MECHANICAL MEASUREMENTS & INSTRUMENTATION (R17A0328)

4TH YEAR B. TECH I- SEMESTER

LIVE TO LEARN & LEARN TO SHARE

MRCET CAMPUS

UGC Autonomous

DEPARTMENT OF MECHANICAL ENGINEERING

COURSE OBJECTIVES

UNIT - 1	**CO1:** To study concept of architecture of the measurments
UNIT - 2	CO2: To deliver working principle of mechanical measurements system.
UNIT - 3	CO3: To impart knowledge of mathematical modeling of the control system under different time domain.
UNIT - 4	CO4: To analyze the stress and strain measurements and humidity measurements.
UNIT - 5	CO5: To understand the measurements of Force, Torque and power and Elements of Control Systems.

UNIT 1

DEFINITION, MEASUREMENT OF DISPLACEMENT

CO1: To study concept of architecture of the measurments

DEPARTMENT OF MECHANICAL ENGINEERING

UNIT – I (SYLLABUS)

Definition

- Basic Principles of Measurements
- Generalized Configuration and Functional descriptions of instruments
- Performance Characteristics
- Classification and Elimination of errors

Measurement of Displacement:

- Construction of Various Transducers
- Piezo electric, Inductive, Capacitance, resistance, ionization and photo electric Transducers
- Calibration Procedures

COURSE OUTLINE UNIT -1

LECTURE	LECTURE TOPIC	KEY ELEMENTS	Learning objectives (2 to 3 objectives)
1	**Definition- Basic Principles of Measurments**	Definition of measurement.	Understanding of basics of measurement and instrumentation
2	Generalized Configuration and Functional Descriptions	Measurement system, Performance Characteristics	• Understand the general measurement system • Learn different Characteristics affecting measurement
3	Classification & elimination of errors	Errors obtained during measurement	Learn to identify and eliminate various errors
4	Definition & Classification of Transducer	Transducer Types	Learn about Transducer and it applicattions
5	Transducers for Measuring Displacement	Piezoelectric & inductive	Learn & understand the principle of the Transducers for measuring displacement
6		Photo Electric & capacitive	
7		Resistance	

LECTURE 1

DEFINITION- BASIC PRINCIPLES OF MEASURMENTS

DEPARTMENT OF MECHANICAL ENGINEERING

TOPICS TO BE COVERED

- Definition of measurement
- Instrumentation
- Methods of Measurement
- Objectives of Measurments
- Applications

LECTURE 1

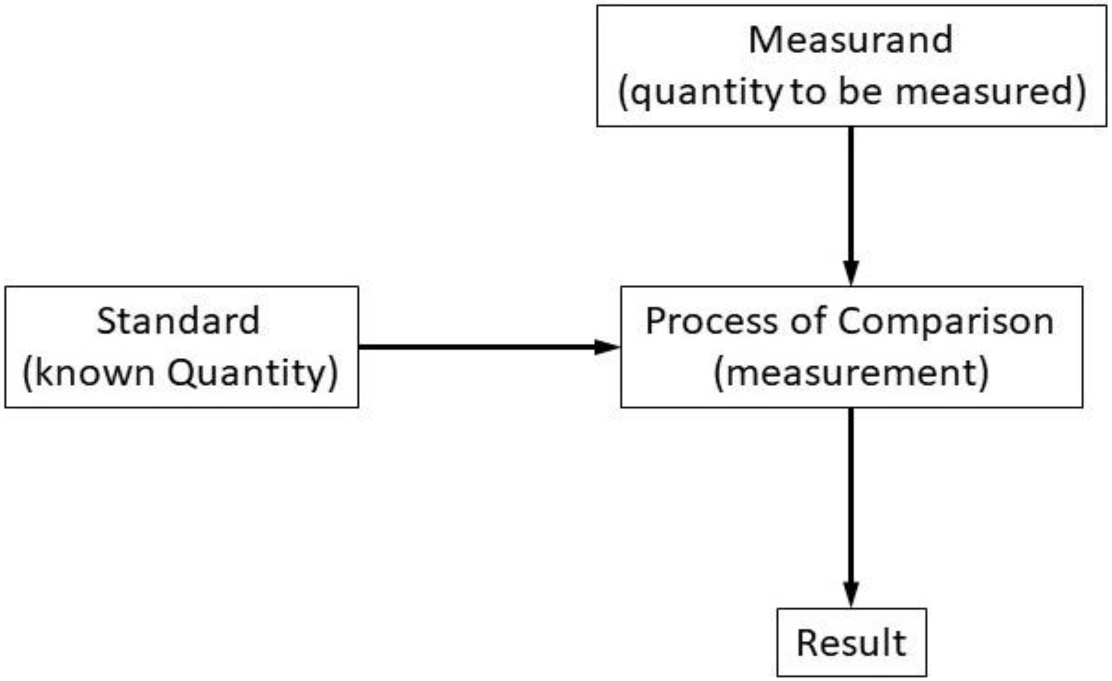
Definition- Basic Principles of Measurments

MEASUREMENT

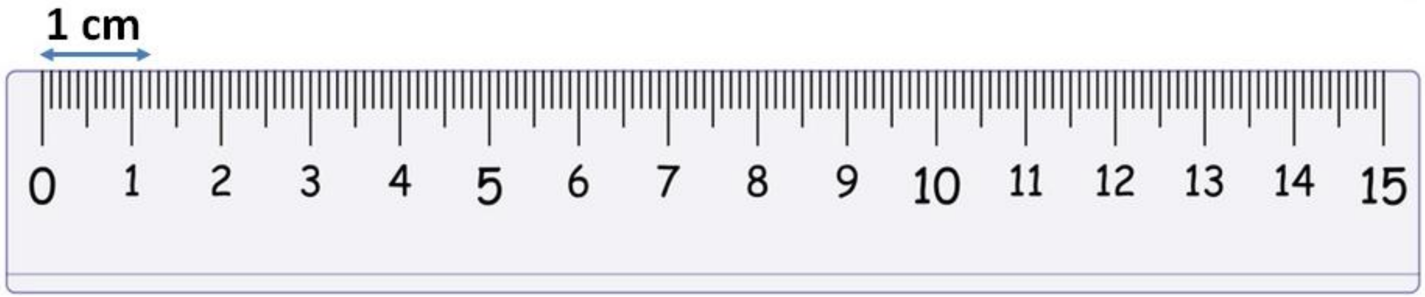
- The word measurement is used to tell us the length, the weight, the temperature, the colour or a change in one of these physical entities of a material.

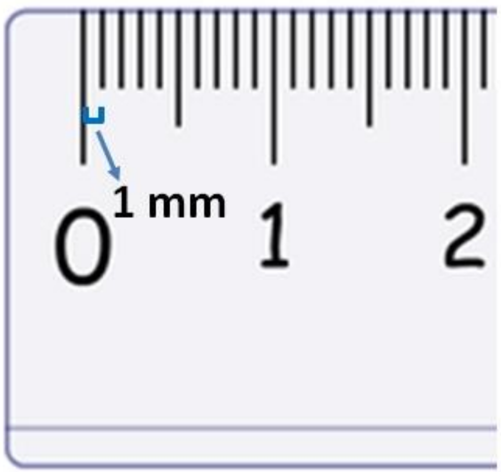
Or

- Measurement provides us with means for describing the various physical and chemical parameters of materials in quantitative terms.



EXAMPLE





So,

millimeter

Centimeter

$$10 \text{ mm} = 1 \text{ cm}$$

$$1 \text{ mm} = \frac{1}{10} \text{ cm}$$

For example, 10 mm length of and object implies that the object is 10 times as large as 1 mm; the unit employed in expressing length

Two requirements which are to be satisfied to get good result from the measurement.

- The standard must be accurately known and internationally accepted.
- The apparatus and experimental procedure adopted for comparison must be provable.

INSTRUMENTATION

- The human senses cannot provide exact quantitative information about the knowledge of events occurring in our environments.

- The firm requirements of precise and accurate measurements in the technological fields have, led to the development of mechanical aids called instruments.

METHODS OF MEASUREMENT

- Direct and indirect measurement
- Primary and secondary & tertiary measurement.
- Contact and non-contact type of measurement

❖ Direct Measurement

The value of the physical parameter is determined by comparing it directly with different standards

Eg: Mass, length and time

❖ Indirect Measurement

The value of the physical parameter is more generally determined by indirect comparison with the secondary standards through calibration.

Eg: The measurement is converting into an analogous signal which subsequently process and fed to the end device at present the result of measurement.

❖ Primary And Secondary & Tertiary Measurement.

Based upon the complexity of the measurement systems, the measurement is generally grouped into three categories.

- Primary
- Secondary
- Tertiary.

❖ Primary measurement.

The sought value of physical parameter is determined by comparing it directly with reference standards the required information is obtained to sense of side and touch.

Example

a) Matching of two lengths is determining the length of a object with ruler.

b) Estimation the temperature difference between the components of the container by inserting fingers.

c) Measurement of time by counting a number of strokes of a block.

❖ Secondary & Tertiary Measurement.

The indirect measurements involving one transmission are called secondary measurements

The indirect measurements involving two convergent are called tertiary measurements

Examples:

a) The convergent of pressure into displacement by means of be allows and the convergent of force into displacement.

b) Pressure measurement by manometer and the temperature measurement by mercury in glass tube thermometer.

c) The measurement of static pressure by boundary tube pressure gauge is a typical example of tertiary measurement.

❖ Contact And Non-contact Type Of Measurements.

Contact type:

Where the sensing element of measuring device as a contact with medium whose characteristics are being measured.

Non-contact type:

Where the sense doesn't communicate physically with the medium.

Example:

The optical, radioactive and some of the electrical/electronic measurement belong to this category.

OBJECTIVES OF INSTRUMENTATION

1. The major objective of instrumentation is to measure and control the field parameters to increase safety and efficiency of the process.
2. To achieve good quality.
3. To achieve auto machine and automatic control of process there by reducing human.
4. To maintain the operation of the plan within the design exportations and to achieve good quantity product.

LECTURE 2

GENERALISED CONFIGURATION AND ITS FUNCTIONAL DESCRIPTIONS

LIVE TO LEARN & LEARN TO SHARE

MRCET CAMPUS

UGC Autonomous

DEPARTMENT OF MECHANICAL ENGINEERING

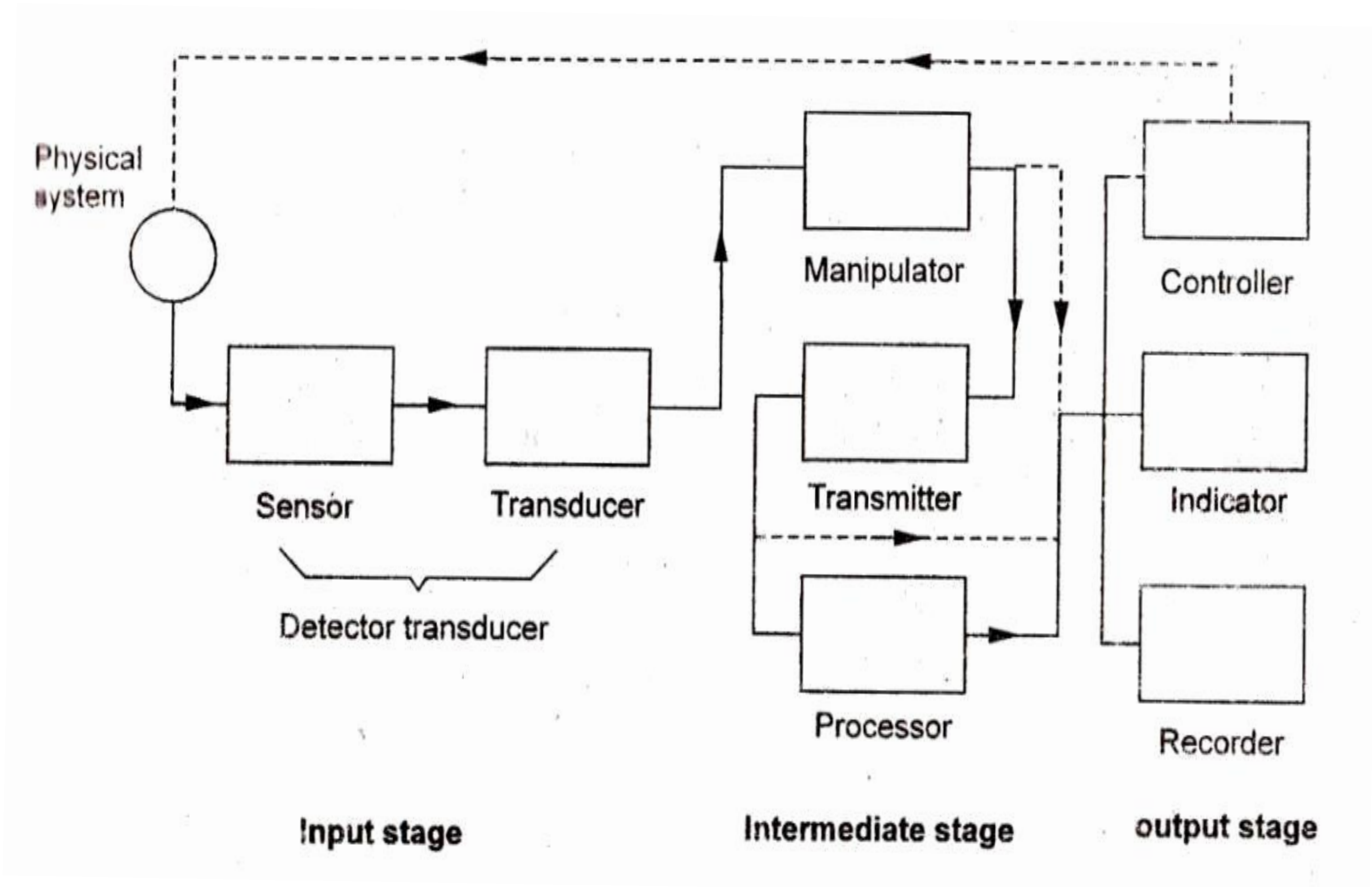
TOPICS TO BE COVERED

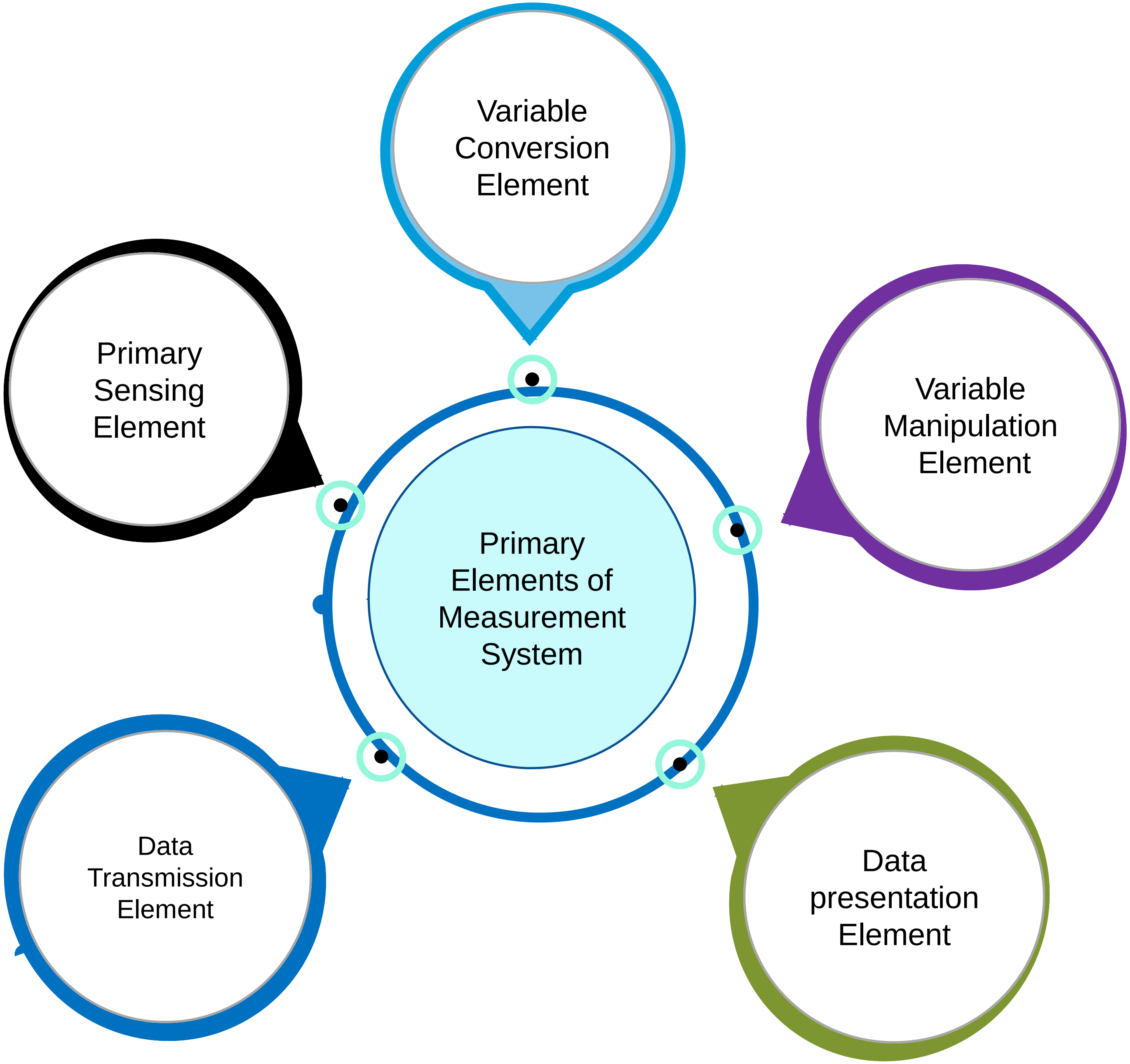
- Generalized Configuration and Functional Descriptions of Measuring Instruments
- Primary Elements of Measurement System
- Performance Characteristics
  - Static
  - Dynamic
- Applications

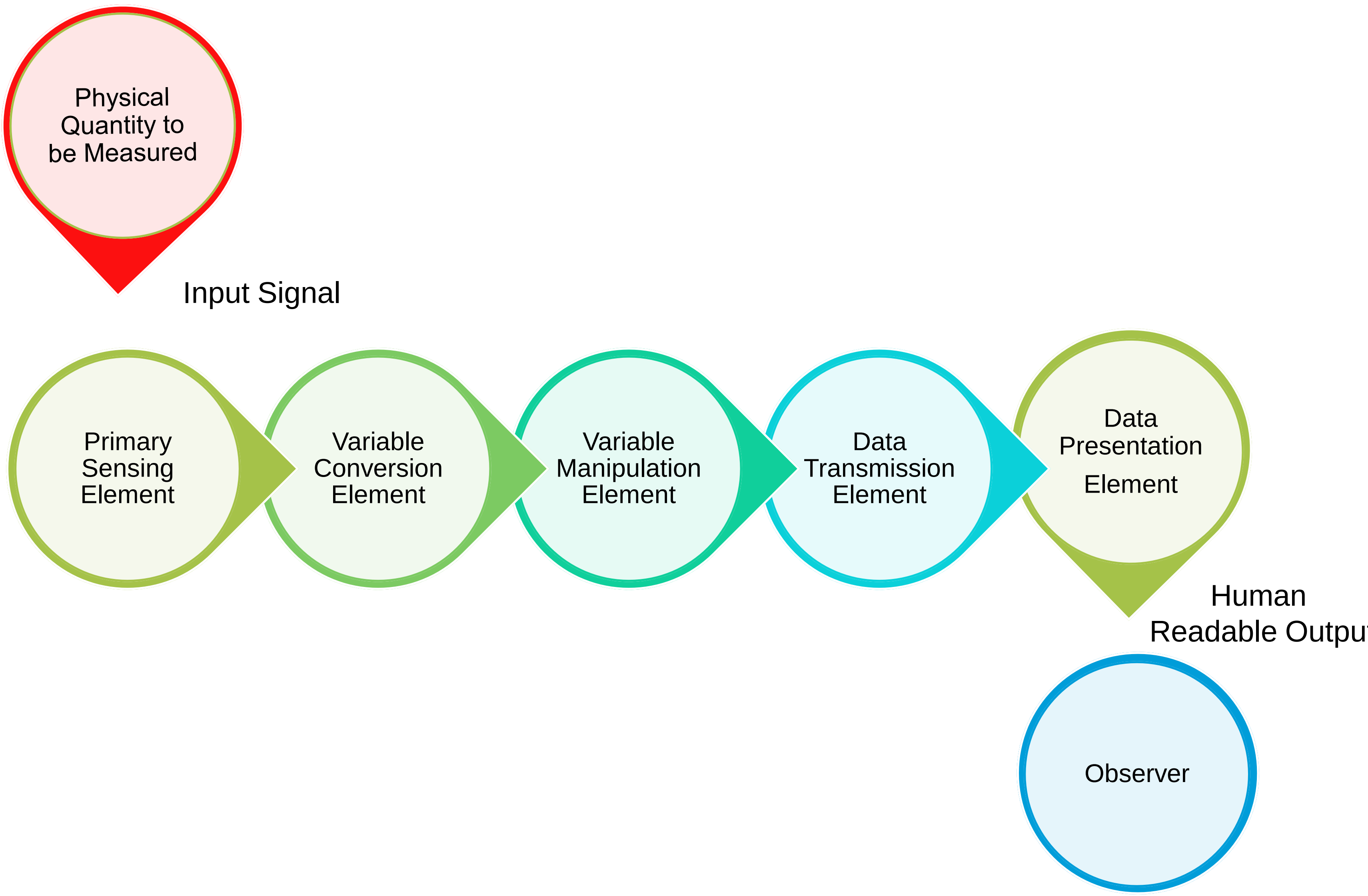
LECTURE 1

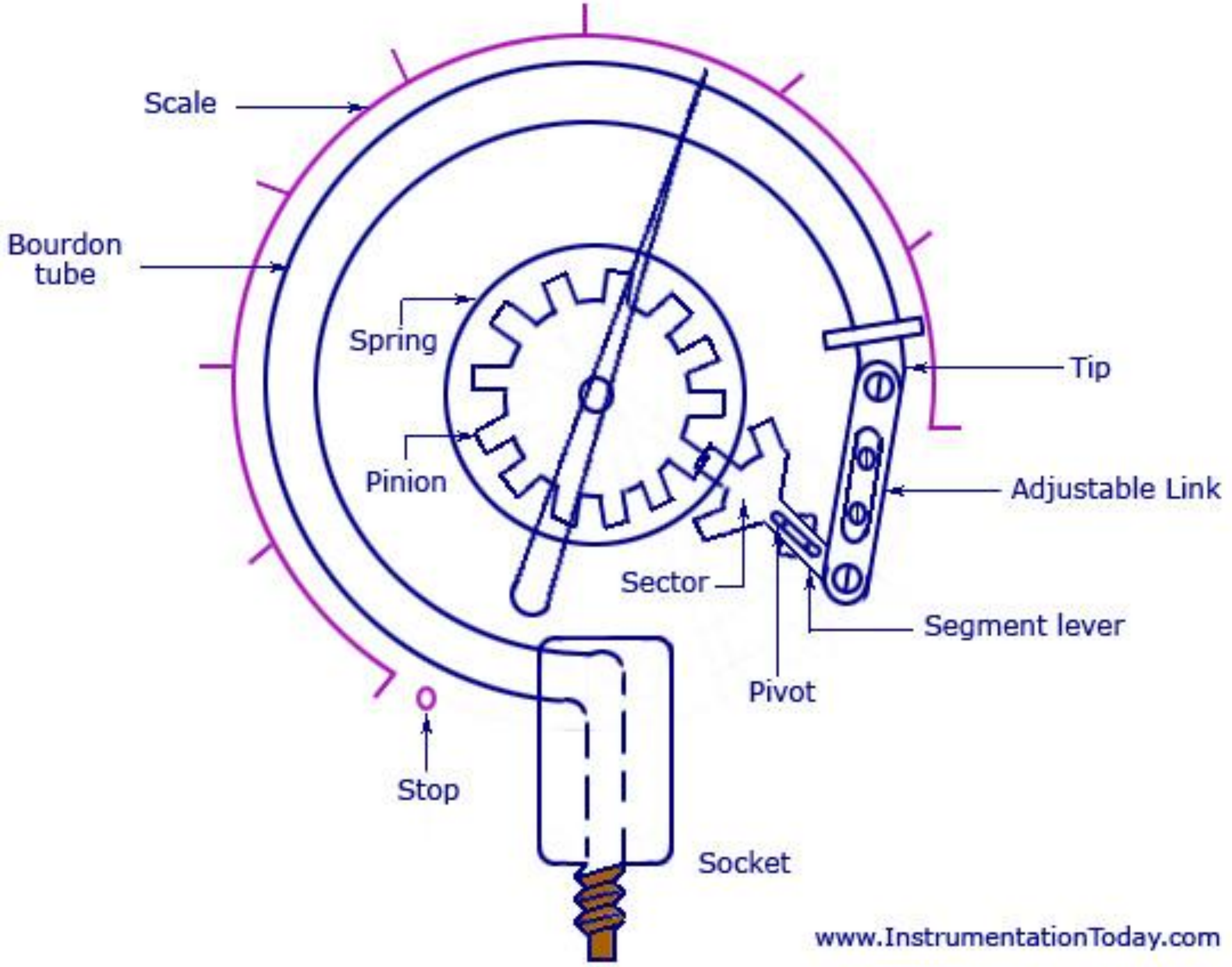
Generalized Configuration and Functional Descriptions

GENERALIZED MEASUREMENT SYSTEM AND ITS FUNCTIONAL ELEMENTS




Variable Conversion Element
Primary Sensing Element
Variable Manipulation Element
Primary Elements of Measurement System
Data Transmission Element
Data presentation Element


Physical Quantity to be Measured
Input Signal
Primary Sensing Element
Variable Conversion Element
Variable Manipulation Element
Data Transmission Element
Data Presentation Element
Human Readable Output
Observer



Bourdon Tube Pressure Gauge

- **Performance characteristics of a measuring instrument**

The performance characteristics of an instrument system is conclusion by low accurately the system measures the requires input and how absolutely it reject the undesirable inputs.

Error = Measured Value ( ) – True Value ( )

Correction = (-).

❖ Static characteristics

1. Range and span,
2. Accuracy, error, correction,
3. Calibration,
4. Repeatability,
5. Reproducibility
6. Precision,
7. Sensitivity,
8. Threshold,
9. Resolution,
10. Drift,
11. Hysteresis, dead zone.

❖ Dynamic characteristics

1. Speed of response and measuring lag,
2. Fidelity and dynamic error,
3. Over shoot,
4. Dead time and dead zone,
5. Frequency response.

LECTURE 3

CLASSIFICATION AND ELIMINATION OF ERRORS

DEPARTMENT OF MECHANICAL ENGINEERING

TOPICS TO BE COVERED

- Classification of Errors
- Elimination of Errors
- Types of Instruments

LECTURE 3

Classification and elimination of Errors

CLASSIFICATION OF ERRORS AND ELIMINATION OF ERRORS:

- No measurement can be made with perfect accuracy
- It is important to find out the accuracy rate and errors occurred
- A study of errors is a first step in finding ways to reduce them.

Errors are Classified into:

1. Gross errors
2. Systematic (or) instrumental errors
3. Random (or) Accidental errors

❖ Gross Errors

Human mistakes in reading instruments and recording and calculating measurement result.

Ex: The temperature is 31.5^0C, but it will write as 21.5^0c

This can be avoided by adopting two means

1. Great care should be taken in reading and recording the data.
2. Two, three (or) even more readings should be taken for quantity under measurement

❖ Systematic Errors

These type of errors are divided into three categories.

a. Instrumental errors

   – Due to inherent short comings of the instrument

   – Due to misuse of instruments

b. Due to loading effects of instruments. Environmental errors

   – These errors are caused due to changes in the environmental conditions in the area surrounding the instrument

c. Observational

   – These errors are caused by the habits of individual observers, which is known as Parallax error

❖ Random Errors

The causes of such errors is unknown (or) not determinable in the ordinary process making measurements.

a. Certain human errors

b. Errors caused due to the disturbances to the equipment’s

c. Errors caused by fluctuating experimental conditions.

LECTURE 4

MEASUREMENT OF DISPLACEMENT

DEPARTMENT OF MECHANICAL ENGINEERING

TOPICS TO BE COVERED

- Definiton- Displacement, Transducer
- Classification of Transducers
  - Classification Based on Power Source
  - Classification based on type of Output
  - Classification based on the electrical principle involved
- Advantages and Limitations of Transducers
- Applications
- Assignment

LECTURE 4

Measurement of Displacement

MRCET CAMPUS
UGC Autonomous

MEASUREMENT OF DISPLACEMENT

Displacement

- A small change in position of an object from one point to another.

Measurement of Displacement

- Displacement can be measured by both mechanical and electrical methods,
- But only electrical methods which are common in industrial use will be described here.

Transducer

It is a small device that converts any physical quantity into measurable electrical signals and vice versa.

Functions of Transducers

- Detects or senses the present and changes in physical quantity being measured.
- Provided a proportional output signal..

❖ Classification of Transducer

Transducers are broadly classified into Three groups :

1. Classification Based on Power Source
   - Active transducers (self-generating type)
   - Passive transducers (Externally powered)

2. Classification based on type of Output
   - Analog Transducer
   - Digital Transducer

3. Classification based on the electrical principle involved

- Variable resistance type
- Variable inductance type
- Variable capacitance type
- Voltage generating type
- Voltage divider type

❖ Transducer for the Measurement of Displacement:

I. Variable resistance transducer

II. Variable inductance transducer

III. Variable capacitance transducer

IV. Piezo electric transducer

V. Photo electric or light detecting transducer

    I. Photo conductive
    II. Photo voltaic
    III. Photo emissive

VI. Ionization transducers.

❖ Advantages of electrical transducers over other transducers

- Mass and inertia effects are minimized
- Amplification or attenuation is minimized
- Effect of friction is minimized
- They are compact in size
- Remote indication is possible
- Power consumption is less and loading errors are minimized.

❖ Limitations

- They need external power supply, and are of High cost
- Instrument electrical properties may change the actual reading of the variable which is to be measured.

LECTURE 5

TRANSDUCERS FOR MEASUREMENT OF DISPLACEMENT

MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

LIVE TO LEARN & LEARN TO SHARE

MRCET CAMPUS

UGC Autonomous

DEPARTMENT OF MECHANICAL ENGINEERING

TOPICS TO BE COVERED

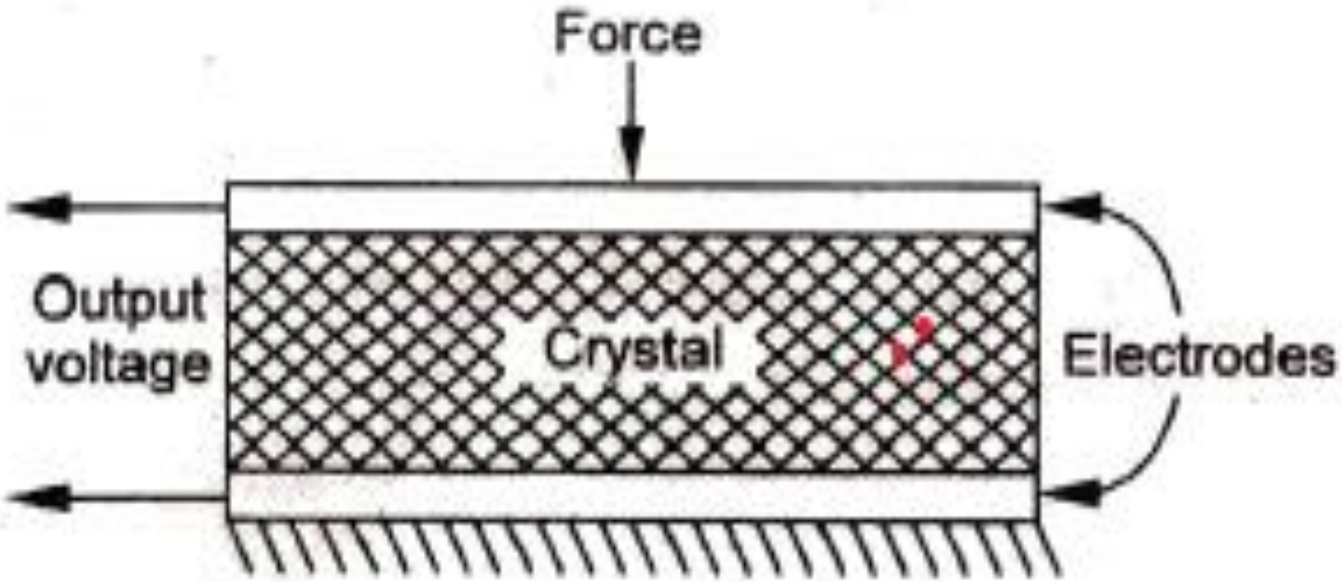
- Piezo Electric Transducer
- Inductive Transducers
  - Linear Variable Differential Transducer
  - Rotary Variable Differential Transducer
  - Synchros
  - Resolvers
- Applications
- Assignment

LECTURE 5

Transducers for Measurement of displacement

MRCET CAMPUS
UGC Autonomous

❖ Piezo Electric transducers



Q α F

Q = K F

Where,

Q is the Charge (in coulombs)

F = Impressed Force (in Newtons)

K = Crystal Sensitivity = C/N

The relationship between the force F and the change t in the crystal thickness t is given by the stress-strain relationship.

$$\text{Young's modulus} = \frac{\text{stress}}{\text{strain}} \quad ; \quad Y = \frac{F/A}{\delta t/t}$$

$$F = A\,Y\frac{\delta t}{t}$$

The charge at electrode gives rise to voltage, such that

$$V_0 = \frac{Q}{C}$$

where C is the capacitance between electrodes. Further more

$$C = \epsilon_0 \epsilon_r \frac{A}{t} \text{ farads}$$

Combining the above equations, we obtain :

$$V_0 = \frac{K}{\epsilon_0 \epsilon_r} t \frac{F}{A}$$

$$= g\,t\,P$$

where g is the crystal voltage sensitivity in Vm/N and P is the applied pressure in N/m^2.

Advantages of Piezoelectric transducers are:

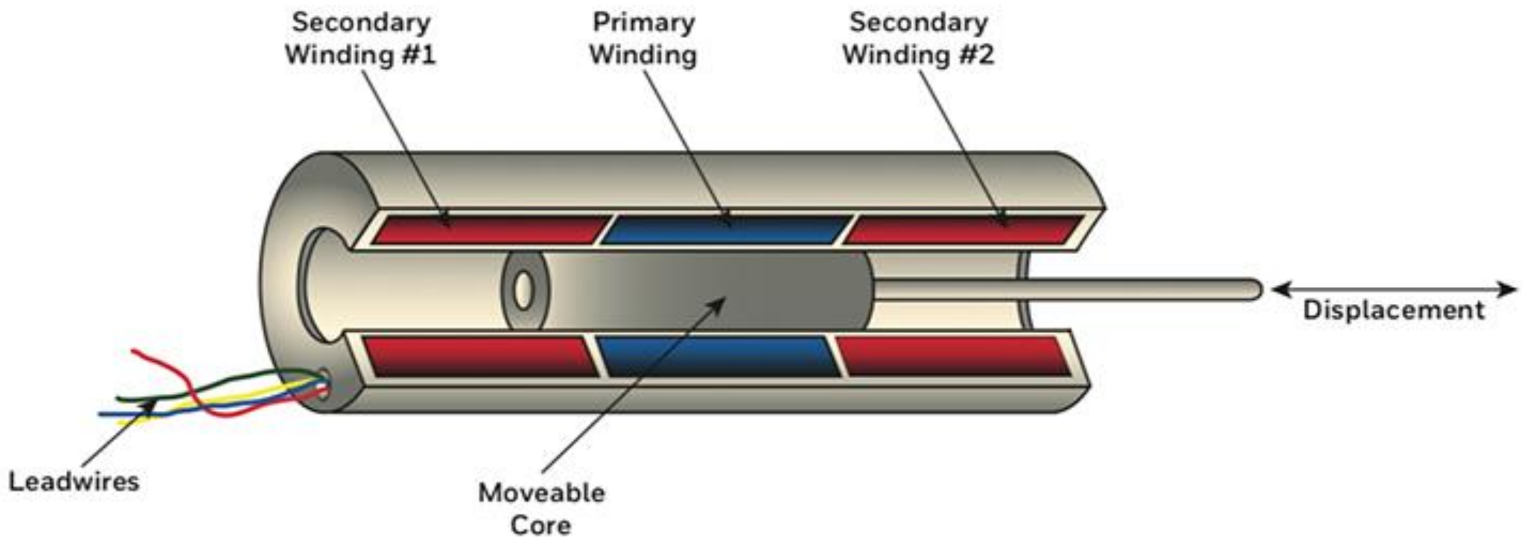
- High frequency response,
- High output,
- Rugged construction
- Negligible phase shift, and
- Small size.

