of material handling systems. (K4)	15
CO5	Develop standardized inventory storage and handling work procedures. (K3)	20
CO6	Choose appropriate material transport system. (K4)	15

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.1, 1.2, 2.5.1, 2.5.2, 4.1.1, 4.2.1
CO2	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.4.5, 4.6.5
CO3	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.4.5, 4.6.5
CO4	TPS4	Analyse	Organise	Complex Overt Responses	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.4.5, 4.6.5
CO5	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.4.5, 4.6.5
CO6	TPS4	Analyse	Organise	Complex Overt Responses	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.4.5, 4.6.5

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3

CO1 (Understand)	M	L	M	-	-	_	–	–	–	–	–	–	_	M	L
CO2 (Apply)	S	M	L	-	-	_	–	–	–	–	–	–	M	_	_
CO3 (Apply)	S	M	L	-	-	_	–	–	–	–	–	–	_	M	M
CO4 (Analyze)	S	S	M	L	-	_	–	–	–	–	–	–	S	_	_
CO5 (Apply)	S	M	L	-	-	_	–	–	–	–	–	–	_	M	M
CO6 (Analyze)	S	S	M	L	-	_	–	–	–	–	–	–	S	M	M

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment/Mini project			Terminal Examination
	1	2	3	1	2	3	
Remember	20	20	20				20
Understand	30	30	30	20			30
Apply	50	30	30	80	40	40	30
Analyse	0	20	20		60	60	20
Evaluate	0	0	0				0
Create	0	0	0				0

Assessment Pattern: Psychomotor

Psychomotor Skill	Mini-project /Assignment/Practical Component
Perception	
Set	
Guided Response	Assignment
Mechanism	Assignment
Complex Overt Responses	Mini-project
Adaptation	
Origination	

Sample Questions for Course Outcome Assessment**

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):

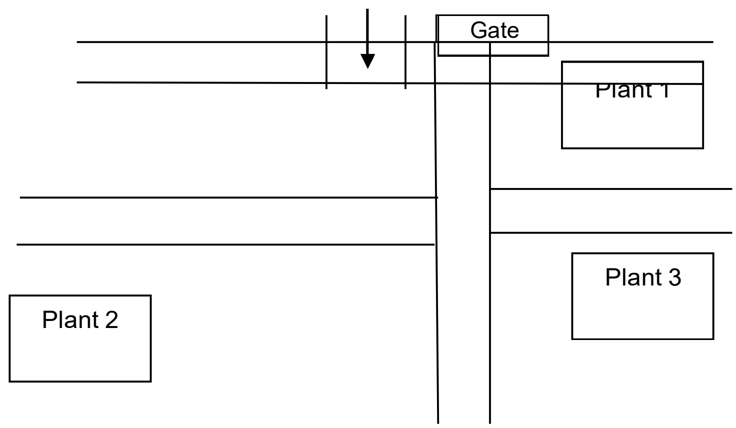
1. Describe different types of Material handling equipments and its limitations.
2. Explain about the various selection criteria for Material handling equipment systems.
3. In one of the manufacturing industry, painted fuel tanks to be transported from paint shop to vehicle assembly. Allowable handling 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	Requiremen t
Assembl y Line	A	5	7	8	70
	B	4	4	6	30
	C	6	7	7	50
	Stock	65	42	43	150

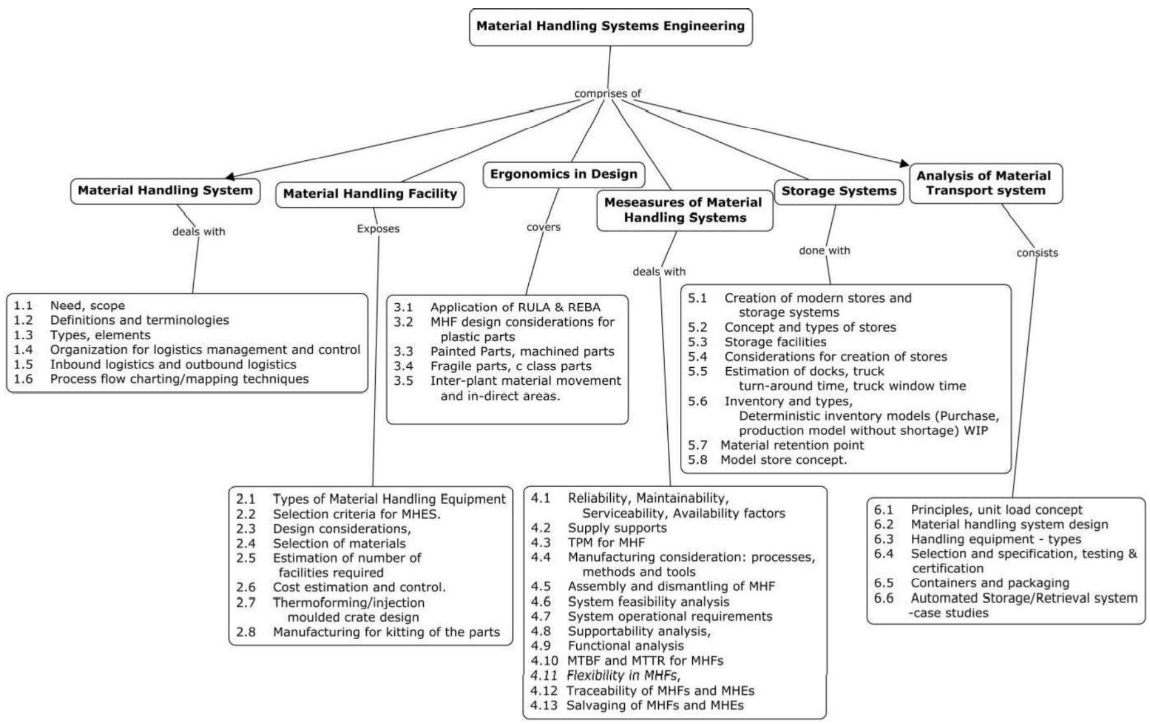
2. In an automotive company, the total inflow of material supply vehicles is 500 trucks/day. The company has two vehicle assembly plants and one supportive machining plant. 150 trucks will be going for plant 1, 100 for Plant 2 and 250 for plant 3 (machining) and from plant 3, 150 will go to plant 1 and 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 moulded 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.

Learning Resources

1. Blanchard and Benjamin "Logistics Engineering and S, 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 ManualsBook1 (Author(s), Title, edition, publisher, year of publication)
8. Inventory management: https://nptel.ac.in/courses/110/105/110105095/

Course Contents and Lecture Schedule

Module No	Topic	No. of hours	Course Outcome
1	**Material Handling System**		
1.1	Need, scope	1	CO 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	CO 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	
2.6	Cost estimation and control	1	
2.7	Thermoforming/Injection moulded crate design	1	
2.8	Manufacturing of kitting of parts		
3	**Ergonomics in design**		
3.1	Application of RULA & REBA	2	CO 3

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	CO 4
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	CO 5
5.2	Concept and 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), WIP	2	
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	CO 6
6.2	Determination of delivery distance	1	
6.3	Conveyor analysis – single direction	1	
6.4	Continuous loop and re-circulating conveyors	1	
	Total	**41**	

Course Designer:

1. ML.Mahadevan mlmmech@tce.edu

18MEPK0	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

18ME430 - Machining Processes

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Explain the types and characteristics of tool materials, cutting tools nomenclature and various tool angle specification	10
CO2	Explain the Mechanics of the machining process	20
CO3	Examine the thermal aspects and cutting fluids	15
CO4	Examine the tool wear, tool life, machinability.	15
CO5	Determine the tool life and surface roughness of machined surfaces	20
CO6	Optimize the machining cost by varying the cutting parameters	20

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.2, 2.4.4, 3.3.1,4.3.2
CO2	TPS2	Understand	Respond	Guided Response	1.2, 2.4.4, 3.3.1,4.3.2
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO5	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO6	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PO1 2	PSO 1	PSO 2	PSO 3
CO 1	M	L	-	-	-	-	-	-	-	-	L	-	S	-	L
CO 2	M	L	-	-	-	-	-	-	-	-	M	-	S	-	L
CO 3	S	M	L	-	-	-	M	-	-	-	M	-	S	-	L
CO 4	S	M	L	-	-	-	M	-	-	-	M	-	S	-	L
CO 5	S	M	L	-	-	-	M	-	-	-	M	-	S	-	L
CO 6	S	M	L	-	-	-	M	-	-	-	M	-	S	-	L

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	30	20	20	-	-	-	20
Understand	70	30	30	-	-	-	30
Apply	00	50	50	100	100	100	50
Analyse	-	-	-	-	-	-	-
Evaluate	-	-	-	-	-	-	-
Create	-	-	-	-	-	-	-

Assessment Pattern: Psychomotor

Psychomotor Skill	Mini project /Assignment/Practical Component
Perception	-
Set	-
Guided Response	-
Mechanism	**Assignment**
Complex Overt Responses	-
Adaptation	-
Origination	-

Sample Questions for Course Outcome Assessment**

Course Outcome 1 (CO1):

1. List the properties of a cutting tool material.
2. Explain the desirable properties of a tool material.
3. Discuss the different elements of a single point cutting tool.

Course Outcome 2 (CO2):

1. Discuss the different elements of a single point cutting tool.
2. Find the suitable mechanics during the milling operation.
3. Estimate the cutting forces in orthogonal cutting process.

Course Outcome 3 (CO3):

1. List the thermal aspects of machining process
2. Describe the benefits of using cutting fluids
3. Identify a suitable cutting fluid for the mild steel machining operation and discuss its properties.

Course Outcome 4 (CO4):

1. List the thermal aspects of machining process
2. Describe the benefits of using cutting fluids
3. Explain the chipping characteristic of tool materials.

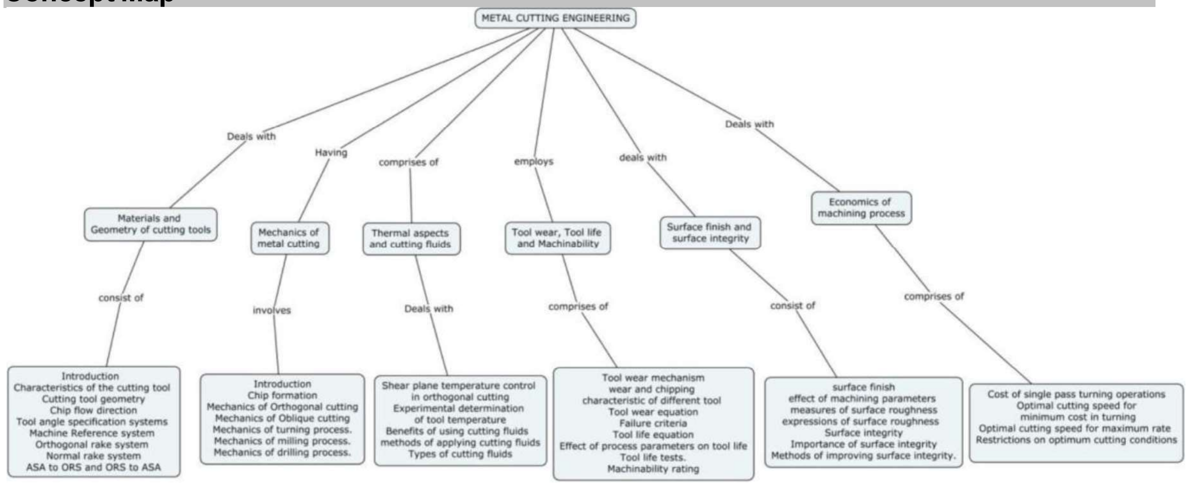
Course Outcome 5 (CO5):

1. Find the various parameters, which will affect the surface roughness.
2. State the need of better surface finish.
3. Identify a suitable technique to improve the surface integrity of the machined surface.

Course Outcome 6 (CO6):

1. List the various machining costs.
2. Explain the various economic aspects involved in machining.
3. Discuss the effect of cutting speed on machining.
4. List the various economics of facing operations and explain in detail.
5. Suggest and explain the various restrictions on optimum cutting conditions.

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 systems – Machine Reference system - Orthogonal rake system – Normal rake system – conversion of tool angle system from ASA to ORS and ORS to ASA – Chip breakers.
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 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 – Machinability – Introduction – Machinability rating
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 – Restrictions on optimum cutting conditions

Learning Resources

1. Cyril Donaldson, V. C. Goold, George H. LeCain, ' **Tool Design'** Tata McGrawHill Education Private Ltd.,, New Delhi, 2012.
2. Juneja. B L, Sekhon G S and Nitin Seth, "**Fundamentals of Metal Cutting and MachineTools**",2nd Edition, New Age International (P) Ltd Publishers, New Delhi, 2015.
3. David A. Stephenson and John S Agapiou, "**Metal Cutting Theory and Practice**", 3rd Edition, CRC Press, 2016.
4. Bhattacharya, A., "**Metal Cutting Theory and Practice**", PB 01 Edition, New Central Book Agency (P) Ltd., Kolkatta, 2008.
5. Milton C Shaw, "**Metal Cutting Principles**" Oxford Series on Advanced Manufacturing, **Second Edition, Oxford University Press, 2005**.
6. Geoffrey Boothroyd, "**Fundamentals of Metal Machining and Machine Tools**", 3rd Edition, CRC Press, 2006.

7. Paul K Wright and Edward M Trent, "**Metal Cutting**"4th Edition, Butterworth-Heinemann, 2000.
8. Serope Kalpakjian and Steven R. Schmid, "**Manufacturing Engineering and Technology**", Fourth Edition, Pearson Education, 2001.

Course Contents and Lecture Schedule

S.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.	1
1.2	Cutting tool geometry- Chip flow direction	1
1.3	Tool angle specification systems – Machine Reference system	1
1.4	Orthogonal rake system	1
1.5	Normal rake system	1
1.6	Conversion of tool angle system from ASA to ORS and ORS to ASA	2
2.1	**Mechanics of metal cutting**	
2.1.1	Introduction – Chip formation	1
2.1.2	Mechanics of Orthogonal cutting	2
2.1.3	Mechanics of Oblique cutting	1
2.1.4	Mechanics of turning process.	1
2.1.5	Mechanics of milling process.	2
2.1.6	Mechanics of drilling process.	1
2.2	**Thermal aspects and cutting fluids**	
2.2.1	Introduction – Shear plane temperature control in orthogonal cutting	1
2.2.2	Experimental determination of tool temperature	1
2.2.3	Benefits of using cutting fluids – methods of applying cutting fluids	2
2.2.4	Types of cutting fluids	1
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	2
3.1.4	Effect of process parameters on tool life – Tool life tests.	2
3.1.5	Machinability – Introduction – Machinability rating	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	Restrictions on optimum cutting conditions	1
	Total	**38**

Course Designers:

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18MEPL0	MOTORCYCLE DYNAMICS

Category	L	T	P	Credit
PE	3	0	0	3

Preamble

Motorcycle dynamics 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.

Prerequisite

- NIL

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Determine the effect of motorcycle geometry on motorcycle kinematics.	20
CO2	Explain motorcycle tyre dynamics.	10
CO3	Determine motorcycle behaviour in rectilinear motion.	25
CO4	Calculate forces and moments in steady turning of motorcycle.	10
CO5	Determine the effect of suspension design of motorcycle on ride.	20
CO6	Calculate motorcycle trim in steady state, a curve, acceleration and braking.	15

*** Weightage depends on Bloom's Level, number of contact hours.

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO2	TPS2	Understand	Respond	Guided Response	1.2, 2.1, 3.2, 4.1.2
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO5	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO6	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3

Mapping with Programme Outcomes and Programme Specific Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	S	M	L	-	-	-	-	S	-	-	-	-	M	-	-
CO2	M	L	-	-	-	-	-	S	-	-	-	-	-	-	-
CO3	S	M	L	-	-	-	-	S	-	-	-	-	M	-	-
CO4	S	M	L	-	-	-	-	S	-	-	-	-	M	-	-
CO5	S	M	L	-	-	-	-	S	-	-	-	-	M	-	-
CO6	S	M	L	-	-	-	-	S	-	-	-	-	M	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive	Continuous Assessment Tests	Assignment	Terminal

Levels	1	2	3	1	2	3	Examination
Remember	10	10	10				10
Understand	50	30	30				30
Apply	40	60	60	100	100	100	60
Analyse							
Evaluate							
Create							

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	
Set	
Guided Response	
Mechanism	Assignment
Complex Overt Responses	
Adaptation	
Origination	

Sample Questions for Course Outcome Assessment

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. Show the contact forces between the motorcycle tyre and road with a neat sketch.
2. List and explain in detail the various moments acting between tyre and road.
3. **Discuss briefly on combined lateral and longitudinal forces acting on tyre.**

Course Outcome 3 (CO3)**:**

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 4 (CO4)**:**

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.

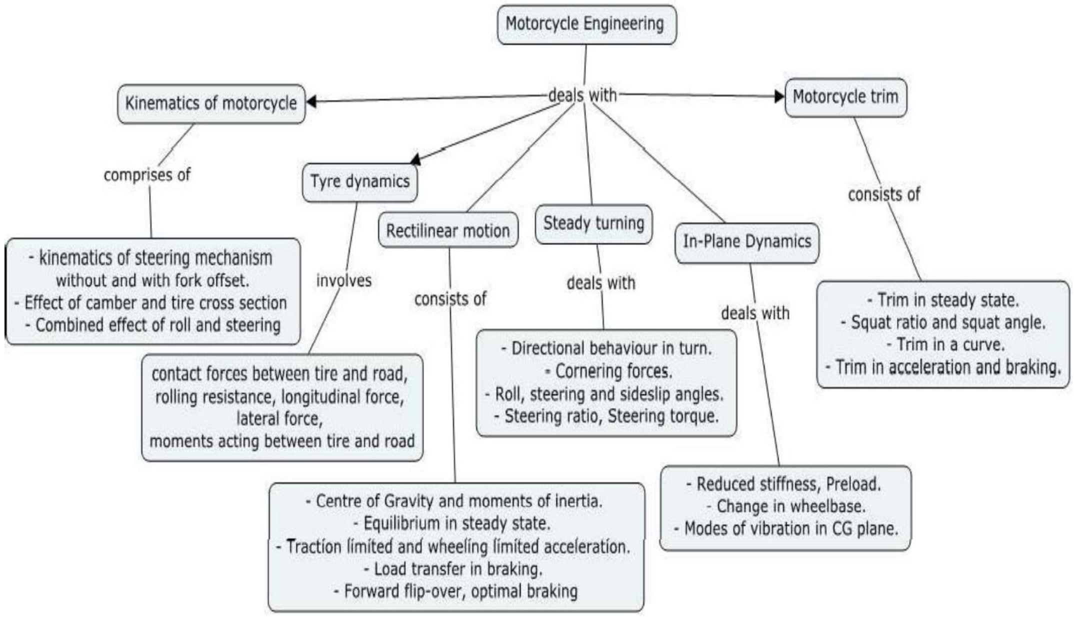
Course Outcome 5 (CO5)**:**

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 6 (CO6)**:**

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. With neat sketch show the effect of load transfer during acceleration and braking on motorcycle trim.

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, front wheel camber angle, kinematic steering angle, the path curvature, effect of tire size on rear frame yaw.

Motorcycle Tires – contact forces between tire and road, The magic formula, rolling resistance, longitudinal force, lateral force, moments acting between tire and road, model of motorcycle tire.

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.

Motorcycle trim – 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, acceleration and braking.

Learning Resources

1. V.Cossalter, "**Motorcycle Dynamics**", 2nd Edition, Race dynamics, 2006.
2. Tony Foale, "**Motorcycle Handling and chassis design**" the art and science, 2006.
3. Thomas D.Gillespie, **"Fundamentals of vehicle dynamics"** Premiere Series Books, 1992.

4. N.K.Giri, "**Automobile Mechanics**",8th Edition, Khanna Publishers, Delhi, 2013.
5. 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 Hours	CO
1	**Kinematics of motorcycle**		
1.1	Definition and geometry of motorcycle.	1	CO1
1.2	Trail, kinematics of steering mechanism without and with zero fork offset	2	CO1
1.3	Roll motion and steering, motorcycle pitch.	1	CO1
1.4	Rear wheel contact point, front wheel camber angle	1	CO1
1.5	The kinematic steering angle, the path curvature, effect of tire size on rear frame yaw.	1	CO1
2	**Motorcycle Tires**		
2.1	Contact forces between tire and road, The magic formula	1	CO2
2.2	Rolling resistance of tires	1	CO2
2.3	Longitudinal force, Lateral force	2	CO2
2.4	Moments acting between tire and road	1	CO2
2.5	Model of motorcycle tire.	1	CO2
3	**Rectilinear motion**		
3.1	Calculation of resistance forces	1	CO3
3.2	Determination of centre of gravity	1	CO3
3.3	Equilibrium in steady state	1	CO3
3.4	Equilibrium in transitory motion – Equivalent mass calculation	1	CO3
3.5	Calculation of traction limited and wheeling limited acceleration.	1	CO3
3.6	Determination of load transfer in braking, forward flip-over.	1	CO3
3.7	Optimal braking.	1	CO3
4	**Steady turning**		
4.1	Motorcycle roll in steady turning, directional behaviour in turn.	1	CO4
4.2	Cornering forces, Linearized model in a turn, multi-body model in steady turning.	2	CO4
4.3	Roll, steering and sideslip angles, steering ratio, steering torque.	2	CO4
5	**In-Plane Dynamics**		
5.1	Front and rear suspension, reduced stiffness, preload.	2	CO5
5.2	Change in distance between centres of driving and driven sprockets, change in wheelbase.	1	CO5

5.3	Models with one degree of freedom – frequency of bounce and pitch	1	CO5
5.4	Models with two degrees of freedom - frequency of bounce and pitch	2	CO5
5.5	Model with four degrees of freedom - introduction	1	CO5
6	**Motorcycle trim**		
6.1	Trim in steady state – rear suspension equilibrium with chain and shaft transmission.	1	CO6
6.2	Inclination of angle of chain, Squat ratio and squat angle.	1	CO6
6.3	Motorcycle trim in a curve.	1	CO6
6.4	Motorcycle trim in acceleration	1	CO6
6.5	Motorcycle trim in braking	1	CO6
	Total	**36**	

Course Designers:

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18MEPM0	ORGANIZATIONAL BEHAVIOR

Category	L	T	P	Credit
PE	3	-	-	3

Preamble

The main objective of Organizational Behavior course is to help the students to understand individual behaviour, group behaviour and organisational systems behaviour, and thereby develop the relevant skills to become effective persons in the organisation and to take rational decisions. People have always been regarded as important in managing organizations. Human aspects are critical in each functional aspects of management and equally so for the effective utilization of resources. In view of this, organizational behavior has assumed great importance.

Prerequisite

Nil

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Explain the concept of organization and organizational behavior, and its relevance.	15
CO2	Relate the study of individual behaviour to the organizational behavior.	20
CO3	Integrate the inter-personal behaviour with the characteristics of personality, perception and emotions.	15
CO4	Appreciate the study of group behaviour in the determination of organizational behavior.	20
CO5	Compare the leadership styles and their suitability to the different organizational situation.	20
CO6	Explain the different organizational structures and its characteristics.	10

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Value	Guided response	1.1, 1.2, 2.5.1, 2.5.2, 4.1.1, 4.2.1
CO2	TPS3	Apply	Value	Mechanism	1.1, 2.1.4, 2.4, 2.5, 3.1 4.1, 4.2
CO3	TPS3	Apply	Value	Mechanism	1.1, 2.4, 2.5,3.1,4.2
CO4	TPS3	Apply	Value	Mechanism	1.1,2.3,2,4,2.5,3.1,3.2,3.3 4.2, 4.3,4.6
CO5	TPS3	Apply	Value	Mechanism	1.1,2.1,2.3,2.4,2.5,3.1,3.2,3.3, 4.1,4.2,4.3,4.4,4.5,4.6
CO6	TPS2	Understand	Value	Guided response	1.1,2.3,2.4,2.4,3.1,3.2,4.1

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	M	L		-	-	-	M	M	-	-	-	M	-	-	L
CO2	M	M	L	-	-	M	S	S	S	S	M	S	-	-	M
CO3	M	M	L	-	-	M	S	S	S	S	M	S	-	-	S
CO4	M	M	L	-	M	M	S	S	S	S	M	S	-	-	S

CO5	M	M	L	-	M	M	S	S	S	S	M	S	-	-	S
CO6	M	L	-	-		M	S	S	S	S	M	S	-	-	L

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	20	20	20	--	--	--	20
Understand	30	30	30	--	--	--	30
Apply	50	50	50	100	100	100	50
Analyse	-	-	-	--	--	--	--
Evaluate							
Create							

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	
Set	
Guided Response	
Mechanism	Assignment
Complex Overt Responses	
Adaptation	
Origination	

Sample Questions for Course Outcome Assessment**

** (2 to 3 at the cognitive level of course outcome)

Course Outcome 1(CO1):
1. Define organisation.
2. Describe the term organizational behaviour
3. Describe the importance of organizational behaviour.

Course Outcome 2(CO2):
1. Suggest the relevance of individual behaviour in the determination of organisational behaviour.
2. Appreciate the role of any one personality theory to the study of individual behaviour.

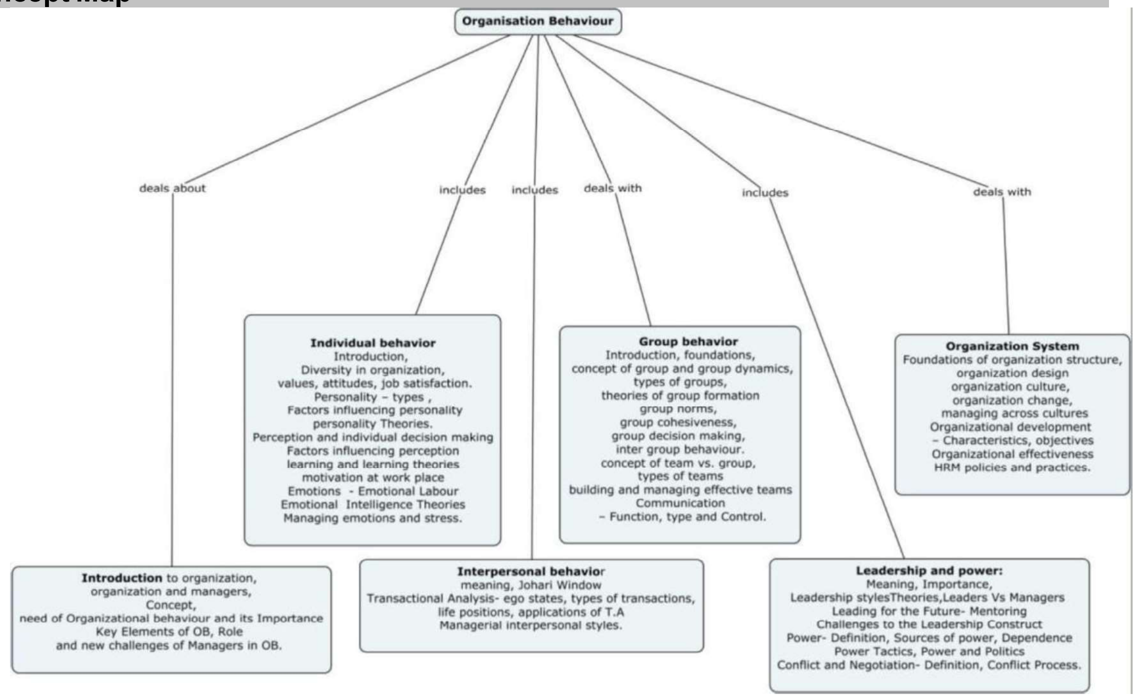
Course Outcome 3(CO3):
1. Appreciate the relevance of Transactional Analysis in the understanding of human behaviour.
2. Study the effect of intpersonal behaviour in an organisation with a suitable example.

Course Outcome 4 (CO4):
1. Trace out the reasons for the formation of the group in an organization.
2. Explain the process of communication.
3. Suggest the ways and means to make organisational communication effectively.

Course Outcome 5 (CO5):
1. Suggest the type of leadership for automobile service unit.
2. Apply the role of effective leader in a manufacturing industry.
3. Show the various types of leadership styles which suits to your organization.

Course Outcome 6(CO6):
1. Explain the organizational change process and suggest ways to overcome the resistance to change.
2. Explain the importance human resource management for the success of an orgnanisation.

Concept Map



Syllabus

Introduction to Organizational Behaviour: Introduction to organization, organization and managers, Concept, need of Organizational behaviour(OB) and its Importance, Key Elements of OB, Role and new challenges of Managers in OB.

Individual behaviour: Introduction, Diversity in organization, values, attitudes, job satisfaction. Personality –types, Factors influencing personality, personality Theories. Perception and individual decision making. Factors influencing perception, learning and learning theories, motivation at work place, Emotions - Emotional Labour, Emotional Intelligence Theories. Managing the emotions and stress.

Interpersonal behaviour: meaning, Johari Window, Transactional Analysis- ego states, types of transactions, life positions, applications of T.A., managerial interpersonal styles.

Group behavior: Introduction, foundations, concept of group and group dynamics, types of groups, theories of group formation, group norms, group cohesiveness, group decision making, inter group behaviour, concept of team vs. group, types of teams, building and managing effective teams. Communication–Function, type and Control.

Leadership and power: Meaning, Importance, Leadership styles, Theories, Leaders Vs Managers , Leading for the Future- Mentoring, Challenges to the Leadership Construct. Power- Definition, Sources of power, Dependence, Power Tactics, Power and Politics.

Conflict and Negotiation- Definition, Conflict Process.

Organization System: Foundations of organization structure, organization design, organization culture, organization change, managing across cultures. Organizational development –Characteristics – objectives. Organizational effectiveness**.** Human resource management policies and practices.

Learning Resources

1. Stephen P. Robins, Organisational Behavior, PHI Learning / Pearson Education, 15th edition, 2012.
2. Joseph E. Champoux**, "**Organizational Behavior: Integrating Individuals, Groups, and Organizations**"**, Fourth Edition, Routledge-Taylor and Francis group, 2011.
3. John B. Miner, Organizational Behavior: Foundations, Theories, and Analyses, Oxford University Press,2002.

4. K . Aswathappa, Organisational Behaviour: Text, Cases & Games, Himalaya Publishing House, 12th edition, 2017.
5. Sushama Khanna, Understanding Organizational Behaviour, Oxford University Press, 4th Edition, 2016.
6. https://www.youtube.com/watch?v=-sLHfYnxh8s- Organizational Behaviour, Dr. Susmita Mukhopadhyay Vinod Gupta, School of Management, IIT -Kharagpur
7. https://nptel.ac.in/courses/110/105/110105034/- Organizational Behaviour (Web Course), Dr. Susmita Mukhopadhyay Vinod Gupta, School of Management, IIT -Kharagpur

Course Contents and Lecture Schedule

Module No	Topic	No. of Lectures	COs
1.	**Introduction to Organizational Behaviour**		
1.1	Introduction to organization, organization and managers, Concept, need of Organizational behaviour and its Importance	2	CO1
1.2	Key Elements of OB, Role and new challenges of Managers in OB.	2	
2.	**Individual behavior**		CO2
2.1	Introduction, Diversity in organization, values, attitudes, job satisfaction.	1	
2.2	Personality – types , Factors influencing personality	1	
2.3	personality Theories.	1	
2.4	Perception and individual decision making	1	
2.5	Factors influencing perception	1	
2.6	learning and learning theories	1	
2.7	motivation at work place	1	
2.8	Emotions - Emotional Labour	1	
2.9	Emotional Intelligence Theories	1	
2.10	Managing emotions and stress.	1	
3.	**Interpersonal behavior**		CO3
3.1	meaning, Johari Window	1	
3.2	Transactional Analysis- ego states, types of transactions,	1	
3.3	life positions, applications of T.A	2	
3.4	Managerial interpersonal styles.	1	
4.	**Group behavior**		CO4
4.1	Introduction, foundations, concept of group and group dynamics, types of groups,	1	
4.2	theories of group formation	1	
4.3	group norms, group cohesiveness, group decision making, inter group behaviour.	1	
4.4	concept of team vs. group, types of teams	1	
4.5	building and managing effective teams	1	
4.6	Communication – Function, type and Control.	1	
5	**Leadership and power**		
5.1	Meaning, Importance, Leadership styles	1	

Module No	Topic	No. of Lectures	COs
5.2	Theories, Leaders Vs Managers	1	CO5
5.3	Leading for the Future- Mentoring	1	
5.4	Challenges to the Leadership Construct	1	
5.5	Power- Definition, Sources of power, Dependence	1	
5.6	Power Tactics, Power and Politics	1	
5.7	Conflict and Negotiation- Definition, Conflict Process.	1	
6	**Organization System**		
6.1	Foundations of organization structure, organization design	1	CO6
6.2	organization culture, organization change, managing across cultures	1	
6.3	Organizational development – Characteristics, objectives	1	
6.4	Organizational effectiveness	1	
6.5	Human resource management policies and practices.	1	
	Total	**37**	

Course Designers:

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18MEPP0	PRODUCT DESIGN AND DEVELOPMENT

Category	L	T	P	Credit
PE	2	1	-	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

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Explain and classify the product design and development processes	10
CO2	Identify methodical approach to collect customer statement and convert them into need statement	20
CO3	Identify methodical approach to convert need statement into product specification and generate product concept for the same.	20
CO4	Evaluate and test the concepts for the final product specification.	20
CO5	Implement the suitable product architecture, prototyping	20
CO6	Explain about industrial design process, design protection and Intellectual Property.	10

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.1, 2.1.1,
CO2	TPS3	Apply	Value	Mechanism	1.2, 2.1.1 , 3.1.2, 3.2.3 .3.2.5 , 4,4,1
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.1.1, 3.1.2, 3.2.3, 3.2.5, 4.4.3
CO4	TPS5	Evaluate	Organise	Adaptation	1.2, 2.1.1, 2.1.2, 2.1.5, 3.2.3, 4.5.1
CO5	TPS4	Analyse	Organise	Complex Overt Responses	1.2, , 2.1.2, 2.1.5, 3.2.5, 4.3.2, 4.5.1
CO6	TPS2	Understand	Respond	Guided Response	1.1, 2.1.1

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	M	L													
CO2	S	M	L			L	L			M			M		M
CO3	S	M	L			L	L			M			M		M
CO4	S	S	S	M		L	L			S			M		M
CO5	S	S	M	L		L				M			S		M
CO6	M	L													

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	10	10	10	-	-	-	10

Understand	20	20	20	-	-	-	20
Apply	30	30	30	50	50		30
Analyse	20	20	20	50	50	50	20
Evaluate	20	20	20			50	20
Create							

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment /Practical Component
Perception	
Set	
Guided Response	
Mechanism	Assignment
Complex Overt Responses	Assignment - Case study response
Adaptation	Assignment - Case study review
Origination	

Course Level Assessment Questions

Course Outcome 1 (CO1:
1. Define product design.
2. Distinguish between functional design and production design, with suitable examples.
3. What is pre project planning?

