# SENSOR & ACTUATOR PRINCIPLES

# Sensing & actuation principles

- Piezo electric effect
- Converse of piezo electric effect
- Magneto striction effect
- Villary effect-Converse  of Magneto striction effect
- Wiedemann effect
- Joule effect
- Matteuci effect-Converse  of Wiedemann effect-Magneto inductive effect
- Nagoka-Honda effect-Magneto volume effect
- Shape memory effect

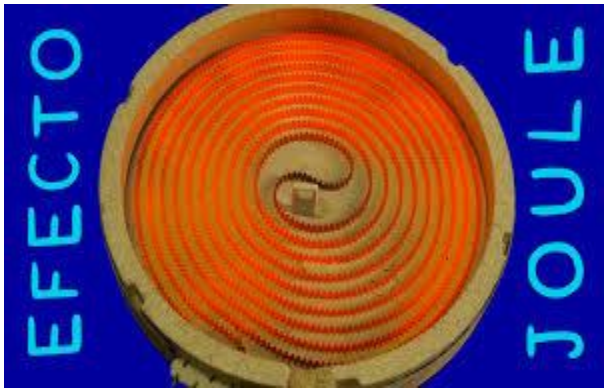
# Magnetostrictive Effects for Actuation

## Direct Effects

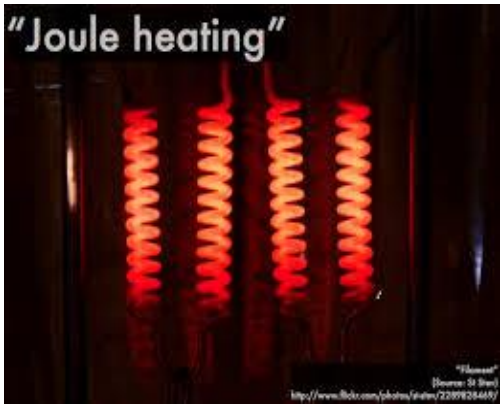
- **Joule Effect: Magnetostriction: Change in Sample Dimension in the magnetic field**
- **Wiedemann effect: Torque induced by helical magnetic field**
- **Magnetovolume effect: Volume change due to magnetostriction**

# Indirect Effects for Sensing

- **Villari Effect: Change in Magnetisation due to Applied Stress**
- **Matteuci Effect: Helical anisotropy and EMF induced by a Torque**
- **Nagoka-Honda Effect: Change in the magnetic state due to change in the volume**




# Joule Effect




**Joule effect and Joule's law are physical effects discovered or characterized by English physicist James Prescott Joule.**

## Joule effects include:

- ✓ **Joule's first law** (Joule heating), a physical law expressing the relationship between the heat generated and current flowing through a conductor.
- ✓ **Joule's second law** which states that the internal energy of an ideal gas is independent of its volume and pressure and depends only on its temperature.
- ✓ **Magnetostriction**, a property of ferromagnetic materials that causes them to change their shape when subjected to a magnetic field.
- ✓ **The Joule–Thomson effect** (during Joule expansion), the temperature change of a gas (usually cooling) when it is allowed to expand freely.
- ✓ **The Gough–Joule effect or the Gow–Joule effect**, which is the tendency of elastomers (polymers with elastic property-rubber) to contract if heated while they are under tension.

# Joule Effect…

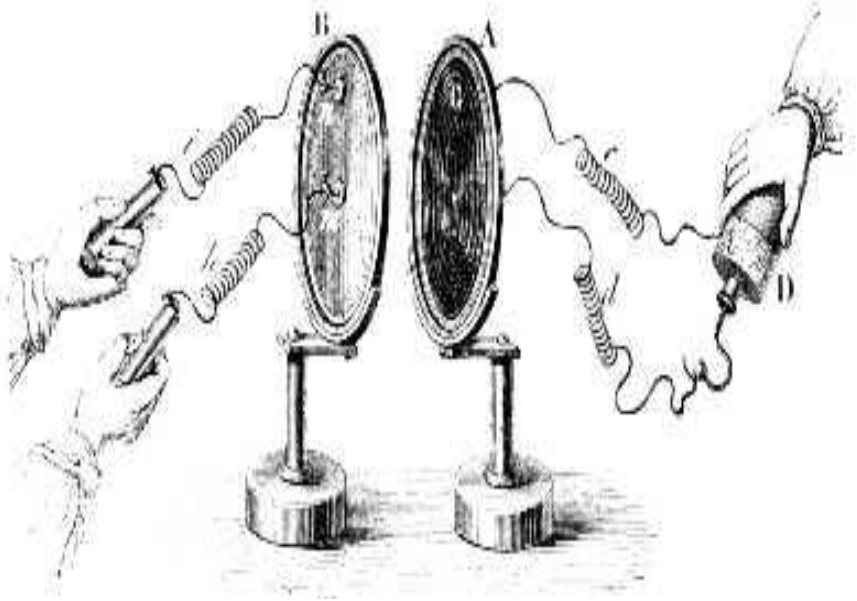
- "A stretched piece of rubber contracts when heated. In doing so, it exerts a measurable increase in its pull. This surprising property of rubber was first observed by James Prescott Joule about a hundred years ago and is known as the Joule effect.“ - Popular Science magazine, Jan1972
- The Joule effect is a phenomenon of practical importance that must be considered by machine designers.
- The simplest way of demonstrating this effect is to suspend a weight on a rubber band sufficient to elongate it at least 50%. When the stretched rubber band is warmed up by an infrared lamp, it does not elongate because of thermal expansion, as may be expected, but it retracts and lifts the weight. -Rubber as an Engineering Material ,by Khairi Nagdi