Applications:

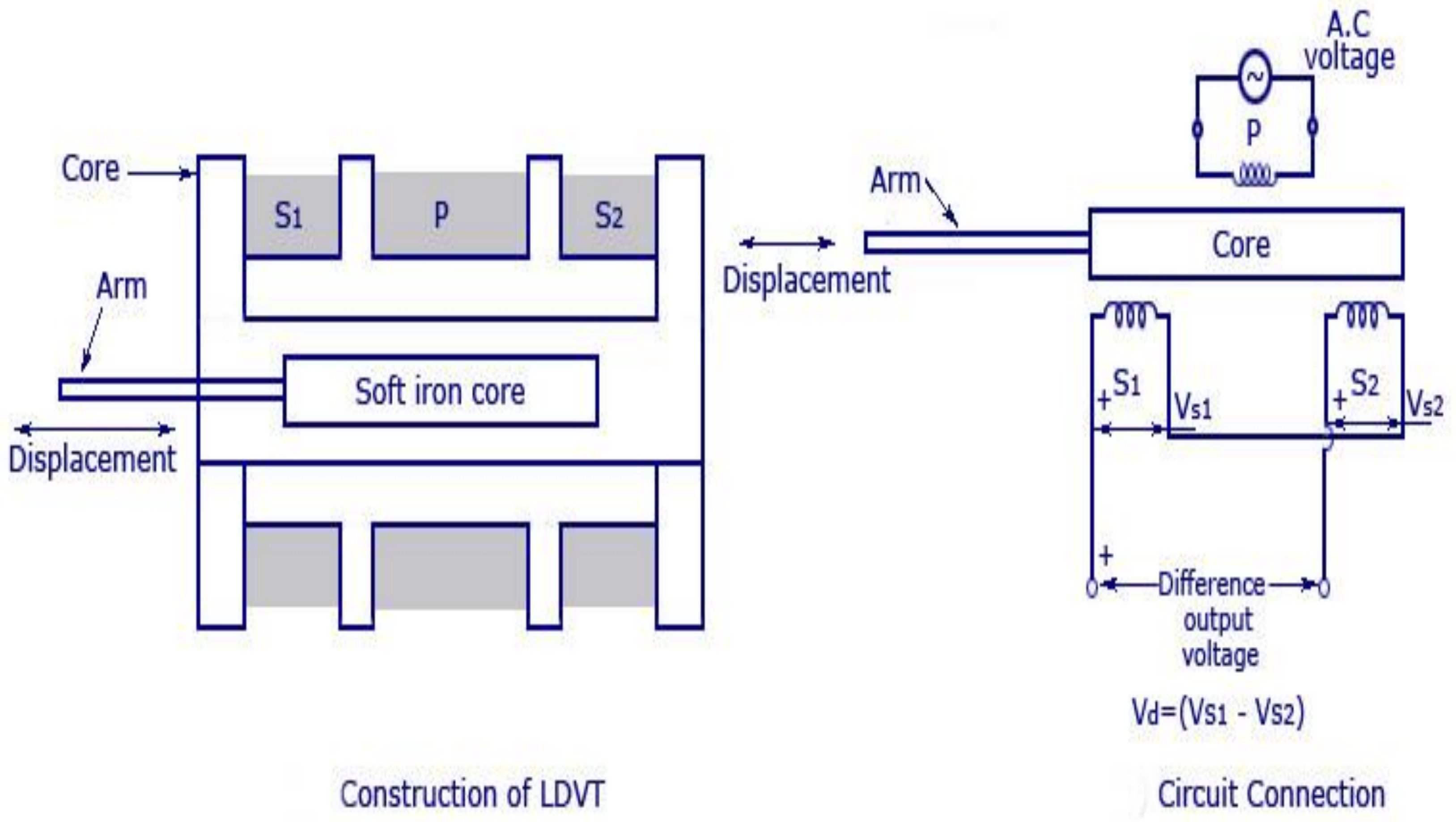
Piezo-electric transducers are most often used for accelerometers, pressure cells and force cells in that order.

❖ Variable Inductance transducers

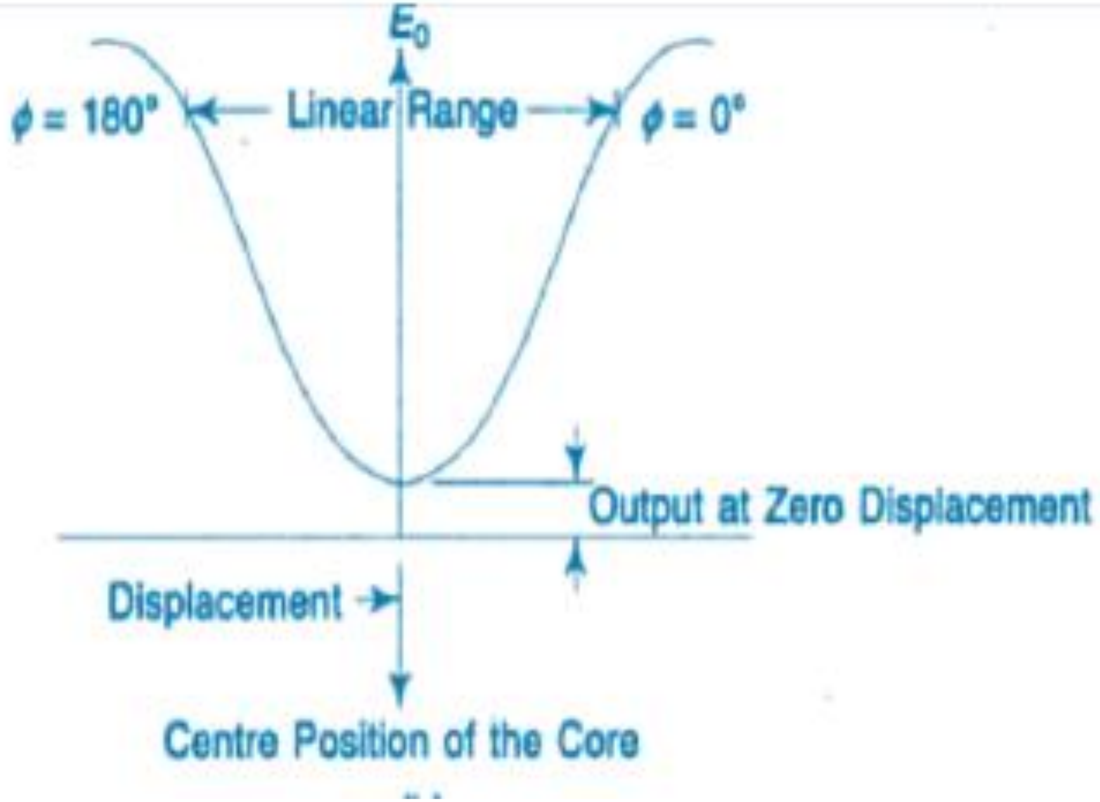
1. Linear Variable Differential Transducer (LVDT)



The linear variable-differential transformer (LVDT) is the most widely used inductive transducer to translate linear motion into electrical signal.



Construction and Circuit of a typical LVDT


E_0
ϕ = 180°
Linear Range
ϕ = 0°
Output at Zero Displacement
Displacement
Centre Position of the Core

Advantages

- The output voltage is practically linear for displacements upto 5 mm.
- Have infinite resolution.
- Can possess a high sensitivity.
- These usually tolerate a high degree of shock and vibration without any adverse effects.
- Simple, light in weight, and easy to align and maintain.

Applications:

- Sensitive to stray magnetic fields but shielding is possible
- Inherently low in power output.

2. Rotary Variable Differential Transducer (RVDT)

- It is used to convert rectangular displacement into electrical signal.
- It is same as that of LVDT except that is employs a cam shaped core.

3. Synchros

- The devices by which the angular position of shaft is converted into electrical signal. The synchros are electromagnetic transducers..

4. Resolvers

- Resolving is nothing but converting from one co-ordinate system to another coordinate system.
- These converts the shafts angular position into Cartesian coordinates i.e., converted into those signals which are proportional to the sine and cosine of the rotor position

LECTURE 6

TRANSDUCERS FOR MEASUREMENT OF DISPLACEMENT

DEPARTMENT OF MECHANICAL ENGINEERING

TOPICS TO BE COVERED

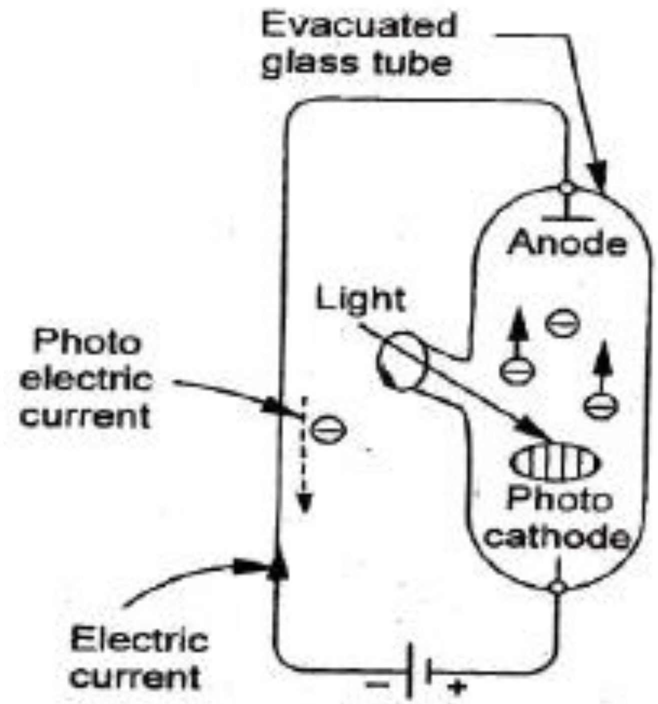
- Photo ElectricTransducer
  - Photo Emissive Cell
  - Photo Conductive Cell
  - Photo Voltaic Cell
- Capacitive Transducers
- Applications
- Assignment

LECTURE 6

Transducers for Measurement of displacement

MRCET CAMPUS
UGC Autonomous

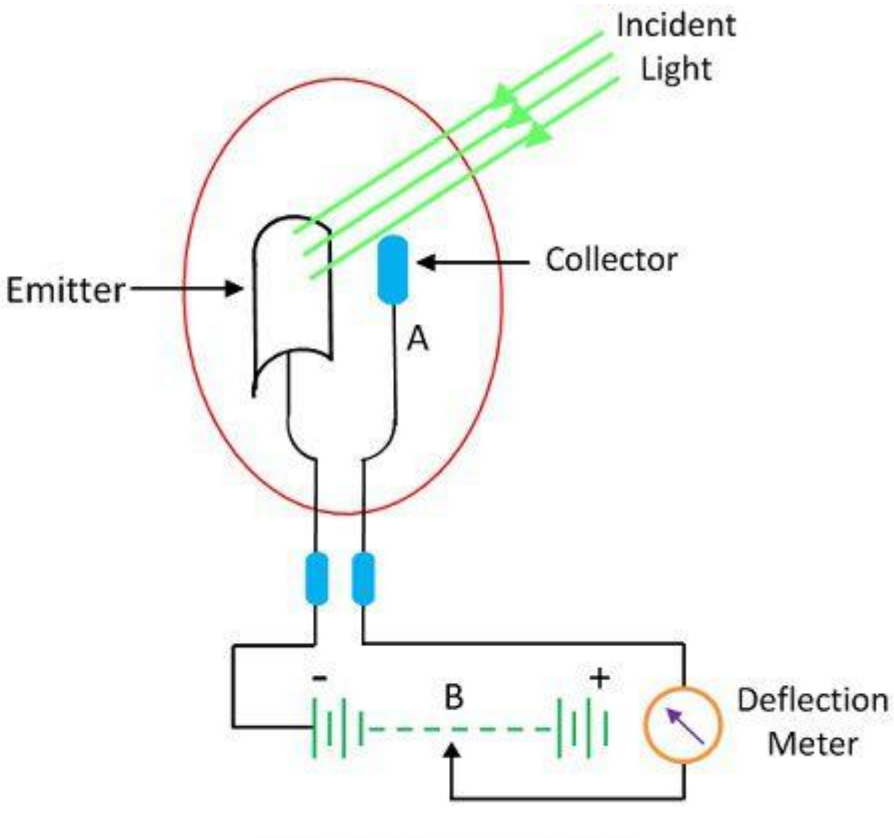
PHOTO ELECTRIC TRANSDUCERS



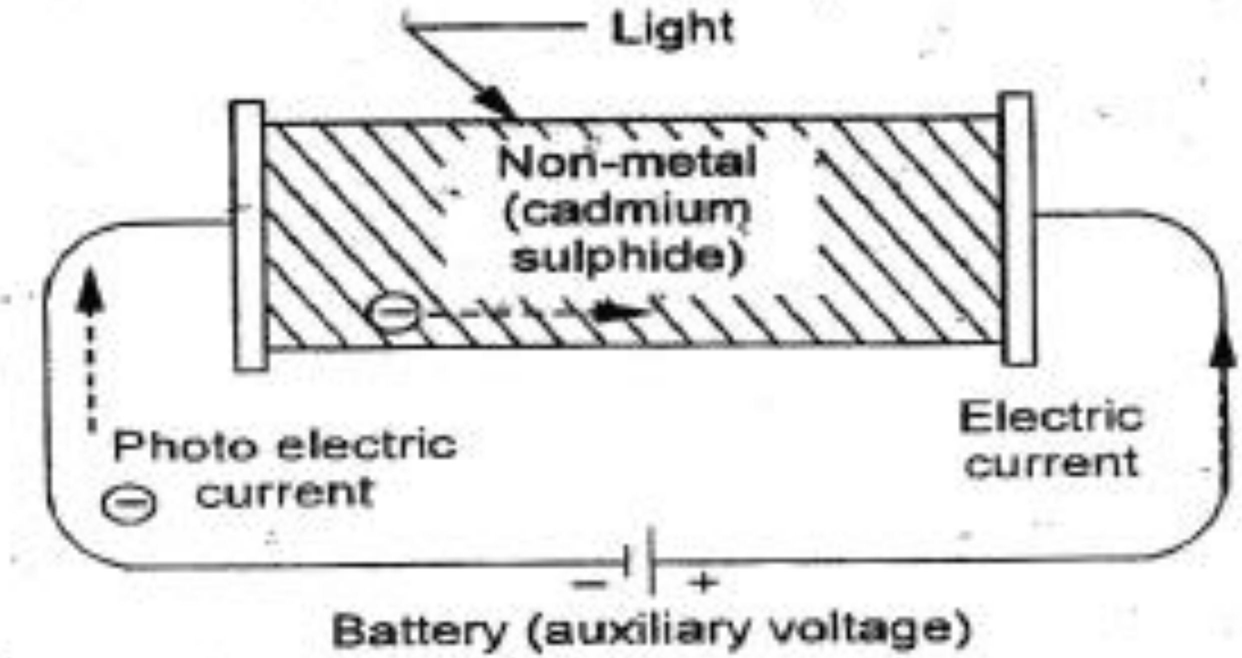
These transducers operate on the principle that when light strikes special combination of materials, a voltage may be generated, a resistance change may take place, or electrons may flow.

Based on the principle of rotation photo electric transducers are classified into the 3 types.

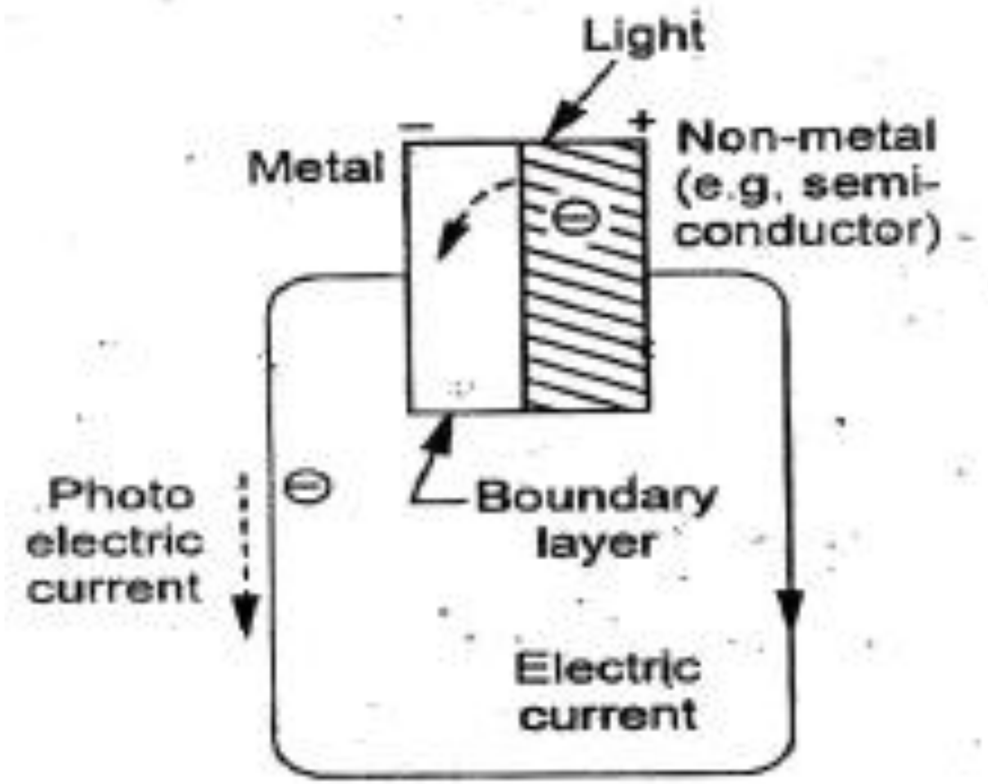
- Photo – Emissive Cell



- Photo – Conductive Cell



- Photo – Voltaic Cell



These transducers operate on the photo-valtaic effect, i.e., when light's trikes a junction of certain dissimilar metals, a potential difference is built up.

Applications:

- Used for a wide variety of purposes in control engineering for precision measuring devices, in exposure meters used in photography.
- They are also used in solar batteries as sources of electrical power for rockets and satellites used in space research.

CAPACITIVE TRANSDUCERS

It works on the principle of a capacitor which comprises of two or more dissimilar metal plate conductors separated by an insulator.

Capacitance is defined as the ratio of the charges to the applied voltage and for a parallel plate capacitor

$$C = \epsilon_o \epsilon_r \frac{A}{t}(N-1)\, farads$$

Where,

A = overlapping area b/w plates (m^2)

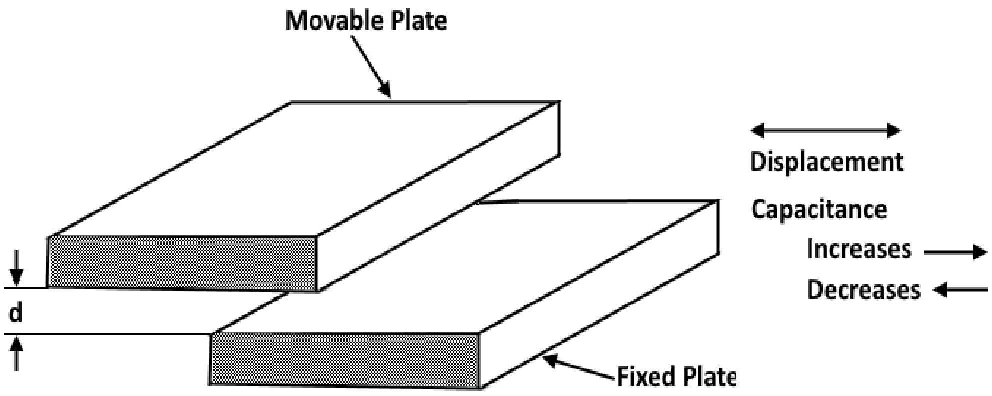
t = distance b/w plates (m)

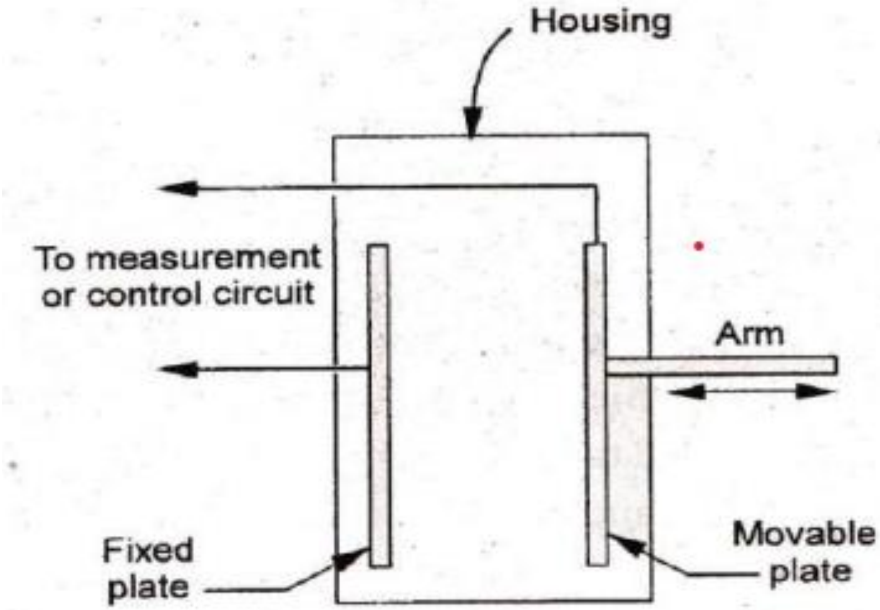
N = No. of plates

ϵ_o = permittivity of free space = 8.854 x 10^{-12} F/m

ϵ_r = = relative permittivity of the material b/w plates

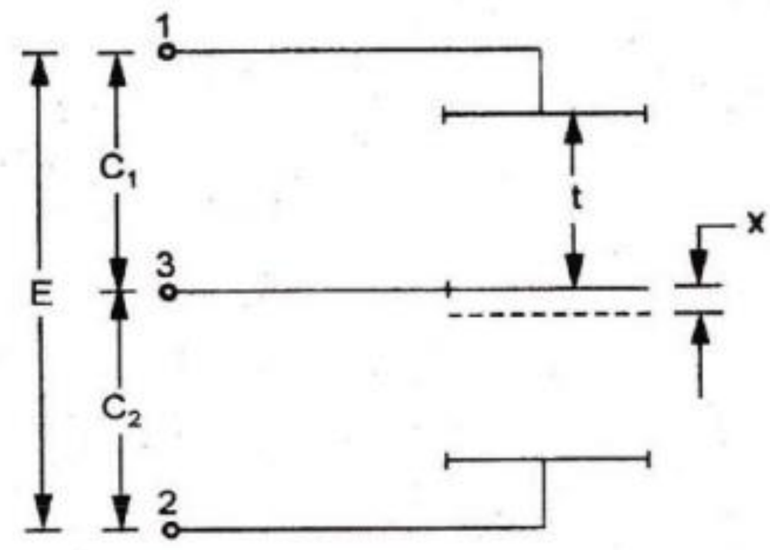
Differential Capacitor:





Let the normal position of the central plate be a line as shown, the capacitances C_1 & C_2 are then identical.

$$C_1 = C_2 = C = \epsilon_o \epsilon_r \frac{A}{t}$$



When the plate is displaced parallel through a distance x, then:

$$C_1 = \epsilon_o \epsilon_r \frac{A}{t+x} \qquad C_2 = \epsilon_o \epsilon_r \frac{A}{t-x}$$

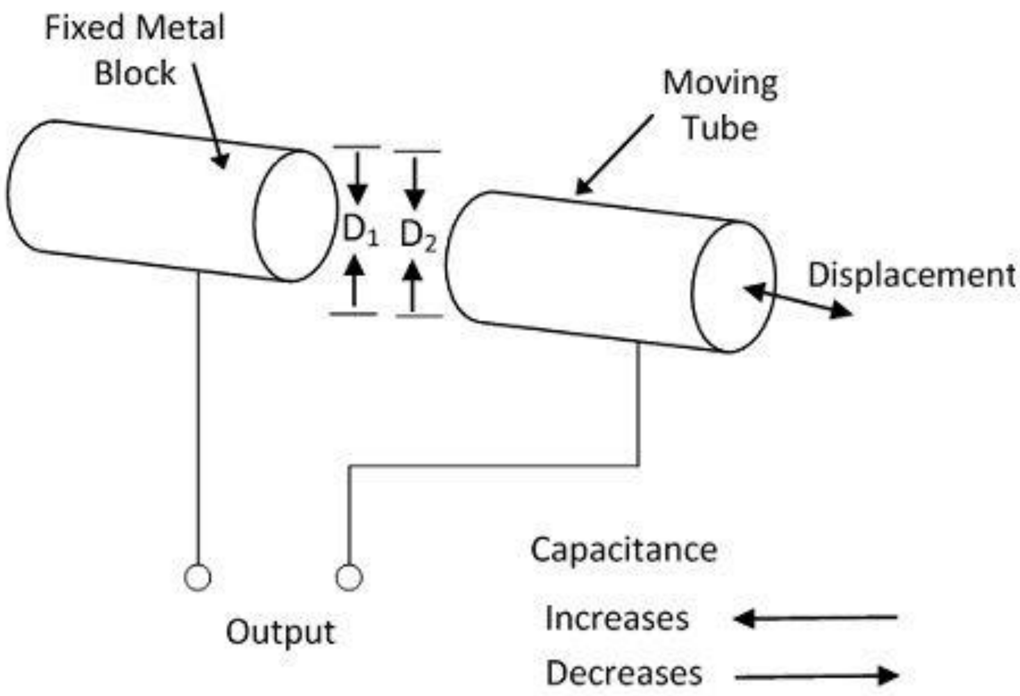
For an alternating Voltage E applied b/w 1 & 2 then C_1 & C_2 are :

$$E_1 = \frac{E\,C_2}{C_1 + C_2} = E\frac{t+x}{2t} \qquad E_2 = \frac{E\,C_1}{C_1 + C_2} = E\frac{t-x}{2t}$$

Therefore, the output from the terminal pairs 1, 3 & 2, 3 is fed into differential measurement

$$E_1 - E_2 = E\frac{x}{t}$$

Cylindrical Capacitor:



$$C = \epsilon_o \epsilon_r \frac{2\pi l}{\log_e(\frac{r_2}{r_1})} \; farads$$

Where,

l = length of overlapping part of cylinder (m)

r_1 = radius of inner cylinder conductor(m)

r_2 = radius of outer cylinder conductor(m)

ϵ_o = permittivity of free space = 8.854 x 10^{-12} F/m

ϵ_r = = relative permittivity of the material b/w plates

LECTURE 7

TRANSDUCERS FOR MEASUREMENT OF DISPLACEMENT

UGC Autonomous

DEPARTMENT OF MECHANICAL ENGINEERING

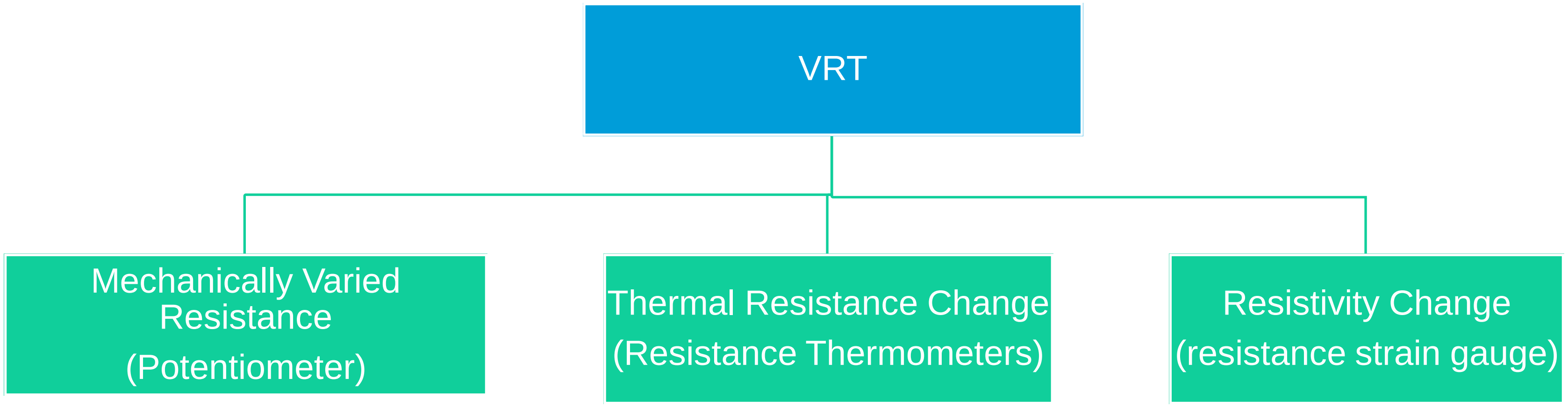
TOPICS TO BE COVERED

- Resistance Transducers
  - Linear motion Potentiometers
  - Angular motion Potentiometers
- Applications
- Assignment

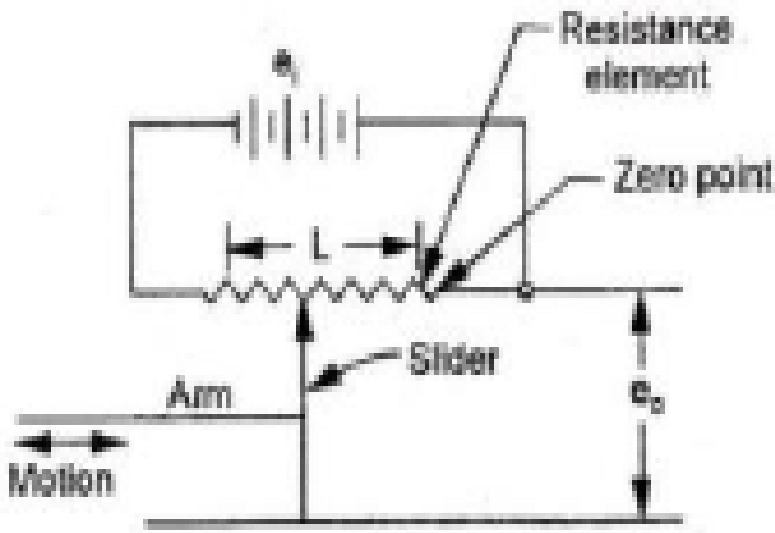
LECTURE 7

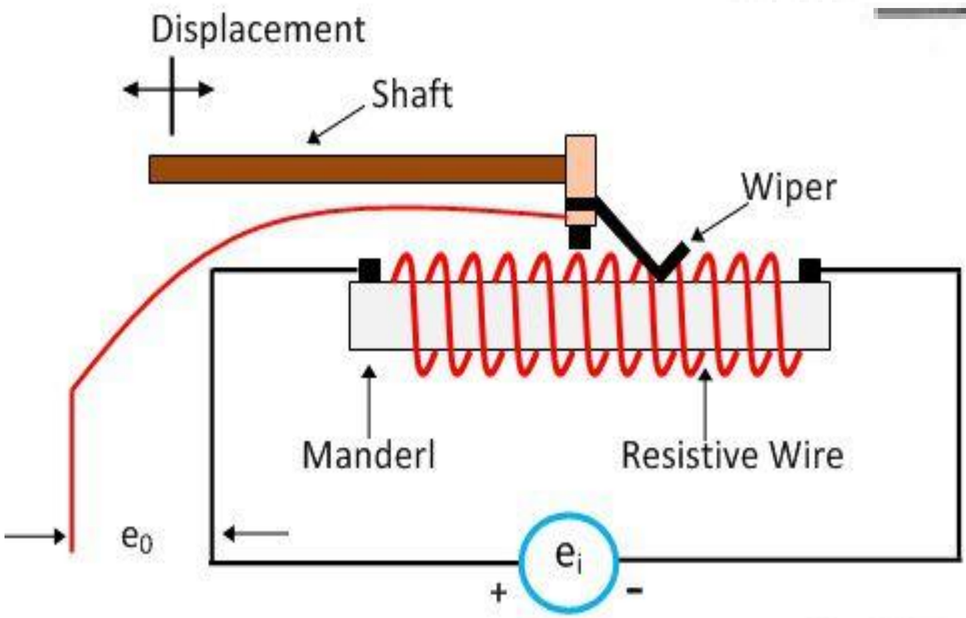
Transducers for Measurement of displacement

VARIABLE RESISTANCE TRANSDUCERS

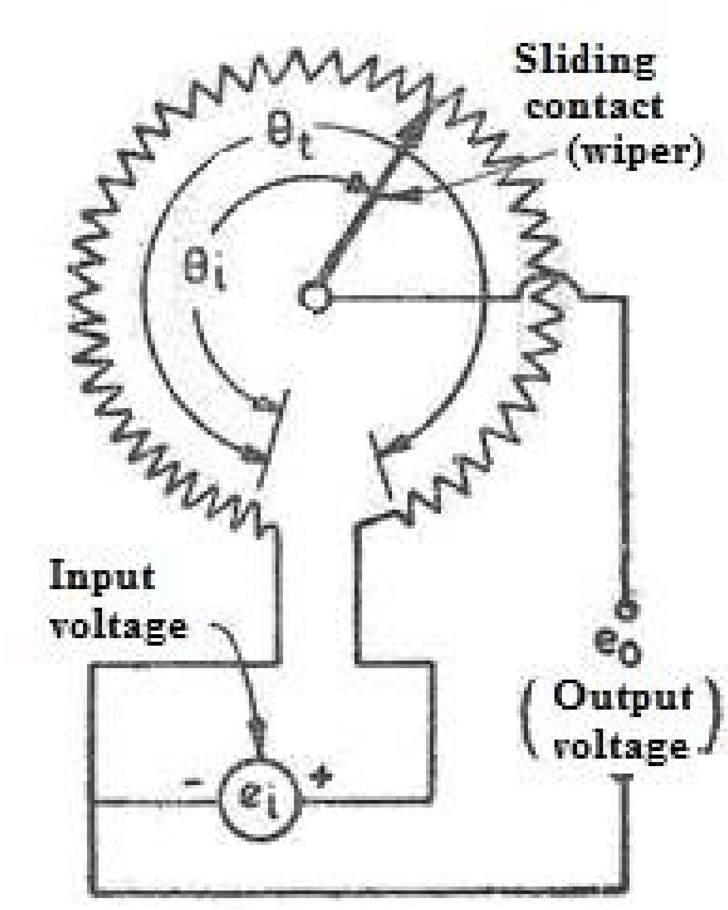


❖ Linear Motion Potentiometers





❖ Rotary Motion Potentiometers



THANK YOU

LIVE TO LEARN & LEARN TO SHARE

MRCET CAMPUS

UGC Autonomous

DEPARTMENT OF MECHANICAL ENGINEERING

UNIT 3

FLOW MEASUREMENT, MEASUREMENT OF SPEED, ACCELERATION & VIBRATION

LIVE TO LEARN & LEARN TO SHARE

MRCET CAMPUS

UGC Autonomous

DEPARTMENT OF MECHANICAL ENGINEERING

UNIT – III

Flow Measurement:

- Rotameter, Magnetic, Ultrasonic, Turbine flow meter, hot-wire anemometer, Laser Doppler anemometer

Measurement of Speed:

- Mechanical tachometers, Electrical tachometer, Stroboscope, Noncontact type of tachometers

UNIT – III

Measurement of Acceleration & Vibration:

- Different simple instruments, Principles of Seismic instruments, Vibrometer and accelerometer using this principle

COURSE OUTLINE

UNIT -3

LECTURE	LECTURE TOPIC	KEY ELEMENTS	Learning objectives
1	Measurement of Flow: Liquid level	Different Type- Hook, Sight & float	
2	Indirect Methods of measurement of flow: Capacitive liquid level, Ultrasonic method	Advantages & disadvantages	
3	Magnetic type level indicator	Cryogenic Fuel & Bubbler level indicator	
4	Types of flow measurement Instruments	Flow meters, Rotamtere	
5	Turbine Flowmeter	Hot wire anemeometer	
6	Ultrasonic Flow measurement	LDA	

COURSE OUTLINE

UNIT -3

LECTURE	LECTURE TOPIC	KEY ELEMENTS	Learning objectives
7	Measurement of Speed, Acceleration and Vibration	Mechanical Tachometer	
8	Electrical Tachometers, Measurement of acceleration	Tachogenerator	

TOPICS TO BE COVERED

- Direct methods
- Hook type level indicators
- Sight Glass
- Float type

LECTURE 1

Measurement of Liquid and Flow

MRCET CAMPUS
UGC Autonomous

MEASUREMENT OF LIQUID LEVEL

- Liquid level refers to the position or height of a liquid surface above a datum line.
- Level measurements are made to a certain quantity of the liquid held with in a container.
- Level offers both the pressure and rate of flow in and out of the container and as such its measurement and control is an important function in a variety of processes.
- The task of liquid level measurement may be accomplished by direct methods and indirect methods.

❑Direct method

❑Indirect Method

DIRECT METHODS

- This is the simplest method of measuring liquid level. In this method, the level of liquid is measured directly by means of the following level indicators:

➢ Hook-type Level Indicator

➢ Sight Glass

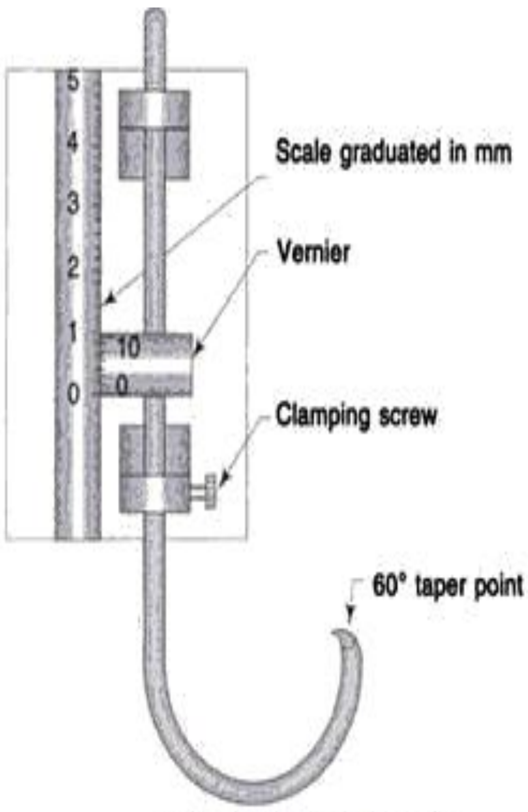
➢ Float-type

➢ Float and shaft liquid level gauge.

DIRECT METHODS

HOOK-TYPE LEVEL INDICATOR

- When the level of liquid in an open tank is measured directly on a scale (the scale may be in the liquid or outside it), it is sometimes difficult to read the level accurately because of parallax error.
- In this case a hook type of level indicator is used.



Hook-type Level Indicator.

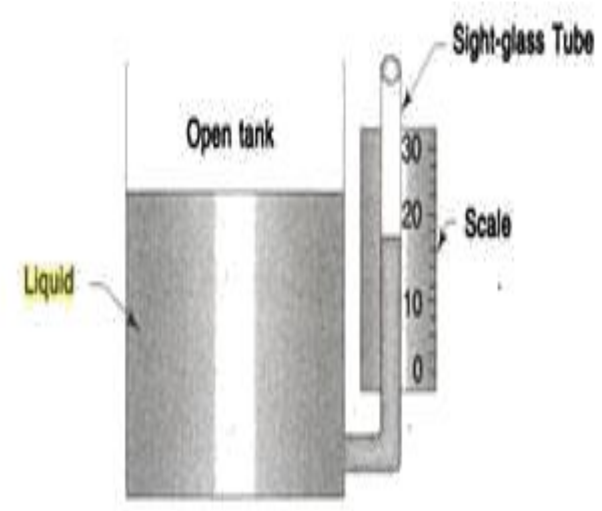
CONSTRUCTION & WORKING

- Hook-type level indicator consists of a wire of corrosion resisting alloy (such as stainless steel) about ¼ in (0.063 mm) diameter.
- Bent into U-Shane with one arm longer than the other as shown in Fig. The shorter arm is pointed with a °60 tater.
- While the longer one is attached to a slider having a Vernier scale. Which moves over the main scale and indicates the level.
- In hook-type level indicator, the hook is pushed below the surface of liquid whose level is to be measured and gradually raised until the point is just about to break through the surface.
- It is then clamped, and the level is read on the scale. This principle is further utilized in the measuring point manometer in which the measuring point consists of a steel point fixed with the point upwards underneath the water surface.