Course Outcome 2 (CO2):
1. Convert the customer statement into need statement for automobiles
2. Explain different method of collecting customer need of a product.
3. As a customer Identify the basic needs while selection a new car

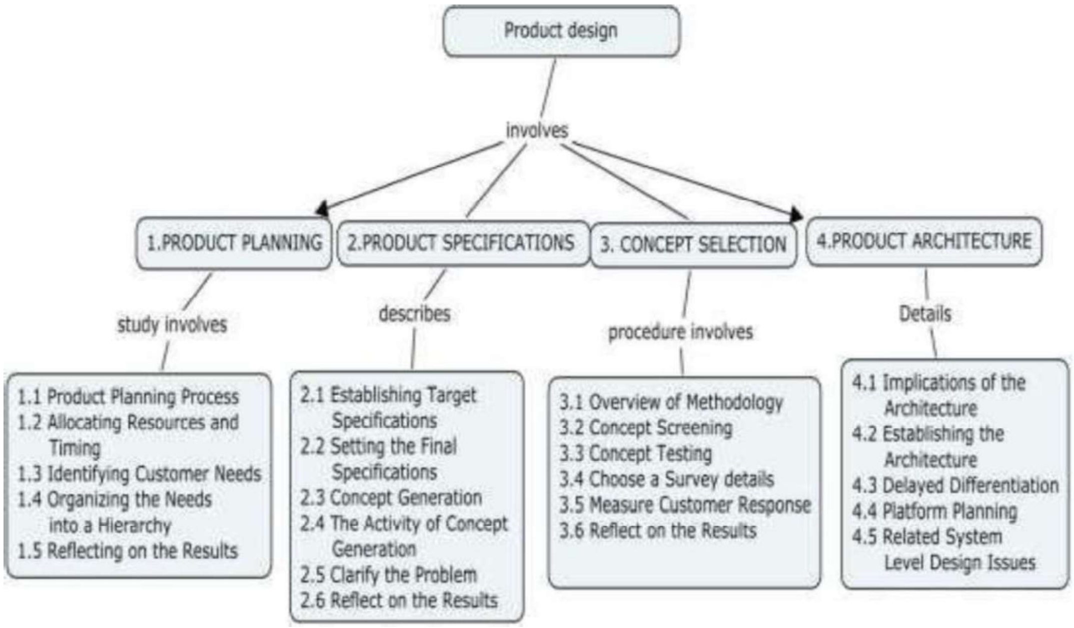
Course Outcome 3 (CO3):
1. What is metrics?
2. List your needs with respect to two wheeler motorcycle suspension and convert to a product specification.
3. How concept selection methods can is used to benchmark or evaluate the existing product?

Course Outcome 4 (CO4):
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. Explain the different steps in concept selection

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

Course Outcome 6 (CO6):
1. What is Intellectual Property?
2. Define different types of patent.
3. Define industrial design process

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 - 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 -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 -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--- System- Level Design Issues - Case study.- Intellectual Property –patent types – copyright – trademark – trade secret

Learning Resources

1. Ulrich, Karl T. and Steven D. Eppinger, '"**Product Design and Development**", Irwin /McGraw-Hill , 6th Edition, 2015.
2. David G.Ullman, "**The Mechanical Design Process**", Tata McGraw Hill , 2011
3. Orwin, Homewood, "**Effective Product Design and Development**", Stephen Rosenthal, Business One 1992,ISBN, 1-55623-603-4
4. Stuart Pugh, "**Tool Design – Integrated Methods for successful Product Engineering**", Addison Wesley Publishing,Neyourk,NY,1991, ISBN 0-202-41639-5
5. 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- 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 .	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
3.5	Measure Customer Response-Interpret the Results.	1
3.6	Case study -Reflect on the Results and the Process.	1
3.7	COSTING: Material – manufacturing –assembly – structure.	2
3.8	Ergonomics and aesthetic aspects	1
4.0	PRODUCT ARCHITECTURE	
4.1	Implications of the Architecture-Establishing the Architecture-System- Level Design Issues. -Case study	2
4.2	Intellectual Property –patent types – copyright – trademark – trade secret	2
	Total	36

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18MEPQ0	REFRIGERATION AND AIR CONDITIONING

Category	L	T	P	Credit
PE	2	1	-	3

Preamble

Refrigeration deals with cooling of bodies (or) fluids to temperatures lower than surroundings temperature. 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

- 18ME340-Thermal Engineering
- 18ME440-Fluid Mechanics

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Determine the COP of air refrigeration cycle.	20
CO2	Determine the COP of vapour compression refrigeration cycle.	20
CO3	Explain the working of components of vapour compression refrigeration system and select environmentally benign refrigerants.	10
CO4	Determine the mass and energy transfer of various psychrometric processes	20
CO5	Explain the functioning of air conditioning systems and understand the requirements of comfort air conditioning.	10
CO6	Calculate the cooling load of an air conditioned space	20

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO2	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO3	TPS2	Understand	Respond	Guided Response	1.2, 2.1.3, 3.2, 4.3.2
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO5	TPS2	Understand	Respond	Guided Response	1.2, 2.1.3, 3.2, 4.3.2
CO6	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	S	M	L	-	_	_	_	S	M	M	_	_	_	L	_
CO2	S	M	L	-	_	_	_	S	M	M	_	_	_	M	_

CO3	M	L	-	-	_	_	_	S	M	M	_	_	_	L	_
CO4	S	M	L	-	_	_	_	S	M	M	_	_	_	M	_
CO5	M	L	-	-	_	_	_	S	M	M	_	_	_	L	_
CO6	S	M	L	-	_	_	_	S	M	M	_	_	_	M	_

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	10	10	10	-	-	-	10
Understand	40	40	40	-	-	-	40
Apply	50	50	50	100	100	100	50
Analyse							
Evaluate							
Create							

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	
Set	
Guided Response	
Mechanism	Assignment
Complex Overt Responses	
Adaptation	
Origination	

Sample Questions for Course Outcome Assessment**
** (2 to 3 at the cognitive level of course outcome)

Course Outcome 1 (CO1):

1. Define the term ton of refrigeration.
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.

Course Outcome 2 (CO2):

1. Explain the working of vapour absorption refrigeration system.
2. State the principle behind the working of vortex tube.
3. 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)	hf (kJ/kg)	hg (kJ/kg)	sf (kJ/kgK)	sg (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. Explain the advantages and disadvantages of hermetic compressor over open type compressor.
3. 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 45°C DBT and 30°C 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.

Course Outcome 5 (CO5):

1. Explain the working of summer air conditioning system with a neat sketch.
2. With the neat diagram, explain the working of a window air conditioner.
3. Draw and discuss various features of Comfort chart.

Course Outcome 6 (CO6):

1. 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°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

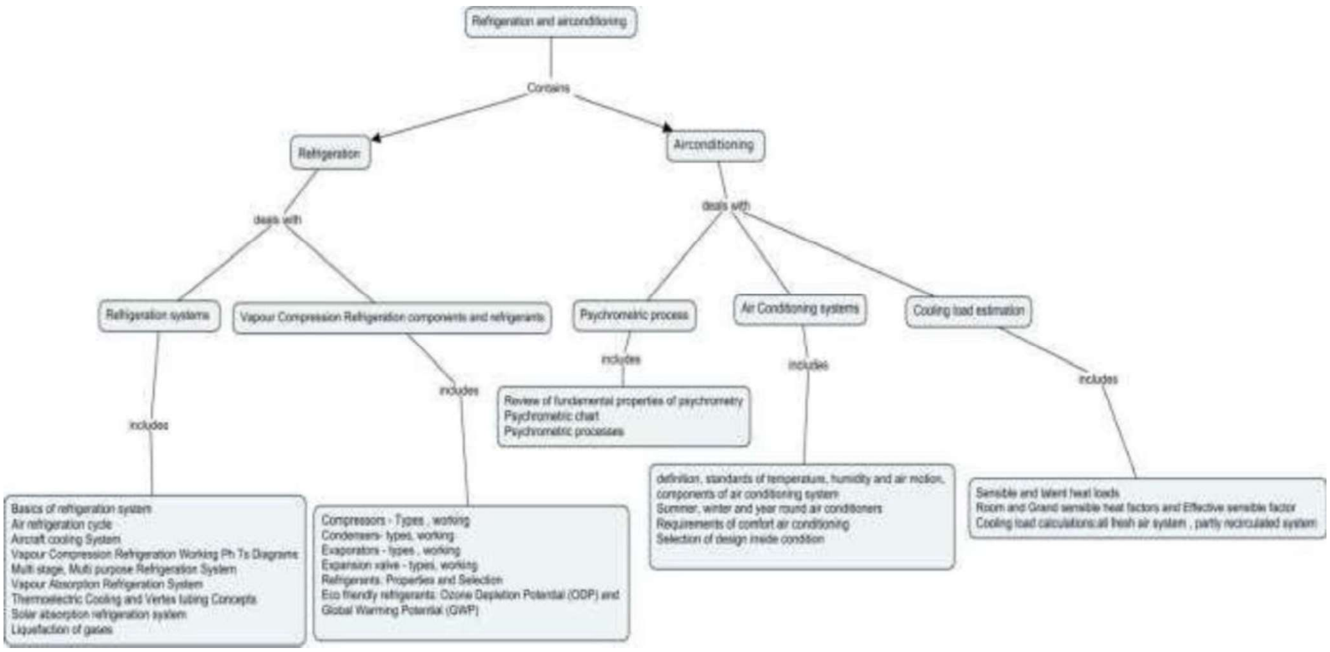
If two-third of recirculated room air and one-third of fresh air are mixed before entering the cooling coils. Determine: Apparatus dew point; (ii) Grand total heat load; and (iii) effective room sensible heat factor.

2. Define RSHF
3. 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.

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, 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 - types and function. 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).

Application of refrigeration–cold storage and process industries, Application of air-conditioning – comfort, automobile and industrial

Learning Resources

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.
3. Ibrahim Dincer and Mehmet Kanoglu, "**Refrigeration Systems and Applications**", John Wiley and Sons, 2010.
4. Domkundwar, Arrora and Domkundwar, "**Refrigeration and Air Conditioning**", Dhanpat Rai and Co, 2009.
5. Manohar Prasad, "**Refrigeration and Air Conditioning**", New Age Publishing Ltd, 2010.
6. Jones, W.P., "**Air Conditioning Engineering**",5th Edition, Butterworth Heinemann, 2005.
7. Rex Miller and Mark R. Miller, "**Modern Refrigeration and Air Conditioning**", McGraw-Hill, 2006.
8. https://nptel.ac.in/courses/112105129/ - NPTEL Lecture Material
9. https://nptel.ac.in/courses/112105128/ - NPTEL Video Lectures by Prof.Ramgopal, Mechanical Engineering, IIT kharagpur

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	Course Outcome
	Refrigeration systems		
	Review of thermodynamic principles of refrigeration	1	CO1
1	**Air cycle refrigeration**:		
1.2	Bell-Coleman cycle – ideal and actual, numerical problems.	2	CO1
1.3	Aircraft cooling system – simple and bootstrap	1	CO1
2	**Vapour compression refrigeration**		
2.1	Working, p-h and T-s diagrams	2	CO2
2.2	Innovative VCR systems- cascade, Multistage compression, Multipurpose refrigeration systems	1	CO2
2.3	Vapour compression refrigeration cycle – ideal and actual, numerical problems.	2	CO2
2.4	Vapour absorption refrigeration – Ammonia Water system, Lithium Bromide Water system, Electrolux system, Solar vapour adsorption refrigeration system	2	CO2
2.5	Thermoelectric Cooling, Vortex tube refrigeration.	1	CO2
2.6	Liquefaction of gases- Linde and Claude system.	1	CO2
3	**Vapour Compression Refrigeration components and refrigerants**		
3.1	Compressors: Types – based on operation and based on arrangement.	2	CO3
3.2	Condensers: Types- air cooled, water cooled and evaporative condensers.	1	CO3
3.3	Evaporators: Flooded and dry expansion types. Expansion valves: Capillary type, automatic expansion valve, Thermostatic expansion valve.	1	CO3

3.4	Refrigerants: Properties and Selection	1	CO3
3.5	Eco friendly refrigerants: Ozone Depletion Potential (ODP) and Global Warming Potential (GWP)	1	CO3
4	**Psychrometric process**		
4.1	Review of fundamental properties of psychrometry, Psychrometric chart.	1	CO4
4.2	Psychrometric processes- Bypass factor, Apparatus Dew Point (ADP) temperature	2	CO4
4.3	Numerical problems	2	CO4
5	**Air Conditioning systems**		
5.1	**Air conditioning** – definition, standards of temperature, humidity and air motion, components of air conditioning system-types and function	2	CO5
5.2	Summer, winter and year round air conditioners	1	CO5
5.3	Window, Split air conditioners, Central air conditioner systems.	1	CO5
5.4	**Requirements of comfort air conditioning**: oxygen supply, body heat and body moisture removal, sufficient air movement, purity of air	1	CO5
5.5	Selection of design inside condition– thermal comfort, factors affecting thermal comfort, indices for thermal comfort, comfort chart, Selection of design outside condition	1	CO5
6	**Cooling load estimation**		
6.1	Sensible and latent heat loads: Internal heat sources, heat transmission through building	1	CO6
	load from occupants, Equipment load, load due to food storage, load due to solar radiation, infiltration, fresh air load, estimation of total load	1	CO6
6.2	Room and Grand sensible heat factors and Effective sensible factor	1	CO6
6.3	Cooling load calculations: without fresh air system	2	CO6
	Cooling load calculations: with fresh air system (mixing before conditioner and mixing after conditioner)	2	CO6
6.4	Application of refrigeration and air-conditioning- cold storage, comfort –building, automobile and industrial	1	CO6
Total		**38**	

Course Designers:

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18MEPR0	ROBOTICS

Category	L	T	P	Credit
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 20th 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. The required modelling approaches in determining kinematic, static and dynamic behaviours, and knowledge representation have been addressed in this course. Moreover, this course facilitates the students to design and develop multi-DOF manipulator and wheeled mobile robot with artificial intelligence and to participate in robotics related contests.

Prerequisite

- Matrix manipulations

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage in %
CO1	Describe the working of the subsystems of robotic manipulator and wheeled mobile robot	10
CO2	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	20
CO3	Develop the static force and dynamic model of two degrees of freedom planar robot arm	20
CO4	Generate a trajectory in joint space using cubic polynomial and trigonometric functions with given kinematic constraints of two and three degree of freedom (DOF) manipulator	20
CO5	Develop a knowledge representation for task planning of robotic applications such as pick and place, palletizing, sorting and inspection of work-parts	20
CO6	Explain various types of control schemes and sensors used in the operation of robot	10

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.3,
CO2	TPS3	Apply	Value	Mechanism	1.3, 2.1.2, 2.1.3, 3.2.5, 4.4.3
CO3	TPS3	Apply	Value	Mechanism	1.3, 2.1.2, 2.1.3, 3.2.5, 4.4.3
CO4	TPS3	Apply	Value	Mechanism	1.3, 2.1.2, 2.1.3, 3.2.5, 4.4.3
CO5	TPS3	Apply	Value	Mechanism	1.3, 2.1.2, 2.1.3, 2.3.1, 3.2.5, 4.4.3
CO6	TPS2	Understand	Respond	Guided Response	1.3,

Mapping with Programme Outcomes and Programme Specific Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	M	L													
CO2	S	M	L										M		
CO3	S	M	L										M		
CO4	S	M	L										M		
CO5	S	M	L										M		

CO6	M	L													

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	20	20	20	-	-	-	10
Understand	20	20	20	-	-	-	30
Apply	60	60	60	100	100	100	60
Analyse	-	-	-	-	-	-	-
Evaluate	-	-	-	-	-	-	-
Create	-	-	-	-	-	-	-

Assessment Pattern: Psychomotor

Psychomotor Skill	Mini-project /Assignment/Practical Component
Perception	
Set	
Guided Response	
Mechanism	Simulation of robot using open source packages like RoboAnalyzer and programming in MatLab
Complex Overt Responses	
Adaptation	
Origination	

Sample Questions for Course Outcome Assessment

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

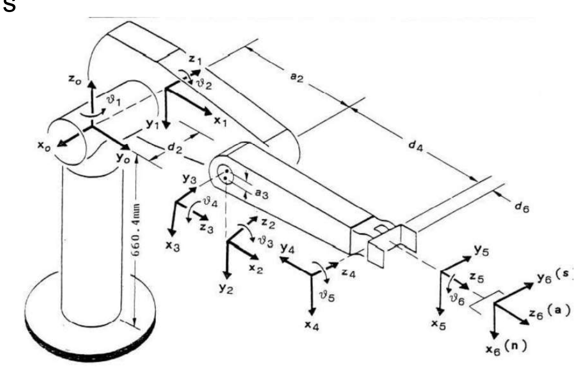


Figure 1

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 $x_0 y_0 z_0$ 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 $x_1 y_1 z_1$ 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 $x_2 y_2 z_2$ 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.

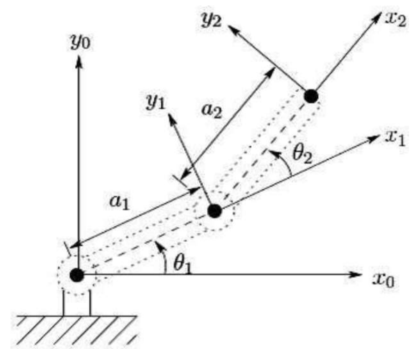


Figure 2

3. 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 for the planar manipulator as shown in figure 3.

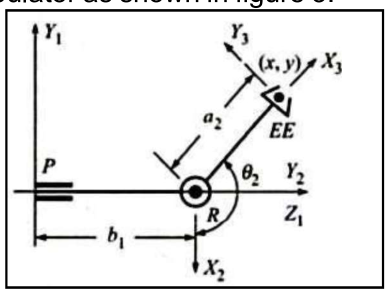


Figure 3

Course Outcome 3(CO3):

1. Develop a dynamic model for two degree of freedom manipulator as shown in figure 4.

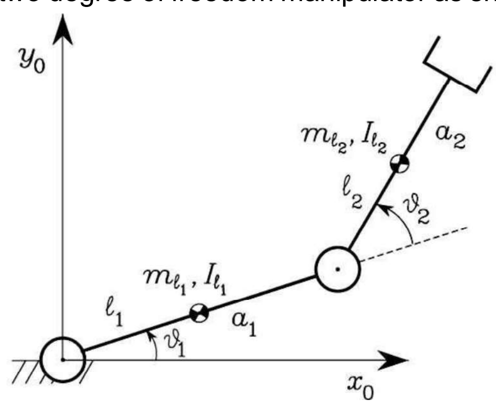


Figure 4

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.

Course Outcome 4 (CO4):

1. 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.

2. A single link rotary joint robot is required to move from $\theta(0) = 30°$ to $\theta(2) = 100°$in 2 seconds. Assume that initial and final velocities are zero. Determine the coefficients of a cubic polynomial trajectory and plot its trajectory for atleast 8 equal time intervals.

3. Generate position, velocity and acceleration profiles for a cycloidal trajectory of the rotary joints of a manipulator with $t(i) = 0$; $t(f) = 8s$; $\theta(i) = 0°$; $\theta(f) = 100°$;

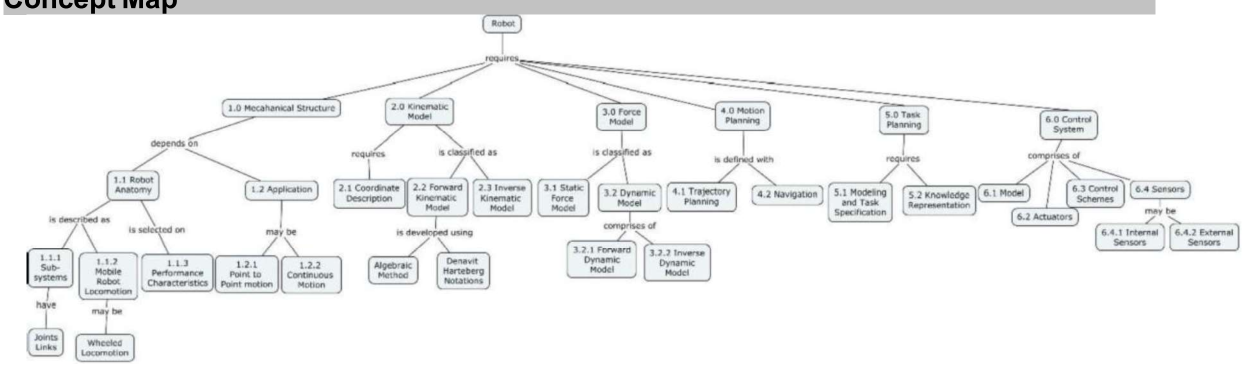
Course Outcome 5 (CO5):

1. 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. Prepare the sequence of tasks with use of semantic map.
2. Prepare a knowledge representation scheme to operate 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.

Course Outcome 6(CO6):

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.

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 – swarm robots.

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 Task Planning -Modeling and Task Specification - Problems in task planning: Spatial relationship, obstacle avoidance and grasp planning-Expert System and Knowledge Engineering: Construction of expert system, Rule-based systems-Knowledge representation.

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.

Learning Resources

1. S.K.Saha, "Introduction to Robotics", Second Edition, McGraw Hill Education (India)Private Limited, New Delhi, 2014.
2. Roland Siegwart and Illah R.Nourbakhsh, "Introduction to Autonomous Mobile Robots", Prentice Hall of India (P) Ltd., 2005.
3. K.S. Fu, R.C Gonzalez and C.S. Lee, Robotics- Control, Sensing, Vision and Intelligence, Tata McGraw-Hill Editions, 2008.
4. Siciliano, B., Sciavicco, L., Villani, L., Oriolo, G., Robotics: Modelling, Planning and Control, First edition, Springer-Verlag London,2009
5. John J.Craig, Introduction to Robotics, Mechanics and control, third edition, Pearson education, 2005.
6. Mark W.Spong, M.Vidyasagar, Robot dynamics and control, Wiley India, 2009.
7. 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.
8. Hertzberg J., Chatila R. (2008) AI Reasoning Methods for Robotics. In: Siciliano B., Khatib O. (eds) Springer Handbook of Robotics. Springer, Berlin, Heidelberg
9. International Federation of Robotics (IFR) Report: Artificial Intelligence in Robotics: https://ifr.org/downloads/papers/Media_Backgrounder_on_Artificial_Intelligence_in_Robotics_May_2018.pdf
10. Sun, X., & Zhang, Y. (2019). *A Review of Domain Knowledge Representation for Robot Task Planning. Proceedings of the 2019 4th International Conference on Mathematics and Artificial Intelligence - ICMAI 2019.* doi:10.1145/3325730.3325756
11. NPTEL Course on Robotics – Prof. Dilip Kumar Prathihar: https://nptel.ac.in/courses/112105249/

Course Contents and Lecture Schedule

Module No.	Topic	No. of Hours	Course Outcome
1.	**Mechanical Structure**		
1.1	Robot Configuration - Robot Anatomy	1	CO1
1.1.1	Sub- systems of Industrial Robot	1	
1.1.2	Mobile robot locomotion: Introduction, key issues for locomotion	1	
1.1.2.1	Wheeled locomotion - wheel design, geometry	1	
1.1.2.2	Stability, manoeuvrability and controllability		
1.1.3	Performance characteristics of robots	1	
1.2	Applications - Progressive advancement in Robots – Point to point and continuous motion applications - Mobile manipulators and its applications - swarm robots.		
2.0	**Kinematic Model**		
2.1	Coordinate Description - Forward Kinematics for two DOF manipulator – Algebraic method	1	CO2
2.1.1	Mechanical structure and notations, Coordinate frames, Description of objects in space	1	
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)	1	

Module No.	Topic	No. of Hours	Course Outcome
	notation,		
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	**Force Model**		
3.1	Static Force Model - Differential relationship - Velocity analysis – Jacobian matrix	2	CO3
3.1.1	Determination of forces and equivalent torques for joints of two link planar robot arm	2	
3.2	Dynamic model - Euler-Lagrangian formulation		
3.2.1	Forward dynamic model for two DOF manipulator	2	
3.2.2	Inverse dynamic model for two DOF manipulator.	1	
4.0	**Motion planning**		
4.1	Trajectory Planning: Definitions and planning tasks, Joint space techniques- Cartesian space techniques	1	CO4
4.1.1	Motion profiles – Cubic polynomial motion	2	
4.1.2	Linear Segmented Parabolic Blends	1	
4.1.3	Cycloidal motion	1	
4.2	Navigation: Graph search path planning	2	
4.2.1	Potential field path planning	1	
4.2.2	Navigation architecture	1	
5.0	**Robot Task Planning**		
5.1	Modeling and Task Specification	1	CO5
5.1.1	Problems in task planning: Spatial relationship, obstacle avoidance and grasp planning	1	
5.1.2	Expert System and Knowledge Engineering: Construction of expert system, Rule-based systems	1	
5.2	Knowledge representation – First Order Logic	2	
6.	**Control System**		
6.1	The manipulator control problem	1	CO6
6.1.1	Linear second-order model of manipulator. Functions of controller and power amplifier		
6.2	Joint actuators- stepper motor, servo motor	1	
6.3	Control Schemes: PID control scheme – Position and force control schemes		
6.4	Robotic sensors and its classification	1	
6.4.1	Internal sensors – Position, velocity, acceleration and force information		
6.4.2	External Sensors – Contact Sensors-Limit switches, piezo-elcetric, pressure pads.	1	
6.4.3	Non-contact sensors –Range sensors, Vision sensor-robotic vision system, Description of components of vision system.		
		37	

Course Designers:

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18MEPS0	SPARK IGNITION ENGINES-DESIGN

Category	L	T	P	Credit
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

18MEPB0 Automotive Engine System

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Explain general ideas and concepts behind various engine layout schemes	15
CO2	Perform design calculations to arrive at the design specs for cylinder head, block, piston and connecting rod assembly	25
CO3	Perform design calculations to arrive at the design specs for crankshaft and flywheel assembly	15
CO4	Solve problems related to design of engines from manufacturing, service and assembly perspective for functional and life requirements	15
CO5	Propose and develop a design verification process to prove engine for performance, durability and reliability	15
CO6	Determine various NVH, thermal and other attributes issues that are connected with the engine behaviour	15

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.2, 2.1.3, 3.2, 4.3.2
CO2	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO3	TPS2	Apply	Value	Mechanism	1.2, 2.1.3, 3.2, 4.3.2
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO5	TPS3	Understand	Respond	Guided Response	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO6	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	M	L	-	-	-	-	-	S	M	M	-	-	-	S	-
CO2	M	L	-	-	-	-	-	S	M	M	-	-	-	S	-
CO3	S	M	L	-	-	-	-	S	M	M	-	-	-	M	-
CO4	S	M	L	-	-	-	-	S	M	M	-	-	-	M	-
CO5	S	S	M	L	-	-	-	S	M	M	-	-	-	M	-
CO6	S	S	S	M	-	-	-	S	M	M	-	-	-	M	-

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

	Continuous	Assignment	

Cognitive Levels	Assessment Tests						Terminal Examination
	1	2	3	1	2	3	
Remember	10	10	10	-	-	-	10
Understand	50	30	30	-	-	-	30
Apply	40	60	60	100	100	100	60
Analyse							
Evaluate							
Create							

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	
Set	
Guided Response	
Mechanism	Assignment
Complex Overt Responses	
Adaptation	
Origination	

Sample Questions for Course Outcome Assessment**

** (2 to 3 at the cognitive level of course outcome)

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):

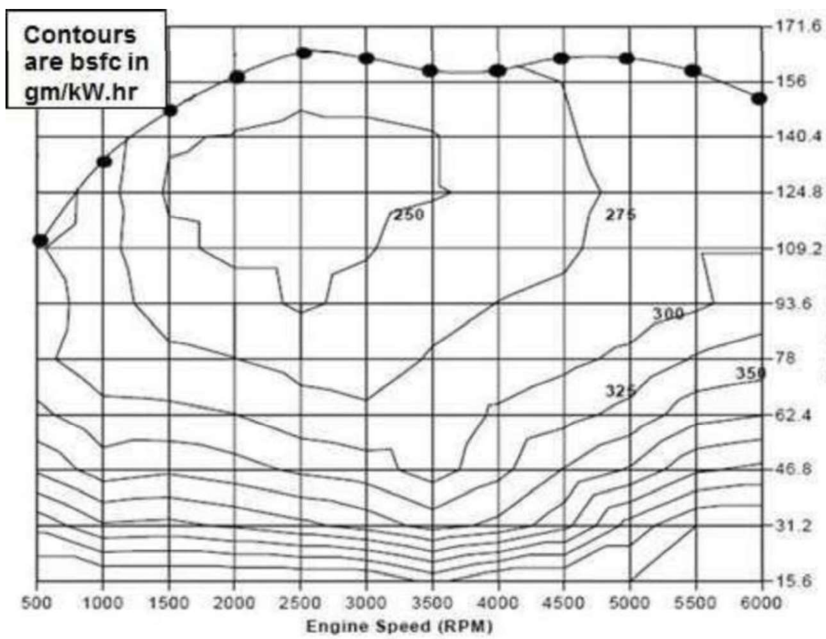
1. Mention the significance of valve size and numbers in combustion chamber design.
2. Explain the various types of cylinder head casting options available for manufacture.
3. Show the difference between full floating and semi floating type piston pins using a schematic drawing.

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?



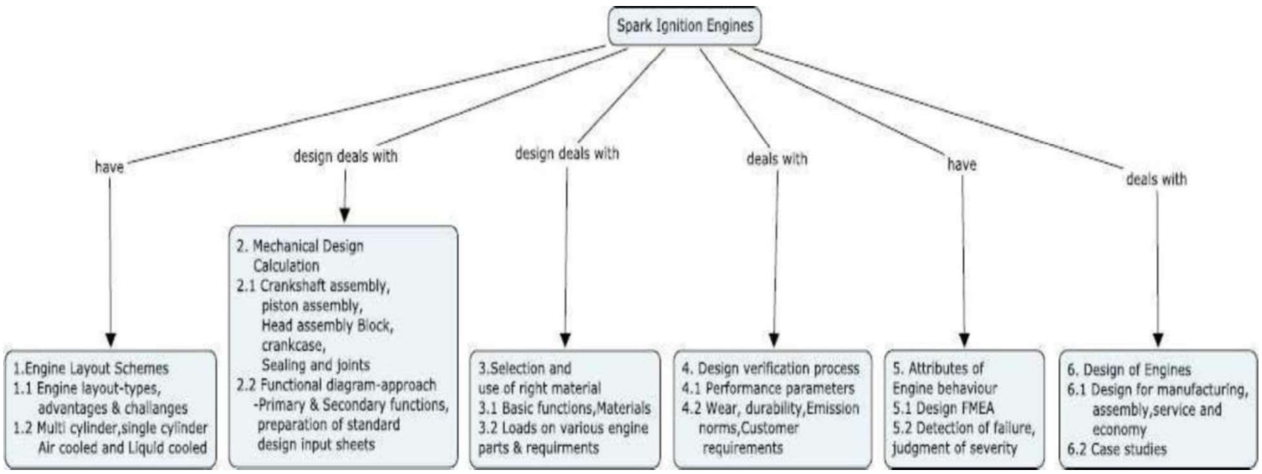
Course Outcome 6 (CO6):

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



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 head, 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 of Engines: Design for manufacturing – Design for assembly – design for service – Design for economy – Design for performance

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.

.