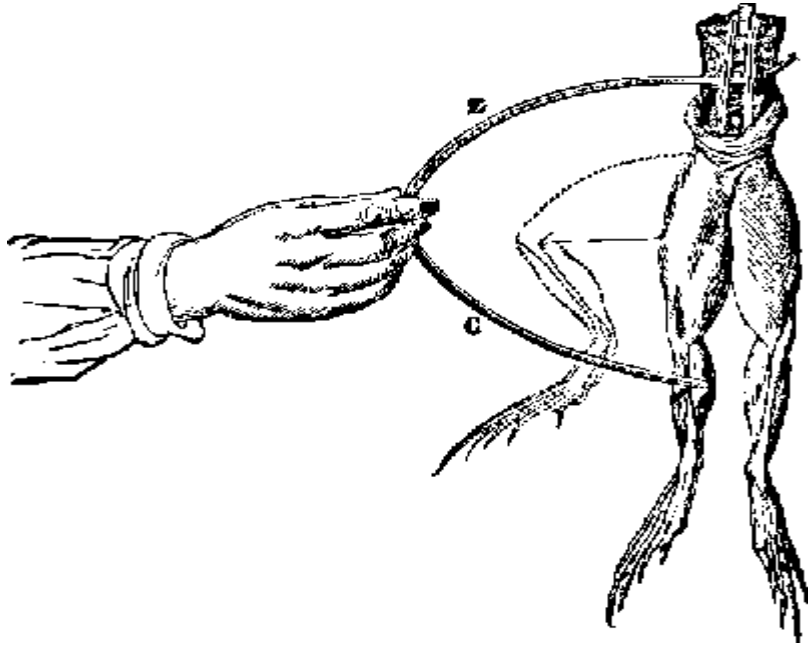
# Matteuci effect

- Matteucci effect is one of the magneto mechanical effects
- It is thermodynamically inverse to Wiedemann effect.
- It is observable in amorphous wires with helical domain structure, which can be obtained by twisting the wire, or annealing under twist.
- The effect is most distinct in the so called 'dwarven alloys' (called so because of the historical cobalt element etymology), with cobalt as main substituent.
- This effect is useful when amorphous materials are used in sensor applications. Amorphous materials in the form of ribbon(1973),wire(1981)and powder(1983) are used in sensors.
- The good combination of magnetic properties- magnetostriction & mechanical strength are utilised.
- A micro-fluxgate sensor was designed based on Matteucci effect of amorphous magnetic fibers.

# Matteucci's Apparatus

- In his experiments in 1830 with electromagnetic induction, Michael Faraday discovered that a change in the magnetic flux produced by one coil produced an EMF in a parallel coil. In his experiments the two coils were close together and linked by a length of iron.
- The Italian experimenter, Carlo Matteucci (1811-1868), in experiments in the mid-eighteen forties, showed that the effect worked over larger distances without the presence of iron.
- He devised a pair of identical flat coils, with wire wound in a spiral pattern on the surface of glass disks about 30 cm in diameter. A Leiden jar was discharged through one of the coils, and an experimenter holding on to wires connected to the other coil felt a shock. The magnitude of the shock increased when the distance between the two coils decreased.
- Matteucci is also known for his work with the electrical conductivity of the earth in 1844. By demonstrating that the earth has an appreciable conductivity, he showed that it was possible to use the earth as a return conductor for telegraph signals, thus making it possible to use one metallic conductor instead of two.


B
A
D


E
C

# Nagoka Honda effect

- Change in the magnetic state due to a change in the volume.
- This change in the volume is observed near the Curie temperature
- Force measurement applications based on magneto volume effect are still under research.
- Study of circumferential magnetic properties of amorphous magnetic wires showed a sensitive magneto-inductive effect.
- The inductance of a zero-magnetistrictive wire of 5mm length changes upto 75% for an external field of 0.8KA/m (10 Oerstead).
- This magneto-inductive effect is applicable to small magnetic heads and cordless data tablet.