DIRECT METHODS

SIGHT GLASS

- A sight glass (also called a gauge glass) is another method of liquid level measurement.
- It is used for the continuous indication of liquid level within, tank or vessel.



Sight Glass for an Open Tank.

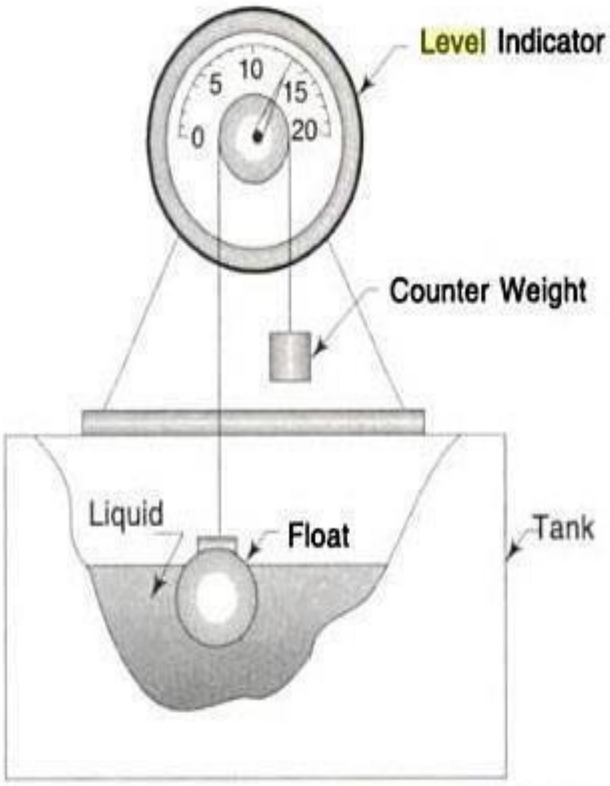
CONSTRUCTION & WORKING

- A sight glass instrument consists of a graduated tube of toughened glass which is connected to the interior of the tank at the bottom in which the water level is required.
- Figure shows a simple sight glass for an open tank in which the liquid level in the sight glass matches the level of liquid in the tank, As the level of liquid in the tank rises and falls, the level in the sight glass also rises and falls accordingly.
- Thus, by measuring the level in the sight glass, the level of liquid in the tank is measured.
- In sight glass, it is not necessary to use the same liquid as in the tank.
- Any other desired liquid also can be used.

DIRECT METHODS

➢FLOAT-TYPE

- Float-Type Level Indicator moat operated level indicator is used to measure liquid levels in a tank in which a float rests on the surface of liquid and follows the changing level of liquid.
- The movement of the float is transmitted to a pointer through a suitable mechanism which indicates the level on a calibrated scale.
- Various types of floats are used such as hollow mewl spheres, cylindrical-shaped floats and disc-shaped floats.



Float-operated Liquid Level Indicator.

CONSTRUCTION & WORKING

- Figure shows the simplest form of float operated mechanism for the continuous liquid level measurement.
- In this case, the movement of the float is transmitted to the pointer by stainless steel or phosphor-bronze flexible cable wound around a pulley, and the pointer indicates liquid level in the tank.
- The float is made of corrosion resisting material (such as stainless steel) and rests on liquid level surface between two grids to avoid error due to turbulence.
- With this type of instrument, liquid level from ½ ft. (152 mm) to 60, ft. (1.52 m) can be easily measured.

THANK YOU

MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY
LIVE TO LEARN & LEARN TO SHARE
MRCET CAMPUS
UGC Autonomous

DEPARTMENT OF MECHANICAL ENGINEERING

TOPICS TO BE COVERED

- Indirect Methods
- Capacitive liquid level sensors
- Ultrasonic method
- Advantages & disadvantages

LECTURE 2

Indirect methods

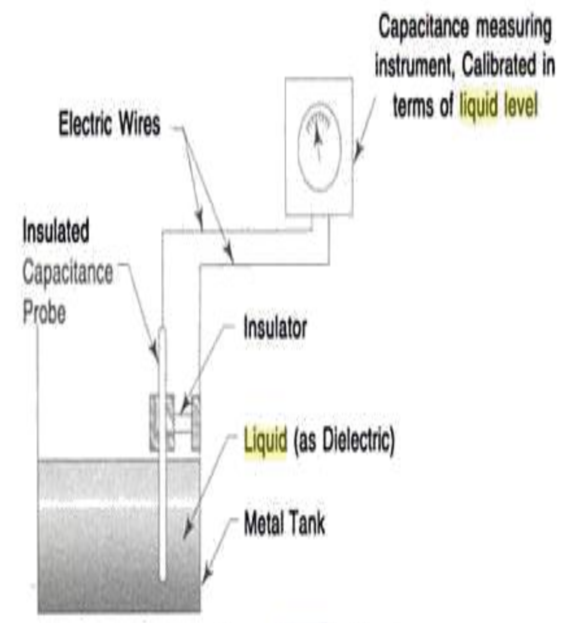
INDIRECT METHODS

- Indirect methods liquid level measurements converts the changes in liquid level into some other form such as resistive, capacitive or inductive beyond force, hydrostatic pressure … Etc. and measures them.
- Thus the change occurred in these parameters gives the measures of liquid level.

INDIRECT METHOD

CAPACITIVE LIQUID LEVEL SENSOR

- The principle of operation of capacitance level indicator is based upon the familiar capacitance equation of a parallel plate capacitor.
- Therefore, it is seen from the above elation that if A and D are constant, then the capacitance of a capacitor is directly proportional to the dielectric constant, and this principle is utilized in the capacitance level indicator



Capacitance Level Indicator.

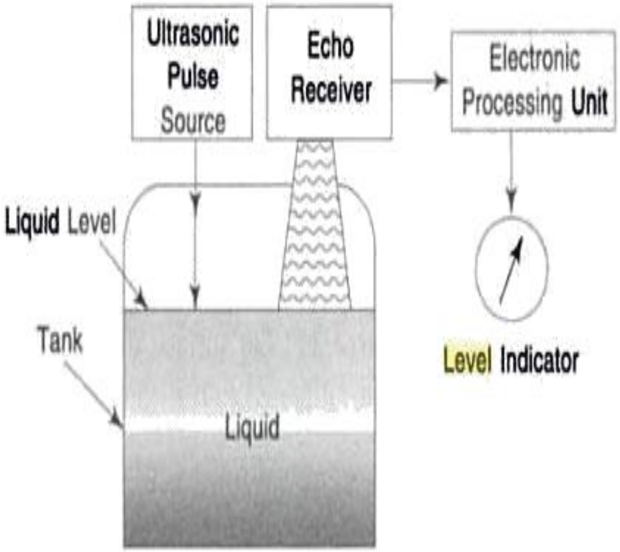
CONSTRUCTION & WORKING

- Figure shows a capacitance type Liquid level indicator.
- It consists of an insulated capacitance probe (which is a metal electrode) firmly fixed near and parallel to the maul wall of the tank.
- If liquid in the tank is non-inductive, the capacitance probe and the tank wall form the plates of a parallel plate capacitor and liquid in between them acts as the dielectric.
- If liquid is conductive, the capacitance probe and liquid form the plates of the capacitor and the insulation of the probe acts as the dielectric.
- A capacitance measuring device is connected with the probe and the tank wall, which is calibrated in terms of the level of liquid in the tank.

INDIRECT METHOD

ULTRASONIC METHOD

- Ultrasonic liquid level works on the principle of reflection of the sound wave from the surface of the liquid.
- The schematic arrangement of liquid level measurement by ultrasonic liquid level gauge is illustrated above



Ultrasonic Level Detector.

CONSTRUCTION & WORKING

- The transmitter ‘T’ sends the ultrasonic wave towards the free surface of the liquid.
- The wave gets reflected from the surface. The reflected waves received by the receiver ‘R’.
- The time taken by the transmitted wave to travel to the surface of the liquid and then back to the receives gives the level of the liquid.
- As the level of the liquid reaches the time taken to reach the surface of the liquid and then back to receiver also changes.
- Thus the change in the level of the liquid are determined accurately.

ADVANTAGES & DISADVANTAGES

- Advantages:-

➢ Operating principle is very simple.

➢ It can be used for various types of liquids and solid substances.

- Disadvantages:-

➢ Very expensive.

➢ Very experienced and skilled operator is required for measurement

THANK YOU

LIVE TO LEARN & LEARN TO SHARE

MRCET CAMPUS

UGC Autonomous

DEPARTMENT OF MECHANICAL ENGINEERING

TOPICS TO BE COVERED

- Magnetic type level indicator
- Cryogenic fuel level indicator
- Bubbler level indicator

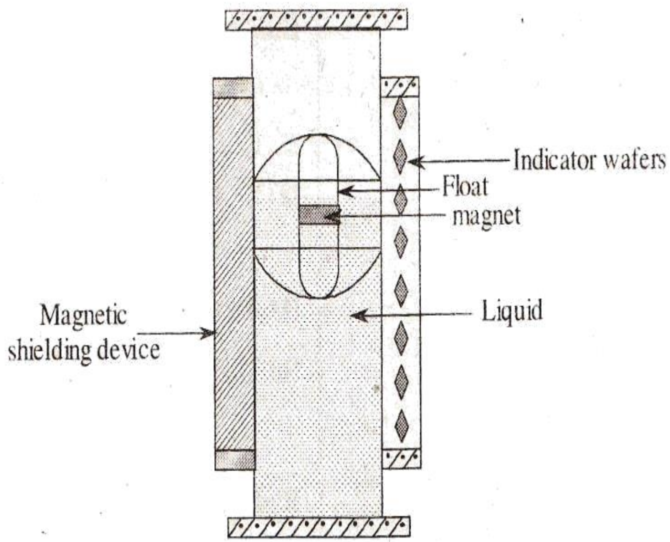
LECTURE 3

Indirect Methods

INDIRECT METHOD

MAGNETIC TYPE LEVEL INDICATORS:

- These are used for measuring the toxic and corrosive liquids.
- It is used to measure the level of liquids which contain corrosive and toxic materials.
- It contains a float in which a magnet is arranged and is placed in the chamber, whose liquid level is to be determined.



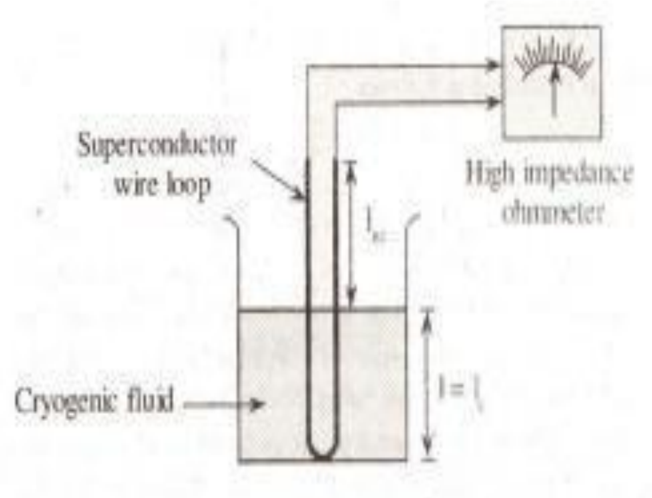
Magnetic Type Level Indicator

- The float moves up and down with the increase and decrease in the level of liquid respectively.
- A magnetic shielding device and an indicator containing small wafers arranged in series and attached to the sealed chamber.
- These wafers are coated with luminous paint and rotate 180*.
- As the level changes the float moves (along with the magnet) up and down.
- Due to this movement of magnet, wafers rotate and present a black coloured surface for the movement of float in opposite direction.

INDIRECT METHOD

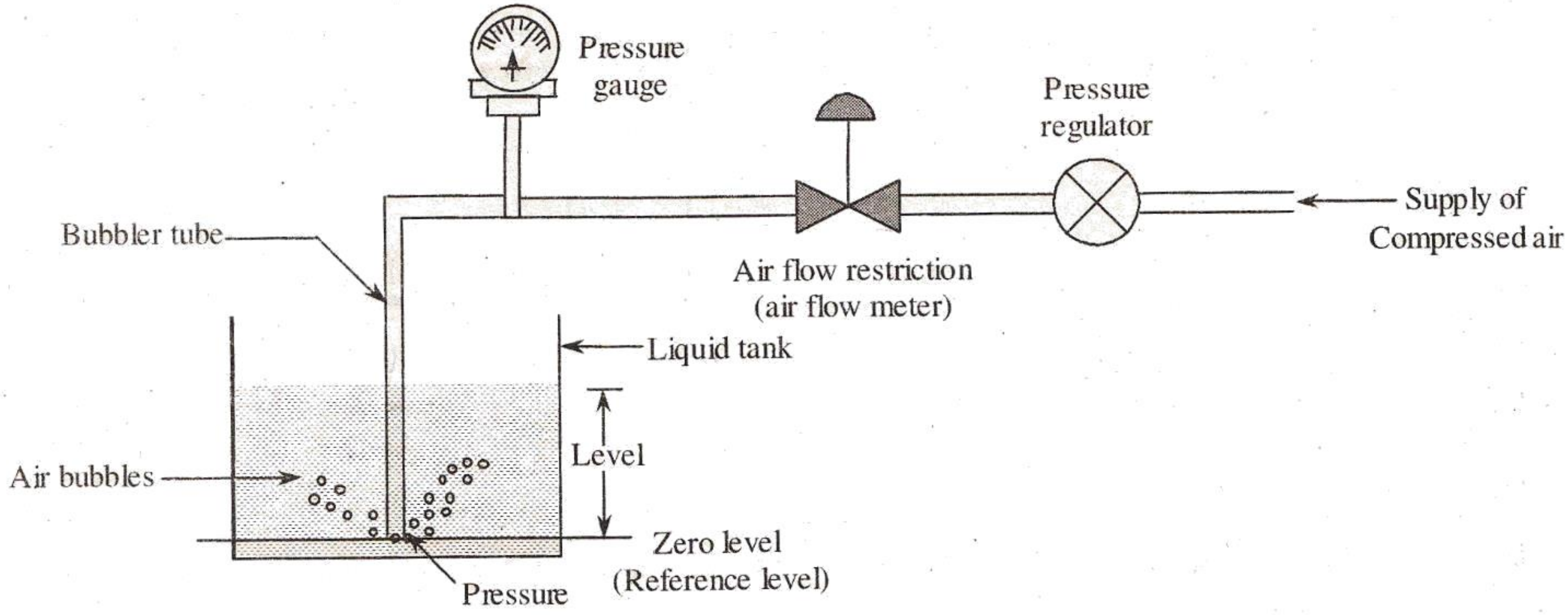
CRYOGENIC FUEL LEVEL INDICATOR:

- A gas which changes its state (gaseous state into liquid state). When cooled to very low temperatures is known as cryogenic fluid.
- A cryogenic fluid exists in liquid state at very low temperatures, which are usually less than the temperature levels at which a superconductor exhibits zero resistance characteristic.



Cryogenic Fluid Level Indicator

BUBBLER LEVEL INDICATOR:



Bubbler Level Indicator

- The Bubbler type level indicator is also known as purge type of liquid level meter.
- In this technique of level measurement, the air pressure in the pneumatic pipeline is adjusted and maintained slightly greater than the hydrostatic pressure at the lower end of the bubbler tube.
- The bubbler tube is dipped in the tank such that its lower end is at zero level i.e., reference level, and the other end is attached to a pressure regulator and a pressure gauge.
- Now the supply of air through the bubbler tube is adjusted so that the air pressure is slightly higher than the pressure exerted by the liquid column in the vessel or tank.

- This is accomplished by adjusting the air pressure regulator until a slow discharge of air takes place i.e., bubbles are seen leaving the lower end of the bubbler tube.

- (In some cases a small air flow meter is arranged to control an excessive air flow if any).

- When there is a small flow of air and the fluid has uniform density, the pressure indicated by the pressure gauge is directly proportional to the height of the level in the tank provided the gauge is calibrated properly in unit of liquid level.

THANK YOU

LIVE TO LEARN & LEARN TO SHARE
MRCET CAMPUS
UGC Autonomous
DEPARTMENT OF MECHANICAL ENGINEERING

TOPICS TO BE COVERED

- Types of flow measuring instruments
- Flow meters
- Rotometer
- Advantages

LECTURE 4

Flow Measurement

FLOW MEASUREMENT

- Measurement of fluid velocity, flow rate and flow quantity with varying degree of accuracy or a fundamental necessity in almost all the flow situations of engineering.
- Studying ocean or air currents, monitoring gas input into a vacuum chamber, measuring blood movement in a vein.
- The scientist or engineer is faced with choosing a method to measure flow.
- For experiment procedures, it may be necessary to measure the rates of flow either into or out of the engines. “Pumps, compressors and turbines”.

- In industrial organizations flow measurement is needed for providing the basis for controlling processes and operations.
- That is for determining the proportions of materials entering or leaving, a continuous manufacturing process.
- Flow measurements are also made for the purpose of cost accounting in distribution of water and gas to domestic consumers, and in the gasoline pumping stations.

TYPES OF FLOW MEASURING INSTRUMENTS

➢ Quantity meters:

- In this class of instruments actual flow rate is measured.
- Flow rate measurement devices frequently required accurate. Pressure and temperature measurements in order to calculate the output of the instrument.
- The overall accuracy of the instrument depends upon the accuracy of pressure and temperature measurements.

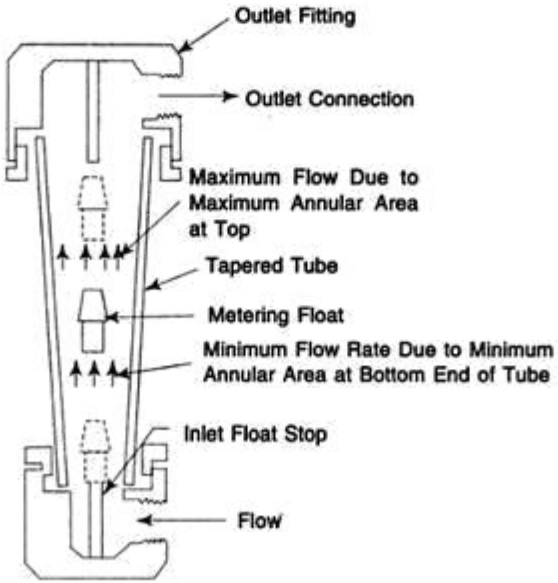
1. Weight or volume tanks.
2. Positive displacement or semi-positive displacement meters

FLOW METERS

- Obstruction meters.
- Orifice Nozzle Venture
- Variable-area meters.
- Velocity probes.
- Static pressure probes.
- Total pressure probes.
- Special methods.
- Turbine type meters.
- Magnetic flow meters.

ROTAMETER

- The rotameter is the most extensively used form of the variable area flow meter.
- It consists of a vertical tapered tube with a float which is free to move up or down within the tube as shown in Fig.
- The tube is made tapered so that there is a linear relationship between the flow rate and position in the float within the tube



Rotameter.

- The free area between float and inside wall of the tube forms an annular orifice.
- The tube is mounted vertically with the small end at the bottom.
- The fluid to be measured enters the tube from the boom and passes upward around the float and exit at the top.
- When there is no flow through the rotameter, the float rests at the bottom of the metering tube where the maximum diameter of the float is approximately the same as the bore of the tube.
- When fluid enters the metering tube, the float moves up, and the flow area of the annular orifice increases.
- The pressure differential across the annular orifice is paranormal to the square of its flow area and to the square of the flow rate.
- The float is pushed upward until the `limns force produced by the pressure differential across its upper and lower surface is equal to the weight of the float

- If the flow rate rises, the pressure differential and hence the lining force increases temporarily, and the float then rises, widening the annular orifice until the force cawed by the pressure differential is again equal to the weight of the Boat.
- Thus, the pressure differential remains constant and the area of the annular orifice (i.e., free area between float and inside wall of the tube) to which the float moves.
- Changes in proportion to the flow rate. Any decrease in flow rate causes the float to drop to a lower position.
- Every float position corresponds to one particular flow rate for a quid of a given density and viscosity.

ADVANTAGES OF ROTAMETER

- Simplicity of operation.
- Ease of reading and installation.
- Relatively low cost.
- Handles wide variety of corrosive fluids.
- Easily equipped with data transmission, indicating and recording devices. Disadvantages:-
- Glass tube subject to breakage.
- Limited to small pipe sizes and capacities.
- Less accurate compared to venture and orifice meters.
- Must be mounted vertically.
- Subject to oscillations.

THANK YOU

DEPARTMENT OF MECHANICAL ENGINEERING

TOPICS TO BE COVERED

- Turbine flow meter
- Advantages & disadvantages
- Hot wire anemometer
- Magnetic flow measurement

LECTURE 5

Flow Measurement

TURBINE FLOW METER

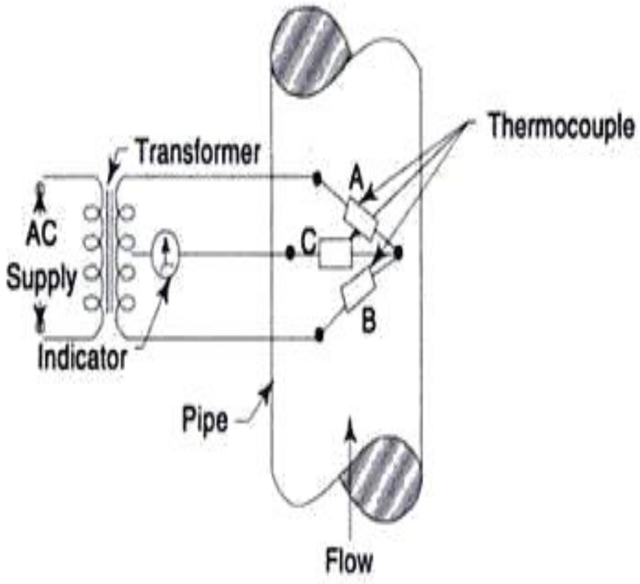
- Principle: - The permanent magnet attached to the body of rotor is polarized at 90° to the axis of rotation.
- When the rotor rotates due to the velocity of the fluid (V), the permanent magnet also rotates along with the rotor.
- Therefore, a rotating magnetic field will be generated which is then cut by the pickup coil.
- Due to this ac-voltage pulses are generated whose frequency is directly proportional to the flow rate.

ADVANTAGES & DISADVANTAGES

- Advantages:-
- Good accuracy and repeatability. Easy to install and maintain.
- Low pressure drop. Electrical output is available. Good transient response.
- Disadvantages:-
- High cost.
- The bearing of the rotor may subject to corrosion.
- Wear and tear problems. Applications:-
- Used to determine the fluid flow in pipes and tubes.
- Flow of water in rivers.
- Used to determine wind velocity in weather situations or conditions.

HOT WIRE ANEMOMETER

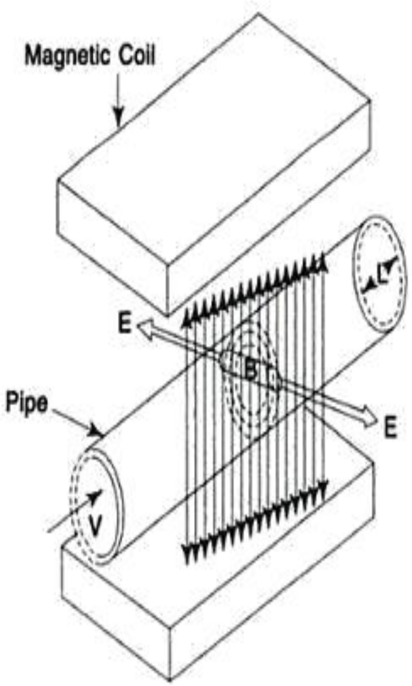
- When a fluid flows over an electrically heated surface, heat transfer takes place from the surface or wire to the fluid.
- Hence, the temperature of the heated wire decreases which causes variations in the resistance.
- The change that occurred in the resistance of the wire is related to the flow rate.



- The sensor is a 5 micron diameter platinum tungsten wire welded between the two prongs of the probe and heated electrically as a part of Wheat stone bridge circuit.
- When the probe is introduced into the fluid flowing, it tends to be cooled by the instantaneous velocity and consequently there is a tendency for the electrical resistance to change.
- The rate of cooling depends up on the dimensions and physical properties of the wire.
- Difference of the temperature between the wire and fluid, physical properties of the fluid, string velocity under measurement.

MAGNETIC FLOWMETER

- Magnetic flow meter depends up on the faradays law of electromagnetic induction.
- These meters utilize the principles of faradays law of electromagnetic induction for making a flow measurement.
- It states that whenever a conductor moves through a magnet field of given field strength; a voltage is induced in the conductor, which is proportional to the relative between the conductor and the magnetic field.



Working Principle of Magnetic Flowmeter.

CONSTRUCTION & WORKING

- In case of magnetic flow meters electrically conductive flowing liquid works as the conductor the induced voltage.
- The length L of which is the distance between the electrodes and equals the pipe diameter.
- As the liquid passes through the pipe section, it also passes through the magnetic field set up by the magnet coils, thus inducing the voltage in the liquid which is detected by the pair of electrodes mounted in the pipe wall.
- The amplitude of the induced voltage is proportional to the velocity of the flowing liquid.
- The magnetic coils may energized either by AC or DC voltage, but the recent development is the pulsed DC-type in which the magnetic coils are periodically energized.

ADVANTAGES & DISADVANTAGES

- Advantages:-
- It can handle greasy materials.
- It can handle corrosive fluids.
- Accuracy is good.
- It has very low pressure drop.
- Disadvantages:-
- Cost is more.
- Heavy and larger in sizes.
- Explosion proof when installed in hazardous electrical areas.
- It must be full at all times.

THANK YOU

DEPARTMENT OF MECHANICAL ENGINEERING

TOPICS TO BE COVERED

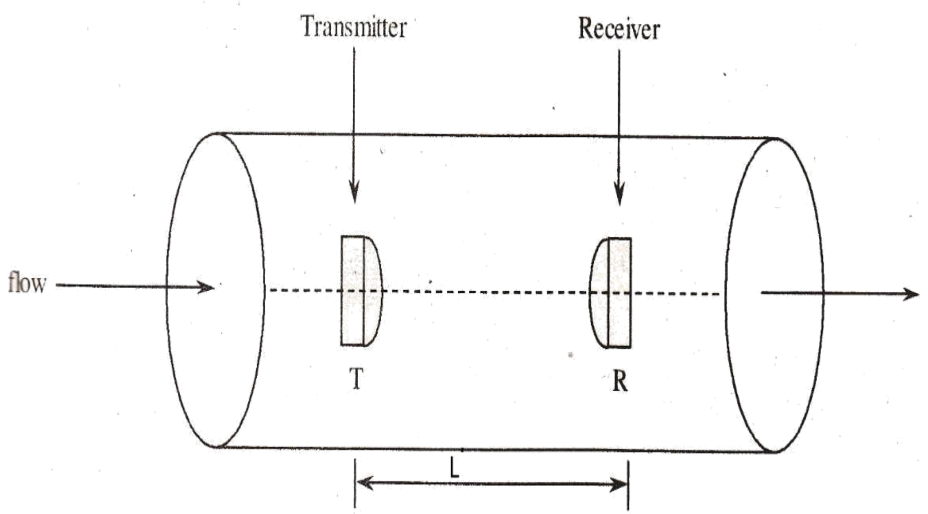
- Ultrasonic Flow measurement
- Laser Doppler Anemometer (LDA)

LECTURE 6

Flow Measurement

MRCET CAMPUS
UGC Autonomous

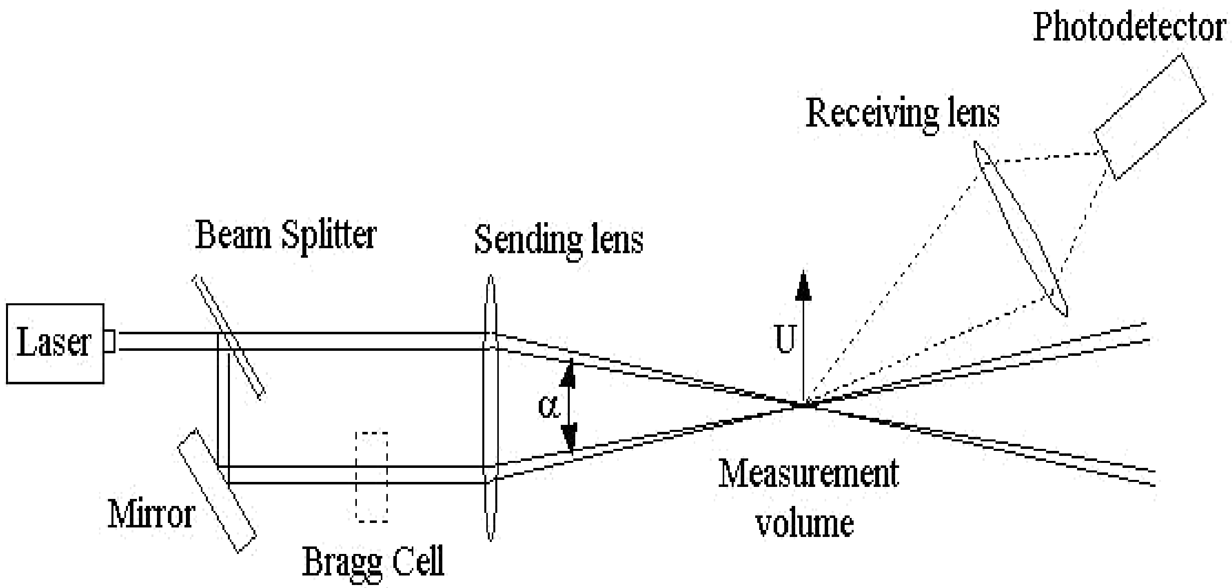
ULTRASONIC FLOW METER



Flow Rate Measurement using Ultrasonic Transducer

- The velocity of propagation of ultrasonic sound waves in a fluid is changed when the velocity of the flow of fluid changes.
- The arrangement of flow rate measurement using ultrasonic transducer contains two piezo-electric crystals placed in the fluid whose flow rate is to be measured of these two crystals one acts as a transmitting transducer and the other acts as a receiving transducer.
- The transmitter and receiver are separated by some distance say “L”.
- Generally the transmitting transducer is placed in the upstream and it transmits ultrasonic pulses.
- These ultrasonic pulses are then received by the receiving transducer placed at the downstream flow. Let the time taken by the ultrasonic pulsed to travel from the transmitter and received at the receiver is “delta”.

LASER DOPPLER ANEMOMETER (LDA)



- The optical flow visualization methods offer the advantage that they do not disturb the flow during the measurement process.
- The LDA is a device that offers the non-disturbance advantages of optical methods while affording a very precise quantitate measurement of flow velocity.
- This instrument is the most recent development in the area of flow measurement, especially measurement of high frequency turbulence fluctuation.
- The operating principle of this instrument involves the focusing of laser beams at a point, where the velocity is to be measured and then sensing with a photo detector.

- The light scattered by then particles carried along with the fluid as it passes though the laser focal point.
- The velocity of the particles which is assumed to be equal to the fluid velocity causes a Doppler shift of the frequency of the scattered light and produces a photo detector signal related to the velocity.

THANK YOU

MRCET CAMPUS
UGC Autonomous

DEPARTMENT OF MECHANICAL ENGINEERING

TOPICS TO BE COVERED

- Mechanical Tachometer
- Tachoscope
- Hand speed indicators
- Slipping Clutch tachometer
- Centrifugal force tachometer
- Vibrating tachometer

LECTURE 7

Measurement of Speed, acceleration & Vibration

MRCET CAMPUS
UGC Autonomous

MEASUREMENT OF SPEED, ACCLERATION AND VIBRATION

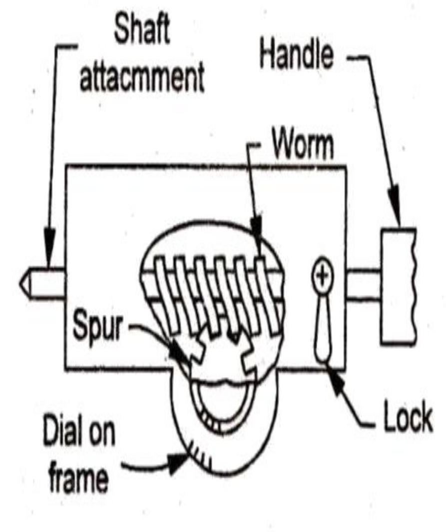
- Speed is a rate variable defined as the time-rate of motion. Common forms and units of speed measurement include: linear speed expressed in meters per second (m/s), and the angular speed of a rotating machine usually expressed in radians per second (rad/s) or revolutions per minute (rpm).
- Measurement of rotational speed has acquired prominence compared to the measurement of linear speed.
- Angular measurements are made with a device called tachometer.
- Tachometers may be broadly classified into two categories:

➢ Mechanical tachometers and

➢ Electrical tachometers.

MECHANICAL TACHOMETERS

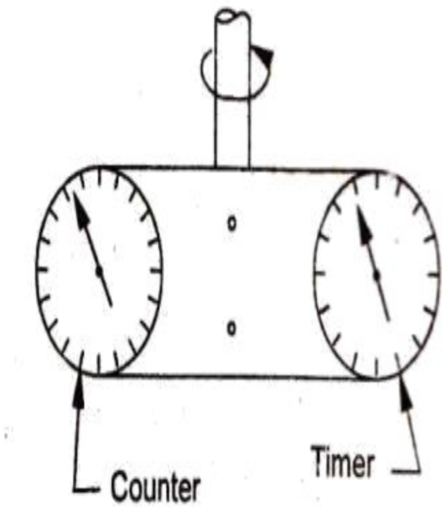
- The revolution counter, sometimes called a speed counter, consists of a worm gear which is also the shaft attachment and is driven by the speed source.
- The worm drives the spur gear which in turn actuates the pointer on a calibrated dial.
- A properly designed and manufactured revolution counter would give a satisfactory speed measure upto 2000-3000 rpm.
-



Revolution counter

TACHOSCOPE

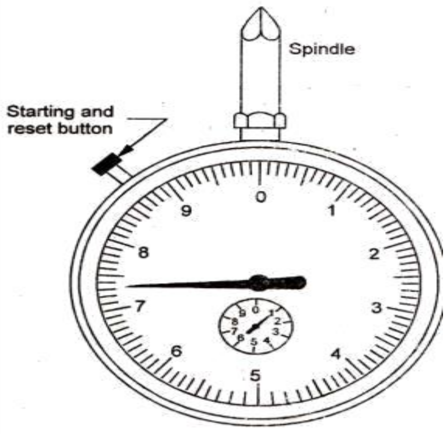
- The difficulty of starting a counter and a watch at exactly the same time led to the development of tachoscope, which consists of a revolution counter incorporating a built-in timing device.
- The two components are integrally mounted, and start simultaneously when the contact point is pressed against the rotating shaft.
- The instrument runs until the contact point is disengaged from the shaft.
- The rotational speed is computed from the readings of the counter and timer.
- Tachoscopes have been used to measure speeds upto 5000 rpm.



Tachoscope

HAND SPEED INDICATOR

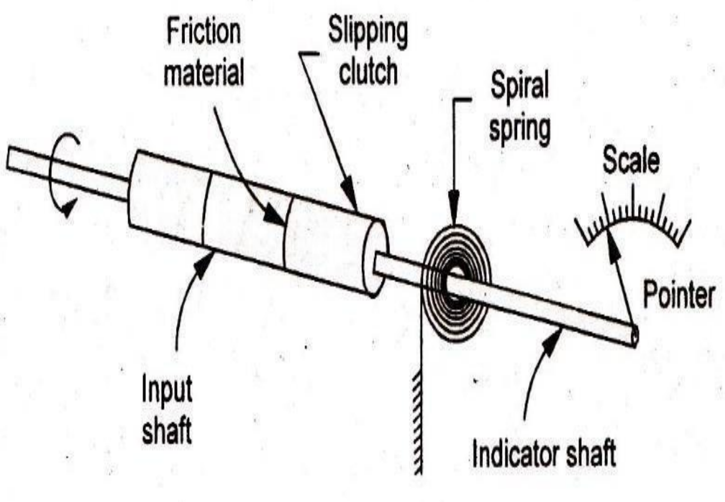
- The indicator has an integral stop watch and counter with automatic disconnect.
- The spindle operates when brought in contact with the shaft, but the counter does not function until the start and wind button is pressed to start the watch and engage the automatic clutch.
- Depressing of the starting button also serves to wind the starting watch. After a fixed time-interval (usually 3 or 6 seconds), the revolution counter automatically gets disengaged.



Hand speed indicator

SLIPPING CLUTCH TACHOMETER

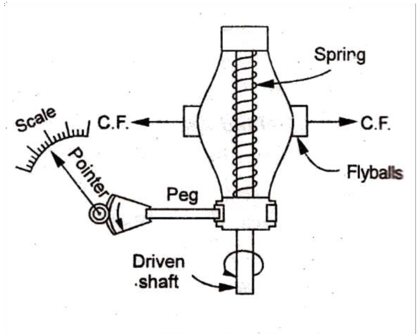
- The rotating shaft drives an indicating shaft through at slipping clutch.
- A pointer attached to the indicator shaft moves over a calibrated scale against the torque of a spring.
- The pointer position gives a measure of the shaft speed.