Learning Resources

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.
3. Heywood J.B., **"Internal Combustion Engine Fundamentals**", McGraw-Hill International Edition, 2011.
4. 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 Hours	Course Outcome
1	**Engine layout schemes**		
1.1	Introduction , types of engine layout	2	CO1
1.2	Various types of engines	2	CO1
2	**Mechanical Design Calculation**		
2.1	Mechanical construction details, Functional diagram – approach	2	CO2
2.2	Primary & Secondary functions, Preparation of standard design input sheets.	1	CO2

2.3	Design procedure for Cylinder block	2	CO2
2.4	Design procedure for Piston	2	CO2
2.5	Design procedure for Connecting rod	2	CO2
2.6	Design procedure for Crankshaft	2	CO2
2.7	Design procedure for Valves	1	CO2
3	**Selection and use of right material for engine**		
3.1	Introduction – functions of critical parts.	2	CO3
3.2	Materials used in automotive engines	1	CO3
3.3	Types of loads on engine and other requirements	2	CO3
4	**Design verification Process**		
4.1	Introduction, performance parameters	2	CO4
4.2	Types of wear, wear limit study, Durability	2	CO4
4.3	Emission norms, Customer requirements.	2	CO4
5	**Attributes of engine behaviour**		
5.1	Various attributes contributing to engine behaviour	2	CO5
5.2	Design FMEA – function, cause, occurrence level	2	CO5
5.3	Detection of failure judgment of severity, opportunities to detect severity	2	CO5
6	**Design of Engines**		
6.1	Design for manufacturing	1	CO6
6.2	Design for assembly	1	CO6
6.3	Design for service ,Design for economy, Design for performance	1	CO6
	TOTAL	**36**	

Course Designers:

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18MEEA0	TOTAL QUALITY MANAGEMENT

Category	L	T	P	Credit
ES	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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Explain fundamental, Evolution and principles of TQM.	15
CO2	Explain the concepts of Statistical process control	10
CO3	Identify the solution for Particular problem through Quality control tools	20
CO4	Implement different techniques of TQM for continuous improvement in an organization.	20
CO5	Prepare Quality systems manuals and documents in compliance with international standards.	15
CO6	Implement the Quality Management Systems in a different organization environment.	20

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.1.1, 2.1.1,2.1.2
CO2	TPS2	Understand	Respond	Guided Response	1.1.1, 2.1.1,2.1.2, 2.3.1
CO3	TPS3	Apply	Value	Mechanism	2.1.1, 2.1.2, 2.1.3, 2.1.4, 2.1.5, 2.3.1, 2.3.3, 2.4.1, 2.4.2 2.5.1, 2.5.4 3.1.1,3.1.2,3.1.4, 3.2.3,3.2.4
CO4	TPS3	Apply	Value	Mechanism	2.1.1, 2.1.2, 2.1.3, 2.1.4, 2.1.5, 2.3.1, 2.3.3, 2.4.1, 2.4.2 2.5.1, 2.5.4 3.1.1,3.1.2,3.1.4, 3.2.3,3.2.4
CO5	TPS3	Apply	Value	Mechanism	2.1.1, 2.1.2, 2.1.3, 2.1.4, 2.1.5, 2.3.1, 2.3.3, 2.4.1, 2.4.2 3.1.1,3.1.2,3.1.4, 3.2.3,3.2.4
CO6	TPS3	Apply	Value	Mechanism	2.1.1, 2.1.2, 2.1.3, 2.1.4, 2.1.5, 2.3.1, 2.3.3, 2.4.1, 2.4.2 3.1.1,3.1.2,3.1.4, 3.2.3,3.2.4

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3

CO1	M	L	_	_	L	_	_	L	_	_	_	_	_	_	_
CO2	M	L	_	-	L	_	_	L	_	_	_	_	_	_	_
CO3	S	M	L	-	M	_	_	L	M	L	_	_	_	_	M
CO4	S	M	L	_	M	_	L	L	_	_	L	_	_	_	L
CO5	S	M	L	_	M	_	L	L	_	_	_	_	_	_	M
CO6	S	M	L	-	M	-	L	L	-	-	-	-	-	-	M

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	20						
Understand	20	40	40	100			40
Apply	60	60	60		60	100	60
Analyse							
Evaluate							
Create							

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component		
	Assignment 1	Assignment 2	Assignment 3
Perception			
Set			
Guided Response			
Mechanism		40	
Complex Overt Responses			
Adaptation			
Origination			

Sample Questions for Course Outcome Assessment**

** (2 to 3 at the cognitive level of course outcome)

Course Outcome 1(CO1):

1. Compare different concepts of Quality Gurus.
2. Discuss in detail the role of senior management.
3. How can you retail your customer in the organization's business?

Course Outcome 2(CO2):

1. Differentiate between specification limit and control limit.
2. How will you calculate process capability ratio?
3. Describe the Steps involved in constructing a Control chart chart for variables and Attributes.

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.

3. Suggest the possible tools to improve the Core Placement in Mechanical Engineering Graduates.

Course Outcome 4 (CO4):

1. Prepare a Quality statement of your own Industry/Company/Organization concern and Prepare a Action plan to implement Quality Policy Deployment.
2. Suggest the methods to implement the 5S Techniques to improve the work place in shop floor.
3. Implement Kaizen techniques to improve the NIRF Ranking for Engineering Education in India.

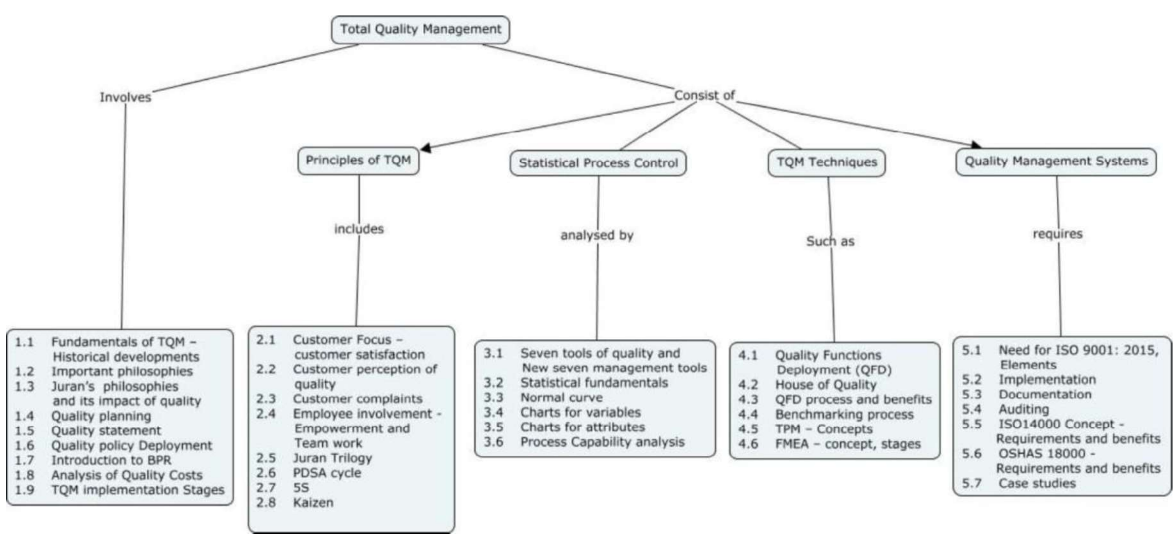
Course Outcome 5 (CO5):

1. Suggest the possible methods to prepare a Quality System manual of your own concern.
2. Prepare a schedule for Auditing with respect to QMS in an Engineering Education Systems.
3. Suggest the possible methods to prepare a Documentation Report of your own concern.

Course Outcome 6(CO6):

1. Implement QMS ISO 9001:2015 Standards to Two wheeler manufacturing Company.
2. Suggest the steps for conducting Internal Audit process for ISO 9001:2015 in Mechanical Engineering Department.
3. Implement QMS ISO 14001:2015 Standards to manufacturing Company.

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. **Process Monitoring:** statistical fundamentals - Normal curve - Seven tools of quality– Histogram, Check Sheet, Cause and Effect Diagram, Control chart, Pareto Chart, Scatter Diagram, Stratification Diagram. Control charts for variables and attributes, Process Capability analysis and New Seven management tools. **TQM Techniques:** - PDSA cycle, 5S, Kaizen. Quality Functions Deployment (QFD) – house of Quality, QFD process and benefits, Benchmarking process, TPM – Concepts, Failure Mode Effect Analysis (FMEA) – DFMEA (Design),PFMEA (Process) and SFMEA (System) concept, stages and Juran Trilogy. **Quality Management Systems:** Need for ISO 9001: 2015 – Elements, Implementation, Documentation and Auditing. ISO14001:2015, ISO 26000, ISO 27000 and ISO45001 – Concept requirements and benefits – Case studies.

Learning Resources

1. Dale H.Besterfiled, Carol Besterfiled-Michna. Glen H. Beseterfiled and Mary Besterfield-Sacre., "**Total Quality Management**", Pearson Education Asia, 2004.
2. Shridhara Bhat, "**TQM – Text and Cases**", Himalaya Publishing House, 2002.
3. Berk, Joseph and Berk, S., "**The Essence of TQM**", Prentice Hall of India, 1998.
4. Narayana and Sreenivasan, "**Quality Management – Concepts and Tasks**", New Age International, 1996.
5. Sharma, D.D, "**Total Quality Management**", Sultan Chand & Sons, 2005.
6. https://www.youtube.com/watch?v=ksR4Xy6tFcM - Introduction to TQM
7. https://www.youtube.com/watch?v=yWIAOFs04go

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures	Course Outcomes
1	**Introduction**		CO1
1.1	Fundamentals of TQM – Historical developments	1	
1.2	Important philosophies - (Deming, Crossby, Ishikawa) & their impact of quality.	2	
1.3	Juran's philosophies and its impact of quality	1	
1.4	Quality planning and Quality statement	1	
1.5	Quality policy Deployment and Introduction to BPR	1	
1.6	Analysis of Quality Costs	1	
1.7	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	Supplier Quality Management	1	
3	**Process Monitoring**		
3.1	Statistical fundamentals , Normal curve	1	CO2 & CO3
3.2	Seven tools of quality - Histogram, Check Sheet, Cause and Effect Diagram, Control chart, Pareto Chart, Scatter Diagram, Stratification Diagram	2	
3.3	Charts for variables		
3.4	Charts for attributes	1	
3.5	Process Capability analysis		
3.6	New seven management tools	1	
4	**TQM Techniques**		
4.1	PDSA cycle and 5S	1	CO4
4.2	Kaizen	1	

4.3	Quality Functions Deployment (QFD)	1	
4.4	House of Quality	1	
4.5	QFD process and benefits	1	
4.6	Benchmarking process	1	
4.7	TPM – Concepts	1	
4.8	FMEA – DFMEA (Design),PFMEA (Process) and SFMEA (System)concept, stages	2	
4.9	Juran Trilogy	1	
5	**Quality Management Systems**		
5.1	Need for ISO 9001: 2015, Elements	1	CO5 & CO6
5.2	Implementation	1	
5.3	Documentation and Auditing	1	
5.4	ISO14001:2015, ISO 26000 and ISO 27000 Concept - Requirements and benefits	2	
5.5	ISO 45001 - Requirements and benefits	1	
5.6	Case studies	1	
	Total	**36**	

Course Designers

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18MEPU0	TURBO MACHINES

Category	L	T	P	Credit
PE	2	1	-	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

- 18ME340-Thermal Engineering
- 18ME440-Fluid Mechanics

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO 1.	Describe the energy transfer, reheating and preheating effects, and efficiencies of turbomachines and blade and cascade nomenclatures	18
CO 2.	Use dimensional and model analysis to turbomachines	10
CO 3.	Calculate the performance parameters of Centrifugal and Axial flow Compressors	18
CO 4.	Compute the performance parameters of Steam and Gas Turbines	18
CO 5.	Calculate the performance parameters of Centrifugal Pumps	18
CO 6.	Compute the performance parameters of Hydraulic Turbines	18

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.2, 2.1.3, 3.2, 4.3.2
CO2	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO5	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO6	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	M	L	-	-	_	_	_	S	M	M	_	_	_	L	_
CO2	S	M	L	-	_	_	_	S	M	M	_	_	_	M	_
CO3	S	M	L	-	_	_	_	S	M	M	_	_	_	M	_
CO4	S	M	L	-	_	_	_	S	M	M	_	_	_	M	_
CO5	S	M	L	-	_	_	_	S	M	M	_	_	_	M	_

CO6	S	M	L	-	_	_	_	S	M	M	_	_	_	M	_

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	10	10	10	-	-	-	10
Understand	30	30	30	-	-	-	30
Apply	60	60	60	100	100	100	60
Analyse							
Evaluate							
Create							

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	
Set	
Guided Response	
Mechanism	Assignment
Complex Overt Responses	
Adaptation	
Origination	

Sample Questions for Course Outcome Assessment**

** (2 to 3 at the cognitive level of course outcome)

Course Outcome 1 (CO1):

1. Classify a turbo machine based on the direction of fluid flow?
2. Explain the nomenclatures of a blade with a neat diagram.
3. 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. 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.

3. 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. Elucidate the phenomenon of surging and stalling in centrifugal compressor.
2. 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 0.18m2 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/m3 and inlet stagnation temperature is 290 K. Neglect the work input factor. Also, find the overall pressure ratio of the compressor.
3. 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 Cp=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. Derive the degree of reaction of axial flow turbine in terms of blade angles.
2. 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 $\gamma = 1.4$.
3. 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 C_{pg} = 1.147kJ/kg K; γ =1.33

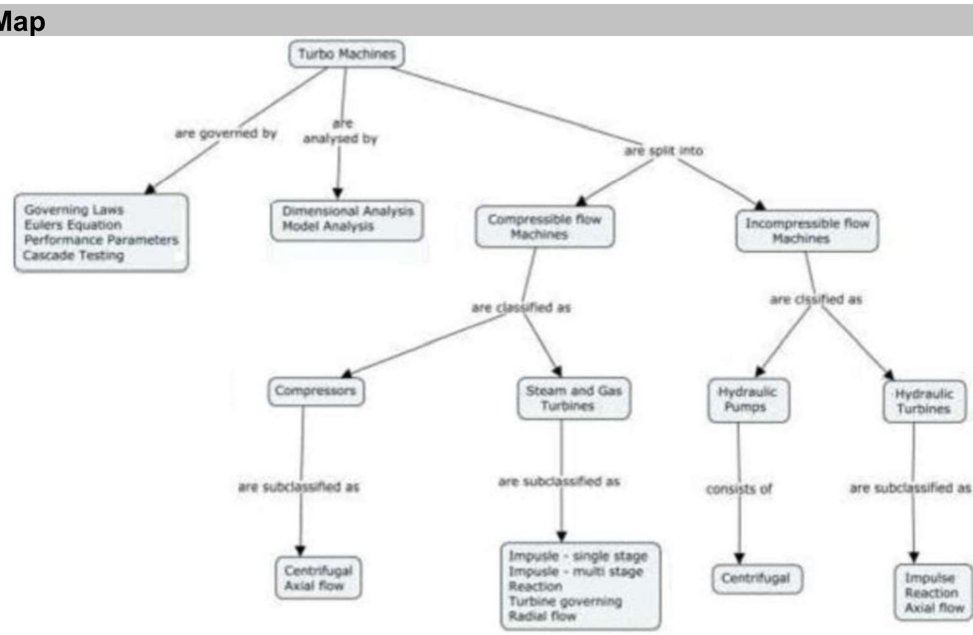
Course Outcome 5 (CO5):

1. What is NPSH?
2. Deduce the minimum speed expression for a centrifugal pump.
3. 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.

Course Outcome 6 (CO6):

1. 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 15o and discharge through the nozzle is 150 lit/s, find (a) power available at the nozzle and (b) hydraulic efficiency of the turbine.
2. 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.
3. A Kaplan turbine is to be designed to develop 9100 kW. The net available head is 5.6m. 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 Testing- Blade Types, Forces acting on blades, Blade nomenclature, Compressor cascade and Turbine cascade nomenclatures, Cascade testing and losses,

Dimensional and Model Analysis

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..

Learning Resources

1. S. M. Yahya, "**Turbines, Compressors & Fans**", Tata-McGraw Hill, 4th edition, 2010.
2. A.Valan Arasu, "**Turbo Machines**", Second Edition, Vikas publishing house Pvt Ltd, 2013.
3. S.L.Dixon and C.A. Hall, "**Fluid Mechanics and Thermodynamics of Turbo machinery** " Butterworth- Heinemann Publishers, 2013.
4. Rama S. R. Gorla and Aijaz A. Khan "**Turbo machinery Design and Theory**", Marcel Dekker Inc. USA, 2003.
5. V. Kadambi and Manohar Prasad **An Introduction to Energy Conversion- Turbomachinery**, Volume III, New Age International Publishers (P) Ltd. 2011.
6. B.K. Venkanna, '**Fundamentals of Turbomachinery'**, PHI Learning Pvt. Ltd., 2009.
7. William W Peng, "**Fundamentals of Turbomachinery**", John Wiley & Sons, Inc. 2008.
8. G.Gopalakrishnan and D.Prithvi Raj, "**A Treatise of Turbomachines**", Scitech Publications, 2008.
9. NPTEL Material on Basics of Turbomachines: http://nptel.ac.in/courses/Webcourse-contents/IIT-KANPUR/machine/ui/TOC.htm
10. NPTEL material on Turbomachinery Aerodynamics: http://nptel.ac.in/courses/101101058/

Course Contents and Lecture Schedule

Module No.	Topic	No. of hours	Course Outcome
1	**Turbo machines**		
1.1	Introduction,Classification, Continuity equation, Laws of thermodynamics, Newton's second law of motion.	1	CO1
1.2	Energy Transfer in Turbo machinery- Euler's Turbine Equation, Components of energy transfer.	1	CO1
1.3	Performance Parameters- Compression and expansion processes on T-S diagrams, Work done.	1	CO1
1.3.1	Preheating and Efficiencies of Compressor, Numerical problems.	1	CO1
1.3.2	Reheating and Efficiencies of Turbine, Numerical problems.	1	CO1
1.4	Cascade Testing		
1.4.1	Blade Types, Forces acting on blades, Blade nomenclature	1	CO2
1.4.2	Compressor cascade and Turbine cascade nomenclatures, Cascade testing and losses	2	CO2
2	**Dimensional and Model Analysis**		
2.1	**Dimensional analysis**		CO2
2.1.1	Dimensions and equations, Advantages, Buckingham Pi Theorem	2	CO2
2.2	**Model Analysis**		CO2
2.2.1	Advantages, Similarity – Geometric, Kinematic and Dynamic	1	CO2
2.2.2	Specific speed, Unit quantities	2	CO2
	Compressible Flow Machines		
3	**Compressors**		
3.1	**Centrifugal Compressors** - Velocity triangle, Slip factor, Work done, Impeller blade types	1	CO3
3.1.1	Numerical problems.	2	CO3
3.2	Characteristics-Stall, Surging and Choking	1	CO3
3.2	**Axial Flow Compressors** - Velocity triangle, Degree of reaction, Stage loading, Numerical problems	2	CO3
3.2.1	Multi-stage performance, Numerical problems, Characteristics – Stalling	2	CO3
4	**Steam and Gas Turbines**		
4.1	**Axial Flow ImpulseTurbine –** Single stage, Velocity triangles and Work output, Mollier diagram,	1	CO4 CO4
4,1.1	Degree of reaction, Blade-loading coefficient, Numerical problems.	2	CO4
4.1.2	Multiage-Pressure compounding, Velocity compounding and Pressure-velocity compounding, Numerical Problems.	1	CO4
4.1.3	**Reaction Turbine**- Velocity diagram, Stage efficiency. Reheat factor, Numerical problems.	2	CO4
4.1.4	Losses in turbines, Governing of turbines.	1	CO4
4.2	**Radial Flow Gas Turbine**-Velocity diagrams and Mollier diagram, Spouting velocity, Efficiency, Numerical problems.	2	CO4
4	**Incompressible Flow Machines**:		
5	**Hydraulic Pumps**		
5.1	**Centrifugal Pumps –** Velocity triangles, Work done,		CO5

	Slip factor, Pump losses, Numerical problems.	2	
5.1.2	Impeller Blade Shape, NPSH, Specific speed, Cavitation.	1	CO5
6	**Hydraulic Turbines**		
6.1	**Impulse Turbine**-Pelton wheel, Velocity triangles, Work done and Efficiencies, Numerical problems.	2	CO6
6.2	**Reaction Turbine**-Francis turbine, Velocity triangles, Work done, Efficiencies, Turbine characteristics, Numerical problems	1	CO6
6.3	**Axial Flow Turbine**- Kaplan turbine, Velocity triangles, Work done, Efficiencies, Numerical problems, Cavitation.	2	CO6
	Total	**38**	

Course Designers:

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18MEPV0	VEHICLE DYNAMICS

Category	L	T	P	Credit
PE	3	0	0	3

Preamble

This course covers determination of road loads, calculation of traction limited acceleration and power limited acceleration, vehicle performance under steady state cornering, effect of suspension design, tyre dynamics and performance of steering and braking systems with various geometries.

Prerequisite

- Nil

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Calculate aerodynamic forces, moments, rolling resistances and fuel consumption.	15
CO2	Determine acceleration and braking performance of a vehicle	15
CO3	Determine vehicle performance under steady state cornering.	15
CO4	Calculate anti/pro-squat, anti/pro-dive anti-pitch for different vehicle layouts and suspension geometries.	15
CO5	Estimate Ackermann's error for vehicle steering geometries.	15
CO6	Explain dynamics of an automotive tyre.	10

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO2	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO5	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO6	TPS2	Understand	Respond	Guided Response	1.2, 2.1, 3.2, 4.1.2

with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	S	M	L	-	-	-	-	S	-	-	-	-	M	-	-
CO2	S	M	L	-	-	-	-	S	-	-	-	-	M	-	-
CO3	S	M	L	-	-	-	-	S	-	-	-	-	M	-	-
CO4	S	M	L	-	-	-	-	S	-	-	-	-	M	-	-
CO5	S	M	L	-	-	-	-	S	-	-	-	-	M	-	-
CO6	M	L	-	-	-	-	-	S	-	-	-	-	-	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive	Continuous Assessment Tests	Assignment	Terminal

Levels	1	2	3	1	2	3	Examination
Remember	10	10	10				10
Understand	30	30	30				30
Apply	60	60	60	100	100	100	60
Analyse							
Evaluate							
Create							

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. Find the front and rear suspension geometry that would be necessary to achieve the following, during braking.
   a) 60 % anti-dive at front
   b) 70 % anti-lift at rear
   c) Find the pitch rate for the above geometries.

Assume the following data:
Front suspension stiffness: 40 kN/m
Rear suspension stiffness: 50 kN/m
Height of CG from ground: 0.5 m
Wheel base: 2.8 m
Gross vehicle weight: 2000 kg
Ratio of front and rear braking force = 60:40

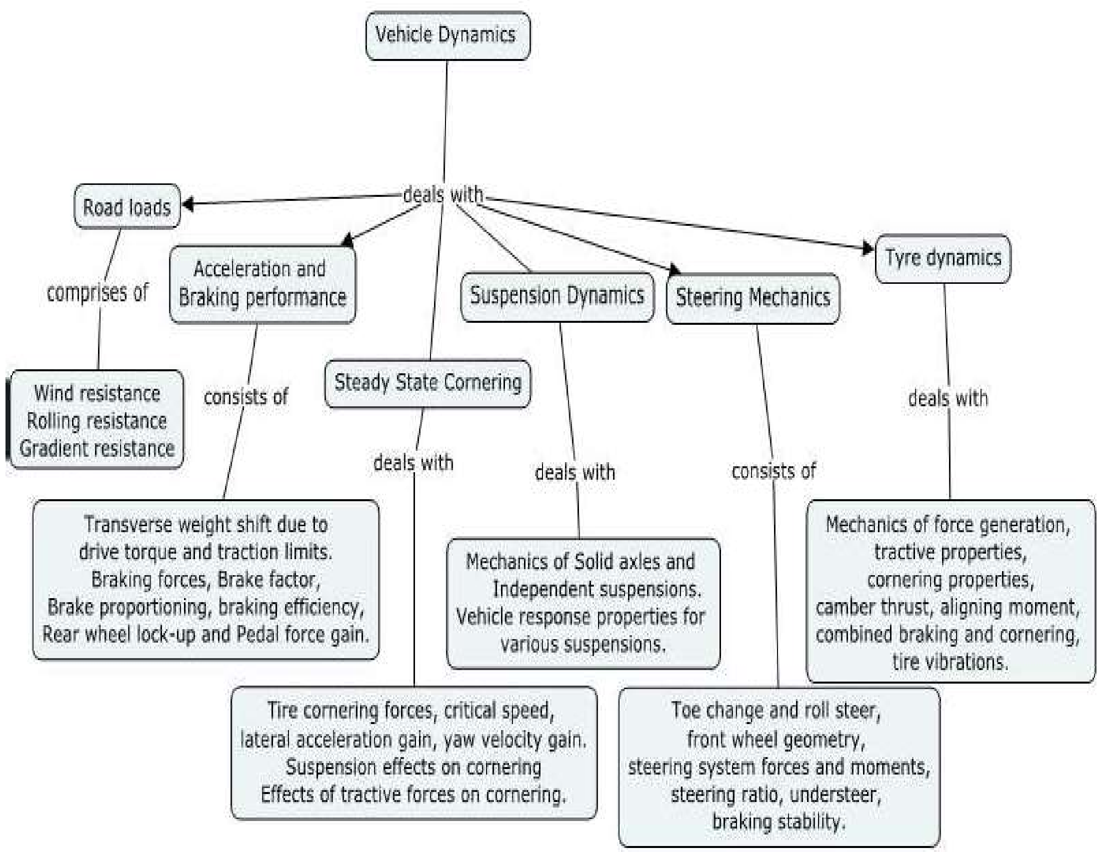
Course Outcome 5 (CO5):

1. Define "Steering geometry error".
2. List and explain various forces and moments acting on steering system.
3. Determine the Ackermann error for the following front wheel steering mechanism.
   Angle between steering arm and longitudinal axis = 8°
   Wheel track = distance between the pivots=1.6 m
   Wheel base = 2.6 m
   Distance of CG from rear axle = 1.5 m
   Inner steering angle = 12°
   Length of steering arm = 0.26 m

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 – Solid axles and Independent suspensions, Anti-squat, Anti-dive and Anti-pitch suspension geometry, Roll centre analysis.

Steering Mechanics – steering linkages, steering geometry error – toe change and roll steer, front wheel geometry, steering system forces and moments, steering system models, Calculation of Ackermann's error for various steering mechanisms.

Tyre Dynamics – Mechanics of force generation, tractive properties, cornering properties, camber thrust, aligning moment, combined braking and cornering, tire vibrations.

Learning Resources

1. Thomas D.Gillespie, **"Fundamentals of vehicle dynamics"** Premiere Series Books, 1992.
2. Reza.N.Jazar, "**Vehicle Dynamics**", Theory and Application, Springer, 2008.
3. William F.Milliken, Douglus L.Milliken, "**Race Car Vehicle Dynamics**", SAE, 1995.
4. N.K.Giri, "**Automobile Mechanics**", 8th Edition, Khanna Publishers, Delhi, 2013.
5. 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 vehicle	1
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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2. Mr. S.B. Sridhar SB.Sridhar@tvsmotor.co.in

		Category	L	T	P	Credit
18MEPW0	**AUTOMOTIVE ENGINEERING**	PE	3		0	3

Preamble

A mechanical engineering graduate is expected to have knowledge on fundamentals of automotive engineering. 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, steering and braking.

Prerequisite

- Nil

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO 1.	Explain construction and working of an automotive engine and its systems.	**20**
CO 2.	Calculate power requirement of an automotive engine, acceleration, gradability, draw bar pull and gear ratios of an automobile.	**20**
CO 3.	Determine centre of gravity, stability of vehicle resting in slope, dynamics of vehicle on a level and banked track, stability of vehicle taking turn.	15
CO 4.	Design steering mechanism and power transmission system of an automobile.	20
CO 5.	Design hydraulic braking system of an automobile.	15
CO 6.	Explain recent developments in the field of automobile engineering	**10**

*** Weightage depends on Bloom's Level, number of contact hours.

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Response	Guided response	1.2, 2.1, 3.2, 4.1.2
CO2	TPS3	Apply	Value	Mechanism	1.1,1.2,2.1,2.4.6,3.2,3.3, 4.1.1,4.1.5
CO3	TPS3	Apply	Value	Mechanism	1.1,1.2,2.1,2.4.6,3.2,3.3, 4.1.1,4.1.5
CO4	TPS3	Apply	Value	Mechanism	1.1,1.2,2.1,2.4.6,3.2,3.3, 4.1.1,4.1.5
CO5	TPS3	Apply	Value	Mechanism	1.1,1.2,2.1,2.4.6,3.2,3.3, 4.1.1,4.1.5
CO6	TPS2	Understand	Response	Guided response	1.2, 2.1, 3.2, 4.1.2

Mapping with Programme Outcomesand Programme Specific Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1.	M	L				L				L					

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			M		
CO6	M	L				L				L					

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	ContinuousAssessmentTests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	10	10	10				10
Understand	40	40	40				40
Apply	50	50	50	100	100	100	50
Analyse	--	-	-	--	--	--	-
Evaluate	--	--	--	--	--	--	--
Create	--	--	--	--	--	--	--

AssessmentPattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	-
Set	-
Guided Response	-
Mechanism	Assignment
Complex Overt Responses	-
Adaptation	-
Origination	-

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Classify automotive engines.
2. Explain the construction and working of a 4-stroke petrol engine.
3. With a neat sketch, explain the circuit and working of battery ignition system.

Course Outcome 2 (CO2):

1. Define: Tractive effortand Gradeability.
2. Narrate the need for different gear ratios in an automobile.
3. The coefficient of rolling resistance for a truck weighing 62293.5 N is 0.018 and the co efficient of air resistance is 0.0276 in the formula $R= KW+K_aAV^2$, the transmission efficiency in top gear of 6.2:1 is 90% and that in the second gear of 15:1 is 85%.The frontal area is 5.574m^2.if the truck has to have a maximum speed of 88 km/h in top gear, Determine the engine BP required and the engine speed if the driving wheels have an effective diameter of 0.825.The maximum grade the truck can negotiate at the above engine speed in second gear and the Maximum draw bar pull available on level at the above engine speed in second gear.

Course Outcome 3 (CO3):

1. Discuss the method of determining the CG position of a vehicle.
2. List the factors responsible for overturning of a vehicle.
3. A vehicle of total weight 49050 N is held at rest on a slope of 10°. It has a wheel base of 2.25 m and its centre of gravity is at 1.0 m in front of the rear axle and 1.5 m above the ground level, Find the normal reactions at the wheels. Assuming that the sliding does not occur first, what will be the angle of slope so that the vehicle will overturn?

Course Outcome 4 (CO4):

1. Explain the construction and working of a power steering with neat diagrams.
2. Discuss the need for limited slip differential and centre differential
3. A track has pivot pins 1.37 m apart, the length of each track arm is 0.17 m and the track rod is behind front axle and 1.17 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. A geometrical construction may be used.

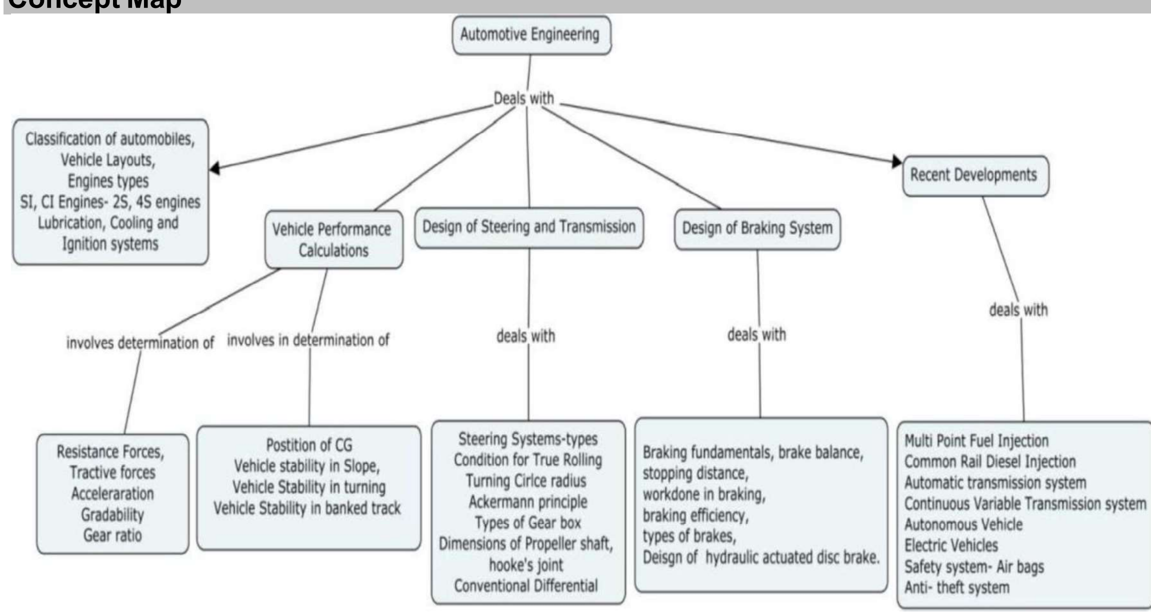
Course Outcome 5 (CO5):

1. Discuss briefly how bleeding is done in hydraulic brake system.
2. Compare drum and disc brakes.
3. In a hydraulic single line braking system, force on the foot pedal is 100N, pedal leverage ratio is 4, cross sectional area of the master cylinder is 4cm^2, cross sectional area of the front pistons 20cm^2, cross sectionalarea of the rear piston 5cm^2 and distance moved by effort is 1 cm. Calculate the front to rear brake ratio, % of front and rear braking, total force ratio, total movement ratio.

Course Outcome 6 (CO6):

1. With a neat sketch, explain the working of Continuous Variable Transmission system
2. Explain the working of Anti- lock Braking system.
3. List the merits and demerits of electric vehicle.

Concept Map



Syllabus

Introduction - Classification of automobiles, Basic layout of an automobile.

Engines -classification, Construction and working of 2-stroke and 4-stroke S.I and C.I.Engines, Lubrication system- Pressurized wet sump, Cooling system- water cooling, ignition system- battery ignition.

Vehicle performance –Various Resistance forces, traction and tractive effort, Road performance curves: acceleration, gradability and draw bar pull, determination of gear ratios.

Centre of gravity of a four-wheeler, Vehicle stability in slope, maximum acceleration, maximum tractive effort and reaction for different drives. Dynamics of vehicle running on banked track, Stability of vehicle turning - 2 wheeled and 4 wheeled vehicle.

Steering mechanism : Function, steering linkages,-Axle beam suspension steering system, independent suspension steering system, joints in live front axle(Tripod joint, Rzeppa joint). Front wheel alignment, Ackermann principle, condition for true rolling, turning circle radius, working of power steering.

Transmission system: Function and types of automotive clutches, working of diaphragm clutch, -Need for gears, working of Sliding mesh, constant mesh and synchromesh gearbox, Design of propeller shaft and Hooke's joint, types of drives, construction and working of conventional differential, need for limited slip differential and centre differential.