Slipping clutch tachometer

CENTRIFUGAL FORCE TACHOMETER

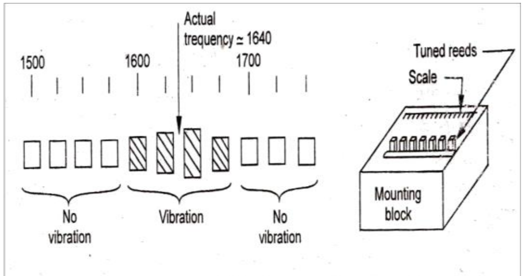
- The device operates on the principle that centrifugal force is proportional to the speed of rotation.
- Two flyballs (small weights) are arranged about a central spindle.
- Centrifugal force developed by these rotating balls works to compress the spring as a function of rotational speed.
- A grooved collar or sleeve attached to the free end of the spring then slides on the spindle and its position can be calibrated in terms of the shaft speed.



Centrifugal tachometer

VIBRATING TACHOMETER

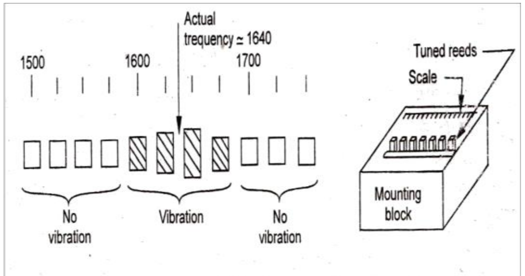
- Tachometers of the vibrating reed type utilize the fact that speed and vibration in a body are interrelated.
- The instrument consists of a set of vertical reeds, each having its own natural frequency of vibration.
- The reeds are lined up in order of their natural frequency and are fastened to a base plate at one end, with the other end free to vibrate.



Vibrating reed tachometer

VIBRATING TACHOMETER

- Tachometers of the vibrating reed type utilize the fact that speed and vibration in a body are interrelated.
- The instrument consists of a set of vertical reeds, each having its own natural frequency of vibration.
- The reeds are lined up in order of their natural frequency and are fastened to a base plate at one end, with the other end free to vibrate.



Vibrating reed tachometer

THANK YOU

MRCET CAMPUS
LIVE TO LEARN & LEARN TO SHARE
UGC Autonomous

DEPARTMENT OF MECHANICAL ENGINEERING

TOPICS TO BE COVERED

- Drug cup tachometer
- Tachogenerator
- Stroboscope
- Measurement of Acceleration

LECTURE 8

Electrical Tachometer

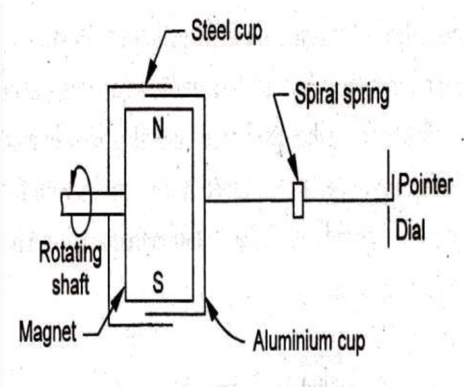
ELECTRICAL TACHOMETERS

- An electrical tachometer depends for its indications upon an electrical' signal generated in proportion to the rotational speed of the shaft.
- Depending on the type of the transducer, electrical tachometers have been constructed in a variety of different designs.

DRUG CUP TACHOMETER

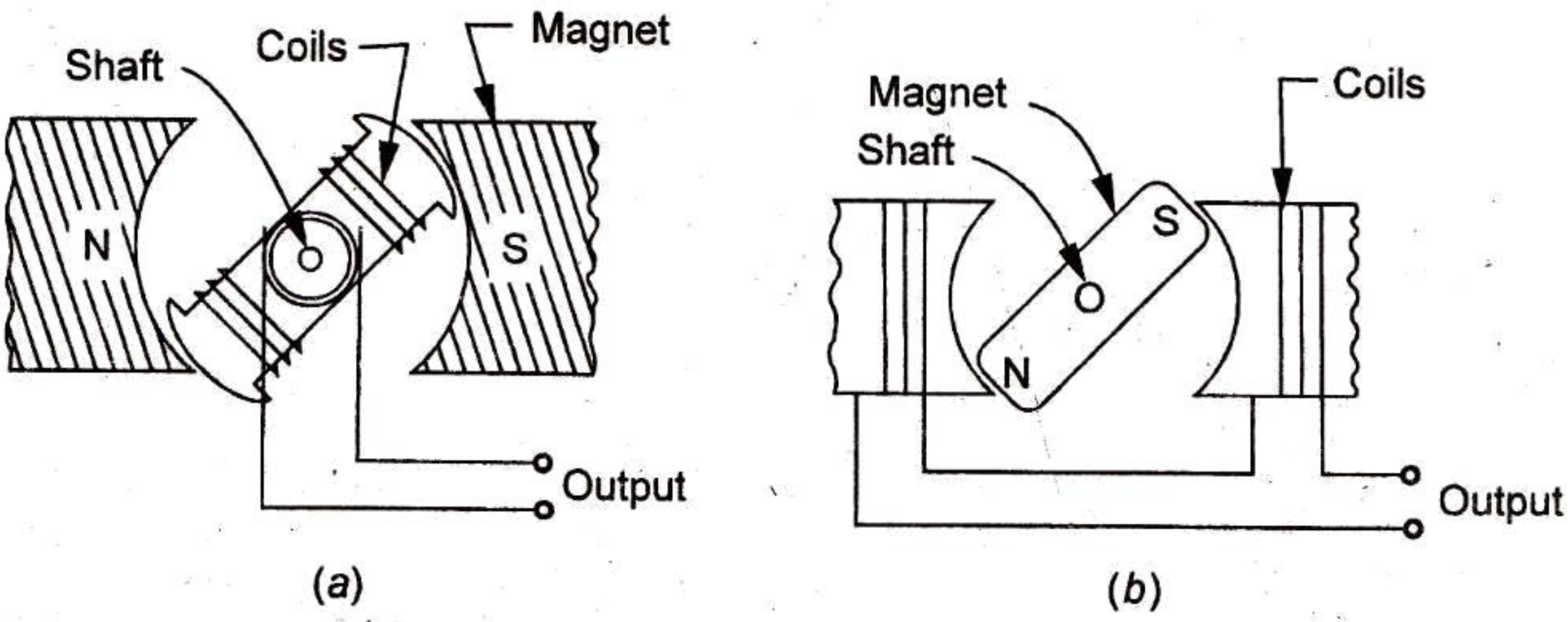
- In an eddy current or drag type tachometer, the test shaft rotates a permanent magnet and this induces eddy currents in a drag cup or disc held close to the magnet.
- The eddy currents produce a torque which rotates the cup against the torque of a spiral spring.
- The disc tums in the direction of the rotating magnetic field until the torque developed equals that of the spring.
- A pointer attached to the cup indicates the rotational speed on a calibrated scale.

....



Drag cup tachometer

TACHOGENEREATORS



(a) D.C. tachometer (b) A.C. tachometer

- These tachometers employ small magnet type d.c or a.c generators which translate the rotational speeds into d.c. or a.c voltage signal.
- The operating principle of such tachometers is illustrated in Fig.
- Relative perpendicular motion between a magnetic field and conductor results in voltage generation in the conductor.
- D. C. tachometergenerator: This is an accurately made dc. generator with a permanent magnet of horse-shoe type.
- A.C. tachometer generator: The unit embodies a stator surrounding a rotating permanent magnet.

STROBOSCOPE

- The stroboscope utilises the phenomenon of vision when an object is viewed intermittently.
- The human sense of vision is so slow to react to light stimuli that it is unable to separate two different light impulses reaching the eye within a very short Period of time (less than 0.1second).
- A succession of impulses following one another at brief intervals are observed by the eye as a continuous unbroken sequence.
- A mechanical disk type stroboscope consists essentially of a whirling disk attached to motor whose speed can be varied and measured.
- A reference mark on the rotating shaft on the shaft appears to be stationary.

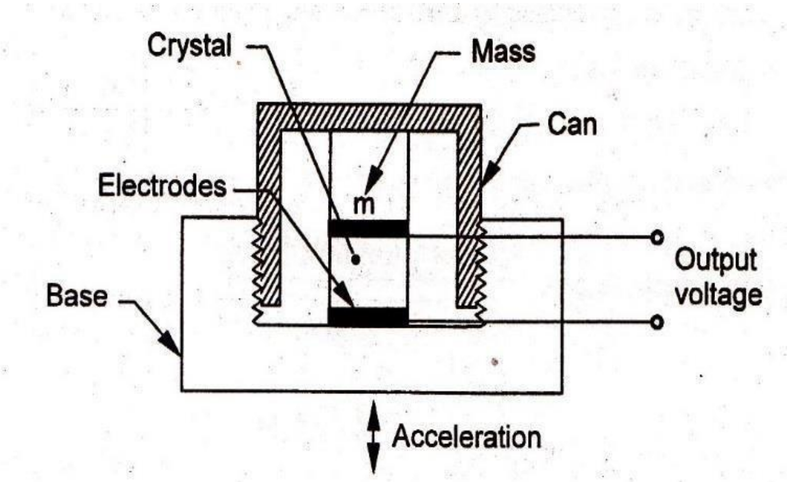
MEASUREMENT OF ACCELERATION:

- There are two types of accelerometers generally used for measurement of acceleration:

  (i) Piezo-eletric type, and (ii) seismic type.

- Piezo-electric accelerometer: The unit is perhaps the simplest and most commonly used transducer employed for measuring acceleration.
- The sensor consists of a piezo-electric crystal sandwitched, between two electrodes and has a mass placed on it.
- The unit is fastened to the base whose acceleration characteristics are to be obtained.
- The can threaded to the base acts as a 'spring and squeezes the mass against the crystal.

- Mass exerts a force on the crystal and a certain output voltage is generated. If the base is now accelerated downward, inertial reaction force on the base acts upward against the top of the can. This relieves stress on the crystal.
- From Newton's second law, force = mass × acceleration



THANK YOU

LIVE TO LEARN & LEARN TO SHARE

MRCET CAMPUS

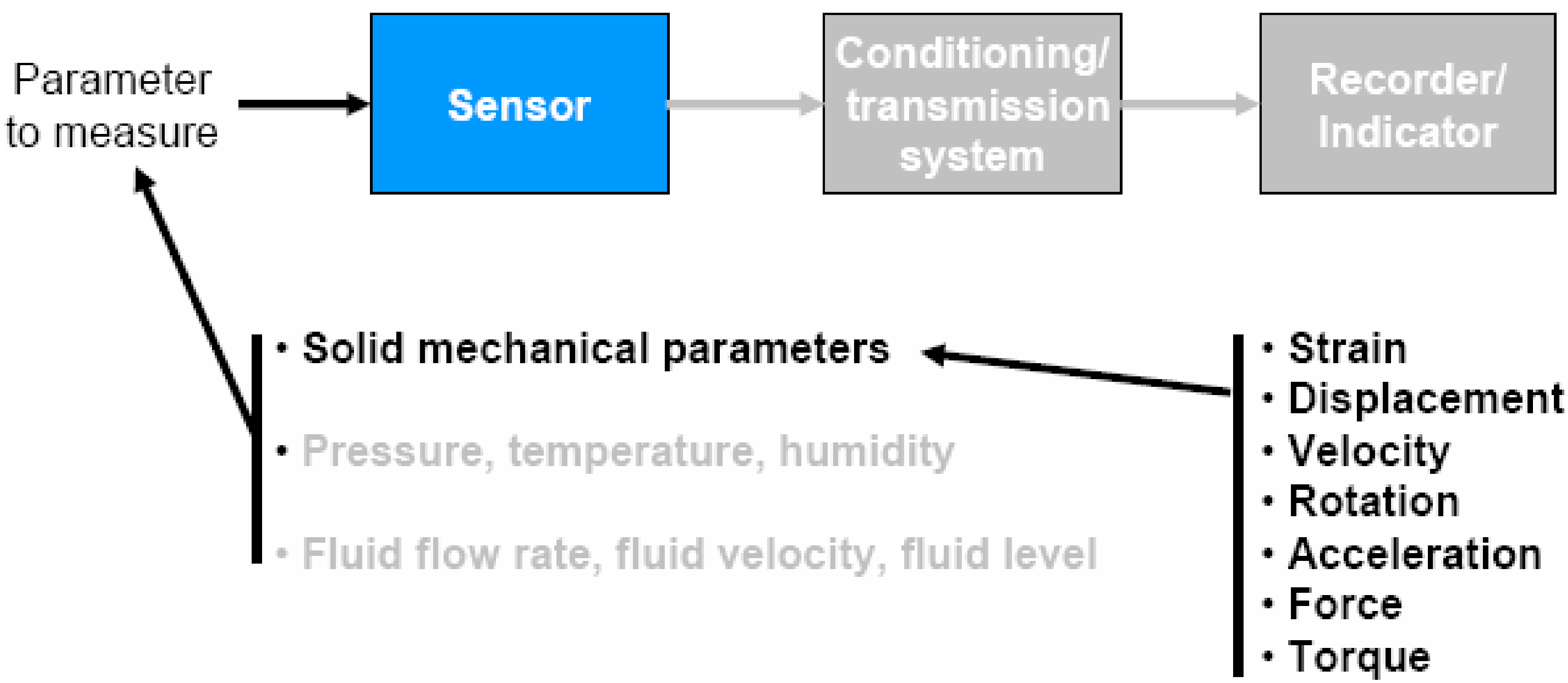
UGC Autonomous

DEPARTMENT OF MECHANICAL ENGINEERING

UNIT-IV

STRESS STRAIN MEASUREMENT

Measurement Systems



Measuring Strain (Strain Gages)

•What is Strain? Strain is the amount of deformation of a body due to an applied force. More specifically, strain is defined as the fractional change in length.

•When a force is applied to a structure, the components of the structure change slightly in their dimensions and are said to be strained.

• Devices to measure these small changes in dimensions are called *strain gages*.

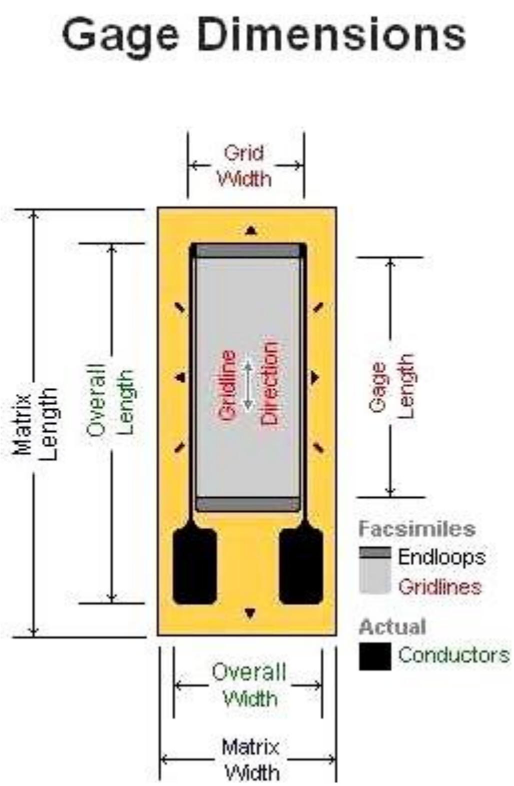
• What devices can be used to measure strain?

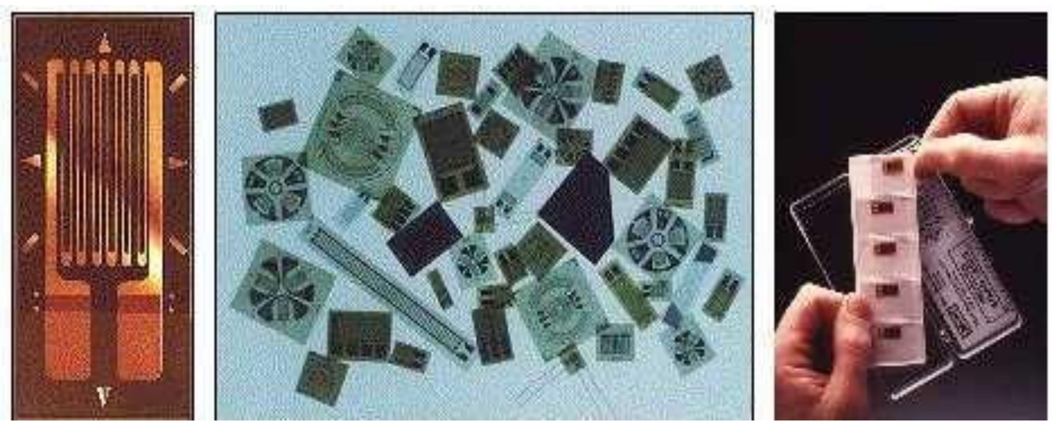
Electrical Resistance Strain Gage

- The ideal sensor for the measurement of strain would
  - Have good spatial resolution, implying that the sensor would measure strain at a point
  - Be unaffected by changes in ambient conditions
  - Have a high-frequency response for dynamic strain measurements.

• A device that closely meets these characteristics is the *resistance strain gage*.

What is Strain Gage?





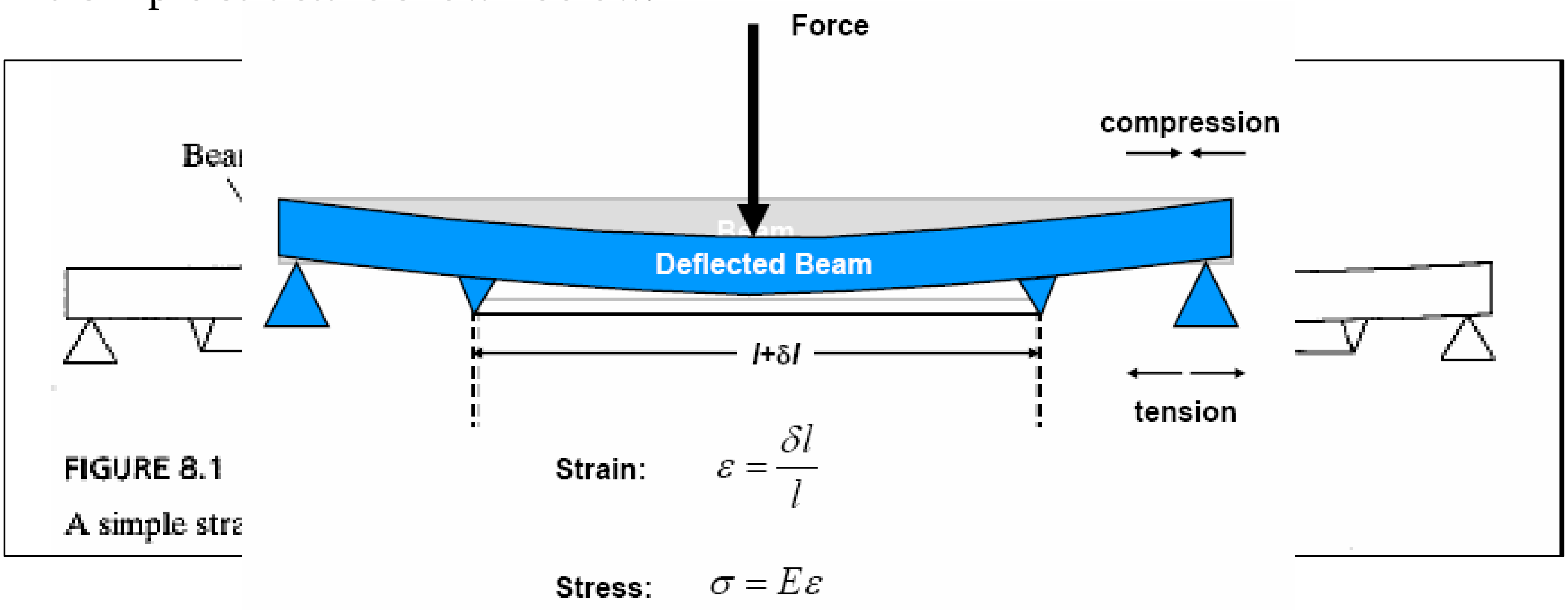
- A strain gauge, a device whose electrical resistance varies in proportion to the amount of strain in the device. The most widely used gage is the bonded metallic strain gage.

Measuring Strain (Strain Gages)

•The electrical resistance strain gage is an extremely common device used to measure strain in structures and also as a sensing element in a wide variety of transducers, including those used to measure force, acceleration and pressure.

•Electrical-resistance strain gages and associated signal conditioners are simple, inexpensive and quite reliable.

•To understand the function of a strain gage, consider the measurement of strain in a simple structure shown below.



Measuring Strain (Strain Gages)

•The figure shows a situation in which a supported beam is bent by applying a lateral force.

•With this type of loading, the beam will become longer on the bottom surface and shorter on the top surface.

•A wire that is attached to the beam using two standoffs functions as a simple strain gage.

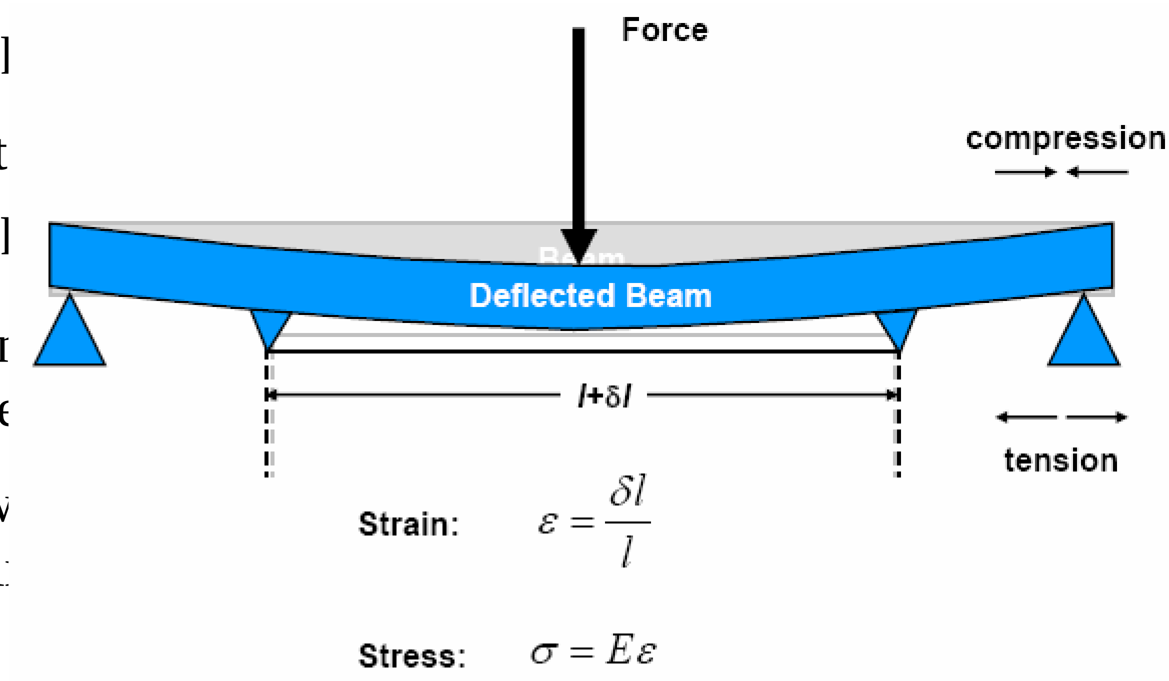
• Consider the original lengt

• When the beam is loaded, t

• The ratio $\delta l/l$ is known as t

•In the above case, the strai r in the lower surface of the be

•The stretching of the wire w the wire is a detector of strai



Measuring Strain (Strain Gages)

•Strain has units of inches per inch or millimeters per millimeter and hence it is dimensionless. In most structures the values of strain are usually very small. For example, low-strength steel will yield (take a permanent deform) at a strain about 0.0014.

• Therefore, usually the strain is expressed in units of *microstrain* (µstrain).

• Thus, 0.0014 strain = 0.0014×10^6 µstrain = 1400 µstrain.

•In the engineering design process, it is often necessary to determine the stresses in a structure experimentally to determine if the structure is sound.

•It is difficult to measure the stress directly, but a strain gage can be used to measure the strain, and then the stress can be determined using the Hooke's law. That is

$$\sigma = E\varepsilon$$

where, σ is the normal stress and E is the modulus of elasticity (also called Young's modulus) which is a material property.

•For a wire to work as a strain gage, the relationship between the change in resistance and the strain must be known.

Measuring Strain (Strain Gages)

• The resistance of a wire is given by

$$R = \frac{\rho L}{A}$$

where, R is the resistance, ρ is the resistivity of wire which is a function of the wire material, L is the length of wire, and A is the cross-sectional area of the wire.

•Taking logarithms of both sides, separating the terms and differentiating each term, we get

$$\frac{dR}{R} = \frac{d\rho}{\rho} + \frac{dL}{L} - \frac{dA}{A}$$

•The above equation relates a small change in resistance to changes in resistivity, length and cross-sectional area.

• The term dL/L is the *axial strain*, ε_a.

• The term dA/A can be evaluated from the equation of the cross-sectional area $A=\pi D$^2/4.

• Taking the logarithm and differentiating the above equation we get

$$\frac{dA}{A} = 2\frac{dD}{D}$$

Measuring Strain (Strain Gages)

• The term *dD/D* is known as the *transverse strain*, ε_t.

• Solid mechanics provides the following relationship between the axial and transverse strain $\varepsilon_t = -v\varepsilon_a$

where, *v* is known as Poisson's ratio and it is the property of material.

•The negative sign indicates that as the wire becomes longer, the transverse dimension decreases.

• Combining the above equations we get

$$\frac{dR}{R} = \frac{d\rho}{\rho} + \varepsilon_a (1 + 2v)$$

•The above equation shows the relationship between the change in resistance of the wire, strain, and the change in resistivity of the wire.

• The strain gage factor, *S*, is defined as $S = \frac{dR/R}{\varepsilon_a}$

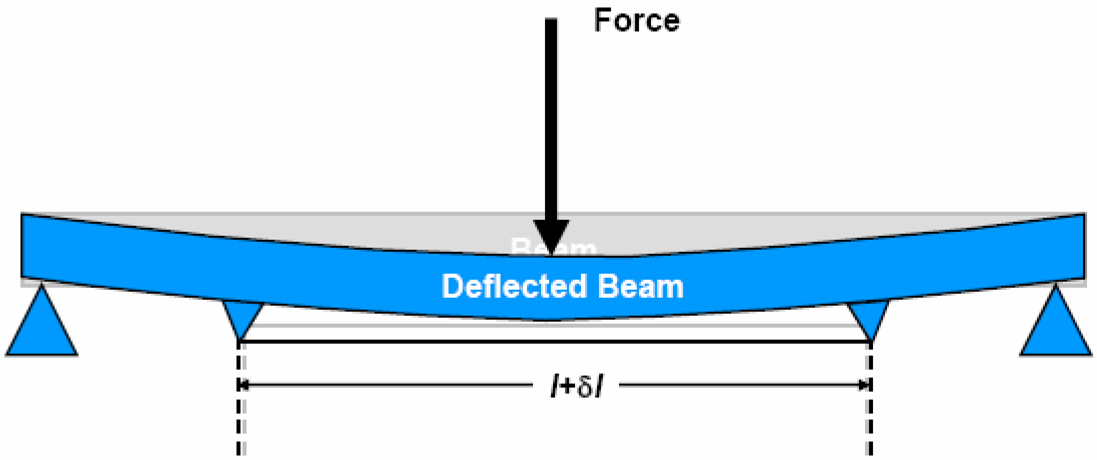
• Combining the above two equations we get $S = 1 + 2v + \frac{d\rho/\rho}{\varepsilon_a}$

Measuring Strain (Strain Gages)

•If the temperature is held constant, the change in resistivity is proportional to the strain.

•The strain gage factor is approximately constant, although it is sensitive to the temperature change.

• In summary, we have following equations:



$$\frac{dR}{R} = \frac{d\rho}{\rho} + \frac{dL}{L} - \frac{dA}{A}$$

Axial strain: $\varepsilon_a = \frac{dL}{L}$ $\qquad \varepsilon_t = -\upsilon\varepsilon_a$

$$\frac{dA}{A} = 2\frac{dD}{D}$$

Transverse strain: $\varepsilon_t = \frac{dD}{D}$ $\qquad \frac{dR}{R} = \frac{d\rho}{\rho} + \varepsilon_a - \left(-2\upsilon\varepsilon_a\right)$

Strain gauge factor: $S = \frac{dR/R}{\varepsilon_a}$

Strain gauge equation: $S = 1 + 2\upsilon + \frac{d\rho/\rho}{\varepsilon_a}$

Measuring Strain (Strain Gages)

•In addition to the strain gages constructed in the form of straight wires, another common type of strain gages are constructed by etching them from thin foil metal sheets that are bounded to a plastic backing, as shown below.

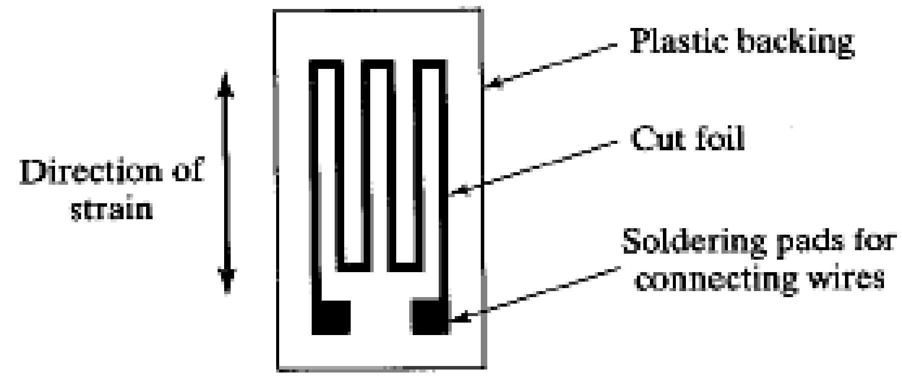
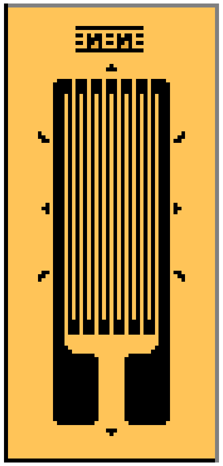


FIGURE 8.2
Foil strain gage.



• This backing is glued to the structure whose strain needs to be measured.

• The dimensions of strain gages vary. They can be as small as 200 μm.

• Strains as high as 200,000 με can be measured.

• Strain gages can also be constructed from semiconductor materials.

•The semiconductor strain gages are commonly used as sensing elements in pressure and acceleration transducers. However, they cannot measure very high strain.

Measuring Strain (Strain Gages)

•If a structure is loaded in a single direction, there exists a transverse strain but no transverse stress.

• This strain can be measured as $\varepsilon_t = -\nu\varepsilon_a$

• This effect is included when manufacturers determine strain gage factors.

•In many situations, the surface of a structure is stressed simultaneously in more than one direction, leading to the so-called *biaxial stress*.

• In biaxial stress there is a transverse strain that results from the transverse stress.

•This transverse strain affects the strain gage output and be described with a transverse gage factor, S_t, defined as

$$S_t = \frac{dR / R}{\varepsilon_t}$$

• The transverse sensitivity effects are usually neglected in the strain measurements.

•To define the strain on a surface, it is necessary to specify two orthogonal linear strains ε_x and ε_y, and a third strain called the shear strain, γ_{xy}, the change in angle between two originally orthogonal lines when the solid is strained.

•These strains can be determined by three suitably placed strain gages in an arrangement called a *strain rosette*.

Measuring Strain (Strain Gages)

- Two common arrangements of the three strain gages are:
    - Rectangular rosette
    - Equiangular rosette
- In rectangular rosette, the gages are placed at angles of 0, 45 and 90 degrees.
- In equiangular rosette, the gages are arranged at 0, 60 and 120 degrees.

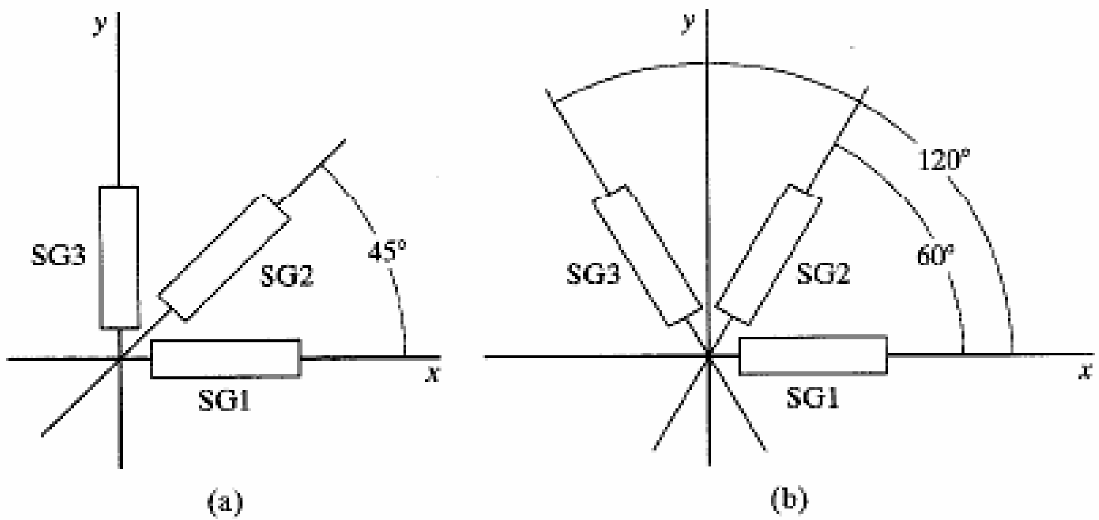


FIGURE 8.3

Orientation of strain gages in common rosettes: (a) rectangular; (b) equiangular.

Measuring Strain (Strain Gages)

- Each of these gages measure the linear strain in the direction of the axis of the gage.
- The rosette provides measurements of ε_{θ_1} , ε_{θ_2} and ε_{θ_3} . The values of ε_x, ε_y and γ_{xy} are obtained as follows.
- For rectangular rosette,

$$\varepsilon_x = \varepsilon_{0^o}$$

$$\varepsilon_y = \varepsilon_{90^o}$$

$$\gamma_{xy} = 2\varepsilon_{45^o} - \left(\varepsilon_{0^o} + \varepsilon_{90^o}\right)$$

- For equiangular rosette,

$$\varepsilon_x = \varepsilon_{0^o}$$

$$\varepsilon_y = \frac{2\varepsilon_{60^o} + 2\varepsilon_{120^o} - \varepsilon_{0^o}}{3}$$

$$\gamma_{xy} = \frac{2}{\sqrt{3}}\left(\varepsilon_{60^o} - \varepsilon_{120^o}\right)$$

Measuring Displacement

•Potentiometers are very common devices used to measure displacement. A linear potentiometer is used for linear measurements and an angular potentiometer is used for angular measurements.

•The linear potentiometer is a device in which the resistance varies as a function of the position of a slider, shown below.

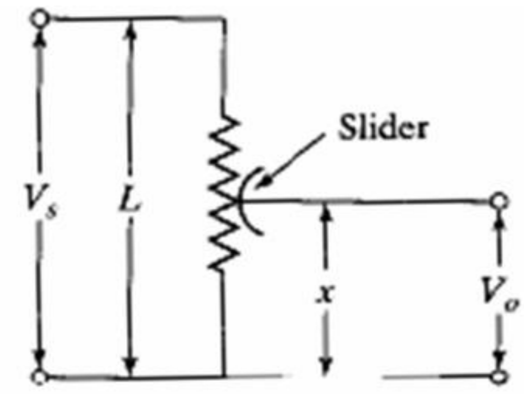


FIGURE 8.9
Linear potentiometer.

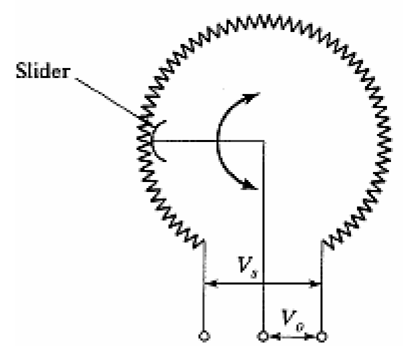


FIGURE 8.10
Angular potentiometer.

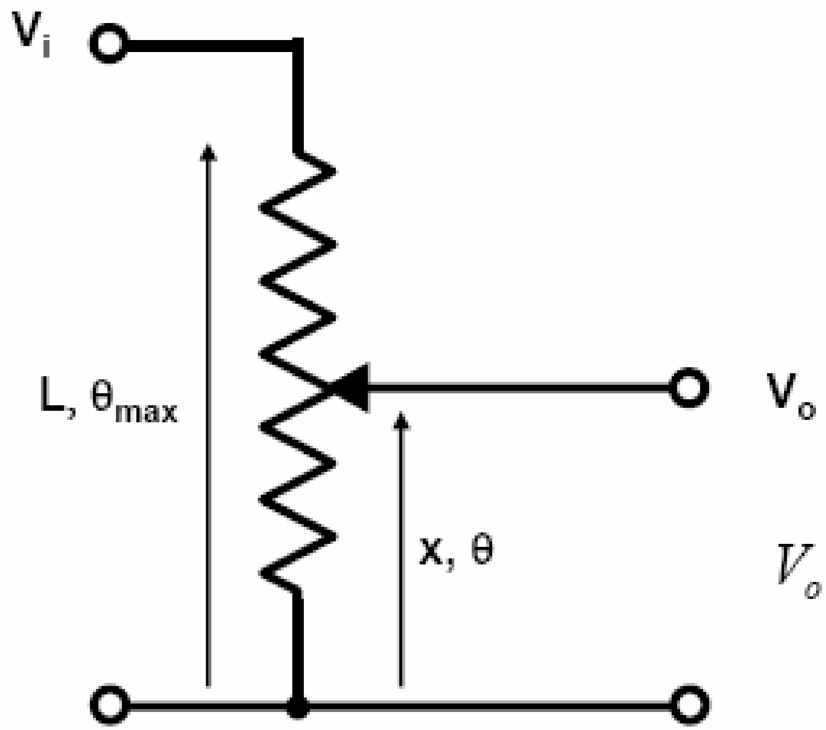
•With the supply voltage (*Vs*), the output voltage (*Vo*) will vary between zero and the supply voltage.