Braking system: Fundamentals, brake balance, stopping distance, work done in braking, braking efficiency, Theory and problems on front wheel and/ or rear wheel braking. Types of brakes-Mechanical, hydraulic, Drum, Disc brake systems, Mechanics and design of hydraulic actuated disc brake.

Recent Developments: Multi Point Fuel Injection (MPFI), Common Rail Diesel Injection (CRDI), Automatic Transmission, Continuously variable transmission (CVT). Antilock Braking System (ABS), Autonomous vehicles, Electric vehicles- types, merits and demerits. Safety Systems- Air bag, anti-theft system.

Learning Resources

1. Dr.N.K.Giri, **"Automobile Mechanics**", Eight Edition, Khanna publishers Pvt. Ltd,New Delhi 2011.

2. Kirpal Singh, **"Automobile Engineering",** Volume-1&2, 13th Edition, Standard Publishers Distributers, 2017.

3. S.S.Srivnivasan , **"Automotive Mechanics",** McGraw Hill Education; 2 edition 2017

4. Joseph Heitner, **"Automotive Mechanics, Principle and practices",** East West Press, (Second Edition), 2001

5.Richard Stone and Jeffrey K. Ball,**"Automotive Engineering Fundamentals"**SAE International, 2011.

https://nptel.ac.in/courses/108102121/
https://www.youtube.com/watch?v=y5p31F_dVJU
https://www.youtube.com/watch?v=wCu9W9xNwtI

Course Contents and Lecture Schedule

Module No	Topic	No. of Lectures	COs
1.	**Introduction**		
1.1	Classification of automobiles, Basic layout of an automobile	1	CO1
1.2	**Engines**: classification, Construction and working of 2-stroke and 4-stroke S.I and C.I.Engines	1	
1.3	Lubrication system- Pressurized wet sump, Cooling system- water cooling, ignition system- battery ignition	2	
2.	**Vehicle performance**		CO2
2.1	Various Resistance forces, traction and tractive effort,	2	
2.2	Road performance curves: acceleration, gradability and	2	

Module No	Topic	No. of Lectures	COs
	draw bar pull		
2.3	Selection of gear ratios for an automobile for given application	2	
3.	**CG and stability**		CO3
3.1	Centre of gravity of a four-wheeler, maximum acceleration, maximum tractive effort and reaction for different drives.	2	
3.2	Dynamics of vehicle running on banked track,Vehicle stability in slope	2	
3.3	Stability of vehicle turning- 2 wheeled and 4 wheeled vehicle	2	
4.	**Steering and Transmission**		CO4
4.1	Steering system: function, steering linkages,-Axle beam suspension steering system, independent suspension steering system	1	
4.2	Joints in live front axle (Tripod joint, Rzeppa joint). Front wheel alignment	1	
4.3	Ackermann principle, condition for true rolling, turning circle radius, Theory and problems.	2	
4.4	Working of power steering.	1	
4.5	Design of transmission system: Function and types of automotive clutches, working of diaphragm clutch	1	
4.6	Need for gears, working of sliding mesh, constant mesh and synchromesh gearbox	1	
4.7	Design of propeller shaft and Hooke's joint, types of drives (live rear axle).	2	
4.8	construction and working of Conventional differential, Need for limited slip differential and centre differential	1	
5	**Brakes**		
5.1	Braking fundamentals, brake balance, stopping distance, work done in braking, braking efficiency, Theory and problems on front wheel and/ or rear wheel braking.	2	CO5
5.2	Types of brakes-Mechanical, hydraulic, Drum, Disc brake systems	1	
5.3	Mechanics and design of hydraulic actuated disc brake.	2	
6	**Recent Developments**		
6.1	Multi Point Fuel Injection (MPFI), Common Rail Diesel Injection (CRDI),	1	CO6
6.2	Automatic Transmission	1	CO6
6.3	Continuously variable transmission (CVT). Antilock Braking System (ABS)	1	CO6
6.4	Autonomous vehicles, Electric vehicles- types, merits and demerits. Safety Systems	1	CO6
6.5	Safety Systems- Air bag, anti- theft system.	1	CO6
	Total	**36**	

Course Designers:

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18MEPY0	ADDITIVE MANUFACTURING

Category	L	T	P	Credit
PE	3	0	0	3

Preamble

Additive Manufacturing (AM) 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 and also provides concepts of reverse engineering

Prerequisite

- Nil

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage in %
CO1	Explain the concepts of prototypes, AM process chain and AM Applications	20
CO2	Select the suitable material based AM process for a given component /part drawing.	40
CO3	Select the suitable rapid tooling method for given application/product	15
CO4	Describe the need and steps involved in reverse engineering	5
CO5*	Demonstrate to recreate and Manipulate the 3D data points from given component	10
CO6*	Create 3D model using Additive manufacturing Method	15

*COs (CO5 and CO6) are assessed through report preparation, Oral explanation and component fabrication as assignments in continuous assessment and are not evaluated in terminal examination.

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.3, 2.5.4,3.2.3, 4.1.2
CO2	TPS3	Apply	Value	Mechanism	1.3, 2.5.4,3.2.3, 4.1.2
CO3	TPS3	Apply	Value	Mechanism	
CO4	TPS2	Understand	Respond	Guided Response	1.3, 2.5.4,3.2.3, 4.1.2
CO5	TPS3	Apply	Value	Mechanism	1.3, 2.5.4, 3.1.1, 3.2.3, 4.1.2, 4.6.2
CO6	TPS3	Apply	Value	Mechanism	1.3, 2.5.4, 3.1.1, 3.2.3, 4.1.2, 4.6.2

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	M	L	-	-	-	-	-	-	-	-	-	-	-	-	-

CO2	S	M	L	-	M	-	-	-	-	-	-	L	M	-	L
CO3	S	M	L	-	-	-	-	-	-	-	-	L	M	-	L
CO4	M	L		-	-	-	-	-	-	-	-		-	-	
CO5	S	M	L	-	M	-	-	-	M	M	M	L	-	-	M
CO6	S	M	L	-	M	-	-	-	M	M	M	L	-	-	M

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	**2**	**3**	1	2	3	
Remember	20	20	20	-	-	-	20
Understand	60	60	40	-	-	-	40
Apply	20	20	40	100	100	100	40
Analyse							
Evaluate							
Create							

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	
Set	
Guided Response	Report Preparation
Mechanism	Manipulation of 3D CAD models and Fabricate the component
Complex Overt Responses	
Adaptation	
Origination	

Sample Questions for Course Outcome Assessment

Course Outcome 1 (CO1):

1. Define Prototype
2. Explain the process chain of additive manufacturing process
3. Discuss the additive manufacturing application in automobile field.

Course Outcome 2 (CO2):

1. Explain the process parameters of Solid Ground Curing (SGC).
2. Select the suitable AM process for the development of Pattern for jewellery application
3. 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. With neat diagram, explain silicon rubber tooling processes in detail.
3. Select the suitable rapid tooling method for fabrication of injection moulding tool.

Course Outcome 4 (CO3):

1. Define reverse engineering
2. Discuss the steps involved in reverse engineering in detail.
3. Explain the applications of reverse engineering with an example

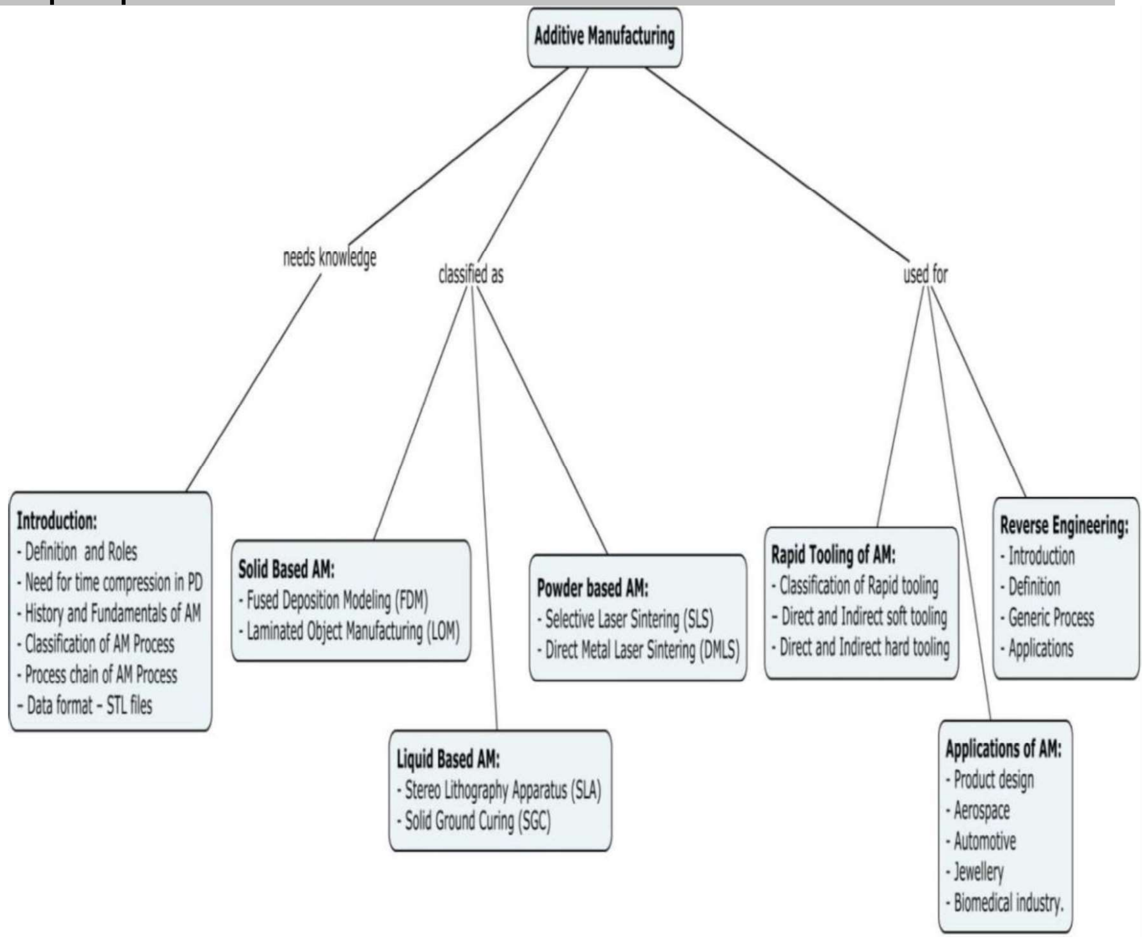
Course Outcome 5: (CO5 - Continuous Assessment only)

Demonstrate to recreate and Manipulate the 3D data cloud points from given component using Scanner and Computer Aided Design Packages (Group activity)

Course Outcome 6: (CO6 - Continuous Assessment only)

Approximately 35cc material (only for FDM) will be given to each student/group (minimum of 3) to fabricate 3D Component through any one of the additive manufacturing method.

Concept Map



Syllabus

Introduction: Definition - Roles of Prototypes - Need for time compression in product development, History of AM Process - Fundamentals of AM Process - Classification of AM Process - Process chain of AM Process – Data format – STL files - Benefits of AM.

Solid Based AM: Fused Deposition Modeling (FDM) Principle – Process parameters – Machine details – Support system - BASS – Water soluble support system – Advantages and limitations, Laminated Object Manufacturing (LOM) – Principle – Processes parameters - Machine details – Advantages and limitations.

Liquid Based AM: Stereo Lithography Apparatus (SLA) – Principle – process parameters – Post processes - Machine details – Advantages and Limitations, Solid Ground Curing (SGC) – Principle – processes parameters – Process details - Machine details - Advantages and Limitations.

Powder based AM: Selective Laser Sintering (SLS) – Principle – process parameters - Machine details – Advantages and Limitations - Direct Metal Laser Sintering (DMLS) – Principle - Machine details - Advantages and Limitations.

Rapid Tooling of AM: Classification of Rapid Tooling – Direct soft tooling - SLS of sand casting – Direct AIM – SL Composite tooling - Indirect soft tooling – Arc spray metal tooling - Silicon rubber molds – Spin casting with vulcanized rubber molds - Direct hard tooling – Rapid tool – Laminated metal tooling – Indirect hard tooling - 3D Keltool – EDM Electrodes - Ecotool.

Applications of AM: Applications of AM in product design, aerospace, automotive, jewellery and biomedical industry.

Reverse Engineering: Introduction – Definition – Generic Process – Scanning – Point Processing – Geometric model development – Applications of reverse engineering.

Practical Component (Continuous Assessments Only)
Demonstration of creation of 3D data cloud points from given component by reverse engineering principle - Manipulation of 3D data points–3D model generation using additive manufacturing method.

Learning Resources

1. Chua, C.K. Leong, K.F. and Lim, C.S. **"Rapid Prototyping: Principles and Applications"**, World Scientific, New Jersey, 2010.
2. Pham, D.T. and Dimov, S.S., **"Rapid manufacturing"**, Springer-Verlag, Londo, 2011.
3. Jacobs, P.F., **"Rapid Prototyping and Manufacturing: Fundamentals of Stereolithography"**, McGraw-Hill, New York, 2011.
4. Hilton. P.D., **"Rapid Tooling"**, Marcel Dekker, New York, 2000.
5. **NPTEL Course:** Rapid Manufacturing
URL: https://nptel.ac.in/courses/112/104/112104265/
6. **Rapid Prototyping Journal**, Emerald Group Publishing Limited
URL: http://www.cheshirehenbury.com/rapid/index.html

Course Contents and Lecture Schedule

Module No.	Topic	No. of Hours	Course Outcome
1	**Introduction:**		
1.1	Definition and Roles of Prototypes	1	CO1
1.2	Need for time compression in product development		CO1
1.3	History of AM Process - Fundamentals of AM Process	1	CO1
1.4	Classification of AM Process - Process chain of AM	1	CO1
1.5	Process – Data format – STL files - Benefits of AM.	1	CO1
2	**Solid Based AM:**		
2.1	Fused Deposition Modeling (FDM) – Principle – Process parameters	2	CO2
2.2	Machine details – Support system - BASS – Water soluble support system	1	CO2
2.3	Advantages and limitations		CO2
2.4	Laminated Object Manufacturing (LOM) – Principle – Processes parameters	2	CO2
2.5	Machine details - Advantages and limitations	1	CO2
3	**Liquid Based AM:**		
3.1	Stereo Lithography Apparatus (SLA) – Principle – process parameters	2	CO2
3.2	Post processes - Machine details - Advantages and Limitations	1	CO2
3.3	Solid Ground Curing (SGC) – Principle – processes parameters	2	CO2

3.4	Machine details - Advantages and Limitations	1	CO2
4	**Powder based AM:**		
4.1	Selective Laser Sintering (SLS) – Principle – process parameters	1	CO2
4.2	Machine details - Advantages and Limitations.	1	CO2
4.3	Direct Metal Laser Sintering (DMLS) – Principle - Machine details	1	CO2
4.4	Advantages and Limitations	1	CO2
5	**Rapid Tooling of AM:**		
5.1	Classification of Rapid Tooling – Direct soft tooling - SLS of sand casting – Direct AIM – SL Composite tooling	1	CO3
5.2	Indirect soft tooling – Arc spray metal tooling - Silicon rubber molds –Spin casting with vulcanized rubber molds	1	CO3
5.3	Direct hard tooling – Rapid tool – Laminated metal tooling	1	CO3
5.4	Indirect hard tooling - 3D Keltool – EDM Electrodes - Ecotool	1	CO3
6	**Applications of AM:**		
6.1	Applications of AM in product design, aerospace	1	CO1
6.2	Automotive, jewellery and biomedical industry.	1	CO1
	Reverse engineering:		
6.3	Introduction – Definition	1	CO4
6.4	Generic Process – Scanning – Point Processing – Geometric model development	1	CO4
6.5	Applications of reverse engineering.	1	CO4
7	**Practical Component** (Continuous Assessments Only)		
7.1	Demonstration of creation of 3D data cloud points from given component by reverse engineering principle	2	CO5
7.2	Manipulation of 3D data points	1	CO5
7.3	3D model generation using additive manufacturing method.	4	CO6
	Total	36	

Course Designers:

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18MEPZ0	ENERGY CONVERSION SYSTEMS

Category	L	T	P	Credit
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

- 18ME340 Thermal Engineering

Course Outcomes

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

Sl. No	Course Outcomes	Weightage in %
CO 1.	Explain with a layout, the working of steam power plant with fuel handling and ash handling systems.	14
CO 2.	Determine the performance parameters of Diesel engine power plants.	15
CO 3.	Determine the power developed and cycle efficiency of gas turbine power plants with reheating and regeneration.	18
CO 4.	Determine the amount of heat transfer in solar thermal energy system and explain the working of various solar energy devices.	18
CO 5.	Describe the working of non-renewable energy conversion systems such as nuclear power plants, wind mill and biofuel systems.	20
CO 6.	Calculate load factor, capacity factor, utilization factor and cost of power generation of power plants.	15

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO 1	TPS2	Understand	Respond	Guided Response	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.6.5
CO 2	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.6.5
CO 3	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.6.5
CO 4	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.6.5
CO 5	TPS2	Understand	Respond	Guided Response	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.6.5
CO6	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	M	L						S		M		L		S	
CO2	S	M	L					S		M		L		S	
CO3	S	M	L					S		M		L		S	
CO4	S	M	L					S		M		L		S	
CO5	M	L						S		M		L		S	
CO6	S	M	L					S		M		L		S	

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	**2**	**3**	1	2	3	
Remember	10	10	10	-	-	-	10
Understand	42	42	42	-	-	-	42
Apply	48	48	48	100	100	100	48
Analyse							
Evaluate							
Create							

Assessment Pattern: Psychomotor

Psychomotor Skill	Mini project /Assignment/Practical Component
Perception	
Set	
Guided Response	
Mechanism	Assignment
Complex Overt Responses	
Adaptation	
Origination	

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the ash handling plant of thermal power station.
2. Differentiate conventional bed and fluidized bed boilers.
3. Discuss the advantages of pulverized fuel firing system.

Course Outcome 2 (CO2):

1. Explain different methods of starting of Diesel Engine 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. Find the air fuel ratio of a stroke, single cylinder water cooled diesel engine power plant with fuel consumption time for 10 cc is 15.3 s. The air consumption time for 0.133 m^3 is 16.3 s. The load on the engine is given by an electrical dynamo meter with 210 Volt and the current is 20 amps. No transmission losses. The calorific value of fuel and specific gravity are 43000 kJ/kg and 0.7. If the rise in temperature of water and exhaust gases are 40 °C and 180 °C, find the brake

power the energy lost in exhaust losses, mass flow rate of cooling water for 30 % heat loss in cooling and unaccounted energy loss.

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. 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/s.
3. Describe the different methods to improve efficiency of gas turbine.

Course Outcome 4 (CO4):

1. In a solar plate collector, air is heated from 28 ^{o}C to 68 ^{o}C. The area of collector plate is 15 m^2. The total solar energy incident on the collector plate is 1100 W/m^2. The mass flow rate of air is 250 kg/h. Specific heat of air is 1.005 kJ/kgK. Calculate the solar power absorbed and collector efficiency. Neglect the top and side loss of energy and assume heat removal factor for the collector plate is 0.98.
2. What are the advantages of wind power generation?
3. Name the different biofuels available for power generation.

Course Outcome 5 (CO5):

1. Describe the fast breeder reactor.
2. Name the types of reactors.
3. Discuss the salient features of PWR reactor.

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:

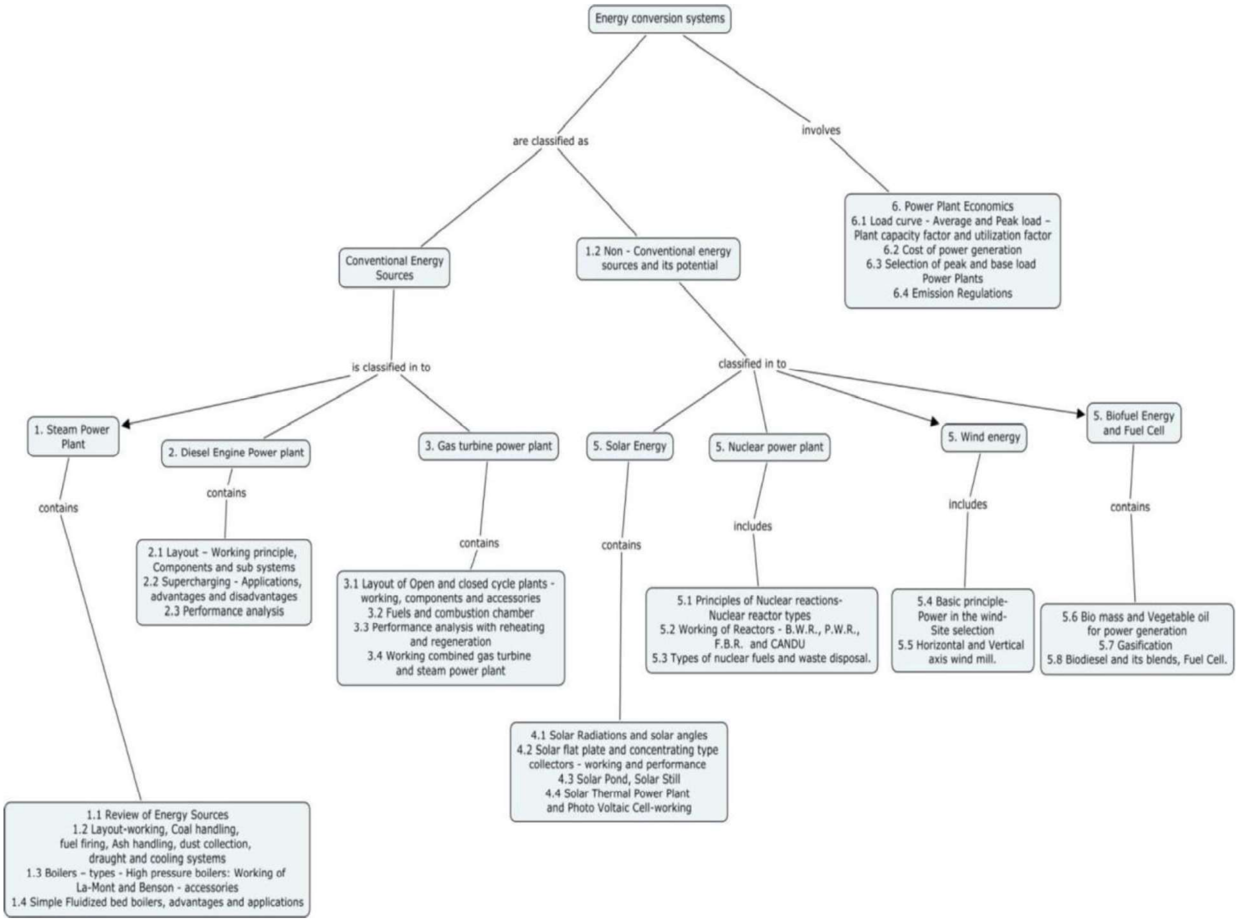
   Annual standby station output = 7.35 x 10^6 kWh;
   Annual base load station output = 101.35 x
   10^6 kWh Peak load on the stand by station =
   12 MW
   Hours of use of stand by station during the year = 2190 hours

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: (i) Average load on power station (ii) Energy generated per year (iii) Demand factor and (d) Diversity factor.

Concept Map



Syllabus

Energy source: Review of energy sources.

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- cogeneration.

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–working of combined gas turbine and steam power plants.

Solar Energy: Solar Radiations and solar angles - latitude angle, declination angle, hour angle, zenith angle - Solar flat plate and concentrating type collectors – performance analysis. Solar pond, Solar Still. Solar Thermal Power Plant, Photo Voltaic Cell.

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 and Fuel Cell: Bio mass and vegetable oil for power generation – Gasification- Biodiesel and its blends-fuel cell.

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.

Learning Resources

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.
4. Volker Quaschning, "**Understanding Renewable Energy Systems** ", Earth scan, 2005.
5. Rajput R.K., **"A Text Book of Power Plant Engineering",** Laxmi Publications (P) Ltd., 2001.
6. Nag P.K., "**Power Plant Engineering**"- second edition, Tata McGraw Hill, New Delhi, 2001.
7. Rai G.D., **Non- Conventional Energy Sources**, Khanna Publishers, New Delhi, 1995.
8. John R Fanchi, **"Energy in the 21st Century"**, World Scientific Publishing Co. Pvt Ltd, 2005.
9. John R Fanchi, **"Energy – Technology and directions for future"**, Elsevier Academic Press, 2004.
10. David Pimentel, "**Bio Fuels, Solar and Wind as Renewable Energy Systems**", Springer, 2008.
11. Bent Sorensen, "**Renewable Energy**", Elsevier Academic Press, 2004.
12. https://www.youtube.com/watch?v=PCv4S9EtHxE - Thermal Power Plant and Coal/Ash Handling
13. https://nptel.ac.in/courses/112103262/ - IC Engines and Gas Turbine Dr. Pranab K. Mondal, IIT Guwahati
14. https://www.youtube.com/watch?v=uulD0KVkmWg – CET, IIT Kharagpur
15. https://nptel.ac.in/courses/121106014/ Non conventional Energy resources, Prof. Pratap Haridoss,
16. https://www.youtube.com/watch?v=mpHZWYpKDJg, Energy resources and Technology Prof.S.Banerjee ,
17. https://nptel.ac.in/courses/112105221/Energy conservation and waste heat recovery , prof, Anatharoop bhattachararya, IIT Kharagpu

Course Contents and Lecture Schedule

Module No.	Topic	No. of Hours	Course Outcome
1	**Steam Power Plant**		
1.1	Review of Energy Sources	1	CO1

Modul e No.	Topi c	No. of Hours	Course Outcome
1.2	Layout – Working, coal handling, fuel firing – grate firing and pulverised fuel firing, Ash handling, dust collection, draught and cooling systems	3	CO1
1.3	Boilers – types - High pressure boilers: Working of La-Mont and Benson - accessories	1	CO1
1.4	Simple Fluidized bed boilers, advantages and Applications	1	CO1
2.	**Diesel engine power plant:**		
2.1	Layout – Working principle, Components and sub systems	1	CO2
2.2	Supercharging - Applications, advantages and disadvantages	1	CO2
2.3	Performance analysis	3	CO2
3.	**Gas turbine power plant:**		
3.1	Layout of Open and closed cycle plants- working, components and accessories	1	CO3
3.2	Fuels and combustion chamber	1	CO3
3.3	Performance analysis with reheating and regeneration	3	CO3
3.4	Working of combined gas turbine and steam power plant	1	CO3
4.0	**Solar Energy:**		
4.1	Solar Radiations and solar angles - latitude angle, declination angle, hour angle, zenith angle	1	CO4
4.2	Solar Collectors - working of flat plate and concentrating type- performance analysis	3	CO4
4.3	Solar pond, Solar Still	1	CO4
4.4	Solar Thermal Power Plant, Photo Voltaic Cell-working	1	CO4
5.	**Nuclear power plant**:		
5.1	Principles of Nuclear reactions- Nuclear reactor types	1	CO5
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	1	CO5
5.3	Types of nuclear fuels and waste disposal.	1	CO5
	Wind energy:		
5.4	Basic principle- Power in the wind- Site selection	1	CO5
5.5	Working of Horizontal and vertical axis wind mill.	1	CO5
	Biofuel Energy and Fuel Cell:		
5.6	Bio mass and Vegetable oil for power generation	1	CO5
5.7	Gasification	1	CO5
5.8	Biodiesel and its blends, Fuel Cell	1	CO5
6.0	**Power Plant Economics:**		
6.1	Load curve - Average and Peak load – Plant capacity factor and utilization factor	1	CO6
6.2	Cost of power generation	3	CO6
6.3	Selection of peak and base load power plant	1	CO6
6.4	Emission Regulations		CO6
	Total	**36**	

Course Designers:

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18MERA0	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

- 18ME340-Thermal Engineering
- 18ME440-Fluid Mechanics

Course Outcomes

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

Sl. No	Course Outcomes	Weigtage in %
CO1.	Solve the thermodynamic cycles involved in the gas turbine.	18
CO2.	Describe the characteristic features of gas turbine components.	12
CO3.	Describe the combustion chamber design and its performance.	12
CO4.	Select suitable matching of gas turbine components.	16
CO5.	Calculate performance parameters of air breathing Jet propulsion systems.	18
CO6.	Calculate performance parameters of Rocket propulsion systems.	24

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO 1	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.4.5, 4.6.5
CO 2	TPS2	Understand	Respond	Guided Response	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.4.5, 4.6.5
CO 3	TPS2	Understand	Respond	Guided Response	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.4.5, 4.6.5
CO 4	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.4.5, 4.6.5
CO 5	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.4.5, 4.6.5
CO6	TPS3	Apply	Value	Mechanism	1.1, 1.2, 2.1,3.2, 4.1.1, 4.1.2, 4.4.5, 4.6.5

Mapping with Programme Outcomes and Programme Specific Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	S	M	-	-	-	-	L	-	L	-	L	M	-	S	-
CO2	S	S	-	-	-	-	L	-	L	-	L	M	-	S	-
CO3	S	M	-	-	-	-	L	-	L	-	L	M	-	S	-
CO4	S	M	-	-	-	-	L	-	L	-	L	M	-	S	-
CO5	S	S	-	-	-	-	L	-	L	-	L	M	-	S	-
CO6	S	S	-	-	-	-	L	-	L	-	L	M	-	S	-

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	12	12	12	-	-	-	12
Understand	48	48	48	-	-	-	48
Apply	40	40	40	100	100	100	40
Analyse							
Evaluate							
Create							

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	
Set	
Guided Response	
Mechanism	Assignment
Complex Overt Responses	
Adaptation	
Origination	

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. Discuss the performance characteristics of a turbine.
3. Explain the various factors to be considered in the selection of blade materials.

Course Outcome 3 (CO3):

1. Describe briefly the factors affecting the combustion chamber design.
2. List the types of combustion chamber.
3. What are the factors considered during combustion?

Course Outcome 4 (CO4):

1. What is the necessity of component matching?
2. Define Equilibrium condition.
3. Discuss briefly the matching of gas generator with free turbine with suitable assumptions made.

Course Outcome 5 (CO5):

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

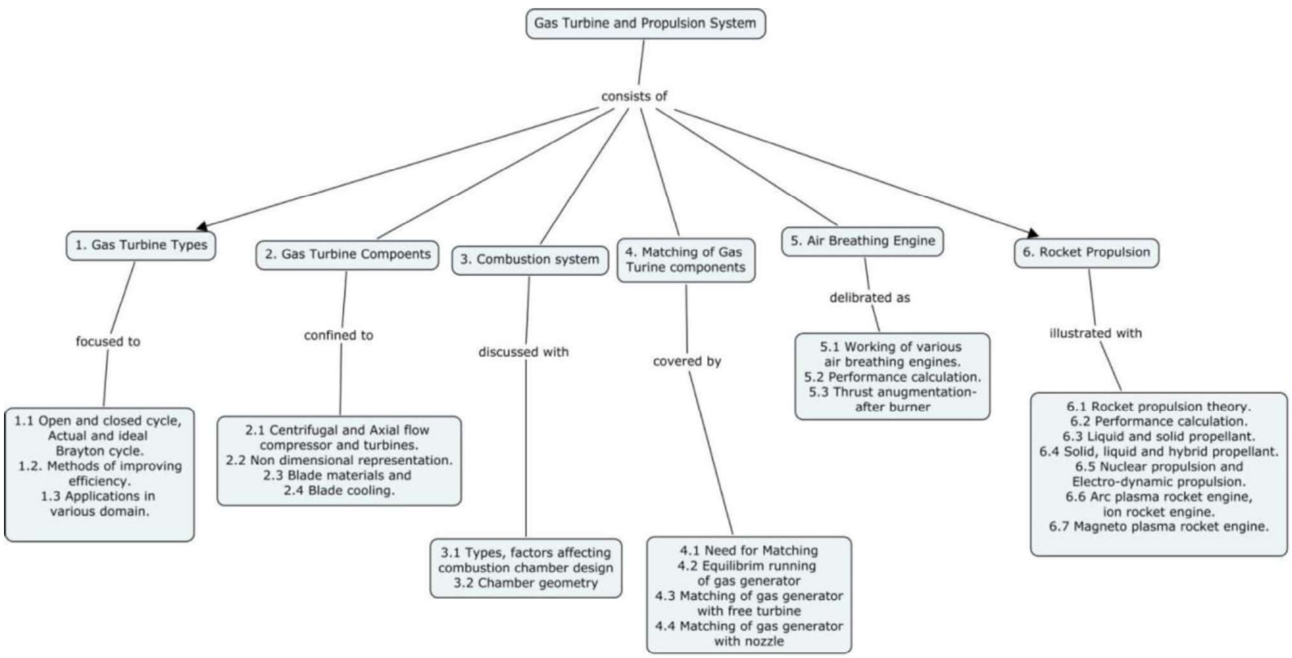
1350m/s and the air flow rate is 78.6 kg/s .Calculate (i) Thrust (ii) Thrust Power

(iii) Propulsive efficiency.

Course Outcome 6 (CO6):

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.

Gas turbine components –Compressor 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 - 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- Process of combustion in a gas turbine, combustion chamber geometry.

Matching of Gas Turbine Components: Component Characteristics - Equilibrium Running of a Gas Generator - Matching of Gas Generator with Free Turbine - Matching of Gas Generator with Nozzle.

Jet Propulsion - 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.

Learning resources

1. V. Ganesan, "**Gas Turbines**" McGraw Hill Education, 3rd Edition, 2017.
2. P.R. Khajuria and S.P.Dubey, "**Gas Turbines and Propulsive Systems**", Dhanpat Rai Publications, 2012.
3. M.L.Mathur, "**Gas Turbine and Jet Rocket Propulsion**", Standard Publishers Distributors, 2010.
4. P. Balachandran, "**Fundamentals of Compressible Fluid Dynamics**",PHI Learning Private Ltd, 2006.
5. S.M. Yahya, "**Turbine, Compressors and Fans**", 4th Edition, McGraw Hill, 2017.
6. https://nptel.ac.in/courses/112103262/ - IC Engines and Gas Turbine by Professor Pranab K. Mondal, IIT Guwahati
7. https://nptel.ac.in/courses/112/103/112103281/ - Aircraft Propulsion by Professor Vinayak N. Kulkarni, IIT Guwahati
8. https://nptel.ac.in/courses/101104078/ - Rocket Propulsion by Professor D.P. Mishra, IIT Kanpur

Course Contents and Lecture Schedule

Module No.	Topic	No. of Hours	CO's
1.0	**Gas turbine Types**		
1.1	Open and closed cycle, air standard Brayton cycle, Actual Brayton cycle	2	CO1
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	
2.0	**Gas turbine components**		
2.1.	Compressors and Turbine – Centrifugal and Axial flow compressor and turbine-principle of operation.	2	CO2
2.2	Non dimensional representation of compressor and turbine-performance characteristics of turbine and compressor.	1	
2.3	Blade materials, factors to be considered in the selection of materials,	1	
2.4	Blade cooling: external, internal, liquid cooling and air cooling.	1	
3.0	**Combustion**		CO3
3.1	Combustion system - types, factors affecting combustion chamber design and its performance.	2	
3.2	Requirements of the combustion chamber- the process of combustion in a gas turbine,	2	
3.3	Combustion chamber geometry.	1	

Module No.	Topic	No. of Hours	CO's
4.0	**Matching of Gas Turbine Components**:		CO4
4.1	Need of Matching of components, Component Characteristics	1	
4.2	Equilibrium Running of a Gas Generator	1	
4.3	Matching of Gas Generator with Free Turbine	2	
4.4	Matching of Gas Generator with Nozzle.	1	
5.	**Air Breathing Jet Propulsion**		CO5
5.1	Working of turbo jet, turbo prop, turbo fan, ramjet and pulse jet engines.	2	
5.2	Performance calculation: Thrust equation, specific thrust, propulsive efficiency thermal efficiency and overall efficiency	3	
5.3	Thrust Augmentation-after burner.	1	
6.	**Rocket propulsion**		
6.1	Rocket Propulsion - Comparison of air breathing and the rocket engines, classification of rockets.	1	CO6
6.2	Performance calculations- specific impulse, specific propellant consumption, thrust power, Jet velocity, overall efficiency, and propellant flow rate.	2	
6.3	Propellants and its desirable characteristics: liquid and solid propellant.	1	
6.4	Working of solid, liquid and hybrid propellant rocket engines.	2	
6.5	Nuclear propulsion-Electro-dynamic propulsion.	1	
6.6	Arc plasma rocket engine- ion rocket engine.	1	
6.7	Magneto plasma rocket engine.	1	
	Total	**36**	

Course Designers:

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18MERB0	HYDRAULICS AND PNEUMATICS

Category	L	T	P	Credit
PE	2	1	0	3

Preamble

This course aims at giving adequate exposure to the function of hydraulic and pneumaticcomponents, its selection and application in the design of hydraulic and pneumatic circuits. Designof Electrical and PLC based pneumatic and hydraulic circuits helps the students in developing aninnovative automation system.

Prerequisite

- NIL

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Explain the properties of hydraulic fluids and air required for hydraulic and pneumatic systems.	10
CO2	Select suitable pumps, motors and cylinders for the stated applications.	15
CO3	Calculate speed, pressure, flow and power for the fluid power circuits	20
CO4	Design the Hydraulic circuits for the given application	20
CO5	Design the pneumatic, hydro-pneumatic circuits for the given application	20
CO6	Design of relay logic and ladder logic diagram,wiring diagram for the given application	15

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.2, 2.4.4, 3.3.1,4.3.2
CO2	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO5	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO6	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO10	PO11	PO12	PSO 1	PSO 2	PSO 3
CO 1	M	L	_	_	_	_	_	_	_	_	_	_	M	_	_
CO 2	S	M	L	_	_	_	_	_	_	_	_	_	M	_	_
CO 3	S	M	L	_	_	_	_	_	_	_	_	_	S	_	M
CO 4	S	M	L	_	_	_	_	_	_	_	_	_	S	_	M
CO 5	S	M	L	_	_	_	_	_	_	_	_	_	S	_	M
CO	S	M	L	_	_	_	_	_	_	_	_	_	S	_	M

6															

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	**2**	**3**	1	2	3	
Remember	20	20	20	-	-	-	20
Understand	20	20	20	-	-	-	20
Apply	60	60	60	100	100	100	60
Analyse	-	-	-	-	-	-	-
Evaluate	-	-	-	-	-	-	-
Create	-	-	-	-	-	-	-

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	-
Set	-
Guided Response	-
Mechanism	**Assignment**
Complex Overt Responses	-
Adaptation	-
Origination	-

Sample Questions for Course Outcome Assessment**

Course Outcome 1 (CO1):

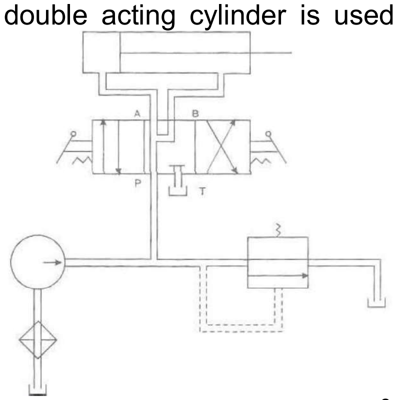
1. Name some importance properties of hydraulic fluids
2. State Pascals Law
3. Define Boyle's Law

Course Outcome 2 (CO2):

1. Hydraulic cylinder is to compress a car body in 10 seconds. The operation requires a stroke of 3 m and a force of 40,000 N. If a 7.5 N/mm^2 pump has been selected. Find the following: Required piston area and piston diameter, the necessary pump flow, The hydraulic power capacity in kW
2. Describe the working principle cushioned cylinder
3. Distinguish between vane pump and gear pump

Course Outcome 3 (CO3):

1. A double acting cylinder is used in a regenerative circuit as shown in the fig below



The relief valve is set at 7.5 N/mm^2, piston area is 150 cm^2 and rod area is 40 cm^2. If pump flow is 20 gallons/mm, find the cylinder speed and load carrying capacities for various positions of the DCV

2. Compare the meter-in and meter-out circuits
3. Discuss in detail the 4/3 direction control valve with example

Course Outcome 4 (CO4):

1. Design a hydraulic circuit for the hydraulic power pressing machine
2. Develop a hydraulic circuit for machine tool application to achieve faster extension
3. Design a hydraulic circuit for the A+B+A-B- using sequence valve

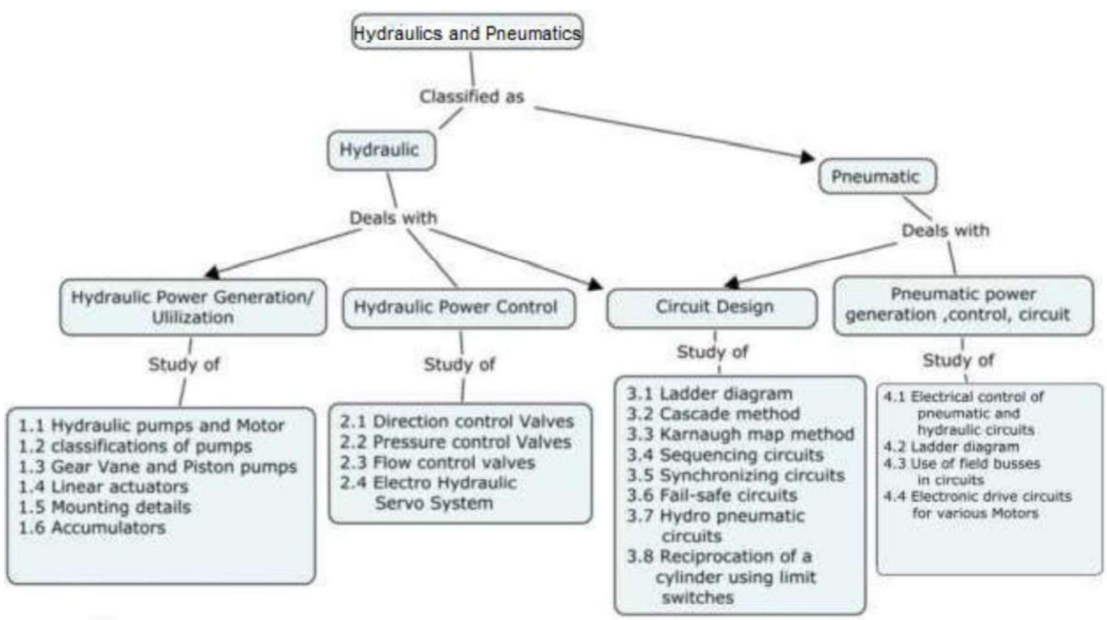
Course Outcome 5 (CO5):

1. Develop a pneumatic circuit for A+B+C+C-B-A- using cascade method
2. Develop a pneumatic circuit for A+B+A-B- using Step counter method
3. Compare Hydraulic, pneumatic, hydro pneumatic systems

Course Outcome 6 (CO6):

1. The fill motor to pump lubricating oil into the tank until the high level sensor turns on. At that point we want to turn off the motor. After oil is filled The oil is heated to 60oC. Then the oil is drained by open the solenoid valve at the bottom of the tank. The level falls below the low level sensor the fill motor turn on again. Then we should turn on the fill motor and repeat the process. Develop a relay logic circuit, to implement this task.
2. A washing machine is to run for a 1-hour cycle when put on a quick wash mode. To get started, construct a ladder logic diagram that performs a basic washing process. Use start switch to initiate the following process. First, filling the drum in the washing machine with hot water for 3 seconds, then activate the drum full indicate light and start washing which is done by alternately rotating forward and backward, each direction for a total 5 seconds. Then, stop the motor and use pump to drain the drum for 3 seconds. Do a 3 seconds fast forward spin afterwards. Finally, shut off the machine.
3. Explain the different elements of PLC with neat bock diagram

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 and motors -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 - Different types- characteristics and performance.
HYDRAULIC PNEUMATIC CIRCUIT DESIGN: Regenerative circuit, Pump unloading circuit, Counter balance valve application circuit , sequence valve application circuit, Speed control circuits, synchronizing circuit, Accumulator circuits, hydro-pneumatic circuits, Fail safe circuit, Sequential circuit design for simple applications using cascade method, step counter method. Relay logic - Electrical control of pneumatic and hydraulic circuits-use of relays, Ladder logic- Ladder diagram using internal relay, timers, and counters. Programmable logic control of Hydraulics Pneumatics circuits, PLC wiring diagram for various circuits,

Learning Resources

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]
3. W.Bolton, Mechatronics, Electronic control systems in Mechanical and Electrical Engineering Pearson Education, 2011.
4. James L. Johnson "Introduction to Fluid Power" Delmar Thomson Learning Publishers 2003.CMTI Handbook
5. Peter croser,Frank abel, Pneumatics,Basic level ,Festo Manual,Edition 10/2002
6. https://nptel.ac.in/courses/112105046/

Course Contents and Lecture Schedule

No	Topic	No.of Lectures	CO
1	**INTRODUCTION**		
1.1	Need for Automation, Hydraulic & Pneumatic basics	1	CO1
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	CO1
2	**FLUID POWER GENERATING/UTILIZING ELEMENTS**		
2.1	Introduction to Hydraulic pumps and Motor – types	1	CO2
2.2	Gear, Vane and Piston pumps	2	CO2
2.3	Gear, Vane and Piston motors	1	CO2
2.3.1	Selection and specification-Drive characteristics	1	CO3
2.3.2	pump performance – Variable displacement pumps	1	CO3
2.4	Compressors – Filter, Regulator, Lubricator Unit – Air control valves	2	CO2
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	CO3
2.6	Cylinder mounting details	1	CO2
2.7.1	power packs – construction	1	CO2
2.7.2	Reservoir , Accumulators-	1	CO3
2.8	Standard circuit symbols	2	CO4
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	CO4
3.2	Flow control valves - Fixed and adjustable	2	CO4
3.3	pressure control - Simple and compound relief valve, pressure reducing valve, sequence valve, counter balance valve	2	CO4
3.4	Methods of actuation – types	1	CO4
3.5	electro hydraulic servo valves- Different types- characteristics and performance	2	CO4
4	**Hydraulic and Pneumatic Circuit Design**		
4.1	Regenerative circuit, Pump unloading circuit, Speed control circuits	2	CO5
4.2	Counter balance valve application circuit , sequence valve application circuit,	1	CO5
4.3	Speed control circuits, synchronizing circuit, Accumulator circuits , hydro-pneumatic circuits , Fail safe circuit,	2	CO5
4.4	Sequential circuit design for simple applications using cascade method, step counter method.	2	CO5 CO6
4.5	Relay logic -Electrical control of pneumatic and hydraulic circuits-use of relays,	2	CO6
4.6	Ladder logic -Ladder diagram using internal relays, timers, counters for Programmable logic control of Hydraulics Pneumatics circuits	1	CO6
4.7	PLC wiring diagram for various pneumatic circuits.	1	CO6
		38	

Course Designers:

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18MERC0	MANUFACTURING SYSTEM ENGINEERING

Category	L	T	P	Credit
PE	3	0	0	3

Preamble

Manufacturing System 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 affect an integrated or "total" approach to problem- solving in Manufacturing Engineering, Industrial Economics and Production Management with productivity improvement as its overall objective.

Prerequisite

Nil

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Explain the various subsystems of a manufacturing system.	10
CO2	Identify the types of waste through value added and nonvalue-added analysis.	20
CO3	Determine flow production & level production rate using JIT tools.	20
CO4	Suggest methods to eliminate waste and implement 5S.	20
CO5	Implement JIT Manufacturing concept at cell level.	20
CO6	Describe the various aspects of Industry 4.0	10

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS 2	Understand	Respond	Guided Response	1.2, 2.4.4, 3.2.3, 4.3.2
CO2	TPS 3	Apply	Value	Mechanism	1.2, 2.4.4, 3.2.3, 4.3.2
CO3	TPS 3	Apply	Value	Mechanism	1.2, 2.4.4, 3.2.3, 4.3.2
CO4	TPS 3	Apply	Value	Mechanism	1.2, 2.4.4, 3.2.3, 4.3.2
CO5	TPS 3	Apply	Value	Mechanism	1.2, 2.4.4, 3.2.3, 4.3.2
CO6	TPS 2	Understand	Respond	Guided Response	1.2, 2.4.4, 3.2.3, 4.3.2

Mapping with Programme Outcomes and Programme Specific Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO 12	PSO 1	PSO 2	PSO 3
CO1	M	L	-	-	-	-	-	-	-	-	-	-	M	-	M
CO2	S	M	L	-	-	-	-	-	-	-	-	-	M	-	M
CO3	S	M	L	-	-	-	-	-	-	-	-	-	L	-	M
CO4	S	M	L	-	-	-	M	-	-	-	-	-	-	-	M
CO5	S	M	L	-	-	-	-	-	-	-	-	-	L	-	M
CO6	M	L	-	-	-	-	-	-	-	-	-	-	-	-	M

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	**20**	**20**	**20**	-	-	-	20

Understand	30	30	30	-	-	-	30
Apply	50	50	50	100	100	100	50
Analyse	-	-	-	-	-	-	-
Evaluate	-	-	-	-	-	-	-
Create	-	-	-	-	-	-	-

Assessment Pattern: Psychomotor

Psychomotor Skill	Mini-project /Assignment/Practical Component
Perception	-
Set	-
Guided Response	-
Mechanism	Assignment
Complex Overt Responses	-
Adaptation	-
Origination	-

Sample Questions for Course Outcome Assessment**

Course Outcome 1(CO1):

1. List the types of production system
2. Describe the significance Push and Pull Production.
3. Discuss the various modes of production.

Course Outcome 2(CO2):

1. Select the most advantageous location for setting a plant for making automobile axles based on the given data.

S. 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		Sankaran
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 hours per shift)
Number of Operators		1 per shift
Available time (Minutes)		450
Work in progress		650 numbers

3. State the purpose of reducing waste.

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 are 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.

Course Outcome 4 (CO4):

1. Discuss the methods to prevent defects in a manufacturing system.
2. Suggest techniques to conduct maintenance activities in a manufacturing system.
3. Elaborate the importance of performing maintenance activities and the consequences of poor maintenance scheduling.

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.

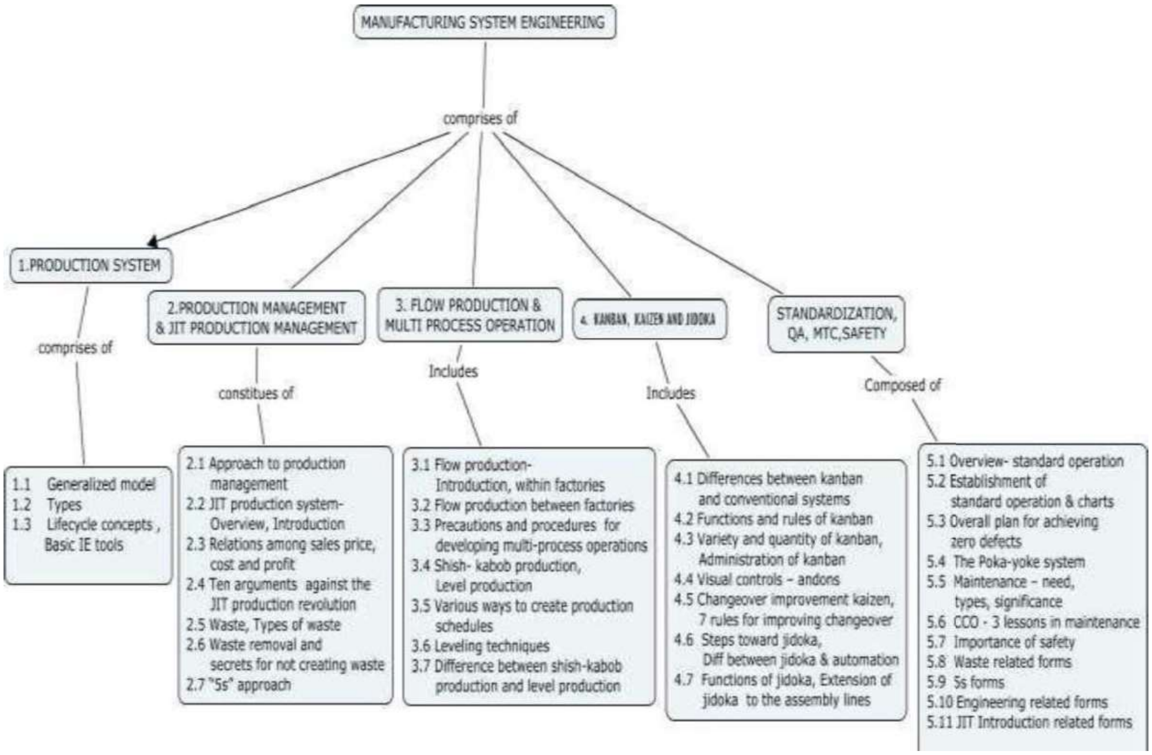
Task	Task	Description	Tasks that must precede
A	45	Position rear axle support -and hand fasten	-
B	11	Four screws to nuts	A
C	9	Insert rear axle	B
D	50	Tighten rear axle support screws to nuts	-
E	15	Position front axle assembly	D
F	12	Fasten with four screws to nuts	C
G	12	Tighten front axle assembly 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

2. Define Jidoka.
3. Explain the steps involved in implementing JIT at a manufacturing system.

Course Outcome 6(CO6):

1. Define Internet of Things.
2. Define Internet of Data.
3. Explain fourth industrial revolution and usage of internet in manufacturing.

Concept Map



Syllabus

Introduction to 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–addons, 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

Industry 4.0
Introduction to smart manufacturing, Internet of Things (IoT), Internet of Services (IoS), Internet of Data (IoD)

Learning Resources

1. Katsundo Hitomi, **Manufacturing Systems Engineering**, Second Edition, Taylor and Francis, 1996.
2. F. Robert Jacobs and Richard B. Chase, **Operations and Supply Chain Management**, Fifteenth Edition, McGraw Hill Education, 2018.
3. Paneer Selvam R, "**Production and Operations Management**", Prentice Hall of India, 2010.
4. Hiroyuki Hirano, "**JIT Implementation Manual**", English Translation Copy Right, Productivity Press, 2009.
5. George Chryssolouris, **Manufacturing Systems: Theory and Practice**, Second Edition, Springer, 2006.
6. Jingshan Li and Semyon M. Meerkov, **Production Systems Engineering**, First Edition, Springer, 2009.
7. Yingfeng Zhang and Fei Tao, **Optimization of Manufacturing Systems Using the Internet of Things**", First Edition, Academic Press, 2017
8. Yasuhiro Monden, **TOYOTA Production System: An Integrated Approach to Just-In-Time**, Fourth Edition, CRC Press, 2012.
9. NPTEL - Manufacturing System Management
   Link: https://nptel.ac.in/courses/110/106/110106044/
10. MIT OCW - Introduction to Manufacturing Systems
   Link:https://ocw.mit.edu/courses/mechanical-engineering/2-854-introduction-to-manufacturing-systems-fall-2016/index.htm

Course Contents and Lecture Schedule

Module No.	Topic	No. of Hours	Course Outcome
1.	**Introduction to Manufacturing Systems**		
1.1	Generalized model of production systems	1	CO 1
1.2	Types of production systems and its impact on system design	1	CO 1
1.3	Lifecycle concepts of production systems, Basic IE tools	1	CO 1
2.	**Production Management and JIT Production Management**		
2.1	Approach to production management	1	CO 2
2.2	JIT production system- Overview, Introduction	1	CO 2
2.3	Relations among sales price, cost and profit	1	CO 2
2.4	Ten arguments against the JIT production revolution	1	CO 2
2.5	Waste, Types of waste	1	CO 2
2.6	Waste removal and secrets for not creating waste	1	CO 2
2.7	"5s" approach	1	CO 2
3.	**Flow Production and Multi Process Operation**		
3.1	Flow production- Introduction, within factories	1	CO 3
3.2	Flow production between factories	1	CO 3
3.3	Precautions & procedures operations for developing multi-process	1	CO 3
3.4	Shish-kabob production, Level production	1	CO 3
3.5	Various ways to create production schedules, Levelling techniques	1	CO 3
3.6	Difference between shish-kabob production and level production	1	CO 3
4.	**Basics of Kanban, Kaizen and Jidoka**		
4.1	Differences between kanban and conventional systems	1	CO 4
4.2	Functions and rules of kanban	1	CO 4
4.3	Variety and quantity of kanban, Administration of kanban	1	CO 4
4.4	Visual controls – addons	1	CO 4
4.5	Changeover improvement kaizen, change over Seven rules for improving	1	CO 4
4.6	Steps toward jidoka, Difference between jidoka and automation	1	CO 4
4.7	Functions of jidoka, Extension of jidoka to the assembly lines	1	CO 4
4.8	Labour cost reduction steps	1	CO 4
5.	**Standard Operations, Quality Assurance, Maintenance and**		

	Safety		
5.1	Overview of standard operation	1	CO 5
5.2	Establishment of standard operation and charts	1	CO 5
5.3	Overall plan for achieving zero defects	1	CO 5
5.4	The Poka-yoke system	1	CO 5
5.5	Maintenance – need, types, significance	1	CO 5
5.6	CCO -three lessons in maintenance	1	CO 5
5.7	Importance of safety, Waste related forms	1	CO 5
5.8	5s forms, Engineering related forms	1	CO 5
5.9	JIT Introduction related forms	1	CO 5
6	**Industry 4.0**		
6.1	Introduction to smart manufacturing	1	CO 6
6.2	Internet of Things (IoT)	1	CO 6
6.3	Internet of Services (IoS), Internet of Data (IoD)	1	CO 6

Course Designers:

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18MERD0	MECHANICAL VIBRATIONS

Category	L	T	P	Credit
PE	2	1	-	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, modelling and their application in mechanical systems.

Prerequisite

- 18ME510 – Kinematics and Dynamics of Machinery

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Explain the importance of vibration in design of Machine parts.	10
CO2	Determine the natural frequency of free vibrations of single degree of freedom with and without damping.	20
CO3	Determine the natural frequency of forced vibrations of single degree of freedom with and without damping.	15
CO4	Determine the natural frequency of two degree of freedom vibrations.	20
CO5	Determine the equation of motion and the natural frequency of multi degree of freedom vibration systems.	25
CO6	Explain the suitable methods for measuring and controlling the motions of mechanical systems.	10

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS - 2	Understand	Respond	Guided response	1.2, 2.1.1, 2.1.2, 2.1.4,2.1.5, 2.4.4,3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3,4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6
CO2	TPS – 3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.4.4,3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3,4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6
CO3	TPS – 3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.4.4,3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3,4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6
CO4	TPS – 3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.4.4,3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3,4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5,

					4.4.6
CO5	TPS – 3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.4.4,3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6
CO6	TPS – 3	Apply	Value	Mechanism	1.2, 2.1.1, 2.1.2, 2.1.4, 2.1.5, 2.4.4,3.2.3, 3.2.5, 4.3.1, 4.3.2, 4.3.3, 4.4.1, 4.4.2, 4.4.3, 4.4.4, 4.4.5, 4.4.6

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	M	M	M	M	_	_	_	_	_	_	_	_	S	_	S
CO2	M	M	M	M	_	_	_	_	_	_	_	_	S	_	S
CO3	S	S	S	S	_	_	_	_	_	_	_	_	S	_	S
CO4	S	S	S	S	_	_	_	_	_	_	_	_	S	_	S
CO5	S	S	S	S	M	_	_	_	_	_	_	_	S	_	S
CO6	S	S	S	S	_	_	_	_	_	_	_	_	S	_	S

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	20	10	10	-	-	-	10
Understand	40	10	40	-	-	-	20
Apply	40	80	50	100	100	100	70
Analyse	0	0	0	-	-	-	0
Evaluate	0	0	0	-	-	-	0
Create	0	0	0	-	-	-	0

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	-
Set	-
Guided Response	-
Mechanism	Assignment
Complex Overt Responses	-
Adaptation	-
Origination	-

Sample Questions for Course Outcome Assessment**

** (2 to 3 at the cognitive level of course outcome)

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 & 3:

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

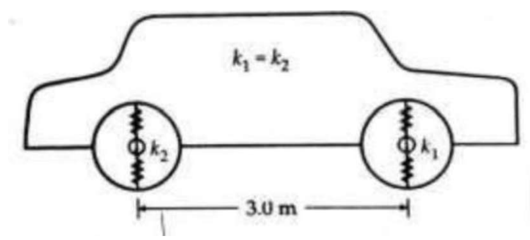
a) the resonant frequency
b) the phase angle at resonance
c) the amplitude at resonance
d) the frequency corresponding to the peak amplitude
e) dampedfrequency. Take C= 40N-sec/m.

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.

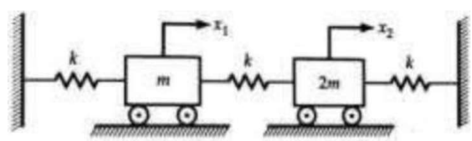
3. A machine of mass one tonne is acted upon by an external force of 2450N at a frequency of 1500rpm. To reduce the effects of vibration, isolator of rubber having a static deflection of 2mm under the machine load and an estimated damping ξ=0.2 are used. Determine
   a) Force transmitted to the foundation
   b) The amplitude of vibration of machine
   c) Phase lag.

Course outcome 4:

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.



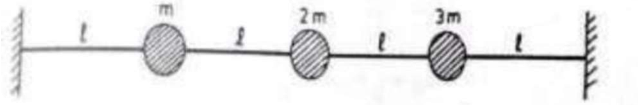
2. Find the natural frequency and amplitude ratio of the system shown in figure.



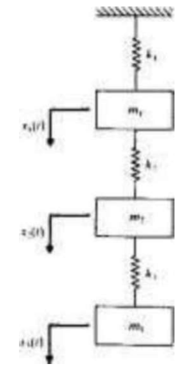
3. Two equal masses of weight 400N each and radius of gyration 40cm are keyed to the opposite ends of a shaft 60cm long. The shaft is 7.5cm diameter for the first 25cm of tis length, 12.5cm diameter for the next 10cm and 8.5cm diameter for the remaining of its length. Find the frequency of free torsional vibrations of the system and position of node. Assume $G=0.84\times10^{11}$ N/m^2.

Course outcome 5:

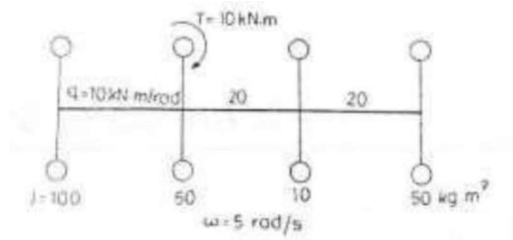
1. Calculate the natural frequency and mode shapes of the vibrating string system shown in figure by influence coefficient method.



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}



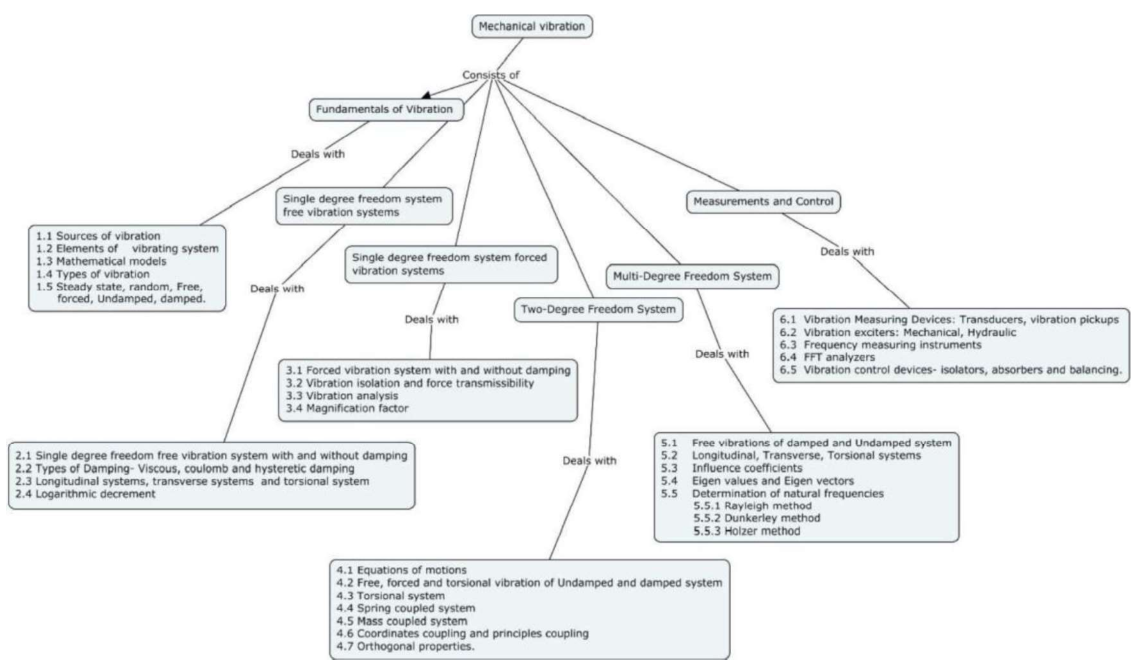
3. Determine the natural frequency of the system shown in figure by Holzer's method.



Course outcome 6:

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



Syllabus

Fundamentals of Vibration: Sources of vibration-Elements of vibrating system-Mathematical models-Types of vibration – steady state, random, Free, forced, undamped, damped.

Single degree freedom system free vibration systems: Single degree freedom free vibration system with and without damping –Types of Damping- Viscous, coulomb and hysteretic damping, longitudinal systems, transverse systems and torsional system, logarithmic decrement-

Single degree freedom system forced vibration systems - forced vibration system with and without damping -vibration isolation and force transmissibility- vibration analysis -magnification factor.

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.