•For linear potentiometer, the output is a simple linear function of the slider position. That is

$$V_o = \frac{x}{L} V_s$$

Measuring Displacement

- Potentiometer



Issues:
- **Noise**
- **Linearity**
- **Resolution**
- **Measurement range**
- **Lifetime**
- **Discrete steps**

$$V_o = \frac{\theta}{\theta_{\max}} V_i$$

$$V_o = \frac{x}{L} V_i$$

•It should be noted that the device measuring *Vo* must have a high impedance to maintain a linear response and avoid loading error.

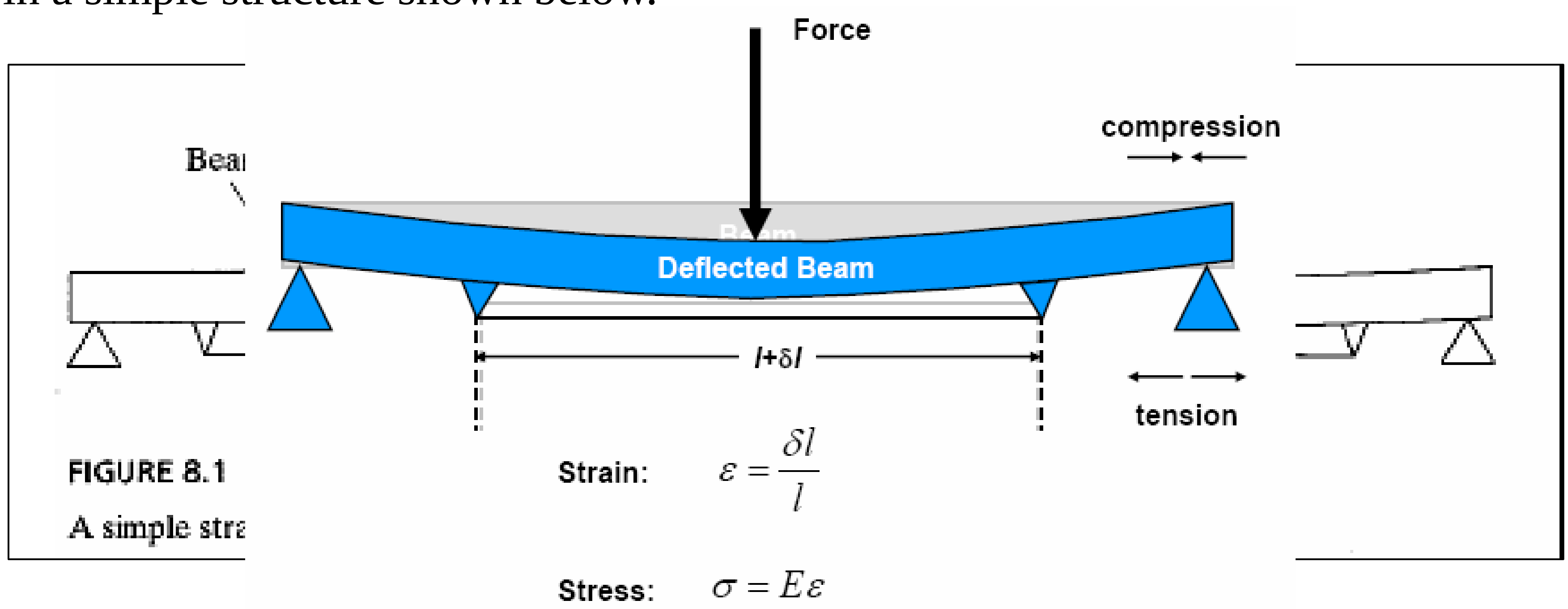
•Linear potentiometers can be used to measure displacements as small as 0.1 to 0.2 in. (2.5 to 5 mm) up to displacements of more than 1 ft.

Measuring Strain (Strain Gages)

•The electrical resistance strain gage is an extremely common device used to measure strain in structures and also as a sensing element in a wide variety of transducers, including those used to measure force, acceleration and pressure.

•Electrical-resistance strain gages and associated signal conditioners are simple, inexpensive and quite reliable.

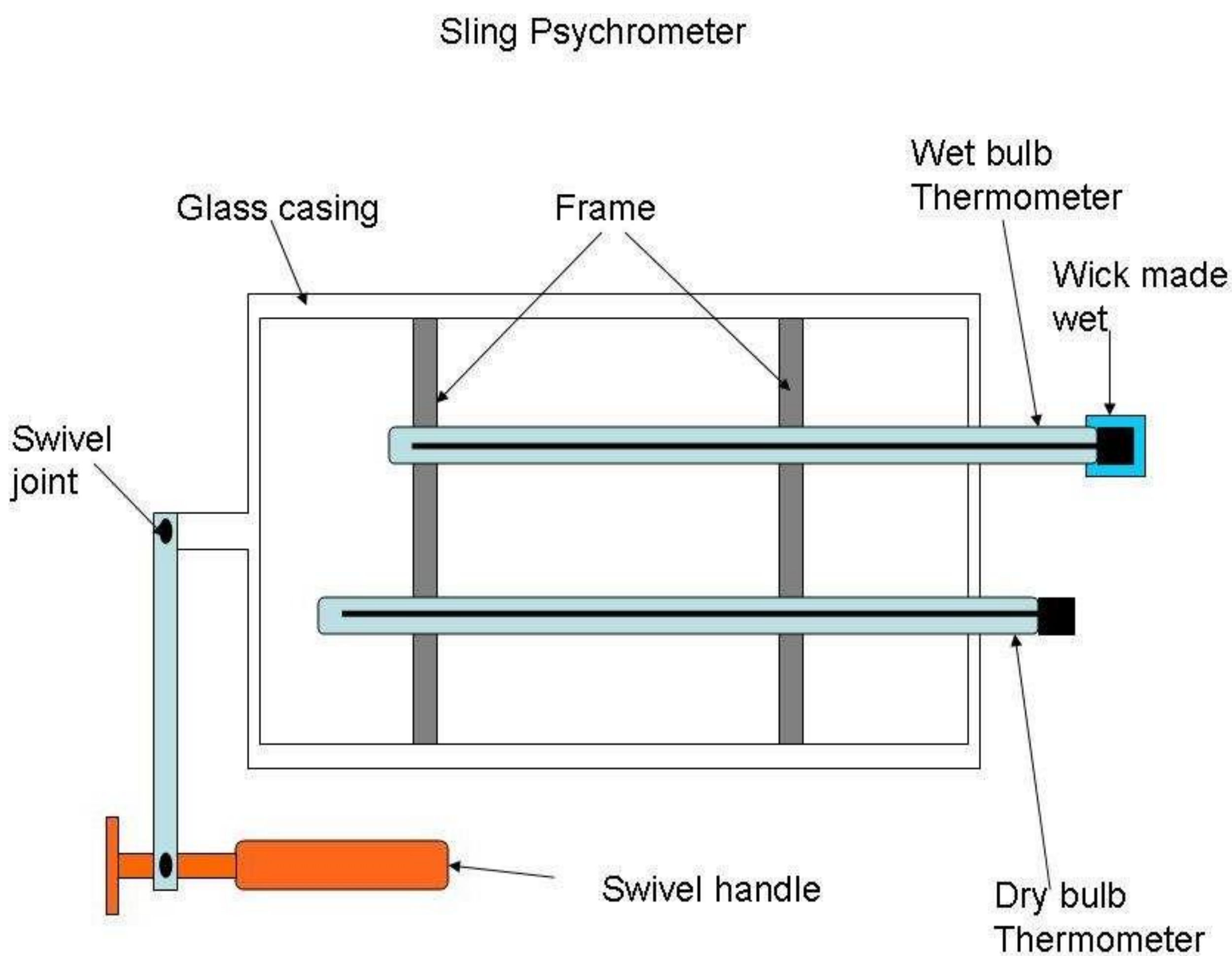
•To understand the function of a strain gage, consider the measurement of strain in a simple structure shown below.



Sling Pyschrometer :-

- A sling psychrometer, which uses thermometers attached to a handle or length of rope and spun in the air for about one minute, is sometimes used for field measurements, but is being replaced by more convenient electronic sensors. A whirling psychrometer uses the same principle, but the two thermometers are fitted into a device that resembles a ratchet or football rattle.

Sling Psychrometer



Operation

- In order to measure the dry bulb and wet bulb temperature, the Psychrometer frame – glass covering – thermometer arrangement is rotated at 5 m/s to 10 m/s to get the necessary air motion. The thermometer whose bulb is bare contacts the air indicates the dry bulb temperature. At the same time, the thermometer whose bulb is covered with the wet wick comes in contact with the air and when this pass on the wet wick present on the bulb of the thermometer, the moisture present in the wick starts evaporating and a cooling effect is produced at bulb. Now the temperature indicated by the thermometer is the wet bulb thermometer which will naturally be lesser than the dry bulb temperature.

  Precautions :-

- If the Psychrometer is rotated for a short period, then the wet bulb temperature recorded will not be proper. If the Psychrometer is rotated for a longer period, the wick will get dried soon and the wet bulb temperature will not be at its minimum value.

Application

- ✓ It is used for checking humidity level in air- conditioned rooms and installations.
- ✓ It is used to set and check hair hygrometer.
- ✓ It is used in the measurement range of 0 to 100% RH.
- ✓ It is used for measuring wet bulb temperature between 0’C to 180’C.

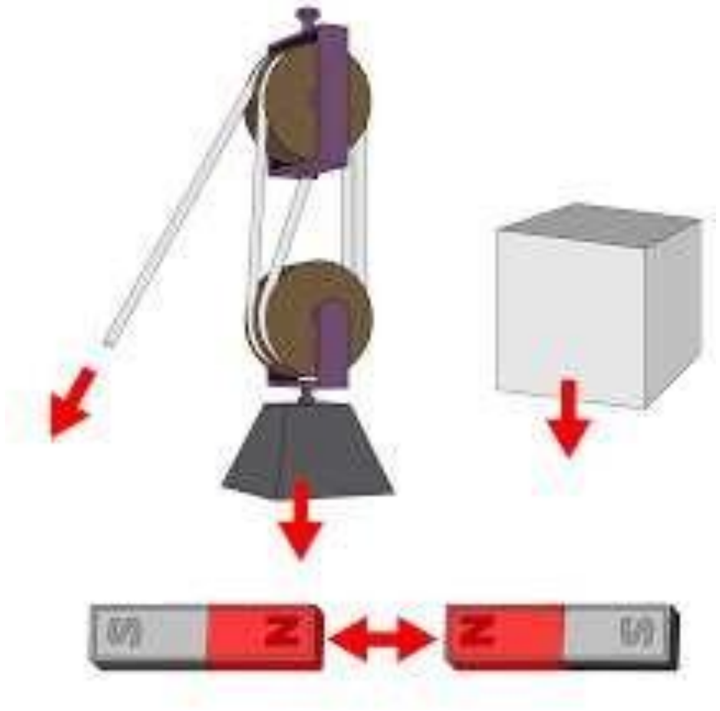
MEASUREMENT OF FORCE, TORQUE AND POWER

UNIT-V

Measurement of force

- Force can be said as any interaction of the object, such that it changes the objects motions or causes the change in velocity.

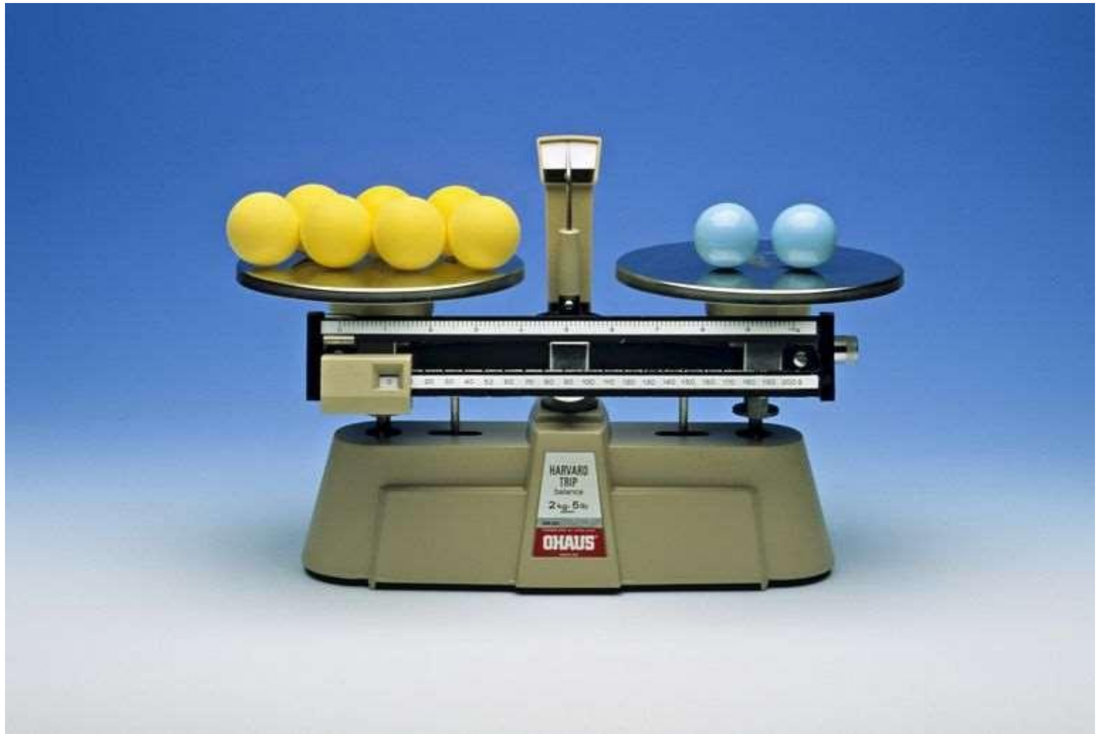
- In other words if the force is unopposed it will change the velocity of the body.



The measurement of Force

- The forces can be measured in many ways as follows

1. Direct methods.
2. Indirect methods.



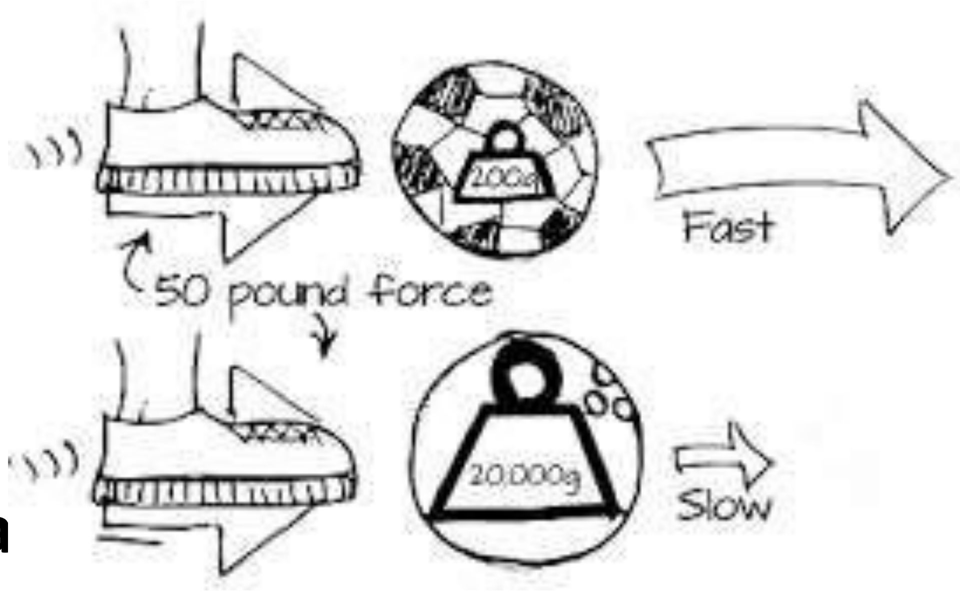
1. **Direct method-It involves a direct companion with known as gravitational force on the standard mass** for Example Balancing mass.

The measurement of Force

- The following methods are used to measure the forces

1. Direct methods
2. Indirect methods

2.Indirect methods- It **involves the measurement of the effects of force on a body such as acceleration of a body known mass subjected to force.**

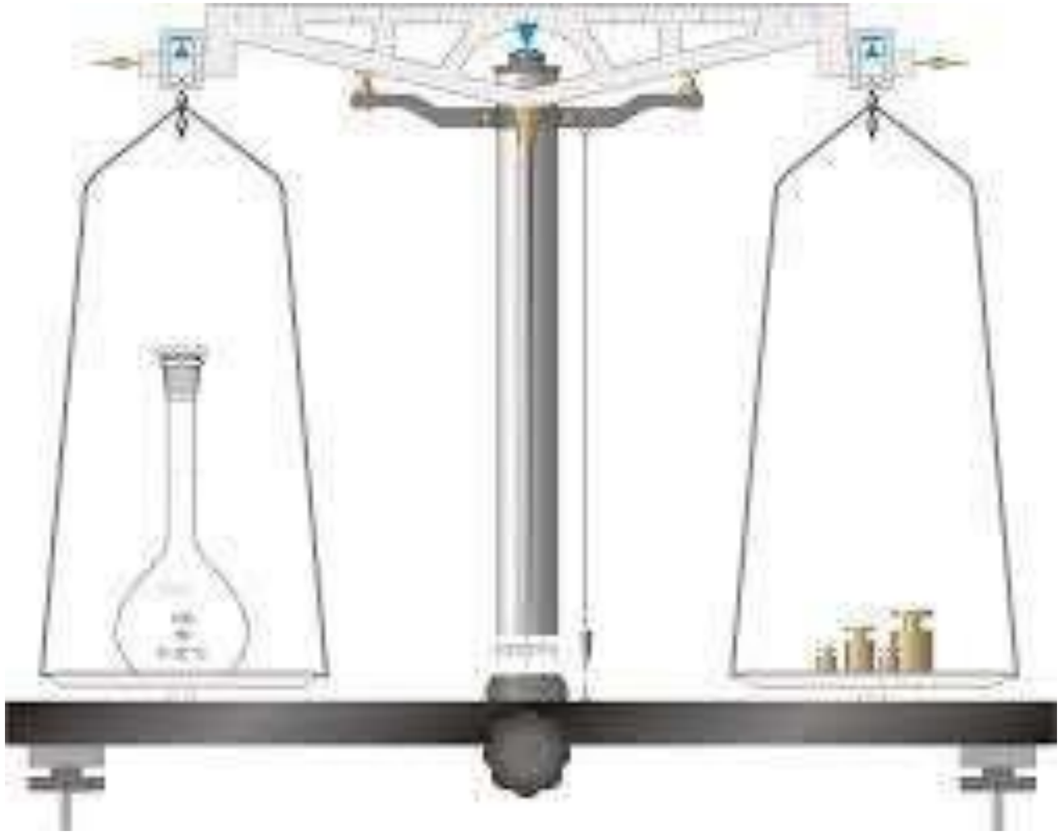


Direct measurement of force measurement

Equal Arm-

It is most simple force measuring system, it basic principle is based **on the moment of comparsion.** This system consist of beam pivoted on a **<u>knife edge of fulcrum placed exactly at the centre of the beam.</u>**

When the a **unknown force is applied at one end of the beam, the mass on the other end of the beam balances the unknown forces.**



Analytical Balance

- Analytical means analyzing or logical reason.
- With Figure shown there are two pivoted arms at point ‘O’ and two forces are held at the two points as W1 and W2, taking W2 as unknown force,
- The unbalance in the weight will be indicated by the arm in certain angular distance.

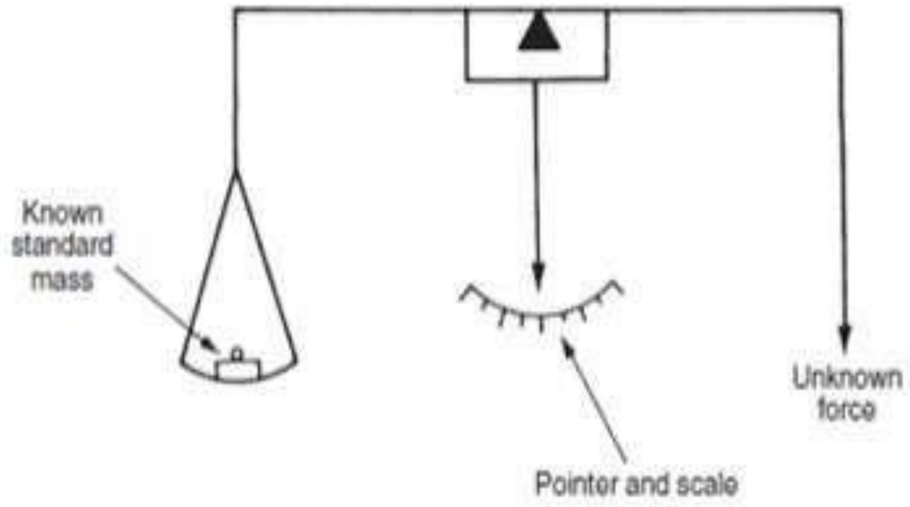
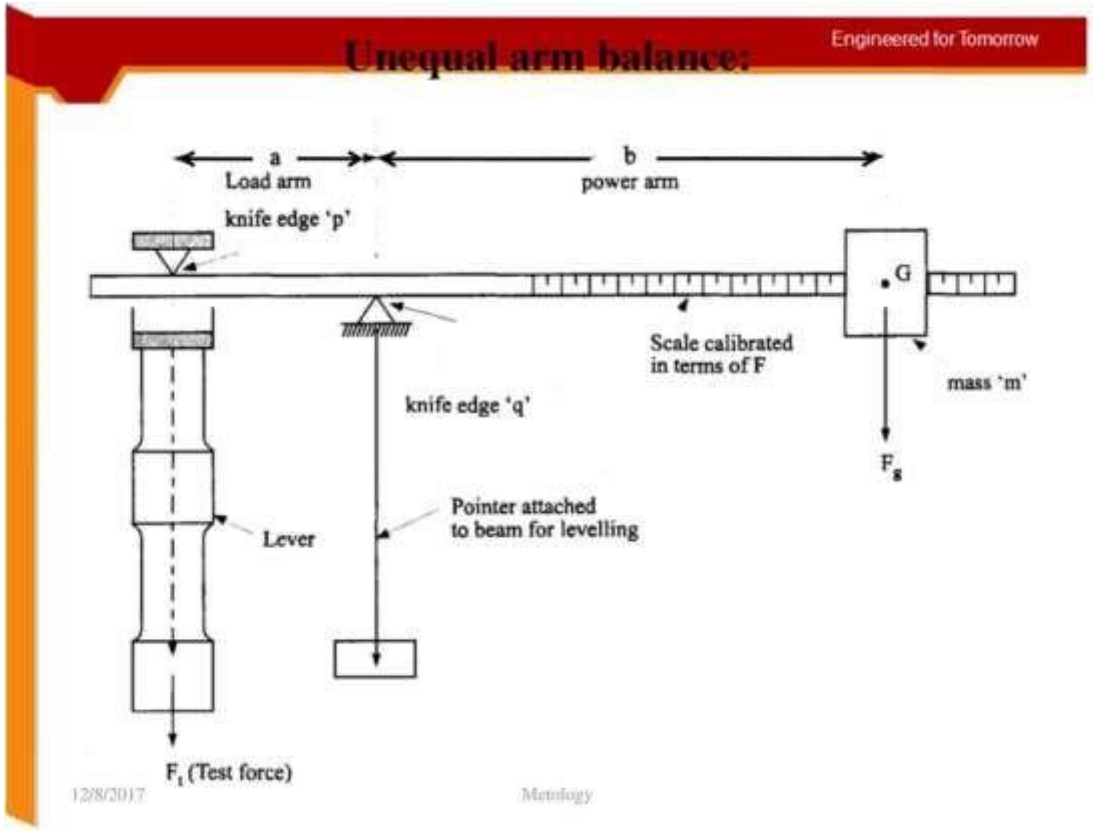


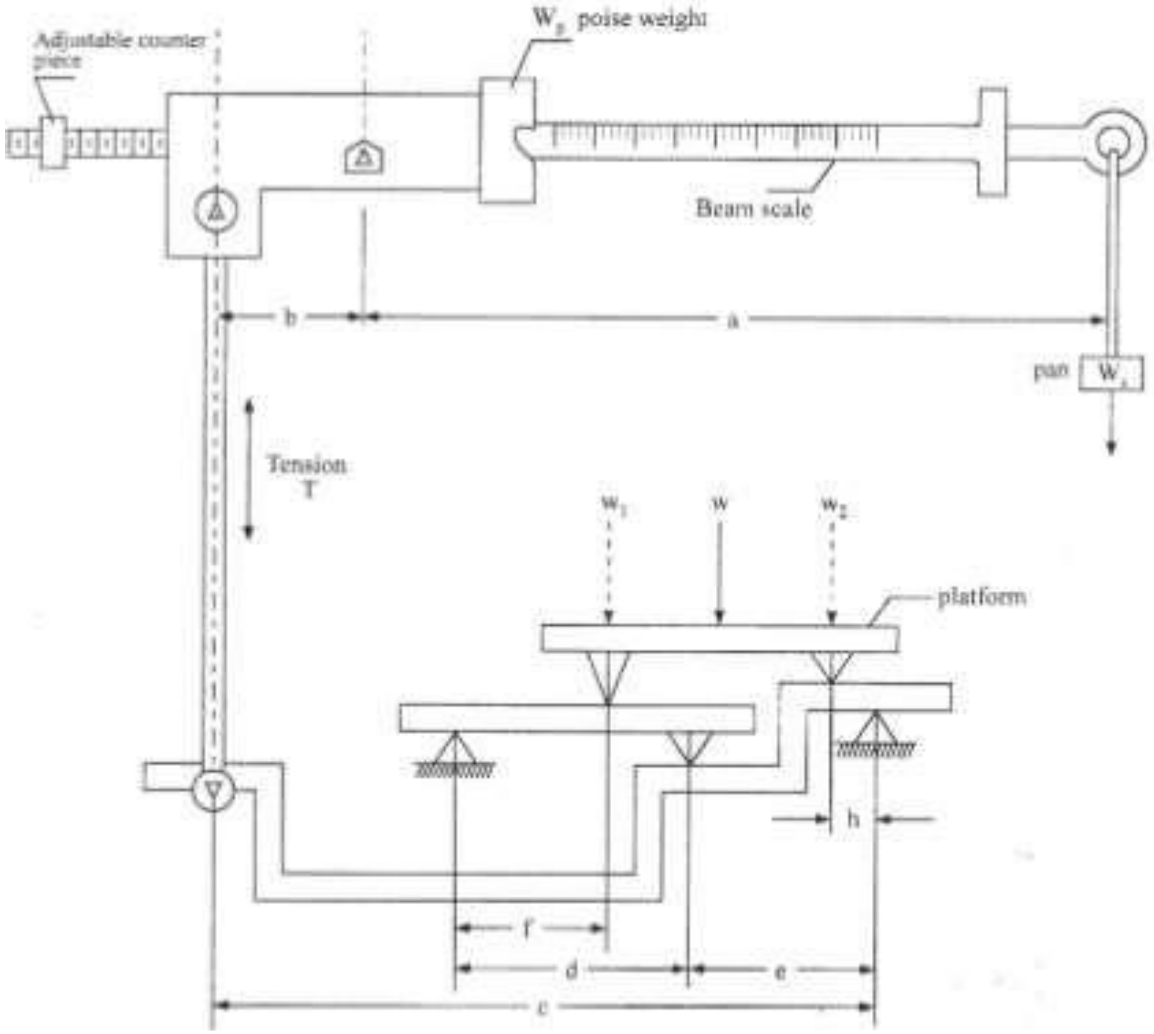
Fig 5.1 Equal Arm Balance

Unequal Arm balance

- Unequal Arm is used to measure the heavier weight with the help of lighter weights. **<u>It uses two arms out of which one is called as load arm, and other is power arm</u>**.
- Load arm is where the load is applied and where as the power arm is used to apply the counter weights to balance in equilibrium.



Platform balance
(Multiple lever system)



Pendulum scale weight

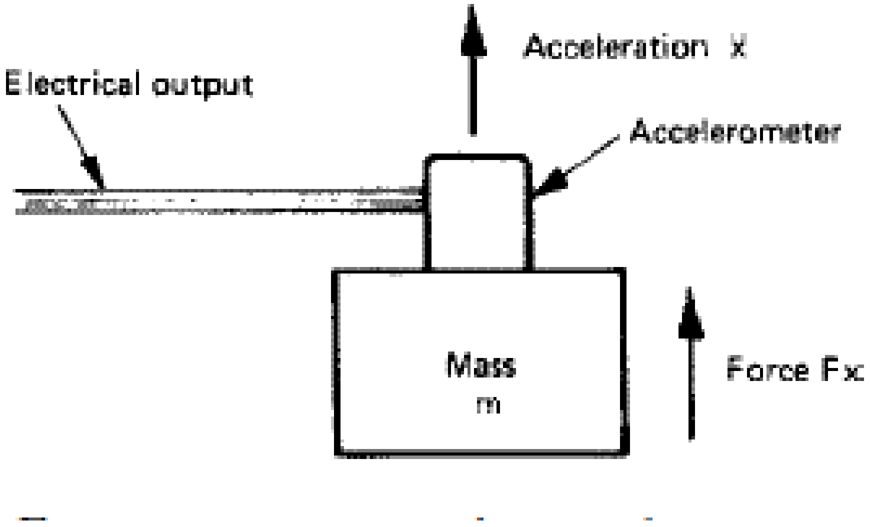
- The input is direct force proportional to the weight. The input is transmitted with the suitable agency and applied to the load rod.
- As the load is applied the sectors rotate about the pivot moving the counter weights outwards .

Indirect methods of Force measurement

- Accelerometer-

A force will make a body to accelerate. By measuring the acceleration, the force may be determined from the equation

F=m.a

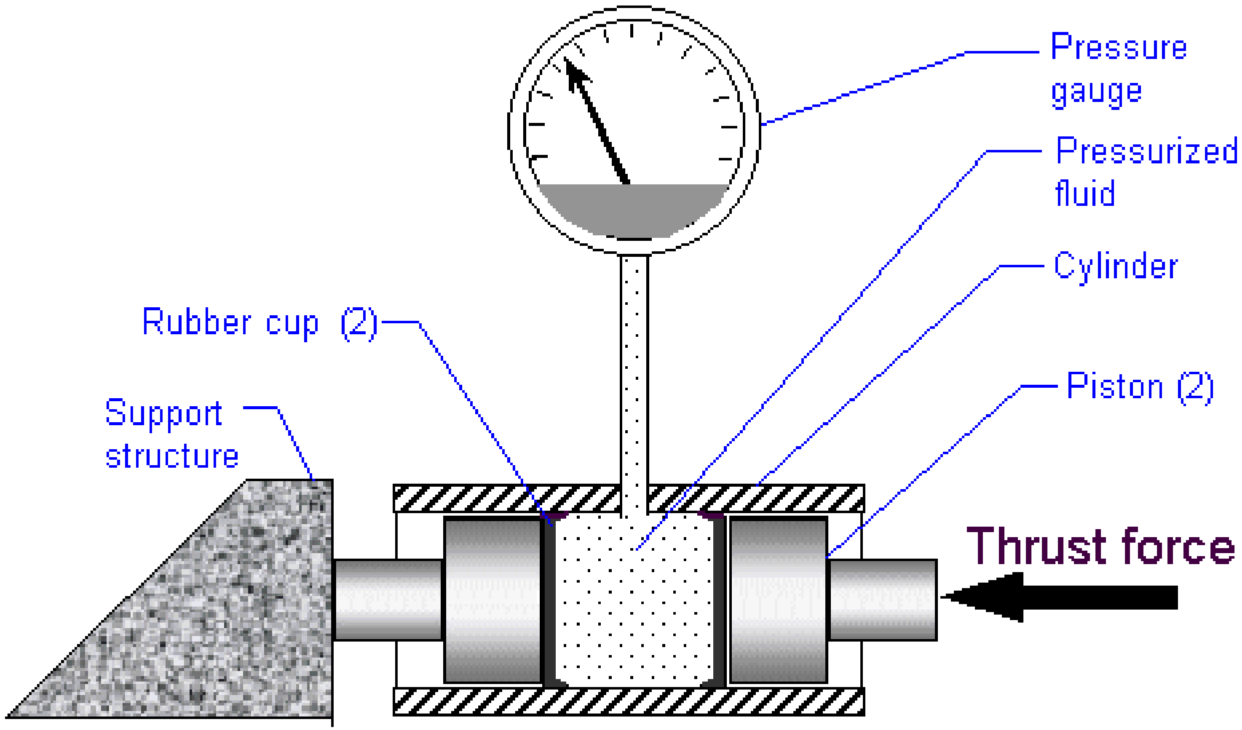


Load cell

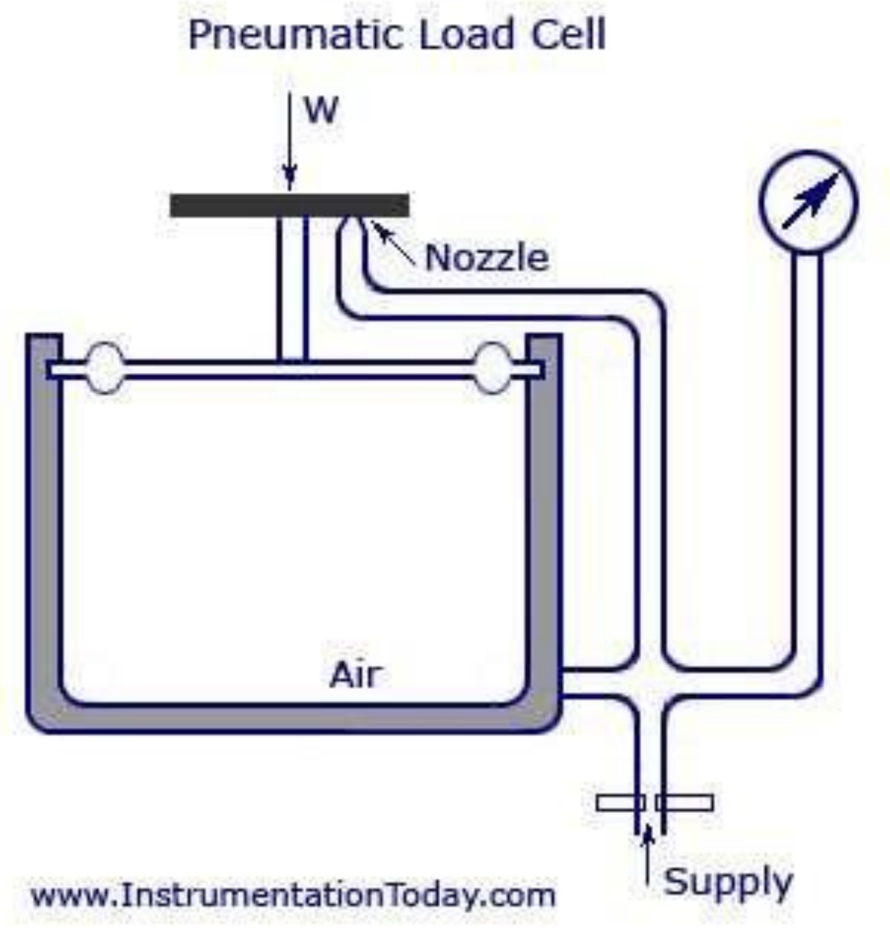
- Load cell is a electromechanical transducer that convert the loads/forces acting on it into an analog electrical signals. The major drawback is the need to minimize the friction.
- Load cell provides accurate measurement of compressive and tensile load/forces.
- Types of load cell.

1. Hydraulic load cell.
2. Pneumatic load cell.

Hydraulic Load cell

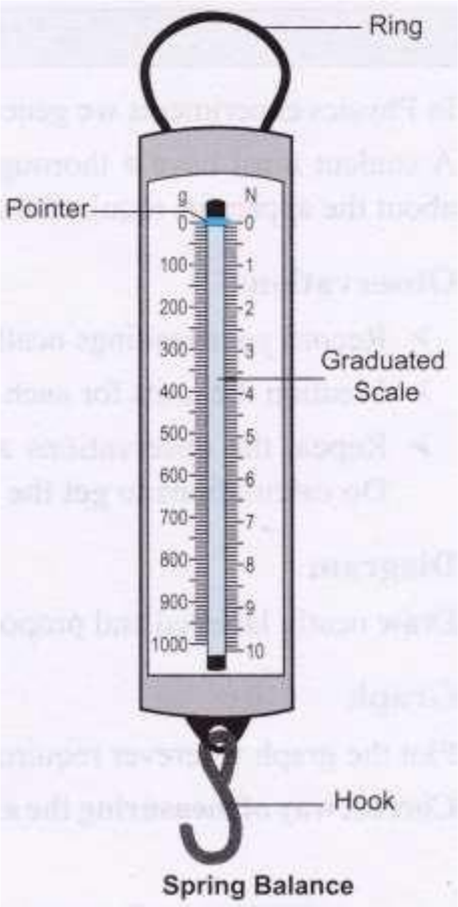


Pneumatic Load cell



Elastic loaded members

- It works with principle of finding the deflection or strain produced in the body to measure the force applied.
- The strain or deflection can be directly measured or in an indirect way by using secondary transducers by converting the displacement into another form of output which naturally electrical in nature.



Proving Rings

- Proving ring is used to measure the displacement caused by the force.
- The displacement transducer is placed on the both ends of the rings.
- With LVDT transformer or Strain gauge the displacement is found out.