Learning Resources

1. Rao, S.S.," **Mechanical Vibrations**," Addison Wesley Longman, Reprint 2015.
2. G.K.Groover., **"Mechanical Vibrations"**, New Chand &Bros, Roorkee, Repint 2014.
3. Ramamurti. V, **"Mechanical Vibration Practice with Basic Theory"**, Narosa, New Delhi, Reprint 2015.
4. Rao V. Dukkipati and J,Srinivas, **"Text book of Mechanical Vibrations"**, Prentice Hall of India, New Delhi, Reprint 2014
5. Thomson, W.T. **"Theory of Vibration with Applications"** , CBS Publishers and Distributors, New Delhi, 2018.
6. Ambekar.A.G. **"Mechanical Vibrations and Noise engineering"**, Prentice Hall ofIndia, New Delhi, 2006.
7. Den Hartog, J.P, **"Mechanical Vibrations"**, Dover Publications, 2007.
8. Mechanical vibrations (Video) ,https://nptel.ac.in/courses/112103112/ **Prof. Rajiv Tiwari** Department of Mechanical Engineering, Indian Institute of Technology, Guwahati **Prof. S.K. Dwivedy ,** Department of Mechanical Engineering, Indian Institute of Technology, Guwahati

Course **Contents** and Lecture Schedule

Sl. No	**Topic**	**No. of Lectures**	**Course Outcome**
1	**Fundamentals of Vibration**		
1.1	Sources of vibration	**1**	**CO1**
1.2	Elements of vibrating system	**1**	**CO1**
1.3	Mathematical models	**1**	**CO1**
1.4	Types of vibration	**1**	**CO1**
1.5	Steady state, random, Free, forced, Undamped, damped.		**CO1**
2	**Single degree freedom system free vibration systems**		
2.1	Single degree freedom free vibration system with and without damping	**2**	**CO2**

2.2	Types of Damping- Viscous, coulomb and hysteretic damping	**2**	**CO2**
2.3	Longitudinal systems, transverse systems and torsional system	**2**	**CO2**
2.4	Logarithmic decrement	**1**	**CO2**
3	**Single degree freedom system forced vibration systems**		
3.1	Forced vibration system with and without damping	**3**	**CO3**
3.2	Vibration isolation and force transmissibility	**1**	**CO3**
3.3	Vibration analysis	**1**	**CO3**
3.4	magnification factor	**1**	**CO3**
4	**Two-Degree Freedom System**		
4.1	Equations of motions	**1**	**CO4**
4.2	Free, forced and torsional vibration of Undamped and damped system	**1**	**CO4**
4.3	Torsional system	**1**	**CO4**
4.4	Spring coupled system	**1**	**CO4**
4.5	Mass coupled system	**1**	**CO4**
4.6	Coordinates coupling and principles coupling	**1**	**CO4**
4.7	Orthogonal properties.	**1**	**CO4**
5	**Multi-Degree Freedom System**		
5.1	Free vibrations of damped and Undamped system	**1**	**CO5**
5.2	Longitudinal, Transverse, Torsional systems	**1**	**CO5**
5.3	Influence coefficients	**1**	**CO5**
5.4	Eigen values and Eigen vectors	**1**	**CO5**
5.5	Determination of natural frequencies 5.5.1 Rayleigh method 5.5.2 Dunkerley method 5.5.3 Holzer method	**5**	**CO5**
6	**Measurements and Control**		
6.1	Vibration Measuring Devices: Transducers, vibration pickups	**1**	**CO6**
6.2	Vibration exciters: Mechanical, Hydraulic	**1**	**CO6**
6.3	Frequency measuring instruments: single reed, multi reed and stroboscope. Experimental modal analysis	**1**	**CO6**
6.4	FFT analyzers	**1**	**CO6**
6.5	Vibration control devices- isolators, absorbers and balancing.	**1**	**CO6**
	Total Number of hours	**38**	

Course Designers:

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18MERE0	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

- 18ME530 - Statistical Quality Control

Course Outcomes

At the end of the course, the students will be able to:

Sl. No	Course Outcomes	Weightage*** in %
CO 1.	Explain the basic concepts of Reliability Engineering and its measures.	10
CO 2.	Predict the Reliability at system level using various models.	15
CO 3.	Design the test plan to meet the reliability Requirements.	20
CO 4.	Estimate the reliability from failure data of a system	20
CO 5.	Implement a Reliability Management Techniques in different Organization.	15
CO6.	Assess the reliability factor related to the performance of the equipment and process	20

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.1.1, 2.1.1,2.1.2, 2.3.1
CO2	TPS3	Apply	Value	Mechanism	2.1.1, 2.1.2, 2.1.3, 2.1.4, 2.1.5, 2.3.1, 2.3.3, 2.4.1, 2.4.2 2.5.1, 2.5.4 3.1.1,3.1.2,3.1.4, 3.2.3,3.2.4
CO3	TPS3	Apply	Value	Mechanism	2.1.1, 2.1.2, 2.1.3, 2.1.4, 2.1.5, 2.3.1, 2.3.3, 2.4.1, 2.4.2 2.5.1, 2.5.4 3.1.1,3.1.2,3.1.4, 3.2.3,3.2.4
CO4	TPS3	Apply	Value	Mechanism	2.1.1, 2.1.2, 2.1.3, 2.1.4, 2.1.5, 2.3.1, 2.3.3, 2.4.1, 2.4.2 3.1.1,3.1.2,3.1.4, 3.2.3,3.2.4
CO5	TPS3	Apply	Value	Mechanism	2.1.1, 2.1.2, 2.1.3, 2.1.4, 2.1.5, 2.3.1, 2.3.3, 2.4.1, 2.4.2 3.1.1,3.1.2,3.1.4, 3.2.3,3.2.4
CO6	TPS4	Analyse	Organise	Complex Overt Responses	1.2.1, 2.1.1, 2.1.2, 2.1.3, 2.5.1

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: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	20						
Understand	20	20	20	100			20
Apply	60	80	60		60	100	60
Analyse			20				20
Evaluate							
Create							

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component		
	Assignment 1	Assignment 2	Assignment 3
Perception			
Set			
Guided Response			
Mechanism		40	
Complex Overt Responses			
Adaptation			
Origination			

Sample Questions for Course Outcome Assessment**

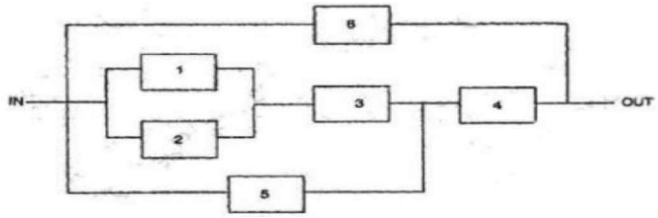
** (2 to 3 at the cognitive level of course outcome)

Course Outcome 1 (CO1):

1. Explain the concept of Reliability
2. Describe the concept of "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
3. Find out the reliability of the following system with 1,2,3,4,5 and 6 as 0.85,0.90, 0.95,0.90,0.80 and 0.85 respectively. Find out the tie sets and cut sets



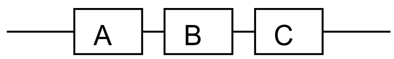
Course Outcome 3 (CO3):

1. Calculate a) the expectation b)the second moment about the origin and c)the variance for the following probability distributions.

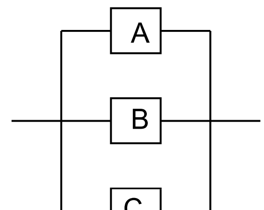
X =	8	12	16	20	24
p(X) =	1/8	1/6	3/8	1/4	1/12

2. Draw Fault -tree diagrams for the systems shown in the following figures:

a)



b)



3. Given a budget of Rs 700 and the following data on three components that must operate in series Determine, using marginal analysis, the optimum number of redundant units. Compute the achieved reliability.

Components	Reliability	Unit Cost
1	0.80	Rs 200
2	0.90	Rs 100
3	0.95	Rs 75

a) Find out the reliability using markov analysis for load sharing units?

Course Outcome 4 (CO4):

1. A manufacturing company operates two production lines when both lines are operating, the production rate on each line is 500 units per hour. At this production rate the failure rate of line 1 is 3 failures per 8-hr day (CFR) and the failure rate of line 2 is 2 failures per 8-hr day. When one line fails, the production rate of the second line must be increased in order to make production quotas. At the increased rate of 800 units per hour, the failure rate of line 1 is 6 per 8 hr day and the failure rate of line is 3 per 8-hr day. Find the reliability and the MTTF and the reliability of the production system over a 1 hr and over an 8 hr production run.
2. A system consists of three components in series having the following parameters. The reliability goal is 0.90 for the system. Do the reliability allocation.

Components	Reliability	Unit Cost
1	0.85	Rs 25
2	0.80	Rs 20
3	0.90	Rs 40

3. Suggest the types of assessment of the design process in safety

Course Outcome 5 (CO5):

1. Determine the upper bound for each of the following aircraft subsystems MTTRs if a system availability goal of 0.95 is desired. Assume the repair restores the subsystem to as good as new and each system has the same availability.

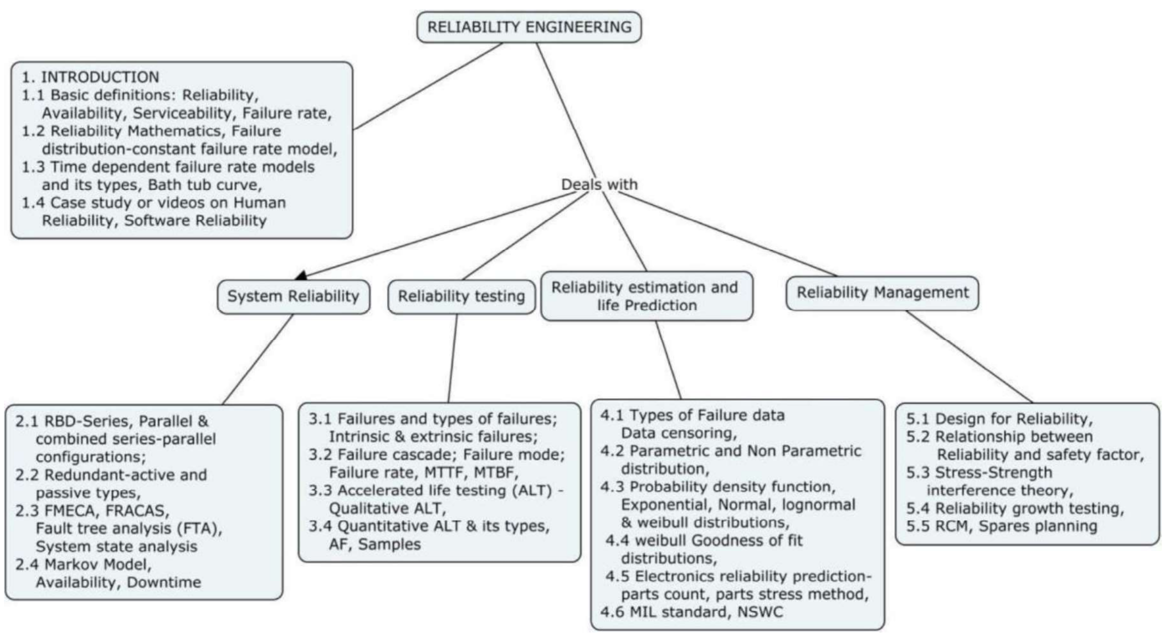
Subsystem	Time Between failures	Parameters
Propulsion	Weibull	θ =1000, β=1.7
Avionics	Exponential	λ=0.003
Structures	Weibull	θ =2000, β=2.1
Electrical	Weibull	θ =870, β=1.8
Environmental	Exponential	λ=0.001

2. Suggest various risk measurement systems in modern industrial scenario
3. Suggest the different methods of risk assessment will support the industrial safety.

Course Outcome 6(CO6):

1. A generator system consist of primary and a standby unit. The primary fails at a constant rate of 2 per month, and the stand by system fails only when online at a constant rate of 4 per month. Repair can begin only when both units have failed. Both units are repaired at the same time with an MTTR of 20 days. Derive the steady state equations for the state probabilities and solve for the system availability.
2. Analyze the different methods of failure data analysis
3. Suggest the different techniques of risk analysis and Interpret it?

Concept Map



Syllabus

Introduction : Basic definitions: Reliability, Maintainability, 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 Specifications for a product, Reliability Block Diagram - Series, Parallel & combined series-parallel configurations; redundant-active and passive types, HALT, HAST and HASS. 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 and Sudden death Test. 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.

Learning Resources

1. Kailash C. Kapur, Michael Pecht, **Reliability Engineering**, John Wiley & Sons, 2014.
2. Srinath L.S, **"Reliability Engineering"**, Affiliated East-West Press Pvt Ltd, New Delhi, 1998.
3. Modarres, **"Reliablility and Risk analysis"**, Marshal Dekker Inc.1993.
4. John Davidson, **"The Reliability of Mechanical system"** published by the Institution of Mechanical Engineers, London, 1988.
5. Smith C.O. **"Introduction to Reliability in Design"**, McGraw Hill, London, 1976.
6. Charles E. Ebeling, "**An introduction to Reliability and Maintainability engineering**", TMH, 2004
7. Roy Billington and Ronald N. Allan, **"Reliability Evaluation of Engineering Systems"**, Springer, 2007.
8. Handbook of Reliability Prediction Procedures for Mechanical Equipment Logistics Technology Support CARDEROCKDIV, NSWC-11 May 2011, West Bethesda, Maryland 20817-5700.
9. https://www.youtube.com/watch?v=_c-iZ2BAXPw
10. https://www.youtube.com/watch?v=uutg8jKrL9w

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures	Course Outcome
1	**INTRODUCTION**		
1.1	Basic definitions: Reliability, Maintainability, Availability, Serviceability, Failure rate	1	CO1
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	Reliability Specifications for a product, RBD-Series, Parallel & combined series-parallel configurations	2	CO2
2.2	Redundant-active and passive types, HALT, HAST and HASS	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	CO3
3.2	Failure cascade; Failure mode; Failure rate, MTTF, MTBF and Sudden death Test.	2	

3.3	Accelerated life testing (ALT) - Qualitative ALT	2	
3.4	Quantitative ALT & its types, AF, Samples	2	
4	**RELIABILITY ESTIMATION AND LIFE PREDICTION**		
4.1	Types of Failure data - Data censoring	1	CO4 & CO5
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	1	
4.6	MIL standard, NSWC	1	
5	**RELIABILITY MANAGEMENT**		
5.1	Design for Reliability	2	CO6
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:

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18MERF0	VEHICLE DESIGN ENGINEERING

Category	L	T	P	Credit
PE	3	0	0	3

Preamble

Vehicle design engineering is the branch of automobile engineering dealing with customer demands and identifying target parameters, 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, standards, tests and norms for automotive parts/system.

Prerequisite

- **NIL**

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Apply House of Quality (HoQ) and DFMEA (Design Failure Modes and Effects Analysis) for an automotive part/system.	20
CO2	Select engine and transmission of a vehicle for a particular application.	20
CO3	Determine forces in engine crank mechanism, Plotting P- ϴ, P-v, side thrust, resultant force and turning moment graphs.	20
CO4	Suggest suitable firing order for engines by balancing forces and moments.	10
CO5	Determine vehicle behaviour in free, forced, undamped and damped vibration.	20
CO6	Explain test procedures, standards and norms for an automobile/sub system.	10

*** Weightage depends on Bloom's Level, number of contact hours.

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO2	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO5	TPS3	Apply	Value	Mechanism	1.2, 2.1, 3.2, 4.3.2, 4.3.3
CO6	TPS2	Understand	Respond	Guided Response	1.2, 2.1, 3.2, 4.1.2

Mapping with Programme Outcomesand Programme Specific Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	S	M	L	-	-	-	-	S	-	-	-	-	M	-	-
CO2	S	M	L	-	-	-	-	S	-	-	-	-	M	-	-
CO3	S	M	L	-	-	-	-	S	-	-	-	-	M	-	-
CO4	S	M	L	-	-	-	-	S	-	-	-	-	M	-	-

CO5	S	M	L	-	-	-	-	S	-	-	-	-	M	-	-
CO6	M	L	-	-	-	-	-	S	-	-	-	-	-	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	10	10	10				10
Understand	30	30	30				30
Apply	60	60	60	100	100	100	60
Analyse							
Evaluate							
Create							

AssessmentPattern: Psychomotor

Psychomotor Skill	Miniproject/Assignment/Practical Component
Perception	
Set	
Guided Response	
Mechanism	Assignment
Complex Overt Responses	
Adaptation	
Origination	

Sample Questions for Course Outcome Assessment

Course Outcome1(CO1):

1. Discuss on methods of collecting customerfeedback.
2. Demonstrate using House of Quality diagram, how typical customer needs are converted into specifications for braking system of a twowheeler.

Course Outcome2(CO2):

1. Discuss on the factors considered in selecting orientation of engine, fuel, method of cooling for given vehicle layout andrequirement.
2. Design a transmission system for a passenger car with the following details.

   Gross vehicle weight = 1500 kg;

   Maximum gradeability = 35%;

   Top speed of the vehicle = 140 km/h;

   Assume appropriate data if required.

Course Outcome3(CO3):

1. Deduce the expressions for instantaneous piston velocity, piston acceleration, connecting rod angular velocity and angular acceleration at any crank angle.
2. The ratio of connecting rod length to crank length of a vertical gasoline engine is 4 with a crank length of 50 mm. The engine bore and stroke are 80 mm and 100 mm respectively. The mass of

reciprocating parts is 1 kg. The gas pressure on the piston is $6x10^5$ Pa, when it has moved 40° from TDC on its power stroke. Calculate,

i) net load on the piston

ii) net load on the crank pin

iii) thrust on cylinder walls

iv) thrust on crankshaft main bearing.

Course Outcome 4 (CO4):

1. Choosea firing order for 4-stroke, 4 - cylinder engine, based on engine balancing.
2. Prove that 4-stroke, 6-cylinder engine with firing order of 1-5-3-6-2-4 is completely balanced.

Course Outcome 5 (CO5):

1. Determine the pitch and bounce frequencies and location of the oscillation centres for an automobile with the following data:

   Mass of the vehicle: 1500 kg

   Wheel base: 3 m

   Distance between front axle and centre of gravity of the vehicle: 1.4 m

   Front spring stiffness: 30 kN/m

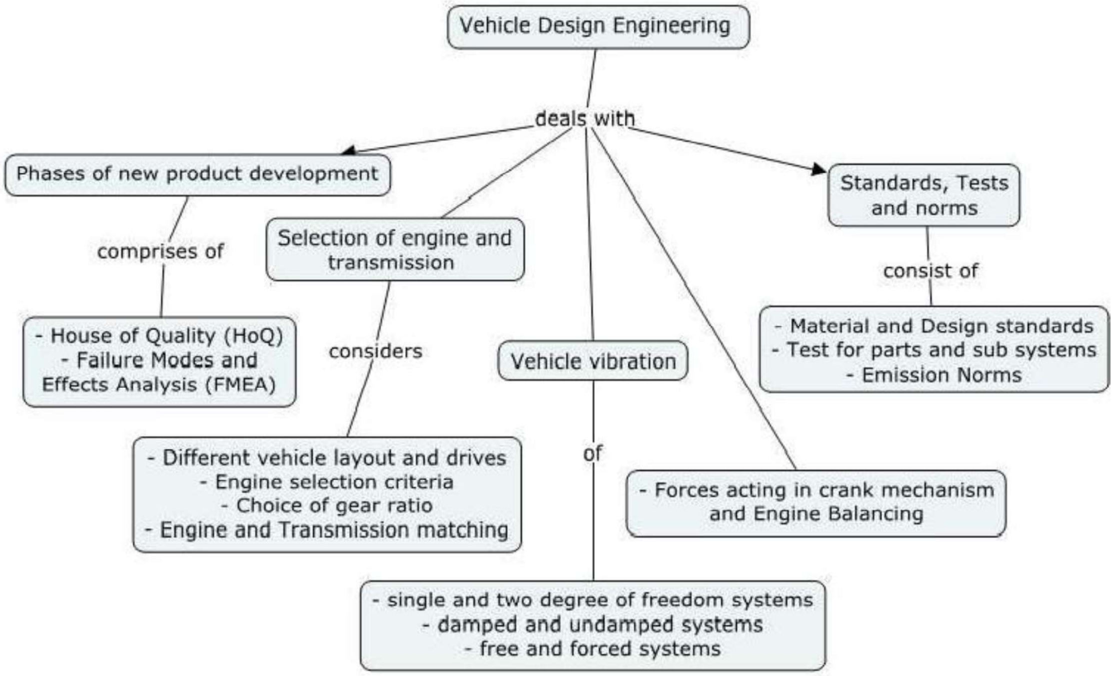
   Rear spring stiffness: 35 kN/m

   Radius of gyration: 1.2 m
2. The springs of a motor vehicle carry a total load of 11280 N with equal springing at front and rear. The combined spring rate is 88300 N/m. Calculate the frequency of vertical natural vibration with the dampers removed. If the dampers are adjusted to give a total damping force of 4415 N-s/m, calculate the frequency of damped vibrations and the ratio of the second downward movement to the first downward movement.

Course Outcome6(CO6):

1. Write down BS-IV norms for 2&3 wheelers powered by petrol.
2. Discuss how rotation bending fatigue test and radial load durability test are done on alloy wheel rims of 2-wheelers.

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, **Casestudies**– HoQfor cars/motorcycles, any part/subsystem. Failure Mode and Effects Analysis(FMEA),Essential components of Design FMEA, **Case studies** - chassis frame, component/systemin transmission , steering, suspension and braking.

Selection of engine and transmission for an automobile– Merits and demerits of different vehicle layouts. Chassis frame design, Engine selection criteria, Matching engine and transmission, Transmission selection - over gearing and under gearing, fuel economy, engine life and pollution. Comparison of manual and automatic transmission characteristics. Power limited acceleration - Effect of inertia and equivalent vehicle weight.

Forces acting in crank mechanism– Instantaneous piston velocity and acceleration, instantaneous connecting rod velocity and acceleration, Plotting P-Ɵ, P-v diagrams, side thrust, resultant force, turning moment of single cylinder and multi-cylinder engines, various forces acting in crank mechanism.

Engine Balancing– Balancing of single cylinder, two cylinder, four cylinder and six-cylinder in-line engines. Comparison of balancing inline and v-type engines.

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.

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, Emission norms.

Learning Resources

1. N.K.Giri, "**Automobile Mechanics**", 8th Edition, Khanna Publishers, Delhi,2013.
2. Kirpal Singh, "**Automobile Engineering**", Volume-1&2, 13th Edition, Standard Publishers Distributers, Delhi,2017.
3. Thomas D.Gillespie, **"Fundamentals of vehicle dynamics"** Premiere Series Books, 1992.
4. Harald Naunheimer, Bernd Bertsche, Joachim Ryborz, Wolfgang Novak, **"Automotive Transmissions - Fundamentals, Selection, and Application", Design** in Collaboration withPeter Fietkau, Second Edition, Springer,2010.
5. G. K. Grover, "Mechanical Vibrations", 8th Edition, Nem Chand & Bros, Rooekee, U.K., India, 2009.
6. Various standards for automotivecomponents/systems.

Course Contents and Lecture Schedule

S.No	Topics	No. of Hours	Course Outcome
1	**Translation of customer's voice into engineering specifications**		
1.1	Different phases of new product development.	1	CO1
1.2	QFD, HoQ for converting customer voice into technical specifications, Feedback collection from customers.	1	CO1
1.3	Enlisting design parameters against each voice - Mapping customers' voice & technical specification of different manufacturers, Interactions between technical requirement & specifications.	1	CO1
1.4	Case studies – HoQ for cars/motorcycles, any part/subsystem	2	CO1
1.5	Introduction, types of FMEA, Essential components of Design FMEA	1	CO1
1.6	Case studies - chassis frame, component/system in transmission, steering, suspension and braking.	2	CO1
2	**Selection of engine and transmission for an automobile**		
2.1	Merits and demerits of different vehicle layouts, Engine selection criteria for a vehicle.	1	CO2
2.2	Chassis frame design – shear force and bending moment calculations.	1	CO2
2.3	Transmission selection - Matching engine and transmission	1	CO2
2.4	Over gearing and under gearing, fuel economy, engine life and pollution.	1	CO2
2.5	Comparison of manual and automatic transmission characteristics.	1	CO2
2.6	Power limited acceleration - Effect of inertia and equivalent vehicle weight.	1	CO2
3	**Forces acting in crank mechanism**		

3.1	Instantaneous piston velocity and acceleration.	1	CO3
3.2	Instantaneous connecting rod velocity and acceleration.	1	CO3
3.3	Plotting P-Θ, P-v diagrams.	1	CO3
3.4	Side thrust, resultant force, turning moment of single cylinder and multi-cylinder engines.	1	CO3
3.5	Various forces acting in crank mechanism.	1	CO3
4	**Engine Balancing**		
4.1	Balancing of single cylinder	1	CO4
4.2	Balancing of two cylinder engine	1	CO4
4.3	Balancing of four cylinder and six cylinder engine	1	CO4
4.4	Balancing of in-line and v-type engines	1	CO4
5	**Vehicle vibration**		
5.1	Load distribution, spring stiffness at front and rear, vertical springs,inclined springs, springs in series, parallel springs, equivalent stiffness	1	CO5
5.2	Quarter car model and half car model, single and two degree of freedom systems.	2	CO5
5.3	Free and forced vibrations, damped and undamped vibrations, frequency, mode shapes.	2	CO5
5.4	Critical velocity, Transmissibility ratio.	1	CO5
5.5	Combined pitch and bounce, pitch centre and bounce centre.	2	CO5
6	**Standards, tests and norms for an automotive part/system**		
6.1	Global material/design/emission standards.	1	CO6
6.2	Working environment of part / sub system / vehicle in usage & handlingby various stake holders.	1	CO6
6.3	Tests & test conditions to verify part against all failure modes – Case study – Wheel, Brake drum, tyre.	2	CO6
6.4	Emission Norms.	1	CO6
	Total	**36**	

Course Designers:

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18MERG0	PROCESSING OF COMPOSITE MATERIALS	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

Composite materials 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. Composite materialsare preferred over traditional materials for their properties which are stronger, lighter or less expensive. This course covers the fundamentals of composite materials and processing of various composite materials

Prerequisite

Nil

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Explain the classification, characteristics and the applications of composites in various domains	10
CO2	Summarize the various Reinforcements and Matrix used in composite materials	10
CO3	Select the appropriate processing method for polymer matrix composites	20
CO4	Select the proper fabrication method for metal matrix composites	20
CO5	Choose the suitable processing method in ceramic matrix composites and carbon- carbon Composites	20
CO6	Choose the suitable processing method in Nanocomposites	20

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.2, 2.4.4, 3.3.1,4.3.2
CO2	TPS2	Understand	Respond	Guided Response	1.2, 2.4.4, 3.3.1,4.3.2
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO5	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO6	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2

Mapping with Programme Outcomes and Programme Specific 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	PSO 1	PSO 2	PSO 3
CO1.	S	M	L	M	-	-	-	M	L	L	-	-	L	-	L
CO2.	S	M	L	M	-	-	-	M	L	L	-	-	L	-	L
CO3.	S	M	L	M	-	-	-	M	L	L	-	-	M	-	M
CO4.	S	M	L	M	-	-	-	M	L	L	-	-	M	-	M
CO5.	S	M	L	M	-	-	-	M	L	L	-	-	M	-	M
CO6.	S	M	L	M	-	-	-	M	L	L	-	-	M	-	M

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	20	20	20	-	-	-	10
Understand	40	20	20	-	-	-	30
Apply	40	60	60	100	100	100	60
Analyse	-	-	-	-	-	-	-
Evaluate	-	-	-	-	-	-	-
Create	-	-	-	-	-	-	-

Assessment Pattern: Psychomotor

Psychomotor Skill	Mini-project /Assignment/Practical Component
Perception	-
Set	-
Guided Response	-
Mechanism	**Assignment**
Complex Overt Responses	-
Adaptation	-
Origination	-

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define composite material
2. Classify composite materilas based on matrix used
3. Write the role of matrix in composite materials.

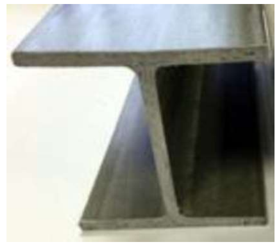
Course Outcome 2 (CO2):

1. Explain the glass fibre manufacturing method with suitable sketches. Define composite material
2. List the important charcteristics of glass fibre, carbon fibre and aramid fibre.
3. Write the advantages, limitations of thermosetting polymers and thermoplastic polymers.

Course Outcome 3 (CO3):

1. Differentiate between thermosetting and thermo plastics
2. Identify the suitable fabrication technique to fabricate the given component shown in Figure 1 and explain the fabrication process with suitable diagram.

3. Suggest and explain the suitable fabrication technique to fabricate the given components shown in Figure 2 with necessary diagram.



Course Outcome 4 (CO4):

1. Identify a simplest and economical, liquid state, metal matrix composite processing technique for the production of Al–SiCp composites and explain the process with suitable diagram
2. Suggest a suitable fabrication technique to make Al_2O_3/SiCparticulate-reinforced Al–5Si–2Fe alloy composites containing 30 wt.% ceramic particulates. Explain this process with necessary diagram.
3. Identify a suitable metal matrix composite processing technique to fabricate the brake rotorsand explain the fabrication process with suitable diagram.
4. Suggest a suitable metal matrix composite fabrication technique with application of high temperature and pressure using matrix alloy foil and fiber arrays. Explain this process with necessary diagram

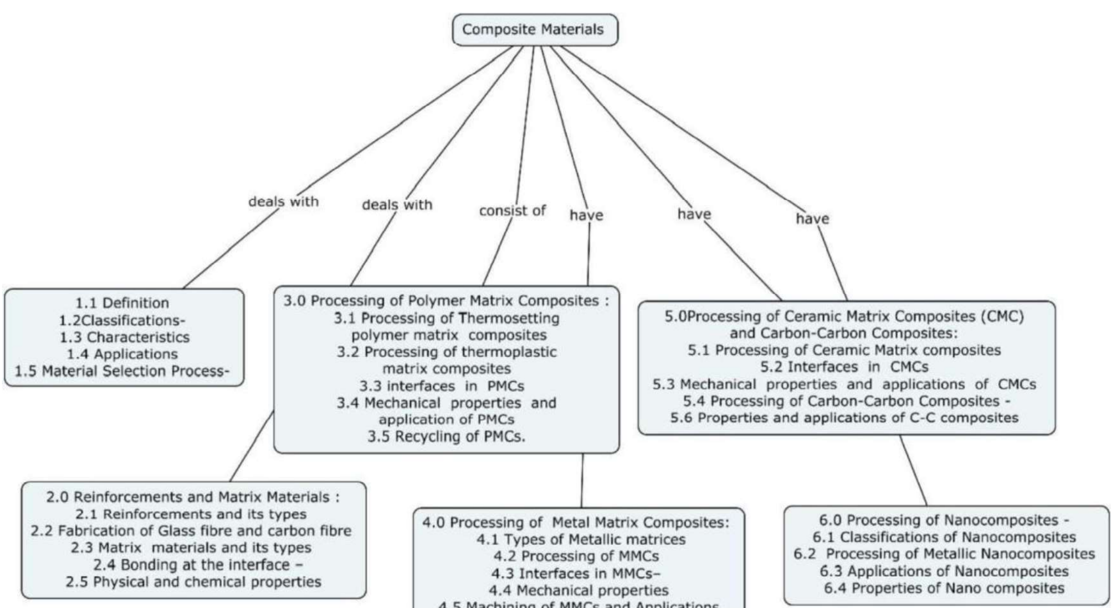
Course Outcome 5 (CO5):

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.
4. With suitable diagram, explain how are ceramic composites are fabricated using chemical vapour infiltration technique.
5. With suitable diagram, explain how are ceramic composites are fabricated using slurry infiltration technique?

Course Outcome 6 (CO6):

1. List the benefits of polymer–clay nanocomposites.
2. List the peculiar properties of nanocomposites.
3. Explain the novel method to form PNCs using CNT aggregates.

Concept Map



Syllabus

Composite Materials: Definition- Need-Classifications- Characteristics- Applications in various industries -Aircraft, Military, Space Applications, Automotive, Sporting Goods, Marine ,Infrastructure. Material Selection Process- Potential Advantages- Strength, Stiffness, Cost and Weight

Reinforcements and Matrix Materials :Reinforcements -Types - Fibers– Glass fiber, Boron fiber, carbon fiber, organic fiber, ceramic and metallic fibers - whiskers Fabrication of Glass fibre and carbon fibre–Matrix materials– Polymers, Classification of Polymers – Properties of Thermo and Thermosetting Plastics- Metals and ceramics and their properties – interfaces – Wettability – Types of bonding at the interface – Physical and chemical properties.

Processing of Polymer Matrix Composites : 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 - Mechanical properties and application of PMCs –recycling of PMCs.

Processing of Metal Matrix Composites: Metallic matrices: Aluminum, 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.

Processing of Ceramic Matrix Composites (CMC) and Carbon-Carbon Composites: Processing of CMC: cold pressing, sintering, reaction bonding, liquid infiltration, lanxide process –In situ chemical reaction techniques: chemical vapour deposition, chemical vapour impregnation, sol-gel method – Interfaces in CMCs – mechanical properties and applications of CMCs – Carbon-carbon Composites – Carbon Fiber ReinforcementsMatrix Systems -Processing of Carbon-Carbon Composites -Properties and applications.

Processing of Nanocomposites - Classifications - Polymer Nanocomposites -Clay–Polymer Nanocomposites -Graphite–Polymer Nanocomposites - Nanofiber-Reinforced Composites -Particulate Nanocomposites -Organic– Inorganic Hybrids (Nano-composites) - Applications of Polymer Nanocomposites - Metal Matrix Nanocomposites - Processing of Metallic Nanocomposites - applications -properties - Ceramic Nanocomposites Processing of Ceramic Nano composites - applications -properties -

Reference Books

1. M. Balasubramanian ,**Composite materials and Processing**, Taylor & Francis Group, LLC, CRC Press, 2014.
2. Krishnan K Chawla, Composite **Materials: Science and Engineering**, International Edition, Springer, 2012.
3. Mallick P.K., **FiberReinforced Composites: Materials, Manufacturing and Design**, CRC press, New Delhi, 2010.
4. Mallick, P.K. and Newman.S., **Composite Materials Technology**, Hanser Publishers, 2003.
5. Bhagwan D. Agarwal and Lawrence J. Broutman, **Analysis and Performance of Fiber Composites**, John Wiley and Sons Indian Edition, 2018.
6. Prof. J. Ramkumar, **"Manufacturing of composites"**, NPTEL, IIT Kanpur - https://nptel.ac.in/courses/112104221/
7. Prof. Nachiketa Tiwari, **"Introduction to composites"**, NPTEL, IIT Kanpur - https https://nptel.ac.in/courses/112104168/

Course contents and Lecture schedule

Module Number	Topics	No. of Lectures	Course outcome
1.0	**Composite Materials**		
1.1	Definition- Need-Classifications- Characteristics	1	CO1
1.2	Applications -Aircraft and Military Applications, Space Applications, Automotive Applications, Sporting Goods	1	CO1

Module Number	Topics	No. of Lectures	Course outcome
	Applications, Marine Applications,Infrastructure		
1.3	Material Selection Process- Potential Advantages- Strength, Stiffness, Cost and Weight	1	CO1
2.0	**Fibers and Matrix Materials**		
2.1	Glass fiber, Boron fiber, carbon fiber, organic fiber, ceramic and metallic fibers - whiskers	1	CO2
2.2	Polymers, Classification of Polymers – Properties of Thermo and Thermosetting Plastics -metals and ceramics and their properties – interfaces – Wettability	2	CO2
2.3	Metals and ceramics and their properties – interfaces – Wettability	1	CO2
2.4	Types of bonding at the interface	1	CO2
2.5	Physical and chemical properties	1	CO2
3.0	**Processing of Polymer Matrix Composites**		
3.1	Processing methods: Polymer matrix composites: hand layup, spray, filament winding, Pultrusion	2	CO3
3.2	Resin transfer moulding, autoclave moulding - bag moulding, compression moulding with Bulk Moulding Compound and sheet moulding Compound	2	CO3
3.3	Thermoplastic matrix composites – film stacking, diaphragm forming, thermoplastic tape laying, injection moulding interfaces in PMCs	1	CO3
3.4	Mechanical properties and application of PMCs	1	CO3
3.5	Recycling of PMCs	1	CO3
4.0	**Processing of Metal Matrix Composites:**		
4.1	Metallic matrices: Aluminium, titanium, magnesium, copper alloys	1	CO4
4.2	Processing of MMCs: liquid state, Solid state, in situ fabrication techniques - Diffusion bonding – powder metallurgy techniques	2	CO4
4.3	Interfaces in MMCs	1	CO4
4.4	Mechanical properties	1	CO4
4.5	Machining of MMCs – Applications.	1	CO4
5.0	**Processing of Ceramic Matrix Composites and Carbon-Carbon Composites**		
5.1.1	**Processing of CMCs:** Cold pressing, Sintering, Reaction bonding, Liquid infiltration method	1	CO5
5.1.2	Lanxideprocess –In situ chemicalreaction techniques: Chemical vapour deposition, Chemical vapour impregnation, Sol-gel methods	1	CO5
5.2	Interfaces in CMCs –	1	CO5
5.3	Mechanical properties and applications of CMCs		CO5
5.4	**Processing of Carbon- Carbon Composites**: Carbon-carbon Composites – Carbon Fiber Reinforcements-Matrix Systems -	1	CO5
5.5	Carbon-Carbon Composites -Mechanical Properties and applications.	2	CO5
6.0	**Nanocomposites**		
6.1	Nanocomposites - Classifications - Polymer Nanocomposites -	2	CO6

Module Number	Topics	No. of Lectures	Course outcome
	Clay Polymer Nanocomposites -GraphitePolymer Nanocomposites - Nanofiber-Reinforced Composites -Particulate Nanocomposites.		
6.2	Organic–Inorganic Hybrids (Nano-composites) - Applications of Polymer Nanocomposites -	1	CO6
6.3	Metal Matrix Nanocomposites - Processing of Metallic Nanocomposites -applications -properties	1	CO6
6.4	Ceramic Nanocomposites Processing of Ceramic Nanocomposites -applications -properties	1	CO6
	Total	36	

Course Designers

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18MEGA0	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. This course enables System Thinking among students and makes them to realise its effectiveness in creating a product or process, which is very much the needed in the industry today.

Prerequisite

18ES390 – Design Thinking

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Explain about the context, principles and working of systems	20
CO2	Explain about the Systems Thinking, System Engineering and its applications.	10
CO3	Choose the various types of Inputs required to achieve the desired outputs of a System.	20
CO4	Illustrate the transformation occurring inside a given system	10
CO5	Select suitable diagnostics tools to identify the vital signs in transformations occurring in System.	10
CO6	Apply System approach frame work to real world problems	30

*** Weightage depends on Bloom's Level, number of contact hours

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.2, 2.3.1, 3.2.3, 4.3.1
CO2	TPS2	Understand	Respond	Guided Response	1.2, 2.3.1, 3.2.3, 4.3.1
CO3	TPS 3	Apply	Value	Mechanism	1.2, 2.3.1, 3.2.3, 4.3.2
CO4	TPS 3	Apply	Value	Mechanism	1.2, 2.3.1, 3.2.3, 4.3.2
CO5	TPS 3	Apply	Value	Mechanism	1.2, 2.3.1, 3.2.3, 4.3.2
CO6	TPS 3	Apply	Value	Mechanism	1.2, 2.3.1, 3.2.6, 4.3.3

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	M	L													
CO2	M	L													
CO3	S	M	L						M			M			
CO4	S	M	L						M			M			
CO5	S	M	L						M			M			
CO6	S	M	L						S			M			

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	30	30	30				10

Understand	30	30	30				30
Apply	40	40	40	100	100	100	60
Analyse							
Evaluate							
Create							

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	
Set	
Guided Response	Case Study
Mechanism	Presentation of Real-time Application
Complex Overt Responses	
Adaptation	
Origination	

Sample Questions for Course Outcome Assessment**

** (2 to 3 at the cognitive level of course outcome)

Course Outcome 1(CO1):

1. Define system based on your perspective.
2. Show the different context of systems with suitable examples.
3. Discuss about the principles of system with suitable examples.

Course Outcome 2(CO2):

1. Define System Engineering.
2. State the limitations of Systems Engineering.
3. Discuss about the significance of System thinking.

Course Outcome 3(CO3):

1. List the various input categories used in system approach.
2. Differentiate Technical outputs and System outputs.
3. Identify the perceived needs for achieving new solutions.

Course Outcome 4 (CO4):

1. Discuss about the importance of transformation in system.
2. Illustrate a transformation of a system and list the process parameters.
3. Use a case study to show the importance of process improvement.

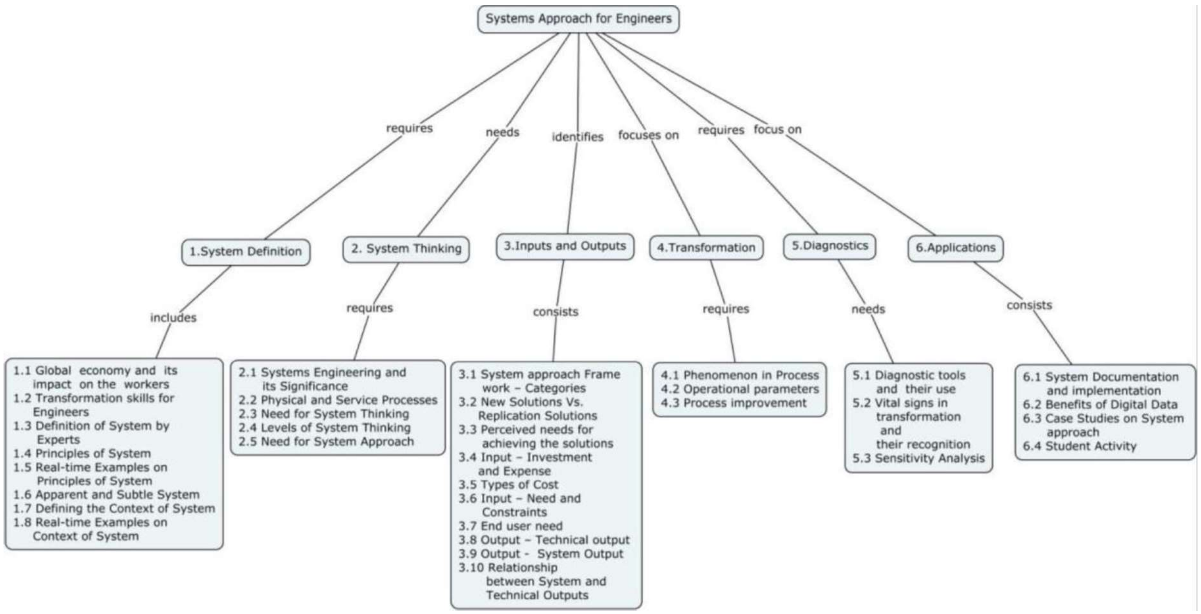
Course Outcome 5 (CO5):

1. Mention the significance Vital signs.
2. Select suitable diagnostic devices to measure transformation in Human body.
3. Illustrate the Signature analysis with suitable examples.

Course Outcome 6 (CO6):

1. Summarise about the importance digital data.
2. Use a case study to show the System approach implementation.
3. Illustrate the system implementation methodology with suitable examples.

Concept Map



Syllabus

System Definition
Global economy and its impact on the workers - Transformation skills for Engineers -
Definition of System by Experts - Principles of System - Real-time Examples on Principles of System - Apparent and Subtle System - Defining the Context of System - Real-time Examples on Context of System.

Systems Thinking
Systems Engineering and its Significance - Physical and Service Processes - Need for System Thinking - Levels of System Thinking - Awareness, Analysis and Synthesis - Need for System Approach.

Inputs and Outputs of System
System approach Frame work – Categories - New Solutions Vs. Replication Solutions - Perceived needs for achieving the solutions - Input – Investment and Expense - Types of Cost - Input – Need and Constraints - End user need - Output – Technical output - Output - System Output - Relationship between System and Technical Outputs.

Transformation
Phenomenon in Process - Operational parameters - Process improvement - Diagnostics
Diagnostic tools and their use - Vital signs in transformation and their recognition - Sensitivity Analysis

Application of System approach
System Documentation and implementation - Benefits of Digital Data - Case Studies on System approach - Student Activity (Development, Review and Presentation)

Learning Resources

1. Dr.K. Subramanian, **"The System Approach"** , Hanser Gardner Publications, First Edition 2000.
2. Learning Material provided by Dr.K.Subramanian, President, STIMS Institute San Jose,California, USA.
3. https://stimsinstitute.files.wordpress.com

Course Contents and Lecture Schedule

Module No.	Topic	No. of Hours	Course Outcome
1.	**System Definition**		
1.1	Global economy and its impact on the workers	1	CO1
1.2	Transformation skills for Engineers	1	CO1
1.3	Definition of System by Experts	1	CO1

1.4	Principles of System	1	CO1
1.5	Real-time Examples on Principles of System	1	CO1
1.6	Apparent and Subtle System	1	CO1
1.7	Defining the Context of System	1	CO1
1.8	Real-time Examples on Context of System	1	CO1
2.	**Systems Thinking**		
2.1	Systems Engineering and its Significance	1	CO2
2.2	Physical and Service Processes	1	CO2
2.3	Need for System Thinking	1	CO2
2.4	Levels of System Thinking - Awareness, Analysis and Synthesis	1	CO2
2.5	Need for System Approach	1	CO2
3.	**Inputs and Outputs of System**		
3.1	System approach Frame work – Categories	1	CO3
3.2	New Solutions Vs. Replication Solutions	1	CO3
3.3	Perceived needs for achieving the solutions	1	CO3
3.4	Input – Investment and Expense	1	CO3
3.5	Types of Cost	1	CO3
3.6	Input – Need and Constraints	1	CO3
3.7	End user need	1	CO3
3.8	Output – Technical output	1	CO3
3.9	Output - System Output	1	CO3
3.10	Relationship between System and Technical Outputs	1	CO3
4.	**Transformation**		
4.1	Phenomenon in Process	1	CO4
4.2	Operational parameters	1	CO4
4.3	Process improvement	1	CO4
5.	**Diagnostics**		
5.1	Diagnostic tools and their use	1	CO5
5.2	Vital signs in transformation and their recognition	1	CO5
5.3	Sensitivity Analysis	1	CO5
6.	**Application of System approach**		
6.1	System Documentation and implementation	2	CO6
6.2	Benefits of Digital Data	1	CO6
6.3	Case Studies on System approach	2	CO6
6.4	Student Activity (Development, Review and Presentation)	2	CO6
		36	

Course Designers:

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18MEGB0	ENERGY CONVERSION TECHNIQUES

Category	L	T	P	Credit
GE	3		0	3

Preamble

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.

Prerequisite

- Nil

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO 1.	Compute the cycle efficiency, heat rate, steam rate of simple Rankine cycle of steam power plant and explain the working of steam power plant subsystems.	18
CO 2.	Describe the working of power plants using Nuclear energy sources	12
CO 3.	Calculate the performance parameters of Diesel engine power plants.	18
CO 4.	Determine the amount of heat transfer and collector area of solar thermal energy systems	18
CO 5.	Explain the working of non-renewable energy wind and bio-fuel, direct conversion techniques such as fuel cell, MHD.	16
CO6.	Compute the performance parameters of gas turbine power plants.	18

*** Weightage depends on Bloom's Level, number of contact hours,

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS3	Apply	Value	Mechanism	1.1,1.2, 2.1.3,3.2,4.1.1,4.1.2
CO2	TPS2	Understand	Response	Guided response	1.1,1.2, 2.1.3,3.2,4.1.1,4.1.2, 4.6.5
CO3	TPS3	Apply	Value	Mechanism	1.1,1.2, 2.1.3,3.2,4.1.1,4.1.2
CO4	TPS3	Apply	Value	Mechanism	1.1,1.2, 2.1.3,3.2,4.1.1,4.1.2
CO5	TPS2	Understand	Response	Guided response	1.1,1.2, 2.1.3,3.2,4.1.1,4.1.2
CO6	TPS3	Apply	Value	Mechanism	1.1,1.2, 2.1.3,3.2,4.1.1,4.1.2

Mapping with Programme Outcomes and Programme Specific 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					S		M				S	

CO2.	M	L						S		M				S	
CO3.	S	M	L					S		M				S	
CO4.	S	M	L					S		M				S	
CO5.	M	L						S		M				S	
CO6.	S	M	L					S		M				S	

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	**Continuous Assessment Tests**			**Assignment**			**Terminal Examination**
	1	**2**	**3**	1	2	3	
Remember	10	10	10	--	--	--	10
Understand	50	50	50	**50**	--	**50**	50
Apply	40	40	40	50	100	50	40
Analyse	--	-	-	--	--	--	-
Evaluate	--	--	--	--	--	--	--
Create	--	--	--	--	--	--	--

Assessment Pattern: Psychomotor

Psychomotor Skill	**Mini project /Assignment/Practical Component**
Perception	-
Set	-
Guided Response	-
Mechanism	Assignment
Complex Overt Responses	-
Adaptation	-
Origination	-

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define conventional energy source
2. Explain the ash handling plant of thermal power station
3. 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.

Course Outcome 2 (CO2):

1. Name the types of reactors.
2. Describe the fast breeder reactor.
3. Explain the chain reaction.

Course Outcome 3 (CO3):

1. Distinguish between brake power and indicated power
2. Compare two stroke and four stroke IC engines
3. 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 = 200 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 = 150 C, Outlet temperature of the

jacket cooling water = 600 C, Temperature of exhaust gases = 3000 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.

.

Course Outcome 4 (CO4):

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.

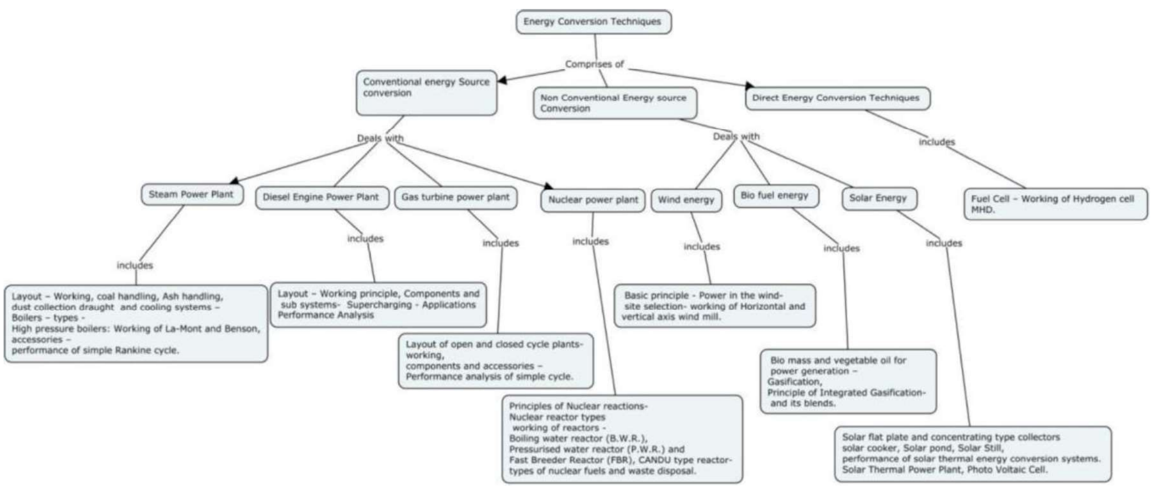
Course Outcome 5 (CO5):

1. List the advantages of wind power generation.
2. Define biomass
3. Name the different biofuels available for power generation.

Course Outcome 6(CO6):

1. Describe the different methods to improve efficiency of gas turbine.
2. Classify gas turbine
3. 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

Concept Map



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.

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.

Diesel engine power plant: Layout –Working principle, Components and sub systems- Supercharging - Applications, advantages and disadvantages, Performance analysis.

Solar Energy: Solar flat plate and concentrating type collectors–solar cooker, Solar pond, Solar Still, performance of solar thermal energy conversion systems. Solar Thermal Power Plant, Photo Voltaic Cell.

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.

Other Techniques: Fuel Cell – Working of Hydrogen cell - MHD.

Gas turbine power plant: Layout of open and closed cycle plants- working, components and accessories –Performance analysis of simple cycle.

Learning Resources

1. Rajput R.K., **"A Text Book of Power Plant Engineering",** Laxmi Publications (P) Ltd.,Fifth edition 2016
2. Nag P.K., "**Power Plant Engineering**"- fourth edition, Tata McGraw Hill New Delhi, 2014.
3. Rai G.D., "**Non- Conventional Energy Sources**", fourth edition 2015, Khanna Publishers, New Delhi
4. M.M.El-Wakil, **"Power plant Technology",** Tata McGraw Hill, New Delhi, 2010.
5. A.K.Raja, Srinvastava, Amit Praksh, **"Power Plant Engineering**" New age International 2016
6. Technology of Bio-Fuels(Ethanol & Biodiesel) Engineers India Research Institute (2010)

Online Resources

https://nptel.ac.in/courses/121106014/ Non conventional Energy resources, Prof. Pratap Haridoss, IIT Madras

https://www.youtube.com/watch?v=mpHZWYpKDJg, Energy resources and Technology Prof.S.Banerjee , IIT Kharagpur

https://nptel.ac.in/courses/112105221/Energy conservation and waste heat recovery , prof, Anatharoop bhattachararya, IIT Kharagpur

Course Contents and Lecture Schedule

Module No.	Topic	No. of hours	CO's
1.	**Energy source:**		
1.1	Conventional energy sources- types	1	
1.2	Non-conventional energy sources-types		CO1
2	**Steam power plant:**		
2.1	Layout – Working, coal handling, 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	Performance of simple Rankine cycle	3	CO2
3	**Nuclear power plant**:		
3.1	Principles of Nuclear reactions- Nuclear reactor types	1	CO2
3.2	Working of Reactors - Boiling water reactor (B.W.R.), Pressurised water reactor (P.W.R.) Fast Breeder Reactor	3	

	(FBR) and CANDU type reactor		
3.3	Types of nuclear fuels and waste disposal.	1	
4	**Diesel engine power plant:**		CO3
4.1	Layout – Working principle, Components and sub systems	2	
4.2	Supercharging - Applications, advantages and disadvantages	2	
4.3	Performance analysis	2	
5	**Solar Energy:**		CO4
5.1	Solar Collectors - working of flat plate and concentrating type	1	
5.2	Solar Cooker, Solar pond, Solar Still	2	
5.3	performance of solar thermal energy conversion systems.	2	
5.4	Solar Thermal Power Plant , Photo Voltaic Cell-working.	1	
6	**Wind energy, Bio fuel energy , Fuel cell and MHD**		CO5
6.1	Basic principle- Power in the wind- Site selection	1	
6.2	Horizontal and vertical axis wind mill.	1	
	Bio-fuel Energy:		
6.3	Bio-mass and Vegetable oil for power generation	1	
6.4	Gasification, Principle of Integrated Gasification	1	
6.5	Biodiesel and its blends.	1	
	Other Techniques:		
6.6	Fuel Cell – Working of Hydrogen cell - MHD	2	
7	**Gas turbine power plant:**		
7.1	Layout of Open and closed cycle plants- working, components and accessories	1	CO6
7.2	Performance analysis.	3	
	Total	**37**	

Course Designers:

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18MEGC0	MODELING AND CONTROL OF ROBOT

Category	L	T	P	Credit
GE	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 20th 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. The required modelling approaches in determining kinematic, static and dynamic behaviours, and knowledge representation have been addressed in this course. Moreover, this course facilitates the students to design and develop multi-DOF manipulator and wheeled mobile robot with artificial intelligence and to participate in robotics related contests.

Prerequisite

- Matrix manipulations

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage in %
CO1	Describe the working of the subsystems of robotic manipulator and wheeled mobile robot	10
CO2	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	20
CO3	Develop the static force and dynamic model of two degrees of freedom planar robot arm	20
CO4	Generate a trajectory in joint space using cubic polynomial and trigonometric functions with given kinematic constraints of two and three degree of freedom (DOF) manipulator	20
CO5	Develop a knowledge representation for task planning of robotic applications such as pick and place, palletizing, sorting and inspection of work-parts	20
CO6	Explain various types of control schemes and sensors used in the operation of robot	10

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.3
CO2	TPS3	Apply	Value	Mechanism	1.3, 2.1.2, 2.1.3, 3.2.5, 4.4.3
CO3	TPS3	Apply	Value	Mechanism	1.3, 2.1.2, 2.1.3, 3.2.5, 4.4.3
CO4	TPS3	Apply	Value	Mechanism	1.3, 2.1.2, 2.1.3, 3.2.5, 4.4.3
CO5	TPS3	Apply	Value	Mechanism	1.3, 2.1.2, 2.1.3, 2.3.1, 3.2.5, 4.4.3
CO6	TPS2	Understand	Respond	Guided Response	1.3

Mapping with Programme Outcomes and Programme Specific Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	M	L													
CO2	S	M	L		L										
CO3	S	M	L		L										
CO4	S	M	L		L										
CO5	S	M	L												
CO6	M	L													

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	20	20	20	-	-	-	10
Understand	20	20	20	-	-	-	30
Apply	60	60	60	100	100	100	60
Analyse	-	-	-	-	-	-	-
Evaluate	-	-	-	-	-	-	-
Create	-	-	-	-	-	-	-

Assessment Pattern: Psychomotor

Psychomotor Skill	Mini-project /Assignment/Practical Component
Perception	
Set	
Guided Response	
Mechanism	Simulation of robot using open source packages like RoboAnalyzer and programming like Python, MatLab, V-Rep
Complex Overt Responses	
Adaptation	
Origination	

Sample Questions for Course Outcome Assessment

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

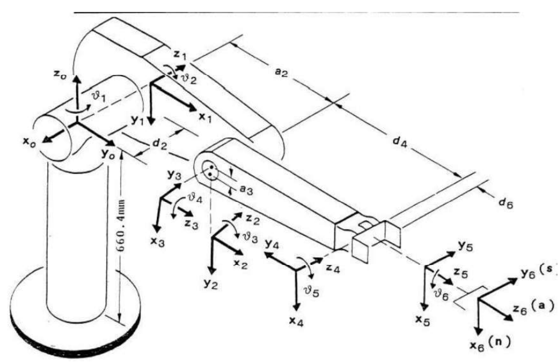


Figure 1

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 $x_0 y_0 z_0$ 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 $x_1 y_1 z_1$ 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 $x_2 y_2 z_2$ 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.

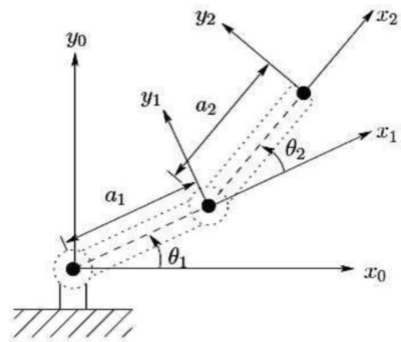


Figure 2

3. 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 for the planar manipulator as shown in figure 3.

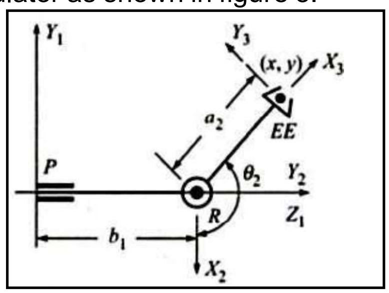


Figure 3

Course Outcome 3(CO3):

1. Develop a dynamic model for two degree of freedom manipulator as shown in figure 4.

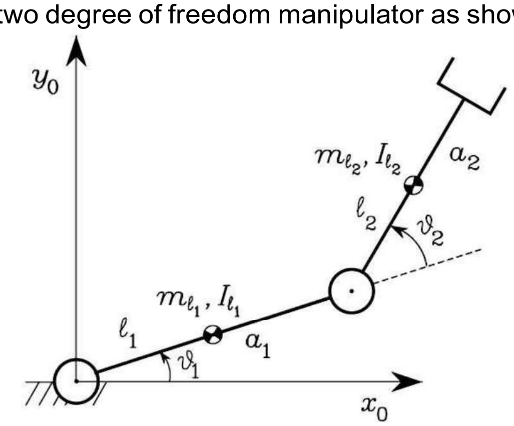


Figure 4

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.

Course Outcome 4 (CO4):

1. 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.

2. A single link rotary joint robot is required to move from $\theta(0) = 30°$ to $\theta(2) = 100°$in 2 seconds. Assume that initial and final velocities are zero. Determine the coefficients of a cubic polynomial trajectory and plot its trajectory for atleast 8 equal time intervals.
3. Generate position, velocity and acceleration profiles for a cycloidal trajectory of the rotary joints of a manipulator with $t(i) = 0$; $t(f) = 8s$; $\theta(i) = 0°$; $\theta(f) = 100°$;

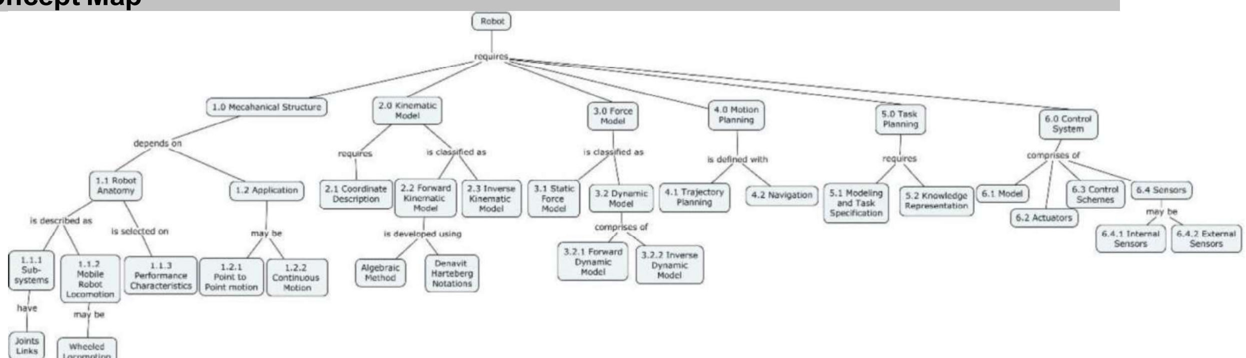
Course Outcome 5 (CO5):

1. 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. Prepare the sequence of tasks with use of semantic map.
2. Prepare a knowledge representation scheme to operate 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.

Course Outcome 6(CO6):

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.

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, and cycloidal motion - Cartesian space techniques. Navigation: Graph search and potential field path planning - navigation architecture - offline and online planning.

Robot Task Planning –Modeling and Task Specification - Problems in task planning: Spatial relationship, obstacle avoidance and grasp planning–Expert System and Knowledge Engineering: Construction of expert system, Rule-based systems– Knowledge representation.

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.

Learning Resources

1. S.K.Saha, "Introduction to Robotics", Second Edition, McGraw Hill Education (India) Private Limited, New Delhi, 2014.
2. Roland Siegwart and Illah R.Nourbakhsh, "Introduction to Autonomous Mobile Robots", Prentice Hall of India (P) Ltd., 2005.
3. K.S. Fu, R.C Gonzalez and C.S. Lee, Robotics- Control, Sensing, Vision and Intelligence, Tata McGraw-Hill Editions, 2008.
4. Siciliano, B., Sciavicco, L., Villani, L., Oriolo, G., Robotics: Modelling, Planning and Control, First edition, Springer-Verlag London,2009
5. John J.Craig, Introduction to Robotics, Mechanics and control, third edition, Pearson education, 2005.
6. Mark W.Spong, M.Vidyasagar, Robot dynamics and control, Wiley India, 2009.
7. 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.
8. Hertzberg J., Chatila R. (2008) AI Reasoning Methods for Robotics. In: Siciliano B., Khatib O. (eds) Springer Handbook of Robotics. Springer, Berlin, Heidelberg
9. International Federation of Robotics (IFR) Report: Artificial Intelligence in Robotics: https://ifr.org/downloads/papers/Media_Backgrounder_on_Artificial_Intelligence_in_Robotics_May_2018.pdf
10. Sun, X., & Zhang, Y. (2019). *A Review of Domain Knowledge Representation for Robot Task Planning. Proceedings of the 2019 4th International Conference on Mathematics and Artificial Intelligence - ICMAI 2019.* doi:10.1145/3325730.3325756
11. NPTEL Course on Robotics – Prof. Dilip Kumar Prathihar: https://nptel.ac.in/courses/112105249/
12. Coursera – Robotics specialization – University of Pennsylvania https://www.coursera.org/specializations/robotics

Course Contents and Lecture Schedule

Module No.	Topic	No. of Hours	Course Outcome
1.	**Mechanical Structure**		
1.1	Robot Configuration - Robot Anatomy	1	CO1
1.1.1	Sub- systems of Industrial Robot	1	
1.1.2	Mobile robot locomotion: Introduction, key issues for locomotion	1	
1.1.2.1	Wheeled locomotion - wheel design, geometry	1	
1.1.2.2	Stability, manoeuvrability and controllability		
1.1.3	Performance characteristics of robots	1	
1.2	Applications - Progressive advancement in Robots – Point to point and continuous motion applications - Mobile manipulators and its applications.		
2.0	**Kinematic Model**		
2.1	Coordinate Description - Forward Kinematics for two DOF manipulator – Algebraic method	1	CO2
2.1.1	Mechanical structure and notations, Coordinate frames, Description of objects in space	1	
2.1.2	Transformation of vectors, Fundamental rotation matrices	1	

Module No.	Topic	No. of Hours	Course Outcome
	(principal axes and fixed angle rotation)		
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	**Force Model**		
3.1	Static Force Model - Differential relationship - Velocity analysis – Jacobian matrix	2	CO3
3.1.1	Determination of forces and equivalent torques for joints of two link planar robot arm	2	
3.2	Dynamic model - Euler-Lagrangian formulation	2	
3.2.1	Forward dynamic model for two DOF manipulator		
3.2.2	Inverse dynamic model for two DOF manipulator.	1	
4.0	**Motion planning**		
4.1	Trajectory Planning: Definitions and planning tasks, Joint space techniques- Cartesian space techniques	1	CO4
4.1.1	Motion profiles – Cubic polynomial motion	2	
4.1.2	Cycloidal motion	1	
4.2	Navigation: Graph search path planning	2	
4.2.1	Potential field path planning	1	
4.2.2	Navigation architecture	1	
5.0	**Robot Task Planning**		
5.1	Modeling and Task Specification	1	CO5
5.1.1	Problems in task planning: Spatial relationship, obstacle avoidance and grasp planning	1	
5.1.2	Expert System and Knowledge Engineering: Construction of expert system, Rule-based systems	1	
5.2	Knowledge representation – First Order Logic	2	
6.	**Control System**		
6.1	The manipulator control problem	1	CO6
6.1.1	Linear second-order model of manipulator. Functions of controller and power amplifier		
6.2	Joint actuators- stepper motor, servo motor	1	
6.3	Control Schemes: PID control scheme – Position and force control schemes		
6.4	Robotic sensors and its classification	1	
6.4.1	Internal sensors – Position, velocity, acceleration and force information		
6.4.2	External Sensors – Contact Sensors-Limit switches, piezo-electric, pressure pads.	1	
6.4.3	Non-contact sensors – Range sensors, Vision sensor-robotic vision system, Description of components of vision system.		
		36	

Course Designers:

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18MEGD0	COMPOSITE MATERIALS	Category	L	T	P	Credit
		GE	3	0	0	3

Preamble

Composite materials 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. Composite materialsare preferred over traditional materials for their properties which are stronger, lighter or less expensive. This course covers the fundamentals of composite materials and processing of various composite materials

Prerequisite

Nil

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Explain the classification, characteristics and the applications of composites in various domains	10
CO2	Summarize the various Reinforcements and Matrix used in composite materials	10
CO3	Select the appropriate processing method for polymer matrix composites	20
CO4	Select the proper fabrication method for metal matrix composites	20
CO5	Choose the suitable processing method in ceramic matrix composites and carbon- carbon Composites	20
CO6	Choose the suitable processing method in Nanocomposites	20

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.2, 2.4.4, 3.3.1,4.3.2
CO2	TPS2	Understand	Respond	Guided Response	1.2, 2.4.4, 3.3.1,4.3.2
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO5	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO6	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2

Mapping with Programme Outcomes and Programme Specific 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	PSO 1	PSO 2	PSO 3
CO1.	S	M	L	M	-	-	-	M	L	L	-	-	L	-	L
CO2.	S	M	L	M	-	-	-	M	L	L	-	-	L	-	L
CO3.	S	M	L	M	-	-	-	M	L	L	-	-	M	-	M
CO4.	S	M	L	M	-	-	-	M	L	L	-	-	M	-	M
CO5.	S	M	L	M	-	-	-	M	L	L	-	-	M	-	M
CO6.	S	M	L	M	-	-	-	M	L	L	-	-	M	-	M

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	20	20	20	-	-	-	10
Understand	40	20	20	-	-	-	30
Apply	40	60	60	100	100	100	60
Analyse	-	-	-	-	-	-	-
Evaluate	-	-	-	-	-	-	-
Create	-	-	-	-	-	-	-

Assessment Pattern: Psychomotor

Psychomotor Skill	Mini-project /Assignment/Practical Component
Perception	-
Set	-
Guided Response	-
Mechanism	**Assignment**
Complex Overt Responses	-
Adaptation	-
Origination	-

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define composite material
2. Classify composite materilas based on matrix used
3. Write the role of matrix in composite materials.