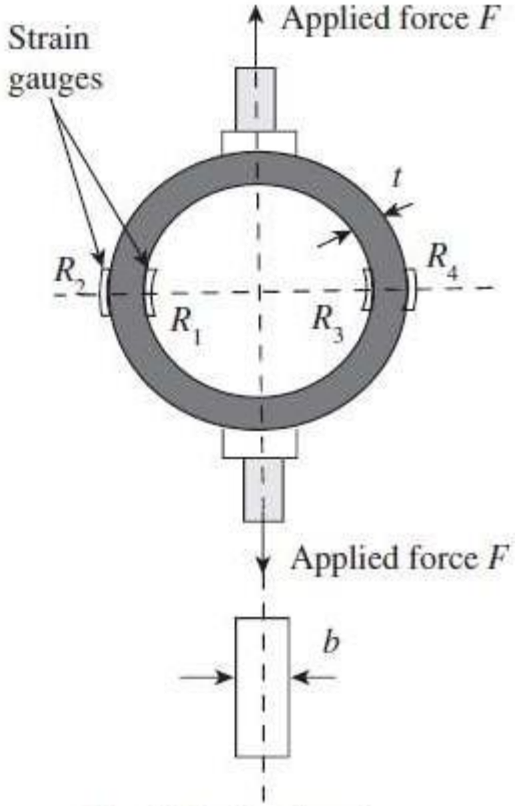


Fig. 14.7 Proving ring

Strain gauge

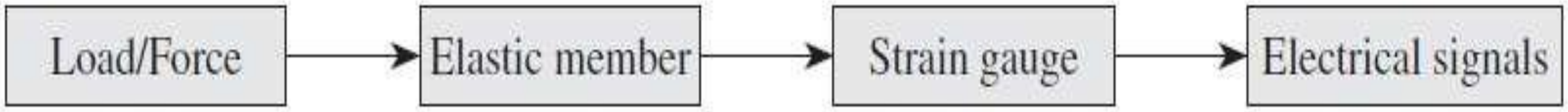


Fig. 14.3 Use of a strain gauge for force determination

Strain Gauge

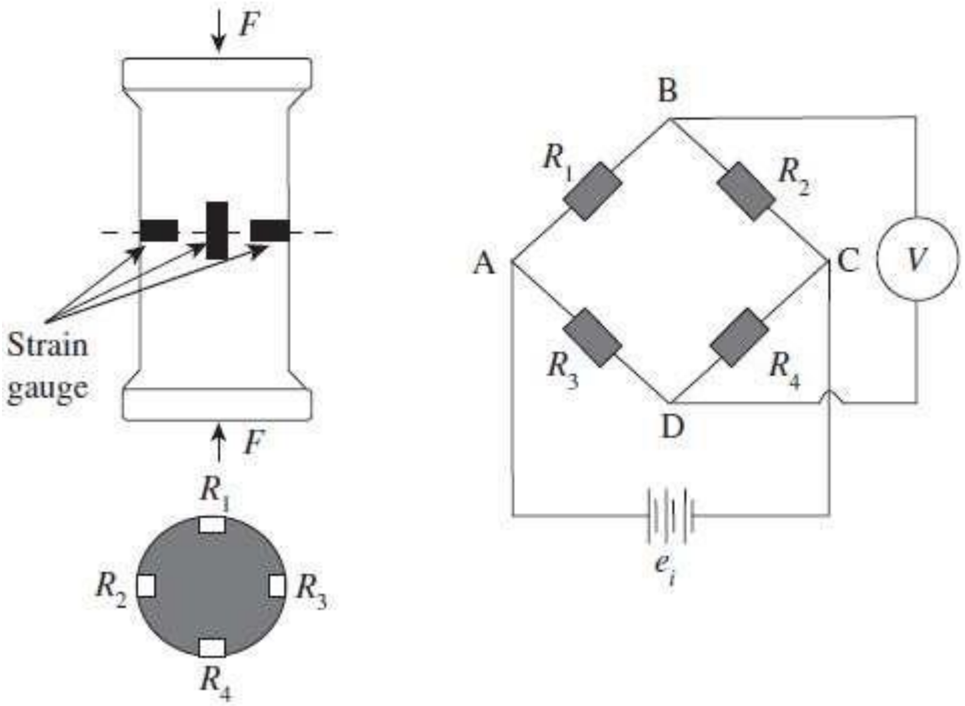
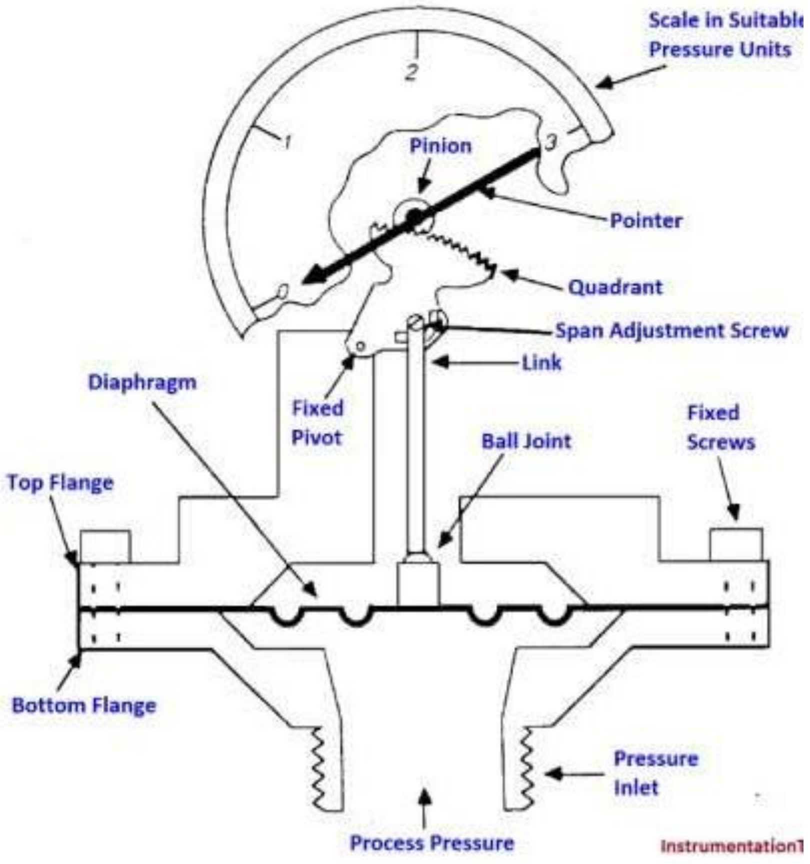


Fig. 14.4 Strain gauge arrangement for a load cell

Diaphragm pressure gauge

- Diaphragm pressure sensor uses the elastic deformation of diaphragm to measure the relative difference between an unknown pressure and reference pressure.
- Diaphragm is made of silicon which is a thin circular membrane



Diaphragm pressure gauge

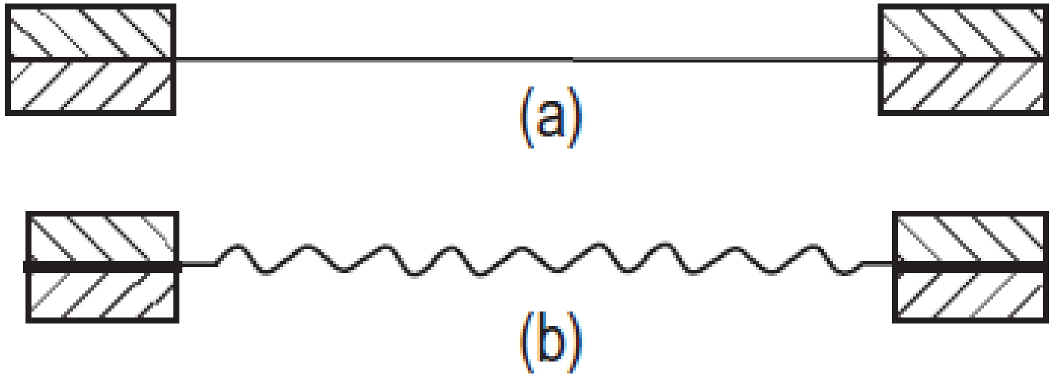


Fig. 16.8 Types of diaphragms (a) Flat diaphragm (b) Corrugated diaphragm

Pressure capsule

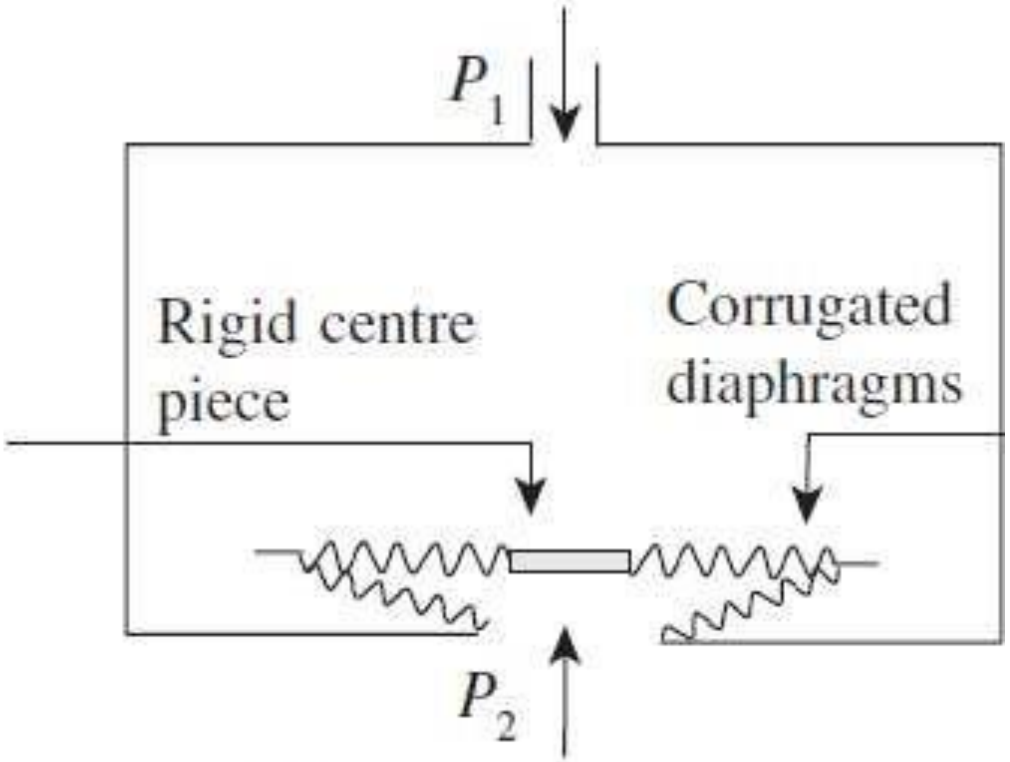


Fig. 16.11 Pressure capsule

Bourdon pressure tube gauge

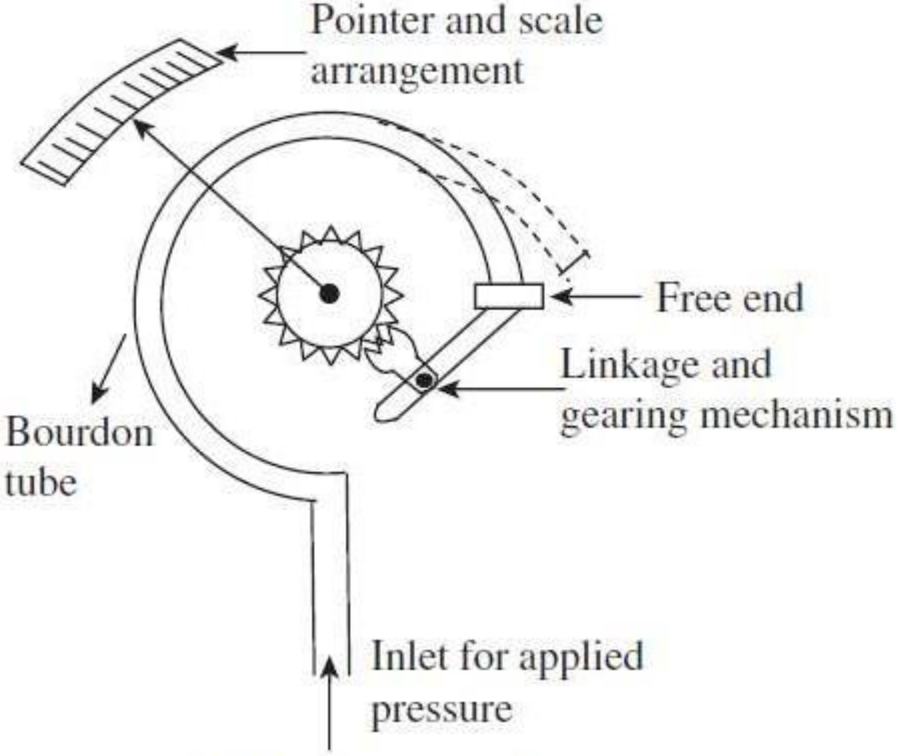
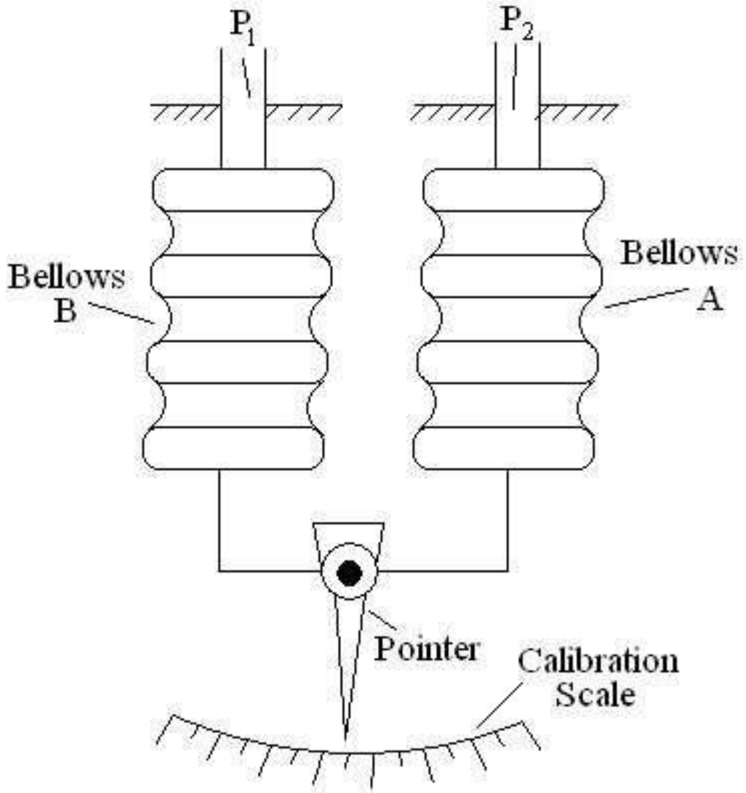


Fig. 16.14 Bourdon tube

Bellows pressure gauge



Bellows

Strain type load gauge

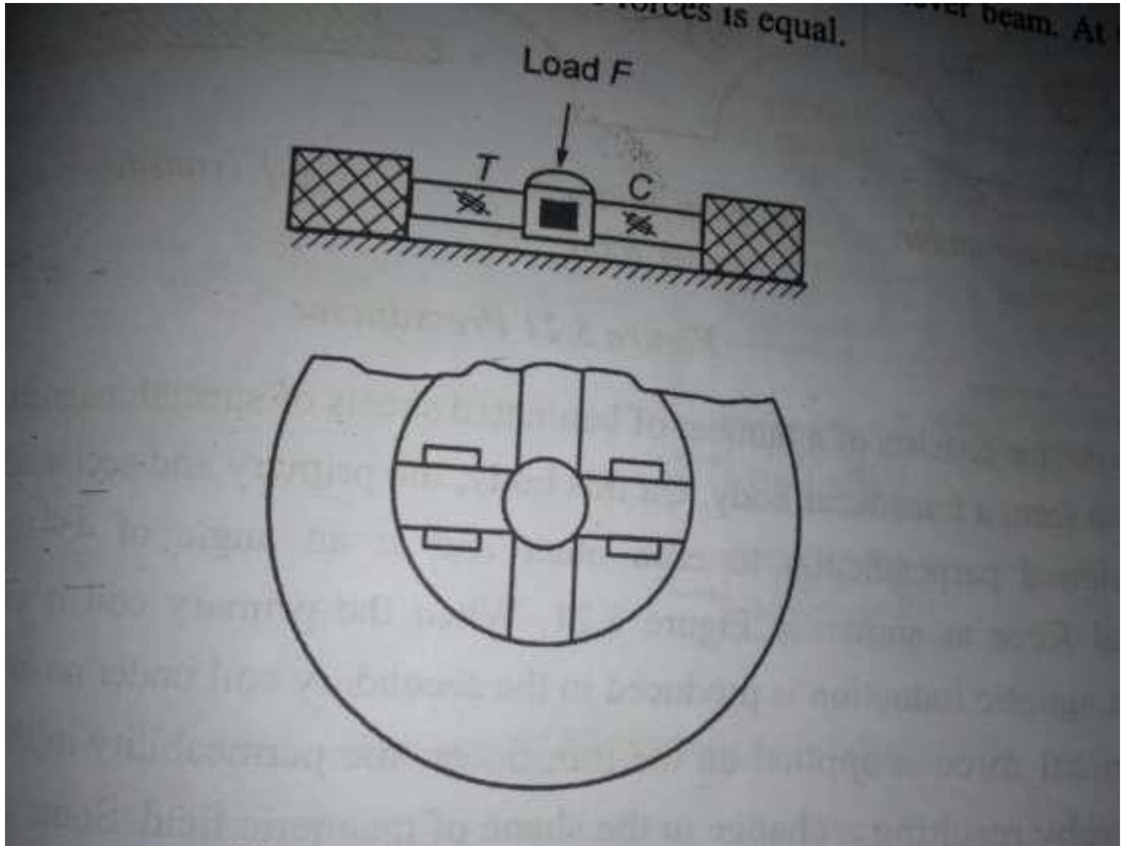


Figure 5.20 Shear type load cell

Electronic Weighing Machine

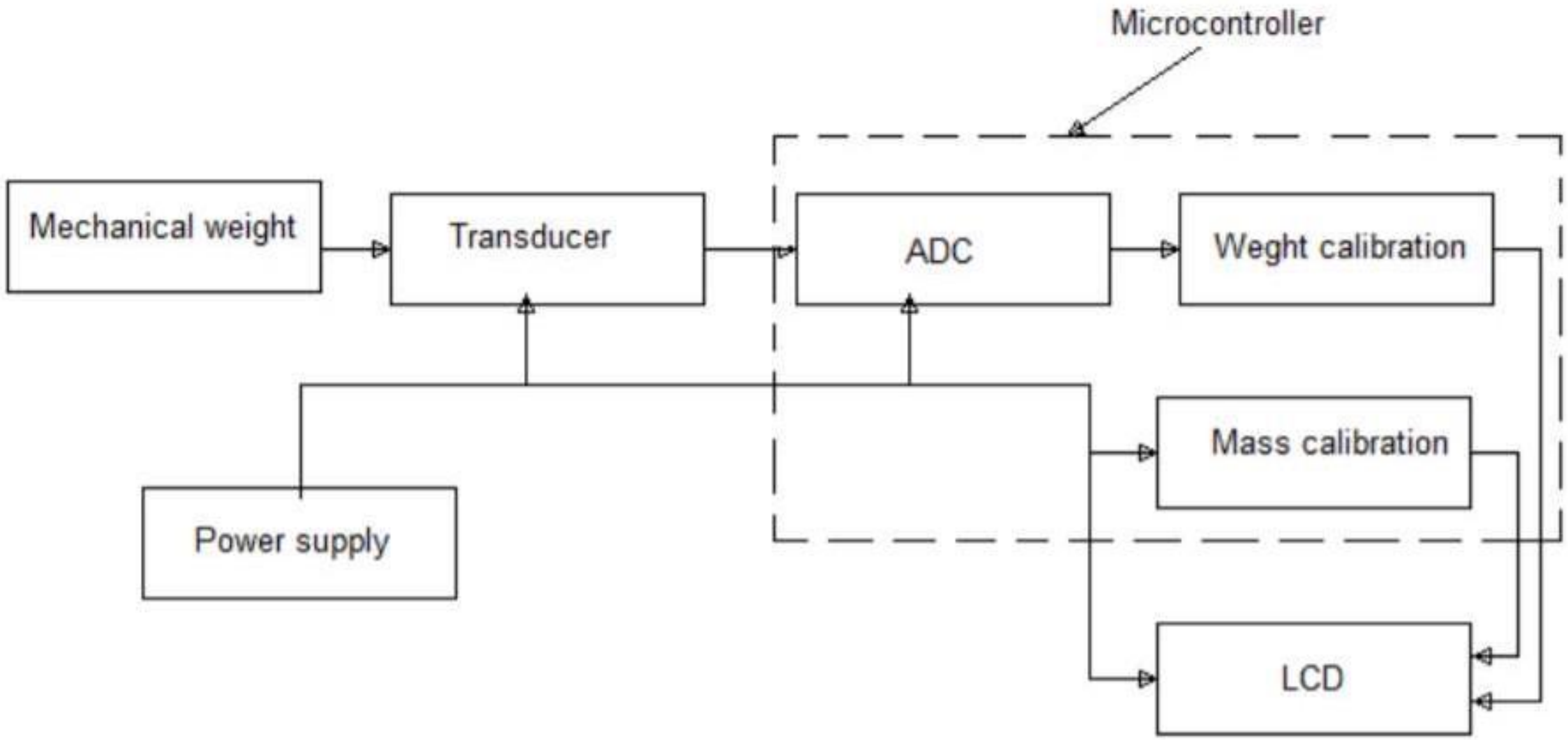


Figure 1: Block diagram of the weighing machine.

Torque measurement

- Torque is the just the rotational force through the distance, it is represented as moment vector force.

Types of Torque measurement devices

1. Prony brake.
2. Torque measurement using the strain gauge.

3.Torque measurement using torsional bar.

i)Optical method.

ii) Capacitive method.

iii)Laser optic method.

Prony brake or absorption dynamometer

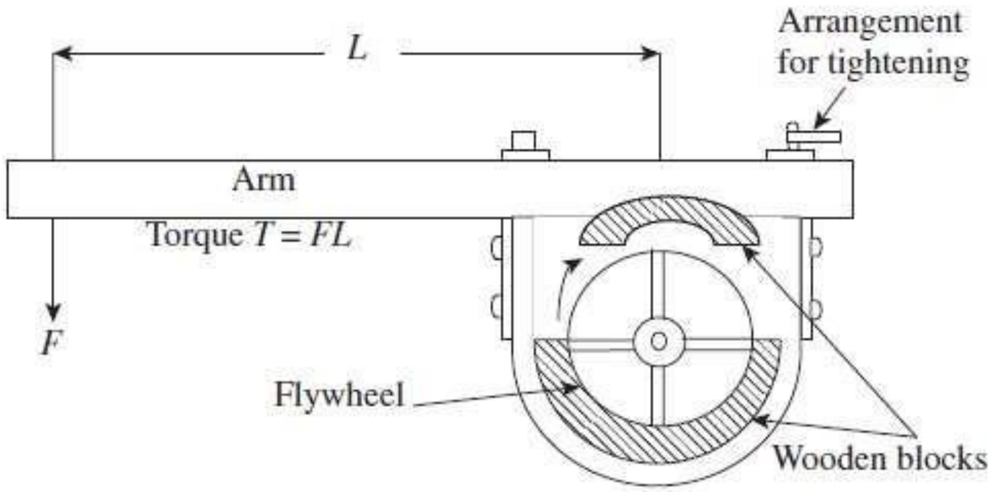
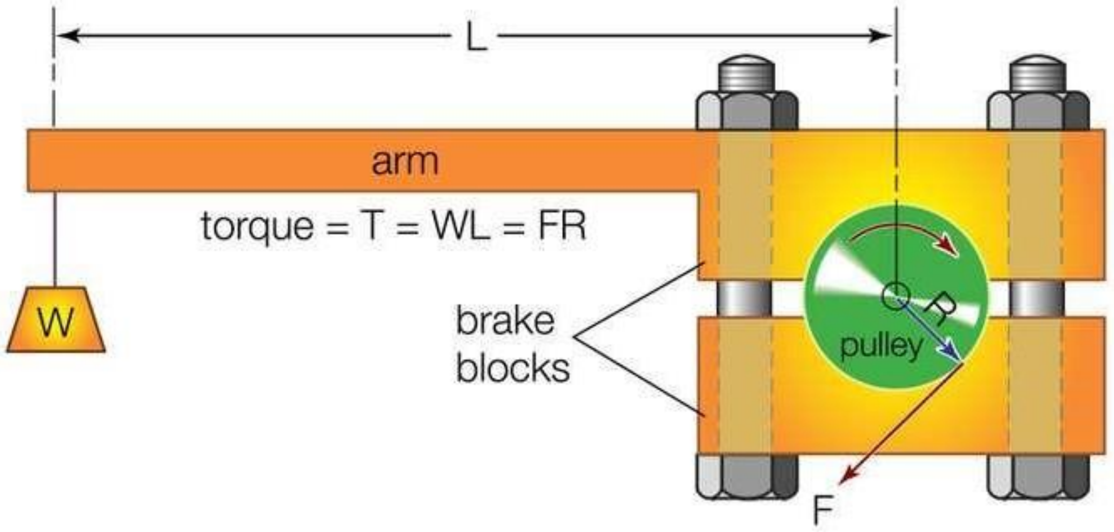


Fig. 14.10 Prony brake dynamometer



Prony brake or absorption dynamometer

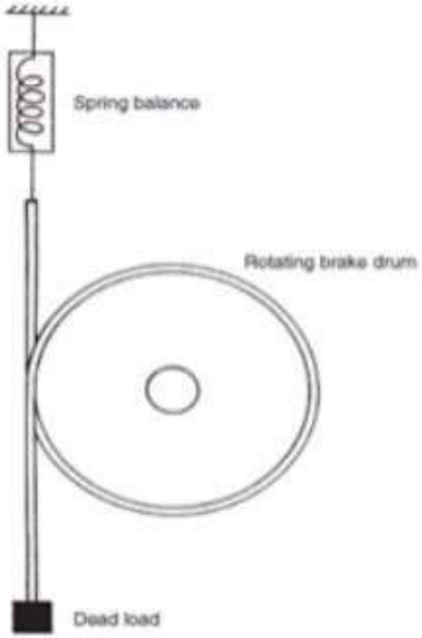
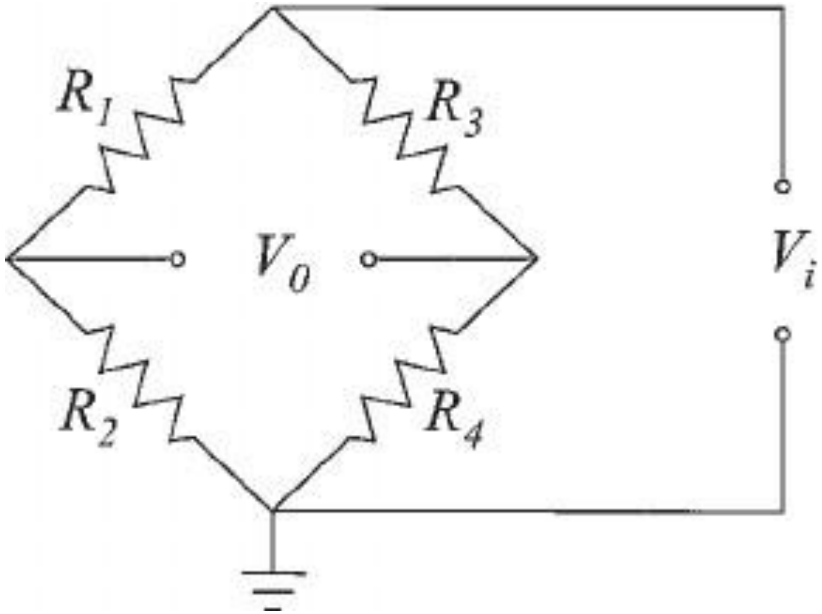
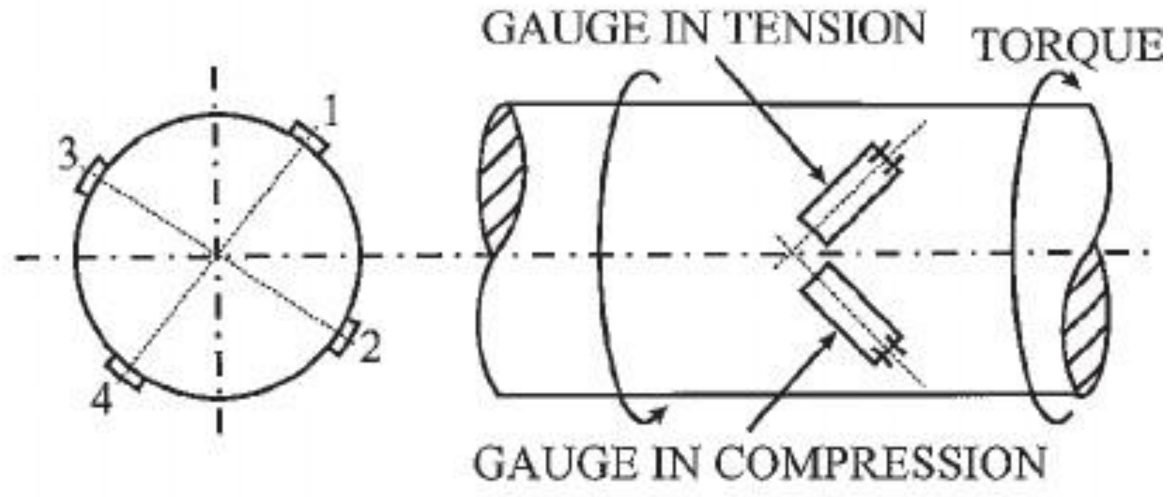


Fig 5.12 Prony Brake

Torque measurement using strain gauge





Torque measurement using torsion bars

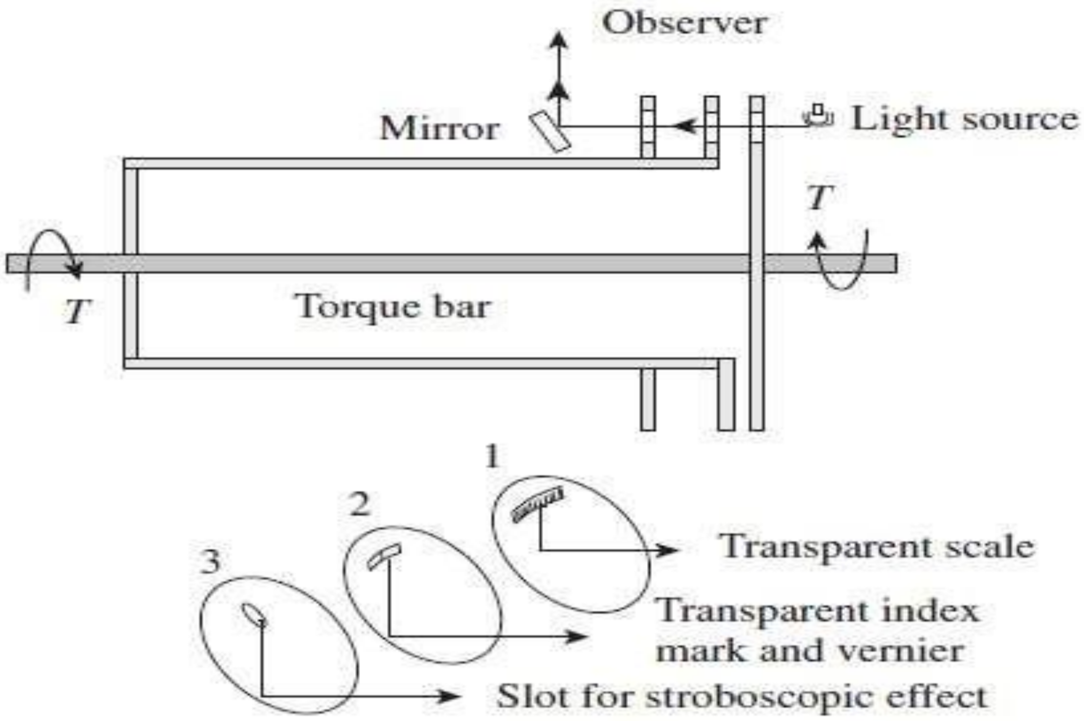
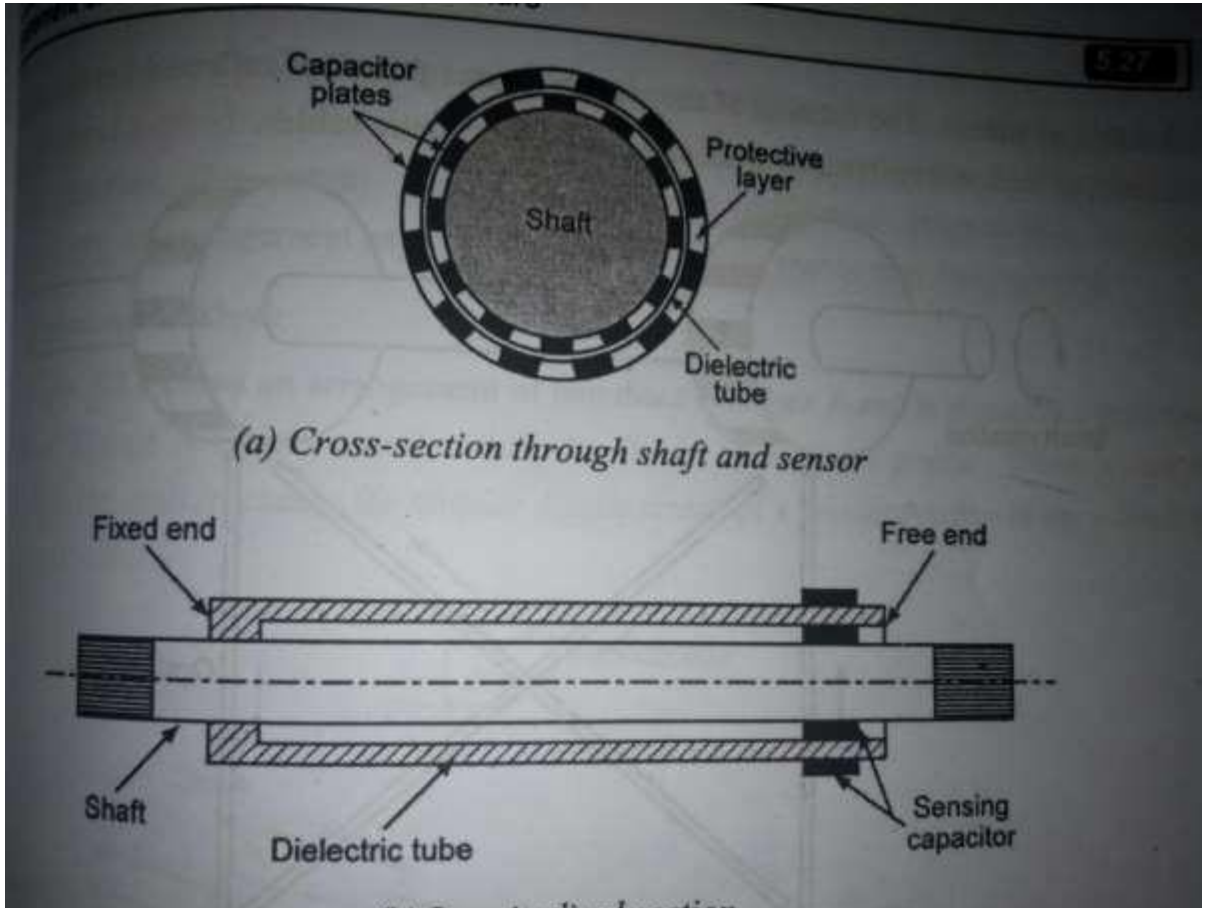


Fig. 14.8 Torsion-bar dynamometer

Capacitive method



(a) Cross-section through shaft and sensor

(b) Longitudinal section

Figure 5.29 Capacitive method

Capacitive method

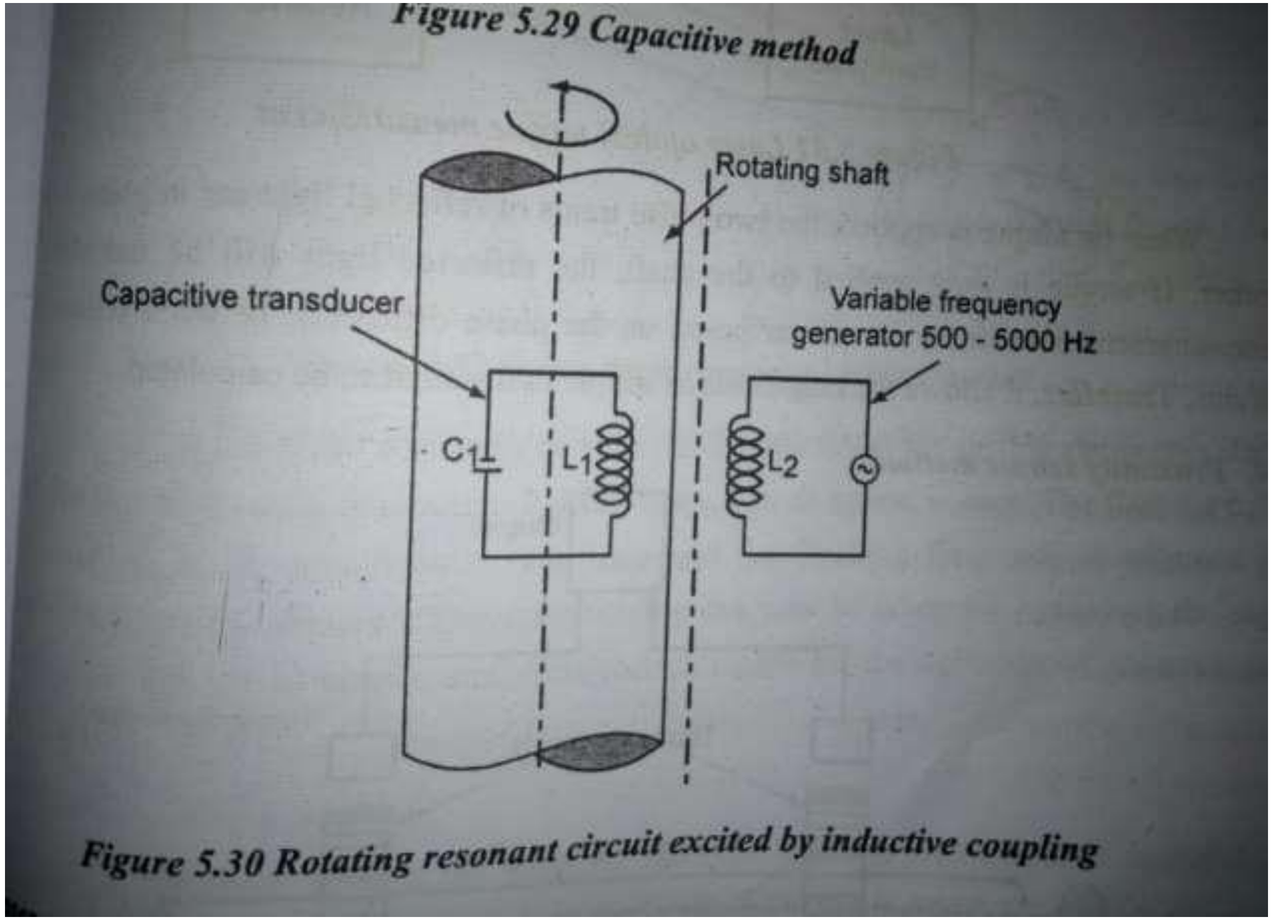


Figure 5.29 Capacitive method

Figure 5.30 Rotating resonant circuit excited by inductive coupling

Laser Optic method

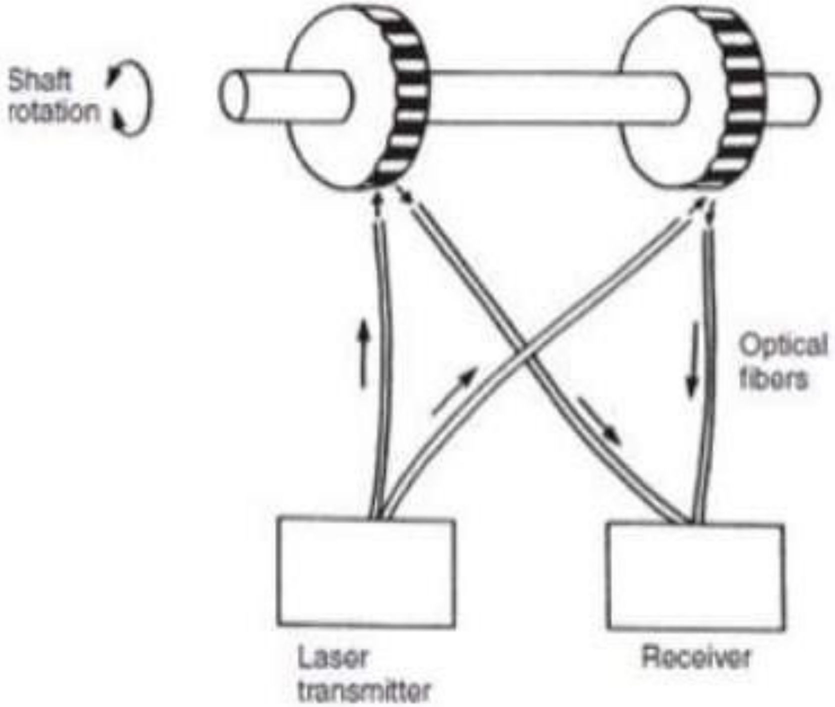


Fig 5.10 Optical Torqu Measurement

Proximity sensor method

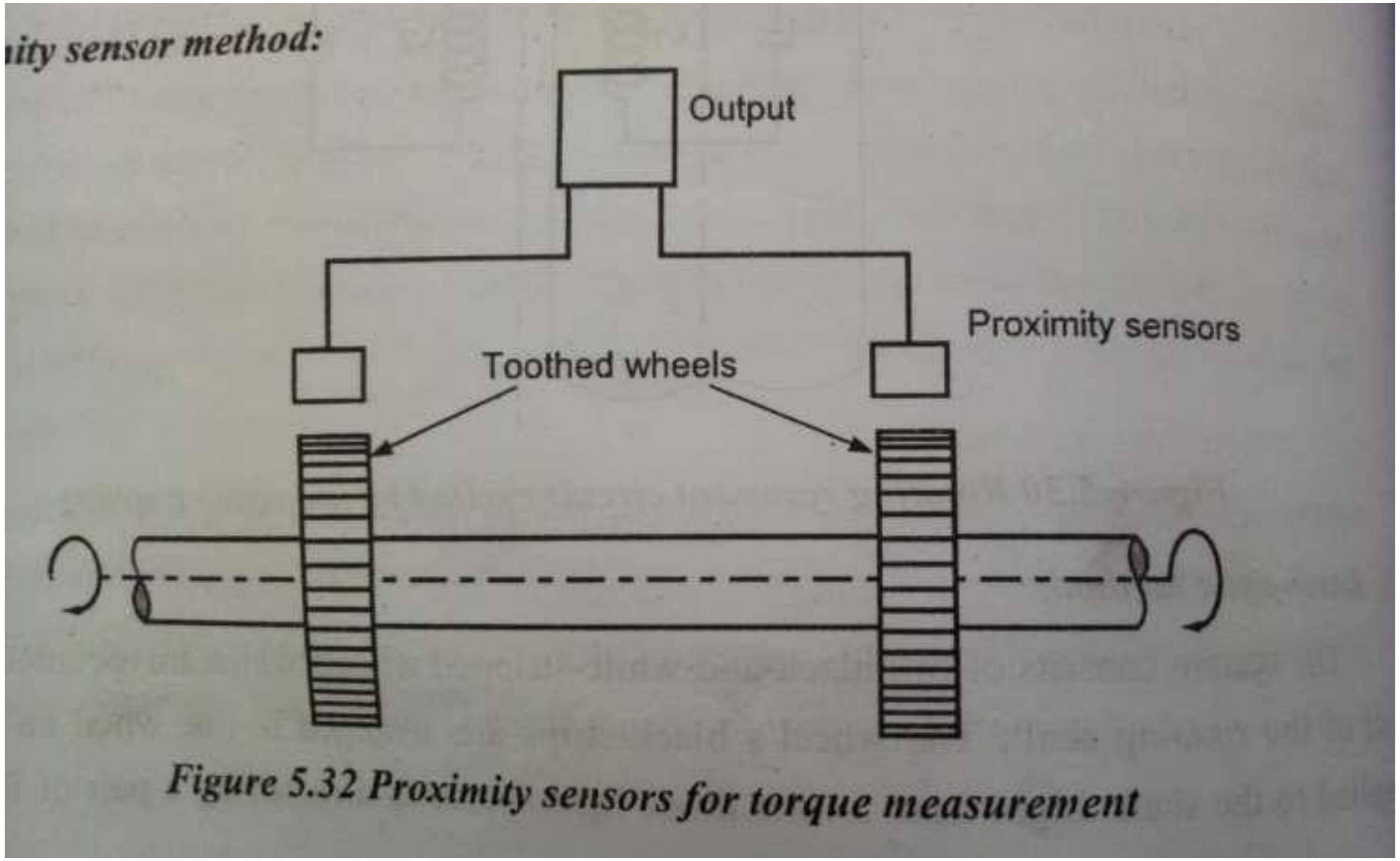


Figure 5.32 Proximity sensors for torque measurement

Surface acoustic wave (SAW) method

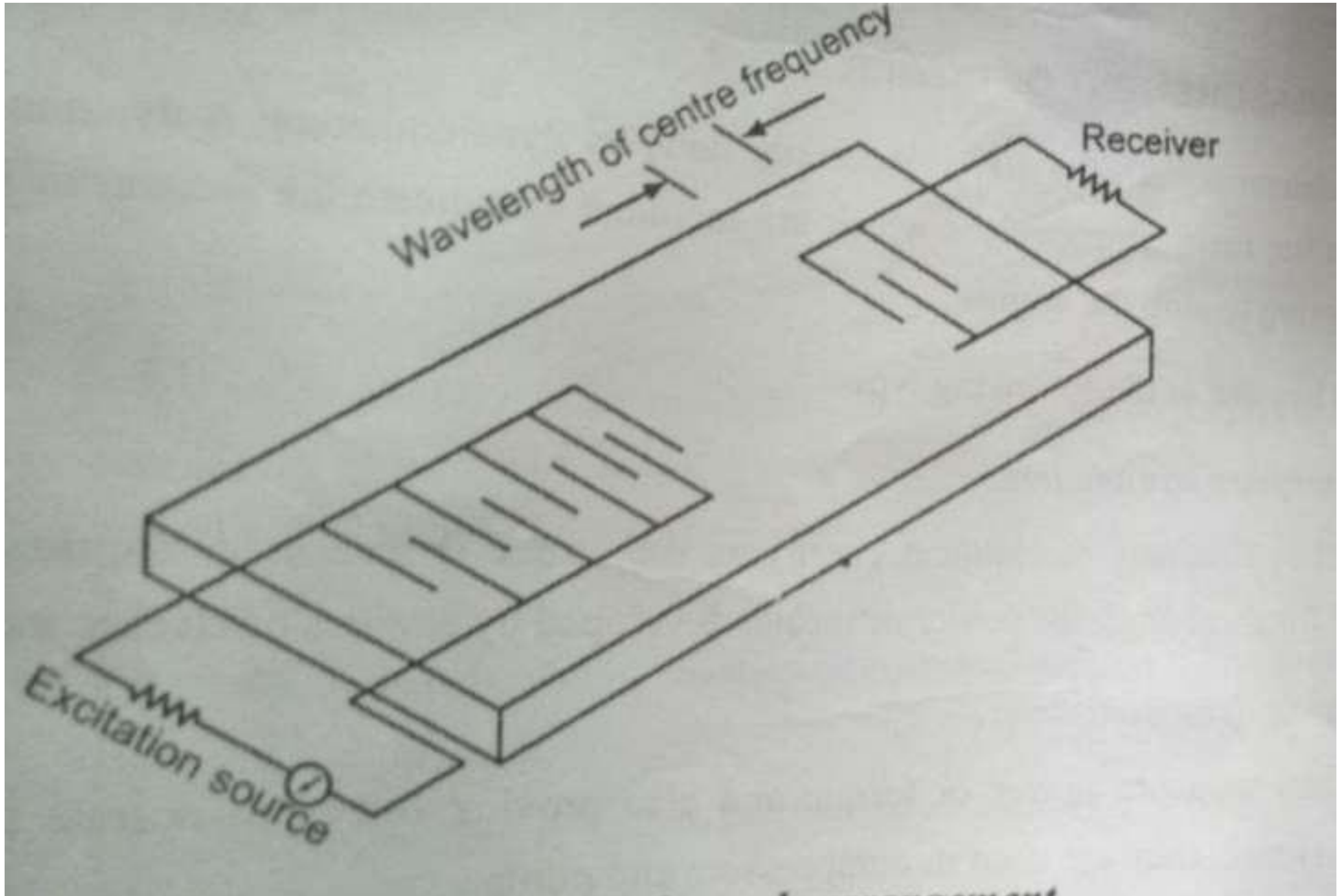


Figure 5.356 SAW electrode arrangement

Surface acoustic wave (SAW) method

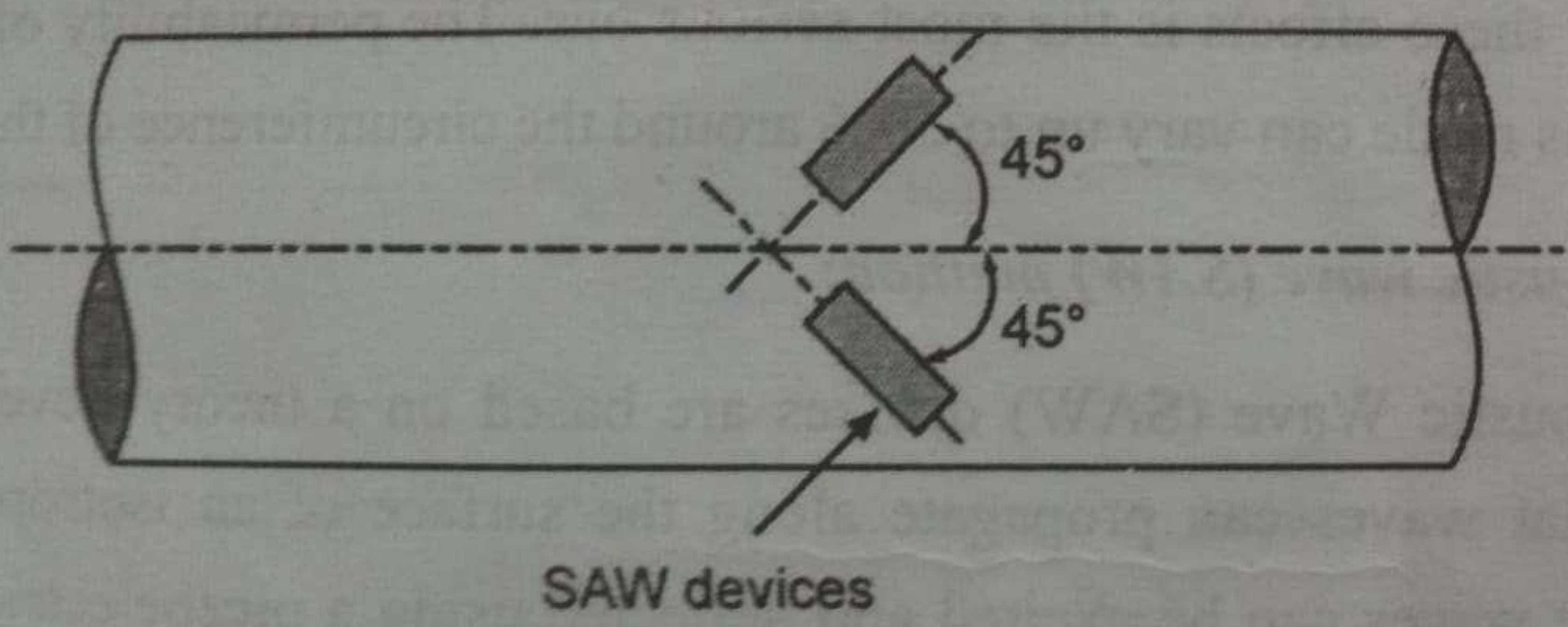


Figure 5.36 SAW transducer for shaft torque measurement

Measurement of Power

- Measurement of power is generally done by the help of dynamometer.
- A dynamometer is brake expect for which it is not measuring device and it will **indicate the magnitude of the force required in attempt to stop the engine.**
- Types of Dynamometer-

1. **Absorption Dynamometer.**
2. **Driving Dynamometer.**
3. **Transmission Dynamometer.**

Type of Dynamometer

- **Absorption dynamometer-**

They **dissipate mechanical energy as the torque is measured**. So they are particularly useful for power measuring the power or torque developed by the engines or electric motor.

- **Driving dynamometer-**

They measure power or torque and also provide energy to operate the device to be tested. Hence they are used in compressor and pumps.

Type of Dynamometer

- **Transmission dynamometer-**

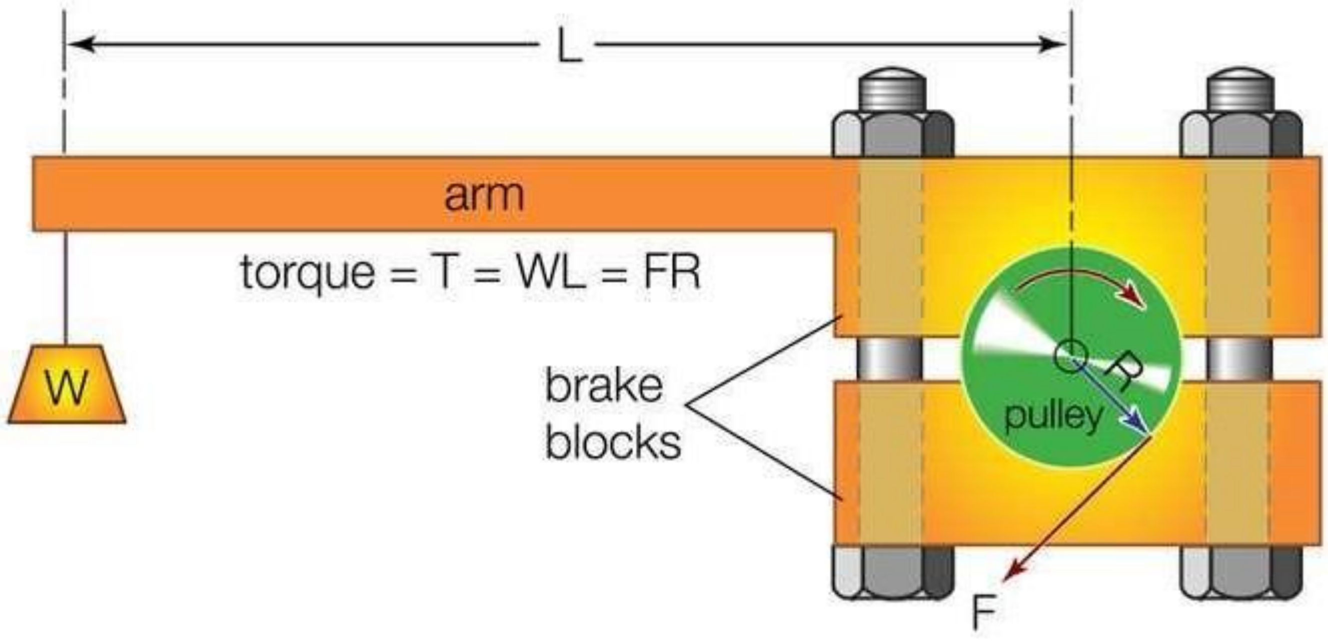
These dynamometer are located at a **particular place in a machine and they sense the torque.** They do not supply or receive energy. These are also called torque meters.

Mechanical Dynamometers-

they come under the absorption type. There are two types of mechanical dynamometer as follows

1. Prony brake.
2. Rope brake.

Prony brake



Rope brake

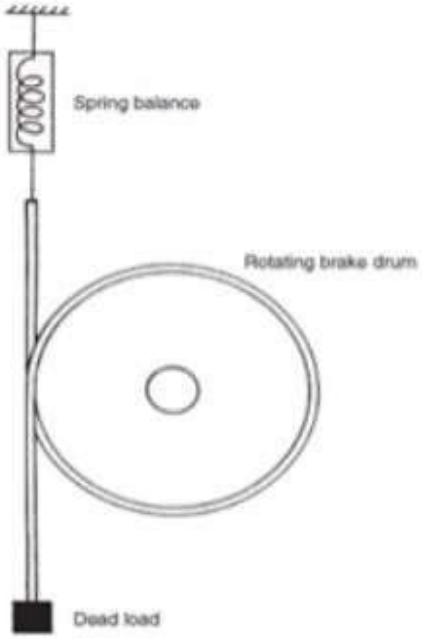


Fig 5.12 Prony Brake

DC Dynamometer

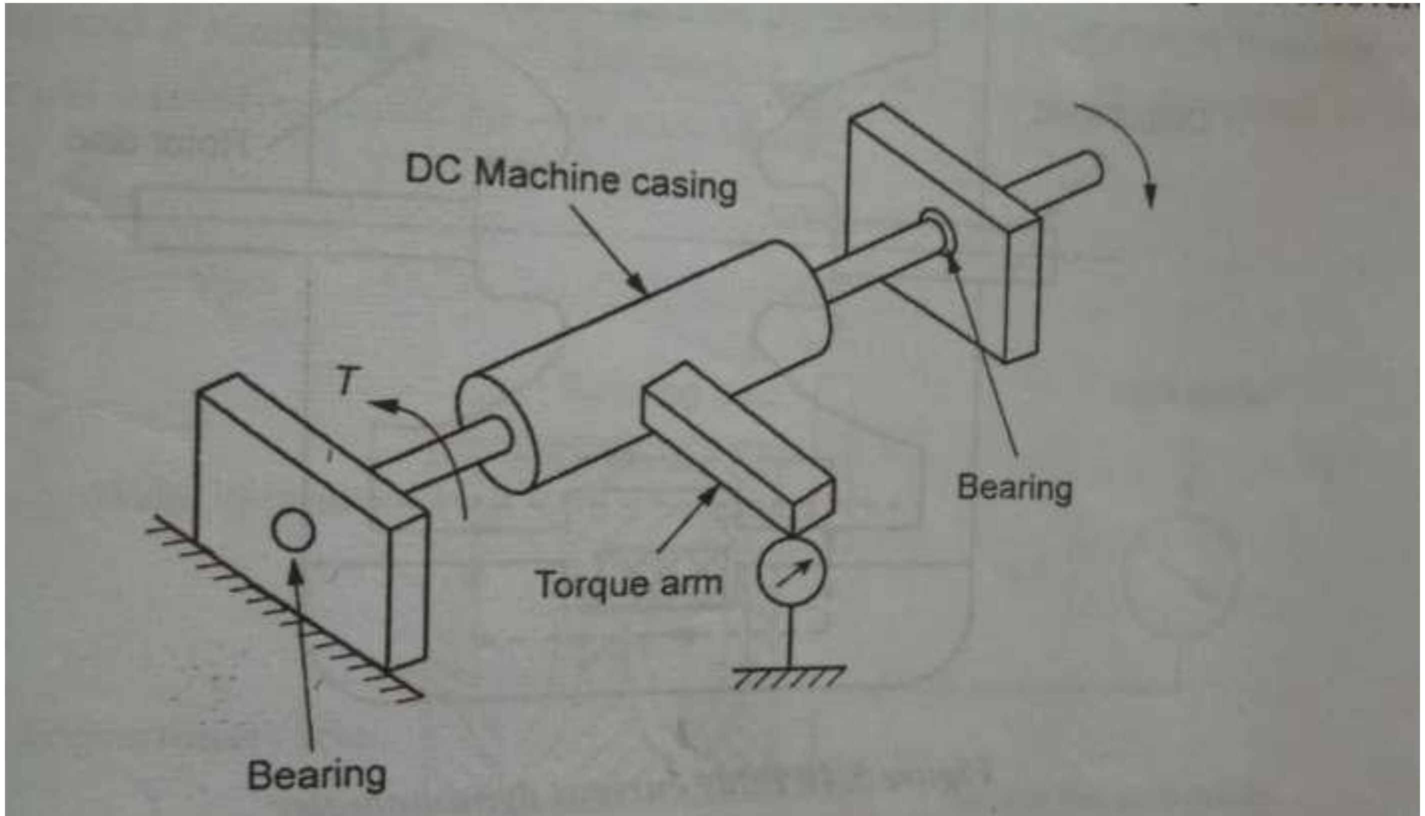


Figure 5.39 DC dynamometer

Servo controlled Dynamometer

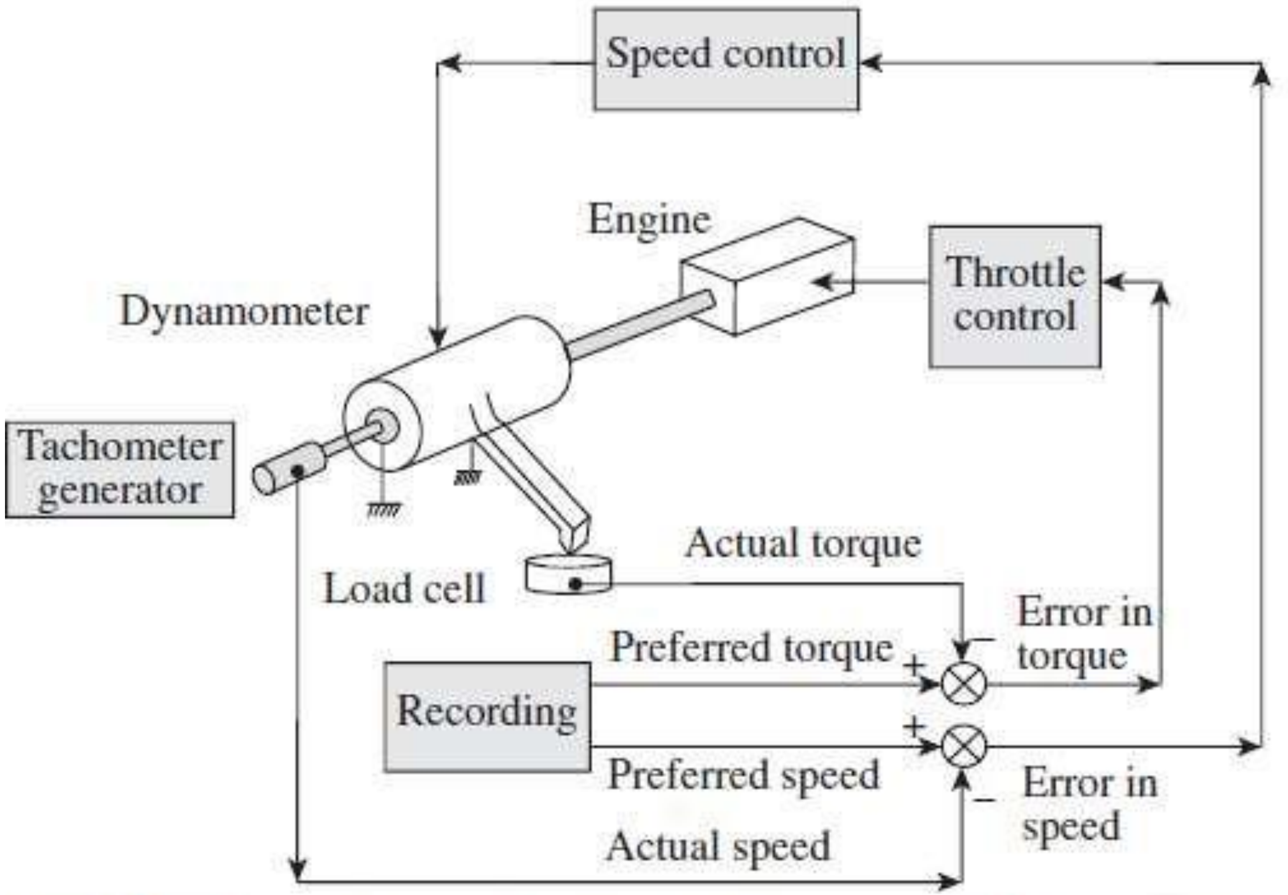


Fig. 14.9 Schematic representation of a servo-controlled dynamometer

Eddy current or Inductor Dynamometer

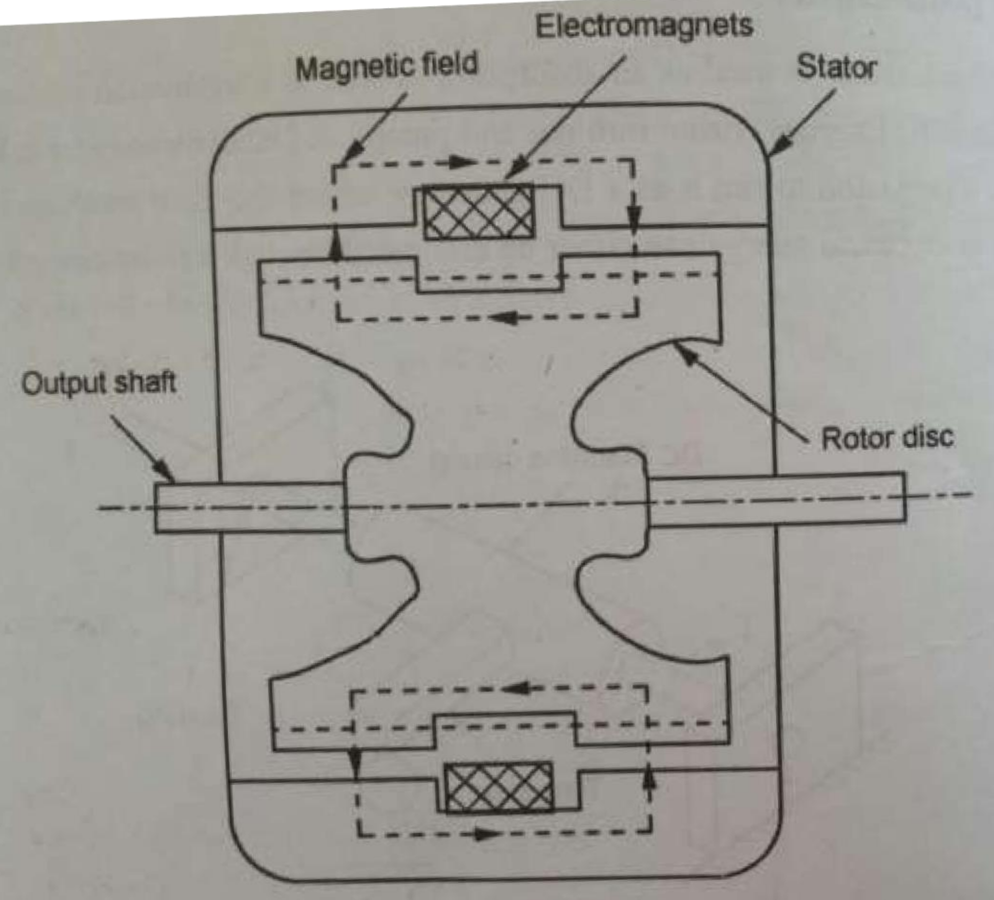


Figure 5.40 Eddy current dynamometer

Hydraulic Dynamometer

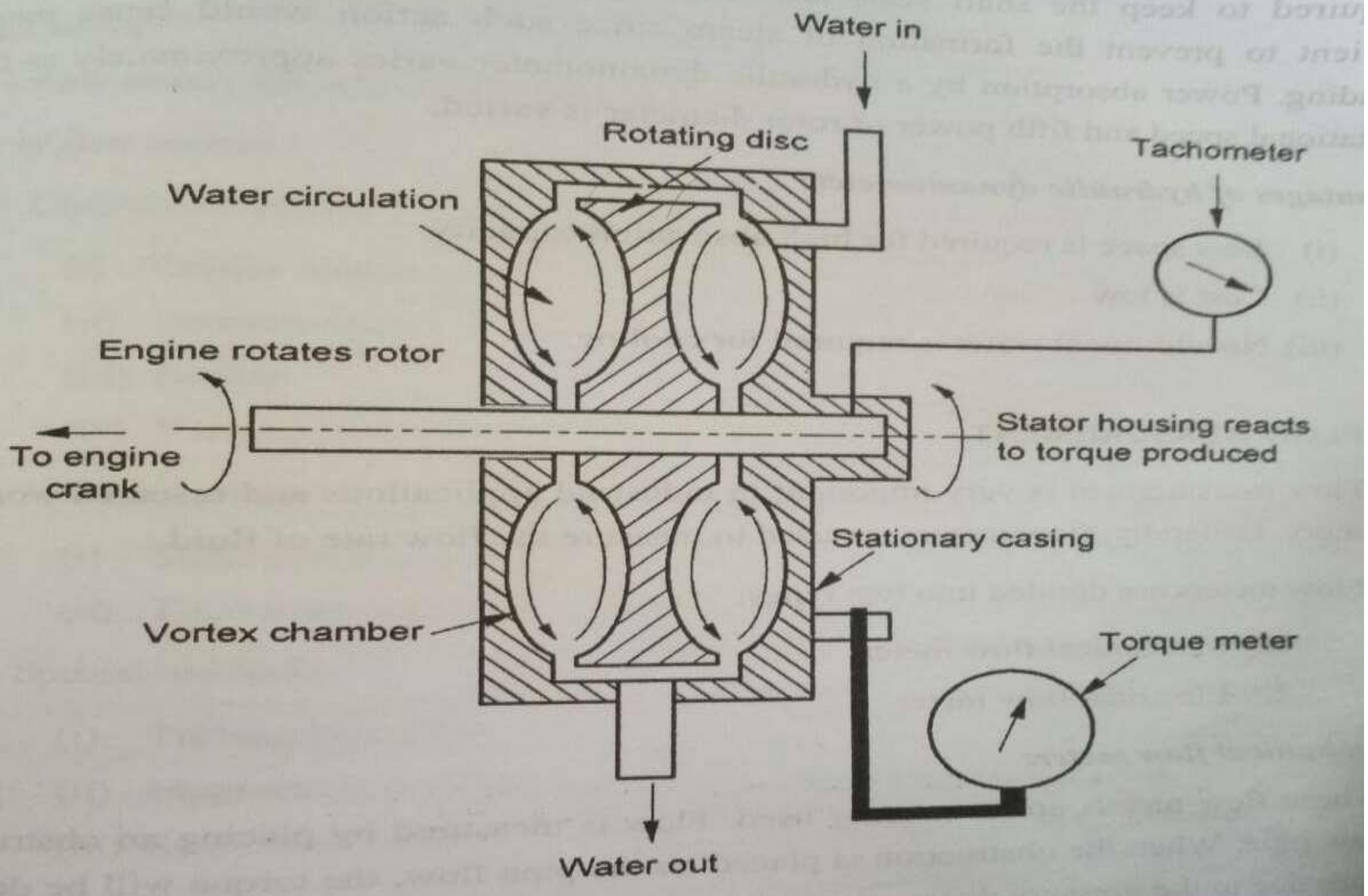


Figure 5.41 Hydraulic dynamometer

Temperature Measurement

- Temperature is the most widely monitored parameter in science and industry .
- Temperature is defined as the average kinetic energy of the individual molecules that comprise the component of the system
- The following are the common methods used to measure the temperature

1. Liquid in thermometer.
2. Bimetallic strip.
3. Resistance temperature detectors (RTDs)

Temperature measurement

Table 15.1 Comparison of temperature scales

Scales	Water boils	Water freezes	Absolute zero
Kelvin	373.16 K	273.16 K	0 K
Celsius	100 °C	0 °C	−273.16°C
Fahrenheit	212 °F	32 °F	−459.7 °F

Classification of temperature measuring device

- Based on contact type

1. **Thermometer.**
2. **Bimetallic strip.**
3. **Thermocouple.**
4. **Liquid in glass thermometer.**
5. **Resistance Temperature detector.**
6. **Thermistors**

Classification of temperature measuring device

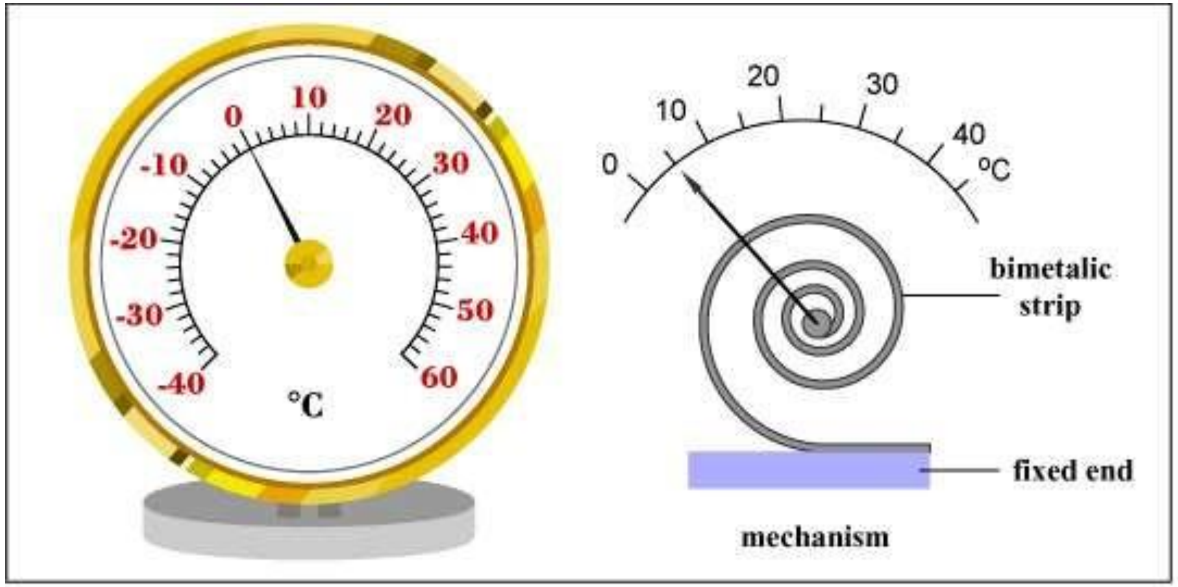
- Based on the non contact type-

1.**Radiation type pyrometer.**

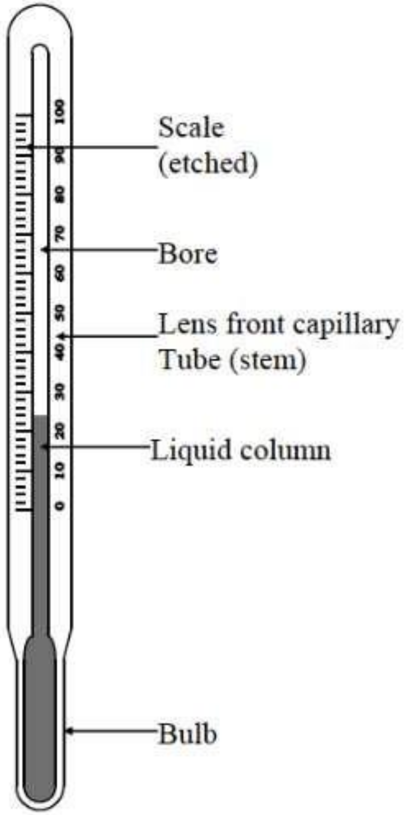
2.Optical pyrometer.

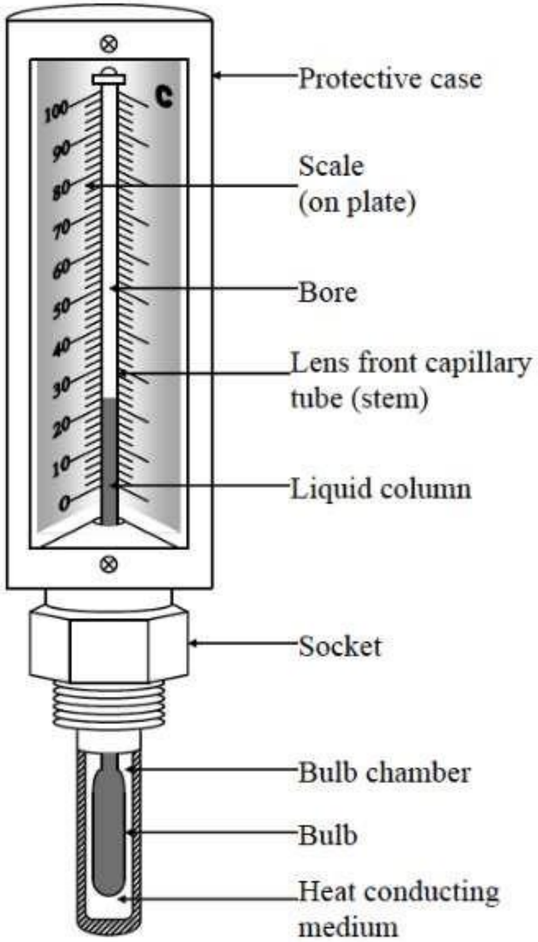
3.Fibre-optic pyrometer.