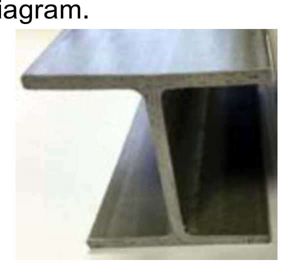
Course Outcome 2 (CO2):

1. Explain the glass fibre manufacturing method with suitable sketches. Define composite material
2. List the important charcteristics of glass fibre, carbon fibre and aramid fibre.
3. Write the advantages, limitations of thermosetting polymers and thermoplastic polymers.

Course Outcome 3 (CO3):

1. Differentiate between thermosetting and thermo plastics
2. Identify the suitable fabrication technique to fabricate the given component shown in Figure 1 and explain the fabrication process with suitable diagram.

3. Suggest and explain the suitable fabrication technique to fabricate the given components shown in Figure 2 with necessary diagram.



Course Outcome 4 (CO4):

1. Identify a simplest and economical, liquid state, metal matrix composite processing technique for the production of Al–SiCp composites and explain the process with suitable diagram
2. Suggest a suitable fabrication technique to make Al_2O_3/SiCparticulate-reinforced Al–5Si–2Fe alloy composites containing 30 wt.% ceramic particulates. Explain this process with necessary diagram.
3. Identify a suitable metal matrix composite processing technique to fabricate the brake rotorsand explain the fabrication process with suitable diagram.
4. Suggest a suitable metal matrix composite fabrication technique with application of high temperature and pressure using matrix alloy foil and fiber arrays. Explain this process with necessary diagram

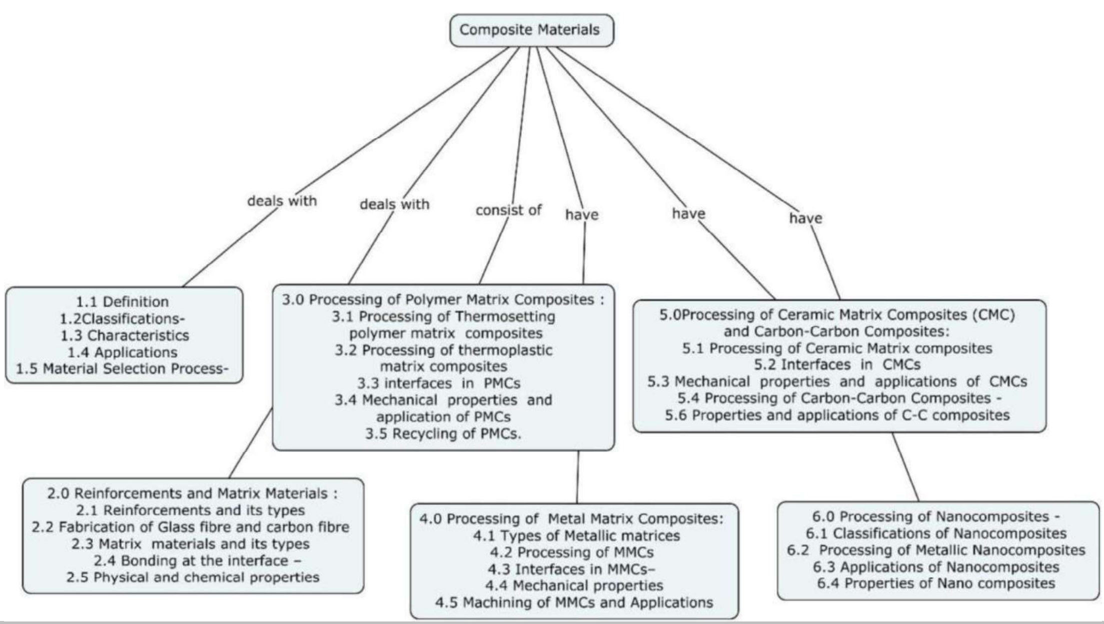
Course Outcome 5 (CO5):

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.
4. With suitable diagram, explain how are ceramic composites are fabricated using chemical vapour infiltration technique.
5. With suitable diagram, explain how are ceramic composites are fabricated using slurry infiltration technique?

Course Outcome 6 (CO6):

1. List the benefits of polymer–clay nanocomposites.
2. List the peculiar properties of nanocomposites.
3. Explain the novel method to form PNCs using CNT aggregates.

Concept Map



Syllabus

Composite Materials: Definition- Need-Classifications- Characteristics- Applications in various industries -Aircraft, Military, Space Applications, Automotive, Sporting Goods, Marine ,Infrastructure. Material Selection Process- Potential Advantages- Strength, Stiffness, Cost and Weight

Reinforcements and Matrix Materials :Reinforcements -Types - Fibers– Glass fiber, Boron fiber, carbon fiber, organic fiber, ceramic and metallic fibers - whiskers Fabrication of Glass fibre and carbon fibre–.Matrix materials– Polymers, Classification of Polymers – Properties of Thermo and Thermosetting Plastics- Metals and ceramics and their properties – interfaces – Wettability – Types of bonding at the interface – Physical and chemical properties.

Processing of Polymer Matrix Composites : 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 - Mechanical properties and application of PMCs – recycling of PMCs.

Processing of Metal Matrix Composites: Metallic matrices: Aluminum, 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.

Processing of Ceramic Matrix Composites (CMC) and Carbon-Carbon Composites: Processing of CMC: cold pressing, sintering, reaction bonding, liquid infiltration, lanxide process – In situ chemical reaction techniques: chemical vapour deposition, chemical vapour impregnation, sol-gel method – Interfaces in CMCs – mechanical properties and applications of CMCs – Carbon-carbon Composites – Carbon Fiber ReinforcementsMatrix Systems -Processing of Carbon-Carbon Composites -Properties and applications.

Processing of Nanocomposites - Classifications - Polymer Nanocomposites -Clay – Polymer Nanocomposites -Graphite – Polymer Nanocomposites - Nanofiber-Reinforced Composites -Particulate Nanocomposites -Organic – Inorganic Hybrids (Nano-composites) - Applications of Polymer Nanocomposites - Metal Matrix Nanocomposites - Processing of Metallic Nanocomposites - applications -properties - Ceramic Nanocomposites Processing of Ceramic Nano composites - applications -properties -

Reference Books

1. M. Balasubramanian ,**Composite materials and Processing**, Taylor & Francis Group, LLC, CRC Press, 2014.
2. Krishnan K Chawla, Composite **Materials: Science and Engineering**, International Edition, Springer, 2012.
3. Mallick P.K., **FiberReinforced Composites: Materials, Manufacturing and Design**, CRC press, New Delhi, 2010.
4. Mallick, P.K. and Newman.S., **Composite Materials Technology**, Hanser Publishers, 2003.
5. Bhagwan D. Agarwal and Lawrence J. Broutman, **Analysis and Performance of Fiber Composites**, John Wiley and Sons Indian Edition, 2018.
6. Prof. J. Ramkumar, **“Manufacturing of composites”**, NPTEL, IIT Kanpur - https://nptel.ac.in/courses/112104221/
7. Prof. Nachiketa Tiwari, **“Introduction to composites”**, NPTEL, IIT Kanpur - https https://nptel.ac.in/courses/112104168/

Module Number	Topics	No. of Lectures	Course outcome
1.0	**Composite Materials**		
1.1	Definition- Need-Classifications- Characteristics	1	CO1
1.2	Applications -Aircraft and Military Applications, Space Applications, Automotive Applications, Sporting Goods Applications, Marine Applications,Infrastructure	1	CO1
1.3	Material Selection Process- Potential Advantages- Strength, Stiffness, Cost and Weight	1	CO1
2.0	**Fibers and Matrix Materials**		
2.1	Glass fiber, Boron fiber, carbon fiber, organic fiber, ceramic and metallic fibers - whiskers	1	CO2
2.2	Polymers, Classification of Polymers – Properties of Thermo and Thermosetting Plastics -metals and ceramics and their properties – interfaces – Wettability	2	CO2

Module Number	Topics	No. of Lectures	Course outcome
2.3	Metals and ceramics and their properties – interfaces – Wettability	1	CO2
2.4	Types of bonding at the interface	1	CO2
2.5	Physical and chemical properties	1	CO2
3.0	**Processing of Polymer Matrix Composites**		
3.1	Processing methods: Polymer matrix composites: hand layup, spray, filament winding, Pultrusion	2	CO3
3.2	Resin transfer moulding, autoclave moulding - bag moulding, compression moulding with Bulk Moulding Compound and sheet moulding Compound	2	CO3
3.3	Thermoplastic matrix composites – film stacking, diaphragm forming, thermoplastic tape laying, injection moulding interfaces in PMCs	1	CO3
3.4	Mechanical properties and application of PMCs	1	CO3
3.5	Recycling of PMCs	1	CO3
4.0	**Processing of Metal Matrix Composites:**		
4.1	Metallic matrices: Aluminium, titanium, magnesium, copper alloys	1	CO4
4.2	Processing of MMCs: liquid state, Solid state, in situ fabrication techniques - Diffusion bonding – powder metallurgy techniques	2	CO4
4.3	Interfaces in MMCs	1	CO4
4.4	Mechanical properties	1	CO4
4.5	Machining of MMCs – Applications.	1	CO4
5.0	**Processing of Ceramic Matrix Composites and Carbon-Carbon Composites**		
5.1.1	**Processing of CMCs:** Cold pressing, Sintering, Reaction bonding, Liquid infiltration method	1	CO5
5.1.2	Lanxideprocess –In situ chemicalreaction techniques: Chemical vapour deposition, Chemical vapour impregnation, Sol-gel methods	1	CO5
5.2	Interfaces in CMCs –	1	CO5
5.3	Mechanical properties and applications of CMCs		CO5
5.4	**Processing of Carbon- Carbon Composites**: Carbon-carbon Composites – Carbon Fiber Reinforcements-Matrix Systems -	1	CO5
5.5	Carbon-Carbon Composites -Mechanical Properties and applications.	2	CO5
6.0	**Nanocomposites**		
6.1	Nanocomposites - Classifications - Polymer Nanocomposites - Clay Polymer Nanocomposites -GraphitePolymer Nanocomposites - Nanofiber-Reinforced Composites - Particulate Nanocomposites.	2	CO6
6.2	Organic–Inorganic Hybrids (Nano-composites) - Applications of Polymer Nanocomposites -	1	CO6
6.3	Metal Matrix Nanocomposites - Processing of Metallic Nanocomposites -applications -properties	1	CO6
6.4	Ceramic Nanocomposites Processing of Ceramic	1	CO6

Module Number	Topics	No. of Lectures	Course outcome
	Nanocomposites -applications -properties		
	Total	36	

Course Designers

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18MEGE0	AUTOMOBILE ENGINEERING

Category	L	T	P	Credit
GE	3		0	3

Preamble

This course deals with general construction and working of an automobile and performance calculations. It covers needs, construction and working of various subsystems of an automobile such as prime mover (I.C.Engine), transmission, braking, steering and their preliminary design. It also focuses on the recent developments in the field of automobile engineering.

Prerequisite

- Nil

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO 1.	Explain construction and working of an automotive engine and its systems.	**20**
CO 2.	Calculate power requirement of an automotive engine, acceleration, gradability, draw bar pull and gear ratios of an automobile.	**20**
CO 3.	Determine centre of gravity, stability of vehicle resting in slope, dynamics of vehicle on a level and banked track, stability of vehicle taking turn.	15
CO 4.	Design steering mechanism and power transmission system of an automobile.	20
CO 5.	Design hydraulic braking system of an automobile.	15
CO 6.	Explain recent developments in the field of automobile engineering	**10**

*** Weightage depends on Bloom's Level, number of contact hours.

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Response	Guided response	1.2, 2.1, 3.2, 4.1.2
CO2	TPS3	Apply	Value	Mechanism	1.1,1.2,2.1,2.4.6,3.2,3.3, 4.1.1,4.1.5
CO3	TPS3	Apply	Value	Mechanism	1.1,1.2,2.1,2.4.6,3.2,3.3, 4.1.1,4.1.5
CO4	TPS3	Apply	Value	Mechanism	1.1,1.2,2.1,2.4.6,3.2,3.3, 4.1.1,4.1.5
CO5	TPS3	Apply	Value	Mechanism	1.1,1.2,2.1,2.4.6,3.2,3.3, 4.1.1,4.1.5
CO6	TPS2	Understand	Response	Guided response	1.2, 2.1, 3.2, 4.1.2

Mapping with Programme Outcomesand Programme Specific Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1.	M	L				L				L					
CO2.	S	M	L			L				L					
CO3.	S	M	L			L				L					

CO4.	S	M	L			L				L					
CO5	S	M	L			L				L					
CO6	M	L				L				L					

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	2	3	1	2	3	
Remember	10	10	10				10
Understand	40	40	40				40
Apply	50	50	50	100	100	100	50
Analyse	--	-	-	--	--	--	-
Evaluate	--	--	--	--	--	--	--
Create	--	--	--	--	--	--	--

AssessmentPattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	-
Set	-
Guided Response	-
Mechanism	Assignment
Complex Overt Responses	-
Adaptation	-
Origination	-

Course Level Assessment Questions

Course Outcome 1 (CO1):
1. Classify automotive engines.
2. Explain the construction and working of a 4-stroke petrol engine.
3. With a neat sketch, explain the circuit and working of battery ignition system.

Course Outcome 2 (CO2):
1. Define: Tractive effortand Gradeability.
2. Narrate the need for different gear ratios in an automobile.
3. The coefficient of rolling resistance for a truck weighing 62293.5 N is 0.018 and the co efficient of air resistance is 0.0276 in the formula $R= KW+K_aAV^2$, the transmission efficiency in top gear of 6.2:1 is 90% and that in the second gear of 15:1 is 85%.The frontal area is 5.574m^2.if the truck has to have a maximum speed of 88 km/h in top gear, Determine the engine BP required and the engine speed if the driving wheels have an effective diameter of 0.825.The maximum grade the truck can negotiate at the above engine speed in second gear and the Maximum draw bar pull available on level at the above engine speed in second gear.

Course Outcome 3 (CO3):
1. Discuss the method of determining the CG position of a vehicle.
2. List the factors responsible for overturning of a vehicle.
3. A vehicle of total weight 49050 N is held at rest on a slope of 10°. It has a wheel base of 2.25 m and its centre of gravity is at 1.0 m in front of the rear axle and 1.5 m above the ground level, Find the normal reactions at the wheels. Assuming that the sliding does not occur first, what will be the angle of slope so that the vehicle will overturn?

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Course Outcome 4 (CO4):
1. Explain the construction and working of a power steering with neat diagrams.
2. Discuss the need for limited slip differential and centre differential

3. A track has pivot pins 1.37 m apart, the length of each track arm is 0.17 m and the track rod is behind front axle and 1.17 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. A geometrical construction may be used.

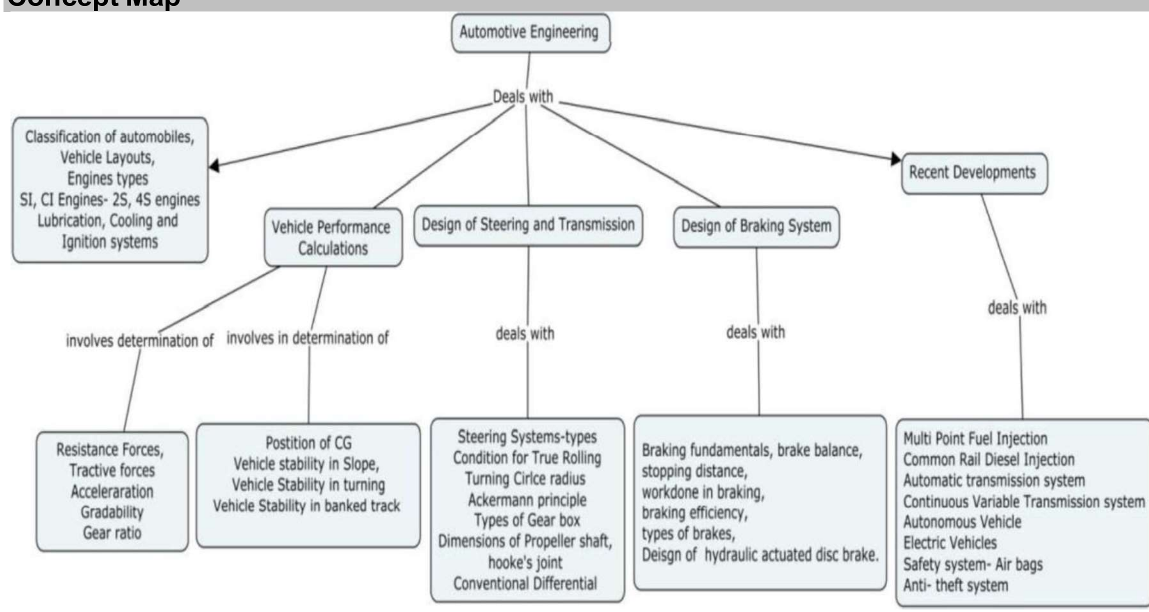
Course Outcome 5 (CO5):

1. Discuss briefly how bleeding is done in hydraulic brake system.
2. Compare drum and disc brakes.
3. In a hydraulic single line braking system, force on the foot pedal is 100N, pedal leverage ratio is 4, cross sectional area of the master cylinder is 4cm^2, cross sectional area of the front pistons 20cm^2, cross sectionalarea of the rear piston 5cm^2 and distance moved by effort is 1 cm. Calculate the front to rear brake ratio, % of front and rear braking, total force ratio, total movement ratio.

Course Outcome 6 (CO6):

1. With a neat sketch, explain the working of Continuous Variable Transmission system
2. Explain the working of Anti- lock Braking system.
3. List the merits and demerits of electric vehicle.

Concept Map



Syllabus

Introduction - Classification of automobiles, Basic layout of an automobile.

Engines -classification, Construction and working of 2-stroke and 4-stroke S.I and C.I.Engines, Lubrication system- Pressurized wet sump, Cooling system- water cooling, ignition system- battery ignition.

Vehicle performance –Various Resistance forces, traction and tractive effort, Road performance curves: acceleration, gradability and draw bar pull, determination of gear ratios.

Centre of gravity of a four-wheeler, Vehicle stability in slope, maximum acceleration, maximum tractive effort and reaction for different drives. Dynamics of vehicle running on banked track, Stability of vehicle turning - 2 wheeled and 4 wheeled vehicle.

Steering mechanism : Function, steering linkages,-Axle beam suspension steering system, independent suspension steering system, joints in live front axle(Tripod joint, Rzeppa joint). Front wheel alignment, Ackermann principle,condition for true rolling, turning circle radius, working of power steering.

Transmission system: Function and types of automotive clutches, working of diaphragm clutch, -Need for gears, working of Sliding mesh, constant mesh and synchromesh gearbox, Design of propeller shaft and Hooke's joint, types of drives, construction and working of conventional differential, need for limited slip differential and centre differential.

Braking system: Fundamentals, brake balance, stopping distance, work done in braking, braking efficiency, Theory and problems on front wheel and/ or rear wheel braking. Types of brakes- Mechanical, hydraulic, Drum, Disc brake systems, Mechanics and design of hydraulic actuated disc brake.

Recent Developments: Multi Point Fuel Injection (MPFI), Common Rail Diesel Injection (CRDI), Automatic Transmission, Continuously variable transmission (CVT). Antilock Braking System (ABS), Autonomous vehicles, Electric vehicles- types, merits and demerits. Safety Systems- Air bag, anti- theft system.

Learning Resources

1. Dr.N.K.Giri, "**Automobile Mechanics** ",Eight Edition, Khanna publishers Pvt. Ltd,New Delhi 2011.

2. Kirpal Singh, **"Automobile Engineering",** Volume-1&2, 13th Edition, Standard Publishers Distributers, 2017.

3. S.S.Srivnivasan , **"Automotive Mechanics",** McGraw Hill Education; 2 edition 2017

4. Joseph Heitner, **"Automotive Mechanics, Principle and practices",** East West Press, (Second Edition), 2001

5.Richard Stone and Jeffrey K. Ball, "**Automotive Engineering Fundamentals** "SAE International, 2011.

https://nptel.ac.in/courses/108102121/
https://www.youtube.com/watch?v=y5p31F_dVJU
https://www.youtube.com/watch?v=wCu9W9xNwtI

Course Contents and Lecture Schedule

Module No	Topic	No. of Lectures	COs
1.	**Introduction**		
1.1	Classification of automobiles, Basic layout of an automobile	1	CO1
1.2	**Engines**: classification, Construction and working of 2-stroke and 4-stroke S.I and C.I.Engines	1	
1.3	Lubrication system- Pressurized wet sump, Cooling system- water cooling, ignition system- battery ignition	2	
2.	**Vehicle performance**		CO2
2.1	Various Resistance forces, traction and tractive effort,	2	
2.2	Road performance curves: acceleration, gradability and draw bar pull	2	
2.3	Selection of gear ratios for an automobile for given application	2	
3.	**CG and stability**		CO3
3.1	Centre of gravity of a four-wheeler, maximum	2	

Module No	Topic	No. of Lectures	COs
	acceleration, maximum tractive effort and reaction for different drives.		
3.2	Dynamics of vehicle running on banked track,Vehicle stability in slope	2	
3.3	Stability of vehicle turning- 2 wheeled and 4 wheeled vehicle	2	
4.	**Steering and Transmission**		CO4
4.1	Steering system: function, steering linkages,-Axle beam suspension steering system, independent suspension steering system	1	
4.2	Joints in live front axle (Tripod joint, Rzeppa joint). Front wheel alignment	1	
4.3	Ackermann principle, condition for true rolling, turning circle radius, Theory and problems.	2	
4.4	Working of power steering.	1	
4.5	Design of transmission system: Function and types of automotive clutches, working of diaphragm clutch	1	
4.6	Need for gears, working of sliding mesh, constant mesh and synchromesh gearbox	1	
4.7	Design of propeller shaft and Hooke's joint, types of drives (live rear axle).	2	
4.8	construction and working of Conventional differential, Need for limited slip differential and centre differential	1	
5	**Brakes**		
5.1	Braking fundamentals, brake balance, stopping distance, work done in braking, braking efficiency, Theory and problems on front wheel and/ or rear wheel braking.	2	CO5
5.2	Types of brakes-Mechanical, hydraulic, Drum, Disc brake systems	1	
5.3	Mechanics and design of hydraulic actuated disc brake.	2	
6	**Recent Developments**		
6.1	Multi Point Fuel Injection (MPFI), Common Rail Diesel Injection (CRDI),	1	CO6
6.2	Automatic Transmission	1	CO6
6.3	Continuously variable transmission (CVT). Antilock Braking System (ABS)	1	CO6
6.4	Autonomous vehicles, Electric vehicles- types, merits and demerits. Safety Systems	1	CO6
6.5	Safety Systems- Air bag, anti- theft system.	1	CO6
	Total	**36**	

Course Designers:

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18MEGF0	3D PRINTING

Category	L	T	P	Credit
GE	3	0	0	3

Preamble

3D Printing and design is designed to impart knowledge and skills related to 3D printing technologies, selection of material and equipment and develop a product using this technique in Industry 4.0 environment.

Prerequisite

NIL

Course Outcomes

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

CO Number	Course Outcome Statement	Weightage*** in %
CO1	Describe the fundamentals and process chain of 3D Printing.	10
CO2	Explain of file formats and software packages used for 3D printing machine.	10
CO3	Select a suitable Photopolymerization / Powder Bed Fusion 3D printing process for an application / product.	25
CO4	Select a suitable deposition 3D printing process for an application / product.	25
CO5	Explain the effects of process parameter in a 3D Printed part quality	10
CO6	Select the different Post processing methods for 3D Printed parts	10
CO7*	Demonstrate to Create 3D model using Additive manufacturing Method s	10

* CO7 is assessed through report preparation and practical component as assignments in continuous assessment and are not evaluated in terminal examination.

CO Mapping with CDIO Curriculum Framework

CO #	TCE Proficiency Scale	Learning Domain Level			CDIO Curricular Components (X.Y.Z)
		Cognitive	Affective	Psychomotor	
CO1	TPS2	Understand	Respond	Guided Response	1.2, 2.4.4, 3.3.1,4.3.2
CO2	TPS2	Understand	Respond	Guided Response	1.2, 2.4.4, 3.3.1,4.3.2
CO3	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO4	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2
CO5	TPS3	Understand	Respond	Guided Response	1.2, 2.4.4, 3.3.1,4.3.2
CO6	TPS3	Apply	Value	Guided Response	1.2, 2.4.4, 3.3.1,4.3.2
CO7	TPS3	Apply	Value	Mechanism	1.2, 2.4.4, 3.3.1,4.3.2

Mapping with Programme Outcomes and Programme Specific Outcomes

Cos	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO1 0	PO1 1	PO1 2	PSO 1	PSO 2	PSO 3
CO 1	M	L	-	-	-	-	-	-	L	-	-	-	S	-	L
CO 2	M	L	-	-	S	-	-	-	L	-	-	-	S	-	L
CO 3	S	M	L	-	M	-	-	-	M	-	M	-	S	-	L

CO 4	S	M	L	-	M	-	-	-	M	-	M	-	S	-	L
CO 5	M	L	-	-	-	-	-	-	L	-	-	-	S	-	L
CO 6	S	M	L	-	-	-	-	-	M	-	-	-	S	-	L
CO 7	S	M	L	-	-	-	-	-	M	-	-	-	S	-	L

S- Strong; M-Medium; L-Low

Assessment Pattern: Cognitive Domain

Cognitive Levels	Continuous Assessment Tests			Assignment			Terminal Examination
	1	**2**	**3**	1	2	3	
Remember	20	20	20	-	-	-	20
Understand	50	40	40	-	-	-	40
Apply	30	40	40	100	100	100	40
Analyse	-	-	-	-	-	-	-
Evaluate	-	-	-	-	-	-	-
Create	-	-	-	-	-	-	-

Assessment Pattern: Psychomotor

Psychomotor Skill	Miniproject /Assignment/Practical Component
Perception	-
Set	-
Guided Response	-
Mechanism	**Assignment**
Complex Overt Responses	-
Adaptation	-
Origination	-

Sample Questions for Course Outcome Assessment**

Course Outcome 1 (CO1):
1. Define Additive Manufacturing?
2. Explain the process chain of 3D Printing process
3. Explain the Time compression engineering in 3D Printing process

Course Outcome 2 (CO2):
1. Explain the different part orientation for creation of 3D model.
2. Write the different CAD file formats suitable for 3D printing.
3. Differentiate between the STL Binary and ASCII format.

Course Outcome 3 (CO3):
1. Select the suitable 3D printing process for the jewellery application
2. Select the suitable 3D printing process for the development of scaffold in biomedical.
3. Select the suitable 3D printing Process be particularly useful for military applications.

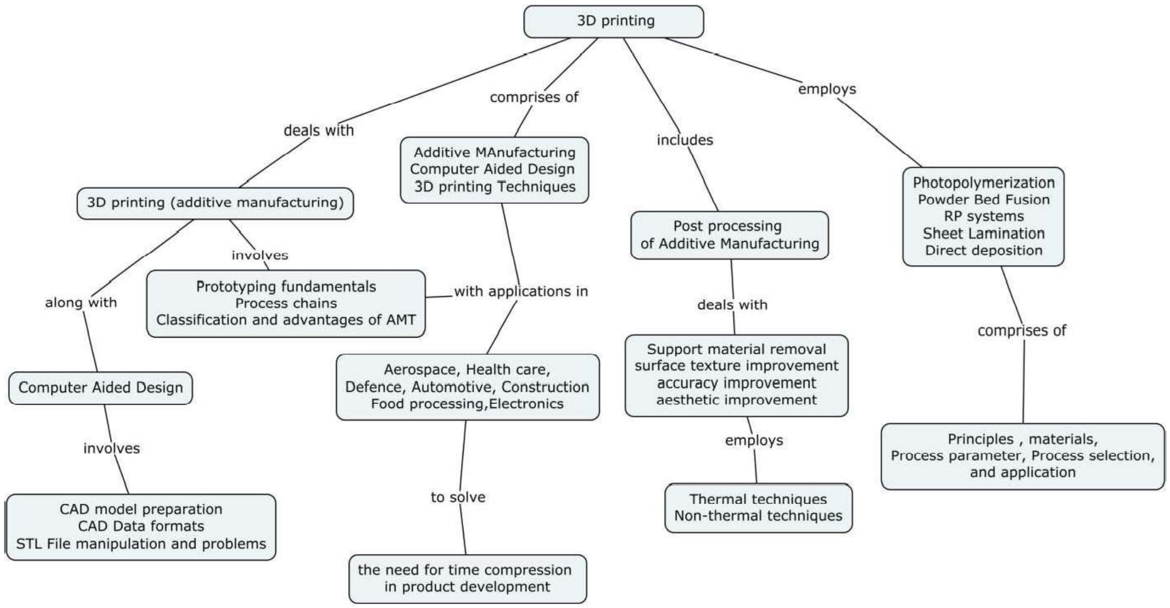
Course Outcome 4 (CO4):
1. Suggest the suitable process parameter in SLS process for making a titanium parts
2. Select the optimum process parameter in FDM process for fabricating the architect models.

Course Outcome 5 (CO5):
1. Discuss the effect of process parameters in FDM parts.
2. Explain the different process parameters used in SLS process.
3. Explain how SLA process parameters effect on the quality of the product.

Course Outcome 6 (CO6):
1. Discuss the Machining strategy for finishing the AM parts and tools.
2. Suggest the few methods for Property Enhancements Using Thermal Techniques.

3. Explain the different methods of support material removal in AM process.

Concept Map



Syllabus

3D Printing: Introduction - Prototyping fundamentals - Historical development - Need for time compression in product development - processes chain- Classification of 3D Printing - Advantages of 3D Printing.

CAD (Computer Aided Design) for 3D Printing: CAD model preparation, Data Interfacing - CAD Data formats - STL File Format, Binary/ASCII – Creating STL Files from a CAD System - Problems with STL Files - STL File Manipulation - Part orientation and support generation.

3D Printing Techniques:

Photopolymerization: Stereolithography (SL) – Principles – Materials - Process details - Process parameter - Applications.

Powder Bed Fusion: Selective laser Sintering (SLS) – Principles – Materials - Process details - Process parameter - Applications.

Extrusion-Based RP Systems: Fused Deposition Modelling (FDM) – Principles – Materials- Process details - Process parameter - Applications

Direct Deposition: Direct Metal Deposition (DMD) – Principle - Materials - Process details - Process parameter - Applications.

Post processing of AM parts: Introduction - Support material removal - surface texture improvement- accuracy improvement - aesthetic improvement - property enhancements using thermal techniques - property enhancements using non-thermal techniques

Applications: Aerospace - Health Care - Defence - Automotive – Construction - Food Processing – Electronics.

Demonstration to Create 3D model using Additive manufacturing Method

Learning Resources

1. Lan Gibson, David W. Rosen and Brent Stucker, **"Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing"**, Springer, 2010.
2. Andreas Gebhardt, **"Understanding Additive Manufacturing: Rapid Prototyping, Rapid Tooling, Rapid Manufacturing"**, Hanser Publisher, 2011.
3. Khanna Editorial, **"3D Printing and Design"**, Khanna Publishing House, Delhi.
4. CK Chua, Kah Fai Leong, **"3D Printing and Rapid Prototyping- Principles and Applications"**, World Scientific, 2017.
5. L. Lu, J. Fuh and Y.S. Wong, **"Laser-Induced Materials and Processes for Rapid Prototyping"**, Kulwer Academic Press, 2001.

6. Patri K. V enuvinod and Wei yin Ma, **"RAPID PROTOTYPING Laser-based and Other Technologies"** Springer Science+Business Media, LLC, 2004.
7. Pham D T and Dimov S S, "**Rapid Manufacturing**", The Technologies and Applications of Rapid Prototyping and Rapid Tooling, Springer 2001.
8. https://nptel.ac.in/courses/112/104/112104265/ -- Rapid Manufacturing.

Course Contents and Lecture Schedule

S.No.	Topic	No. of Lectures
1	**3D Printing (Additive Manufacturing):**	
1.1	Introduction - Prototyping fundamentals - processes chain -	2
1.2	Historical development - Need for time compression in product development	1
1.3	Classification of AMT process - Advantages of AM	1
2.0	**CAD (Computer Aided Design) for 3D Printing:**	
2.1	CAD model preparation - Data Interfacing	1
2.2	CAD Data formats - STL File Format, Binary/ASCII – Creating STL Files from a CAD System - Problems with STL Files - STL File Manipulation	2
2.3	Part orientation and support generation	2
3.0	**3D Printing Techniques**:	
3.1.	Photopolymerization: Stereolithography (SL) – Principles – Materials - Process details	2
3.1.1	Process parameter - Process Selection for various applications.	1
3.2	Powder Bed Fusion: Selective laser Sintering (SLS) – Principles – Materials - Process details -	2
3.2.1	Process parameter - Process Selection for various applications	1
3.3	Extrusion-Based RP Systems: Fused Deposition Modelling (FDM) – Principles – Process details -	2
3.3.1	Process parameter, Process Selection for various applications,	1
3.3.2	Practical demonstration on FDM – Fabrication of one prototype using FDM.	2
3.4	Sheet Lamination: Laminated object Manufacturing (LOM) - Principles – Materials - Process details -	2
3.4.1	Process parameter - Process Selection for various applications.	1
3.5.	Beam Deposition: Direct Metal Deposition (DMD) – Process details -	2
3.5.1	Process parameter - Process Selection for various applications	1
4.0	**Post processing of AM parts:**	
4.1	Support material removal - surface texture improvement	1
4.2	accuracy improvement	2
4.3	aesthetic improvement	1
4.4	property enhancements using non-thermal techniques.	1
4.5	property enhancements using thermal techniques.	1
5.0	**Applications:**	
5.1	Aerospace - Health Care - Defence	1
5.2	Automotive – Construction - Food Processing – Electronics .	1
5.3	Demonstration to Create 3D model using Additive manufacturing Method	2
	Total	**36**

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