Liquid in Glass Thermometer



Liquid In Glass Thermometers





Pressure thermometer

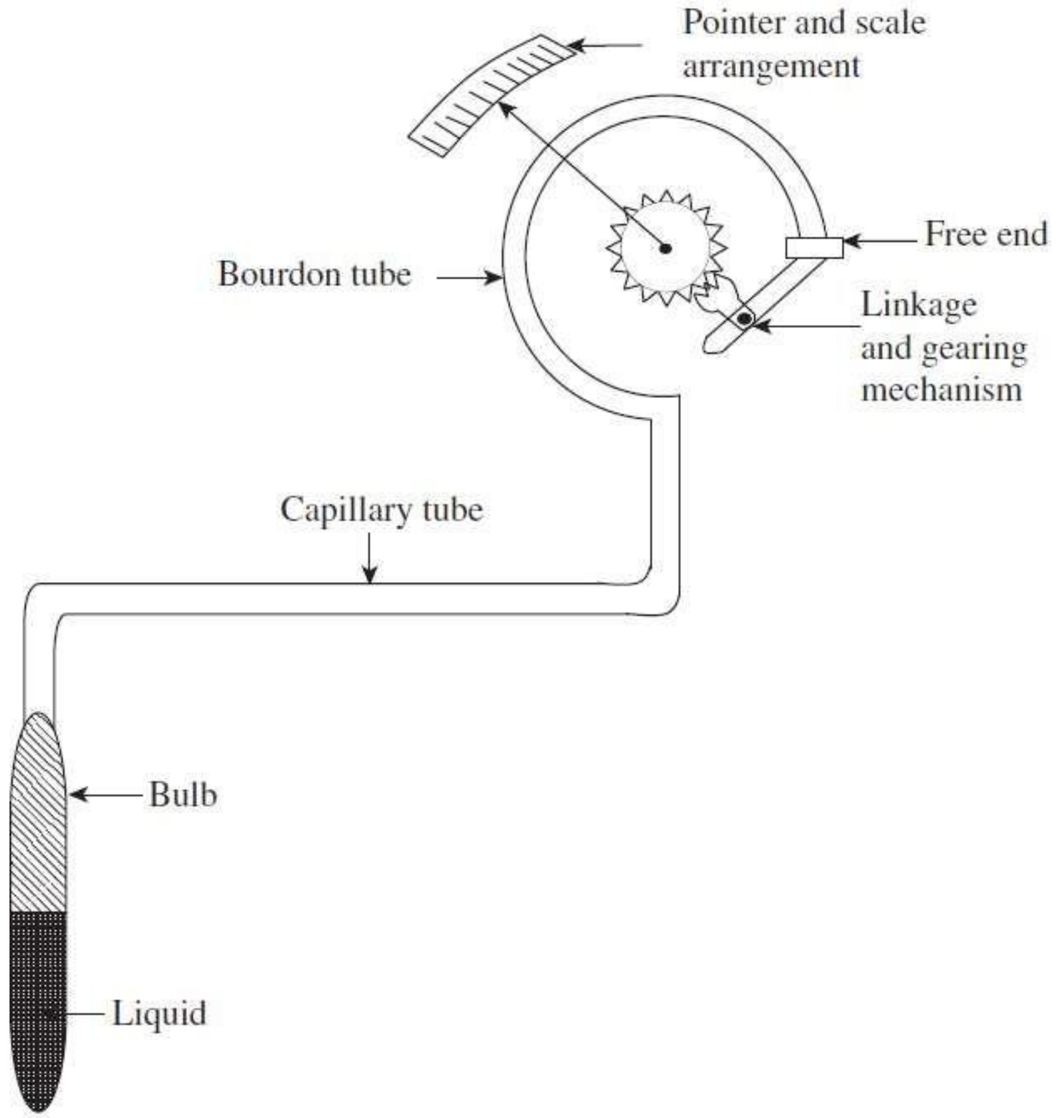
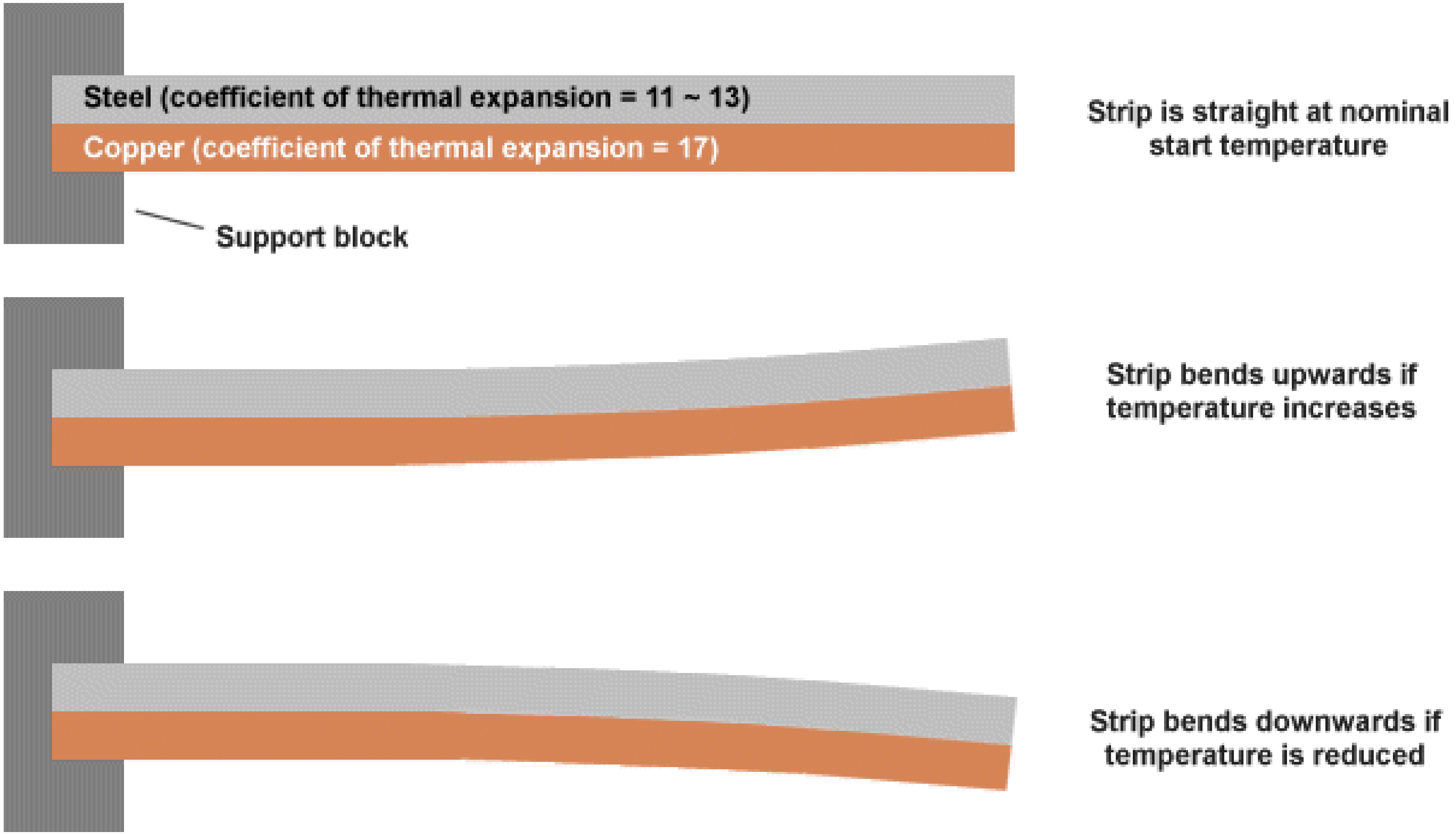


Fig. 15.11 Pressure thermometer

Bimetallic strip



Bimetallic strip

Thermocouple

- The thermocouple is a device that converts thermal energy into electrical energy. Thermocouple are very simple and durable temperature sensors.

- Thermocouple uses of dissimilar metals to generates a voltage proportional to the temperature.

Thermocouple

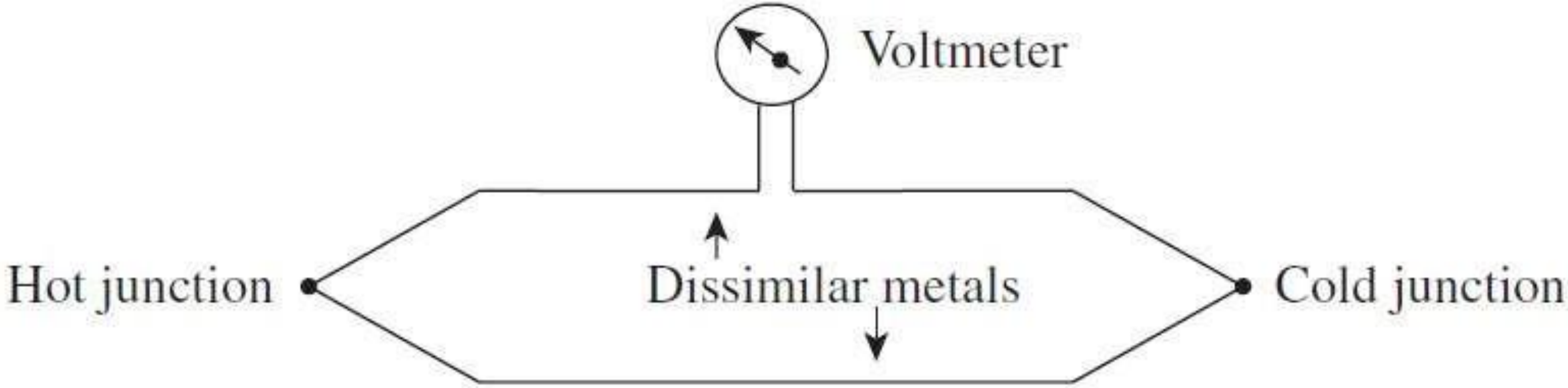


Fig. 15.1 Basic thermocouple circuit

Laws of thermocouple

- Law of Homogeneous circuit-

" This law states that a thermoelectric effect current cannot be sustained in a circuit of a single homogenous materials, regardless of variation in its cross section and by the application of heat alone."

This law suggest that two dissimilar materials are required for formation of any thermocouple circuit.

Laws of thermocouple

- Law of Intermediate metals-

“If an intermediate metal is inserted into a thermocouple circuit at any point. The net emf will not be affected provided the two junctions introduced by the third metal are at identical temperature.”

this law allows the measurement of the thermoelectric emf by introducing a device into the circuit at any point without affecting net emf, provided that additional junction introduced are all the same temperature.

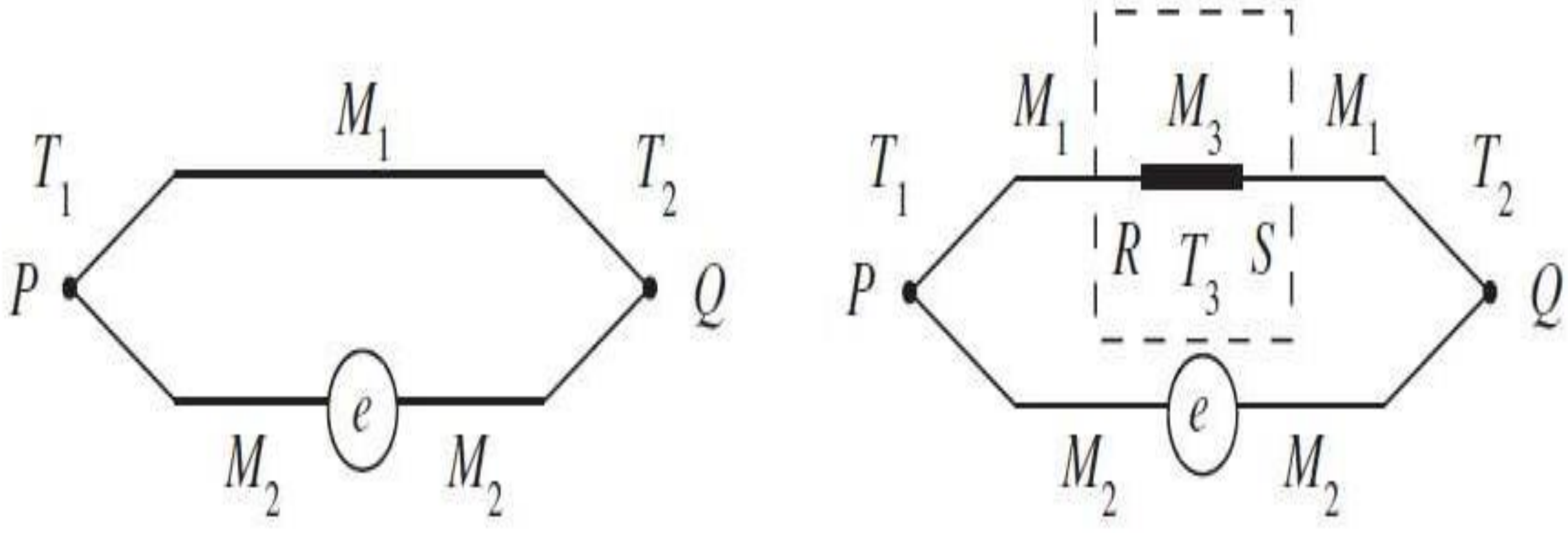


Fig. 15.2 Law of intermediate metals

It is clear from Fig. 15.2 that when a third metal, M_3, is introduced into the system, two more junctions, R and S, are formed. If these two additional junctions are maintained at the same temperature, say T_3, the net emf of the thermocouple circuit remains unaltered.

Law of intermediate temperature

“ If a thermocouple circuit generates an emf e1 and when its two junction are at temperature T1 and T2, and e2 when the two junction are at the temperature are maintained at T1 and T3, then the thermocouple will generate an emf of e1 and e2 when its junction temperature are maintained at T1 and T3”

Law of intermediate temperature

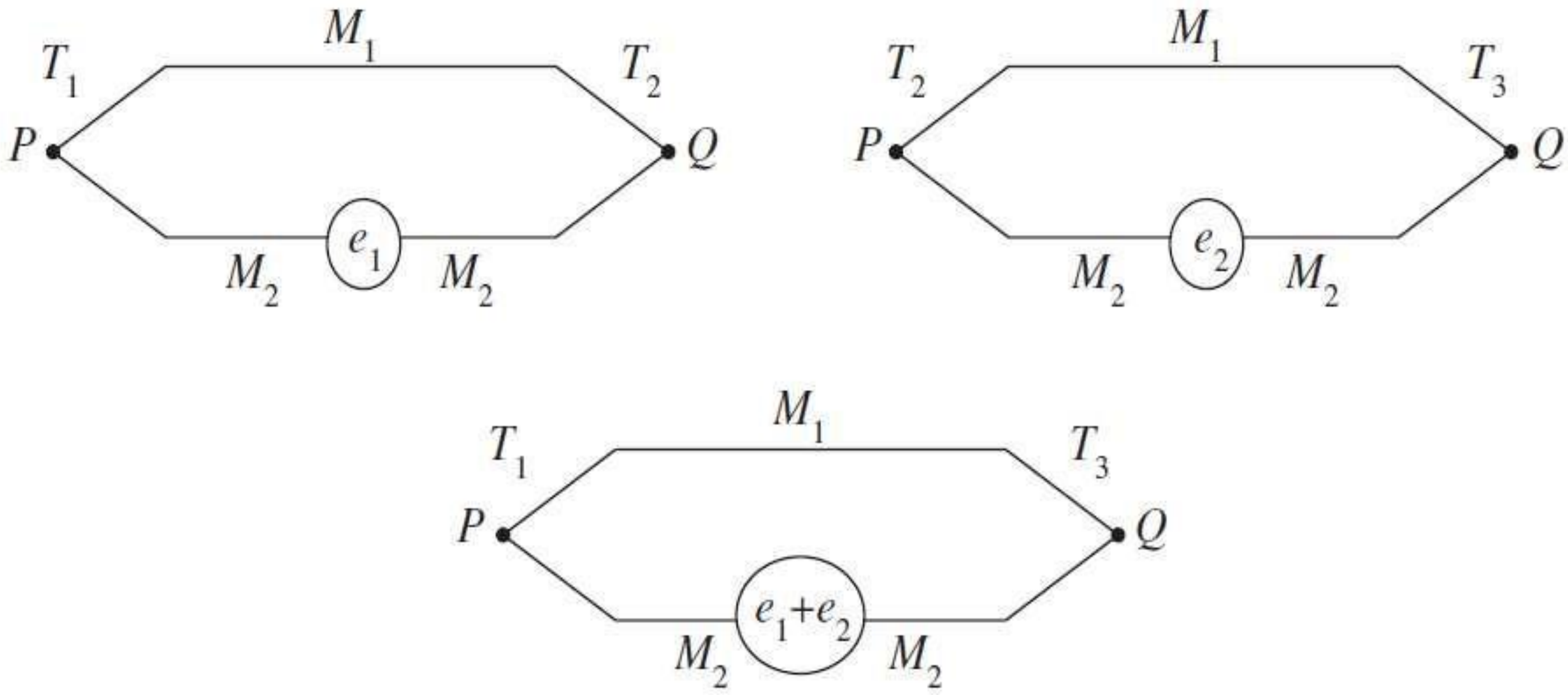


Fig. 15.3 Law of intermediate temperatures

Various materials in Thermocouple

Table 15.2 Temperature range of various thermocouple materials

Type	Thermocouple materials	Temperature range (°C)
Base metal type		
T	Copper (40%)–constantan (60%)	−200 to 350
J	Iron–constantan	−150 to 750
E	Chromel–constantan (57% Cu, 43% Ni)	−200 to 1000
K	Chromel (90% Ni, 10% Cr)–Alumel (94% Ni, 2% Al, 3% Mn, 1% Si)	−200 to 1300
Rare metal type		
S	Platinum (90%)–rhodium–platinum (10%)	0–1500
R	Platinum–rhodium (87% Pt, 13% Rh)–platinum	0–1500

thermocouple

- Seebeck effect where **two dissimilar metals A and B are used to close loop and connecting Junctions are at two different temperature T1 and T2. the e.m.f produced is found to be almost linear in temperature and very repetitive for constant materials**.

- The e.m.f produced by the thermocouple loop is approximately given by

$$E=\alpha(T1-T2)$$

Advantages of thermocouple

The following are some distinct advantages that merit the use of thermocouples:

1. Temperature can be measured over a wide range.
2. Thermocouples are self-powered and do not require any auxiliary power source.
3. A quick and good response can be obtained.
4. The readings obtained are consistent and hence are consistently repeatable.
5. Thermocouples are rugged, and can be employed in harsh and corrosive conditions
6. They are inexpensive.

Thermopiles

- An extension of Thermocouple is the thermopile. Thermopiles comprises a number of thermocouples connected in series, wherein the hot junction are arranged side by side or in a star formation.
- In such cases the total output is given by sum of individual emfs.
- **The advantages of combining thermocouples to form a thermopiles is that a much more sensitive element is obtained For Eg a sensitivity of 0.002 C at 1m V/C can be achieved with the chromal-constantan thermopile consisting of 14 thermocouple.**

thermopiles

- If n identical thermocouples are combined to form a thermopile then the total emf will be n times the output of the single thermocouple
- For special purpose application such **as measurement of temperature of sheet glass thermopiles are constructed using a series of semiconductors. For average temperature measurement thermocouple can be connected in parallel.**
- **During formation one has to ensure that the hot junction of the individual thermocouples are properly insulated from the one another.**

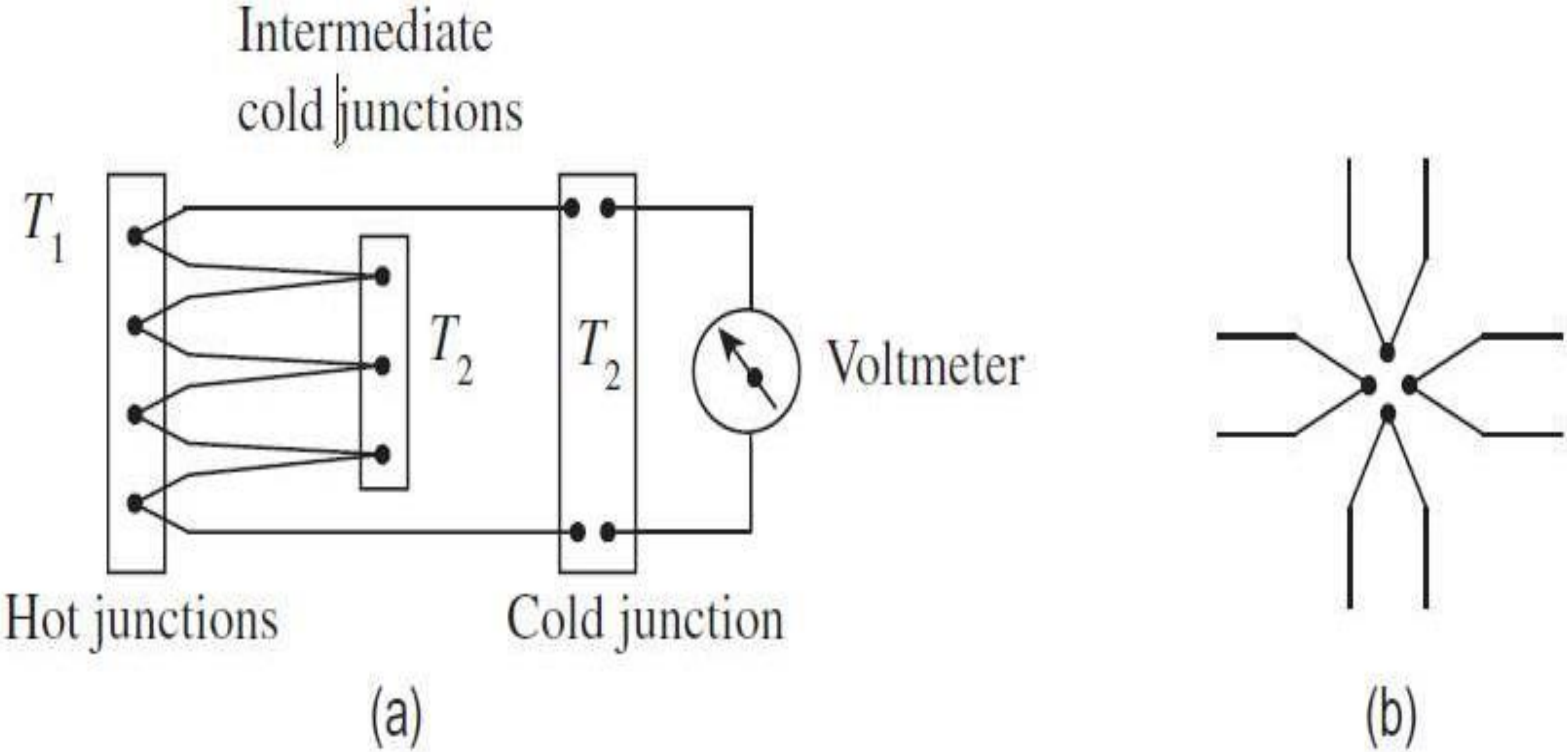


Fig. 15.4 Thermopiles (a) Series connection (b) Star connection

Resistor temperature Detector (RTD)

- The resistance of the metal highly dependent on temperature.
- **When the wire is heated, the resistance of the wire increases so a temperature can be measured using the resistance and it conversely decrease the resistance as the temperature also decreases.**
- **Resistance temperature detectors (RTDs) act similar to an electrical transducer and it coverts the temperature to voltage signals by the measurement of resistance.**

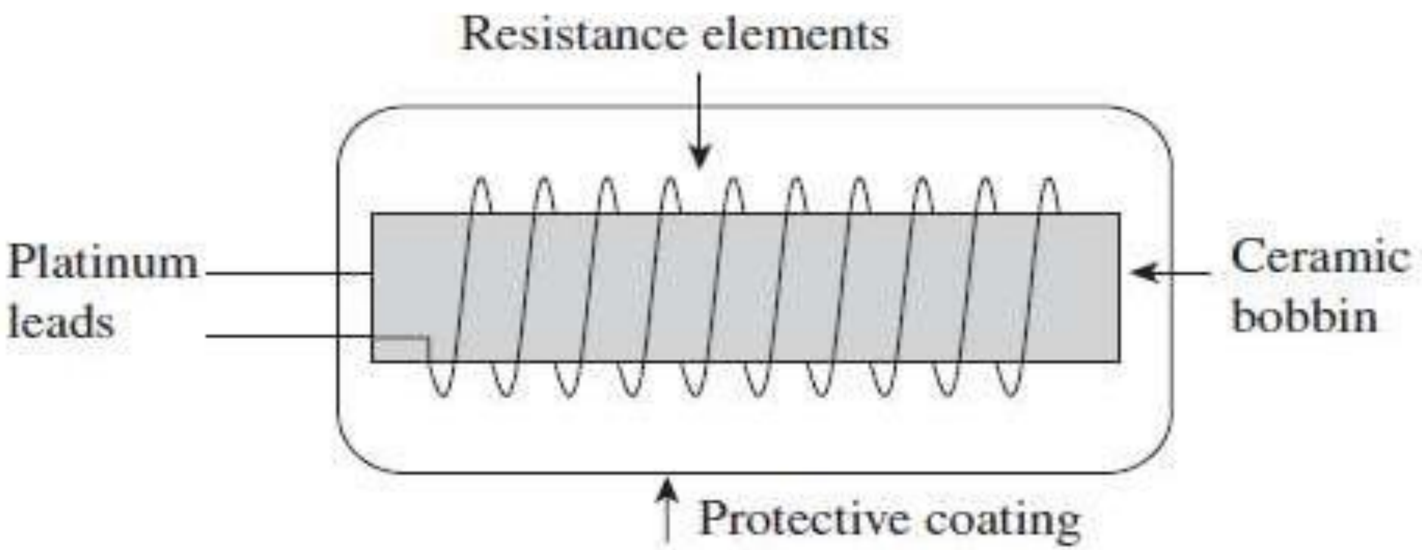


Fig. 15.5 Wire-wound RTD

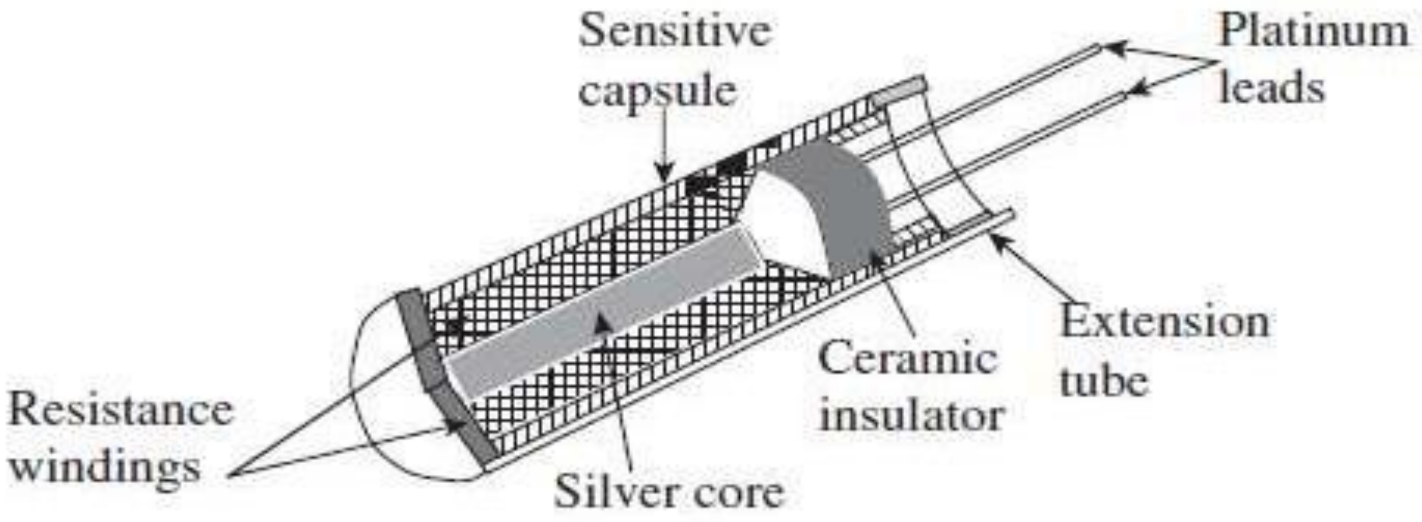


Fig. 15.6 General construction of an RTD

Resistor temperature Detector (RTD)

- An RTD is a temperature sensor that works on the principle that the **resistance of electrically conductive materials is proportional to the temperature** to which they are exposed.
- **Resistance of a metal increases with an increase in temperature. Hence metals can be classified as per their positive temperature coefficient (PTC).**
- The RTD metals are best suited because of their coefficient of resistance and ability to withstand repeated temperature cycle.

Resistor temperature Detector (RTD)

- The temperature range of RTDs are about 200 to 650 ‘C.
- RTDs are more rugged and have more less linear characteristic over a wide temperature.

- Many Materials are commonly used for making resistance thermometer such **Platinum, nickel and copper.**
- **However mostly popular and widely used is platinum. So popular as they are called as Platinum resistance thermometer.**

Resistor temperature Detector (RTD)

- Some of the following reasons for choosing platinum are.

1. **Chemical inertness.**
2. **Almost Linear relationship with temperature and resistance.**
3. **Large temperature Coefficient of resistance, resulting in readily measurable values of resistance change due to variations in temperature.**
4. **It must have resist to corrosion.**
5. **It should be inexpensive.**

Thermistor

- Thermistor is a temperature sensitive resistor.
- Unlike metals it shows a decrease in resistance value with the increase value of Temperature.
- It is made of oxides of nickel, cobalt or manganese and sulphides of iron. Aluminum or coppers.

Thermistor

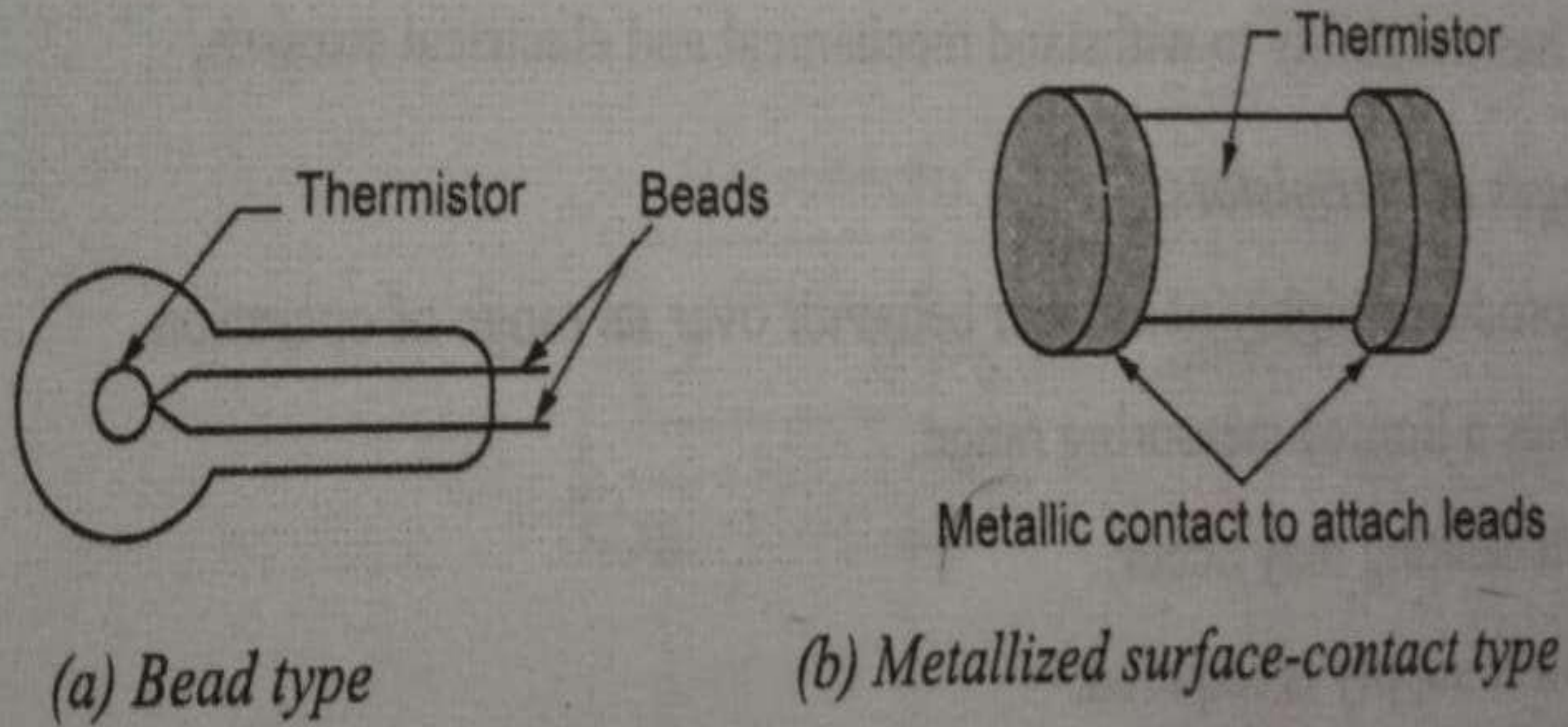


Figure 5.66 Thermistors

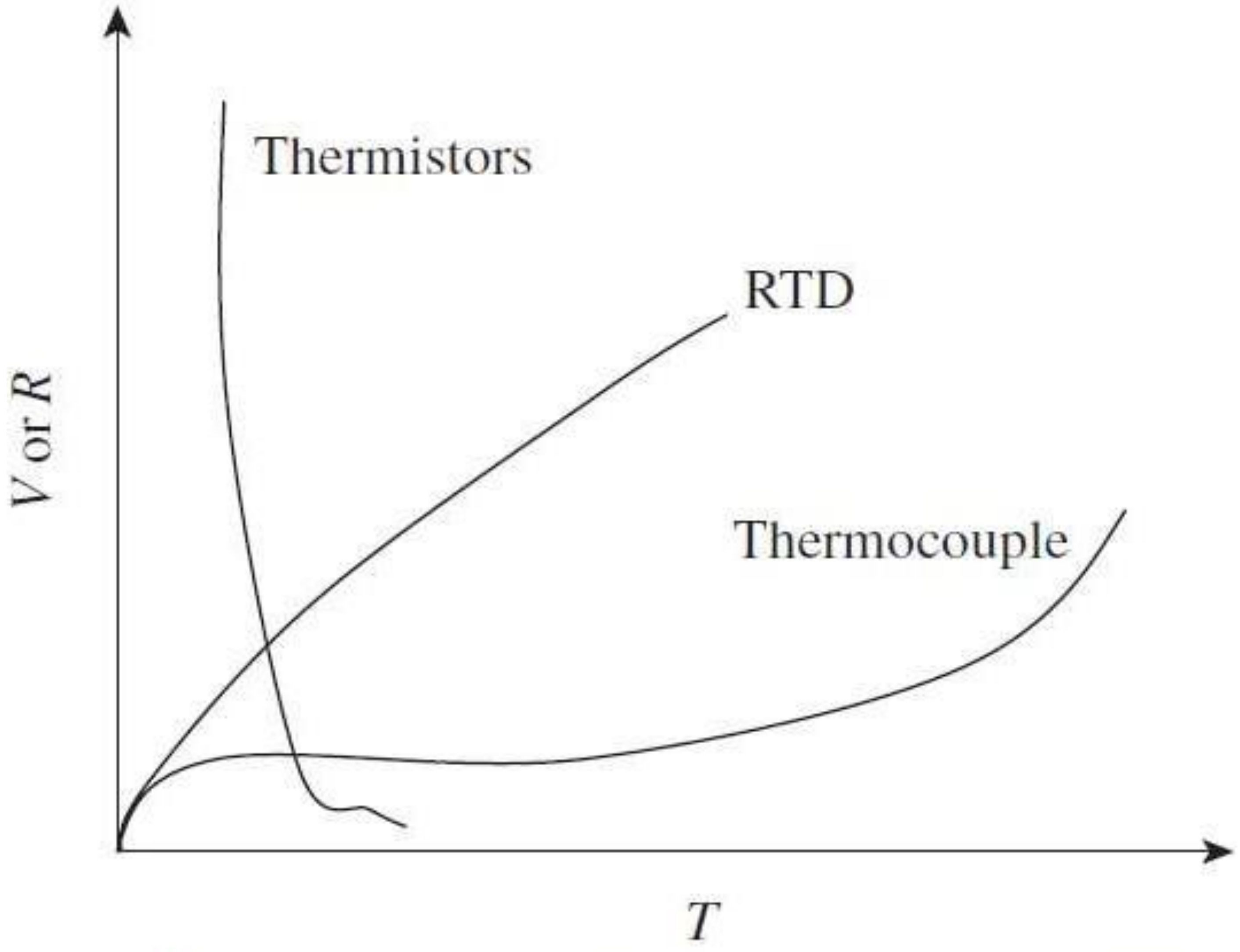


Fig. 15.9 Comparison of temperature characteristics

Thermistor

- **Materials used in the thermistors for temperature measurement have very high temperature coefficient (8-10 times higher than platinum and copper) and higher resistivity.**
- Thus they are very sensitive to small variations in temperature and respond quickly.
- The temperature range of thermistor is -250 C to 650C
- **Thermistors are also produced using oxides of manganese,Nickel cobalt, Nickel copper, iron zinc, titanium and tin.**

thermistor

- There are two type of thermistor depending upon temperature coefficient of resistance (k)

1. **Positive temperature coefficient (PTC)**
2. **Negative temperature coefficient (NTC)**

Positive temperature coefficient- the resistance will increase with increase in temperature.

Negative temperature coefficient- the resistance will decrease with the increase in temperature.

pyrometer

- The pyrometer temperature measurement is based on the change in the intensity and color of radiation.
- The pyrometer are used in temperature measurement by radiation.
- It is possible to determine the temperature of a body through a measurement of the thermal radiation emitted by the body.
- Types of pyrometer

1. Total radiation pyrometer.
2. Infrared pyrometer.
3. Optical radiation pyrometer.

If E is the radiation impinging on a body (W/m^2), α is the fraction of radiation power absorbed by the body, and e is the total emissivity, then

$$e = \frac{\alpha E}{E} = \frac{\text{Radiation emitted from a body}}{\text{Radiation falling upon the body}}$$

Total Radiation Pyrometer

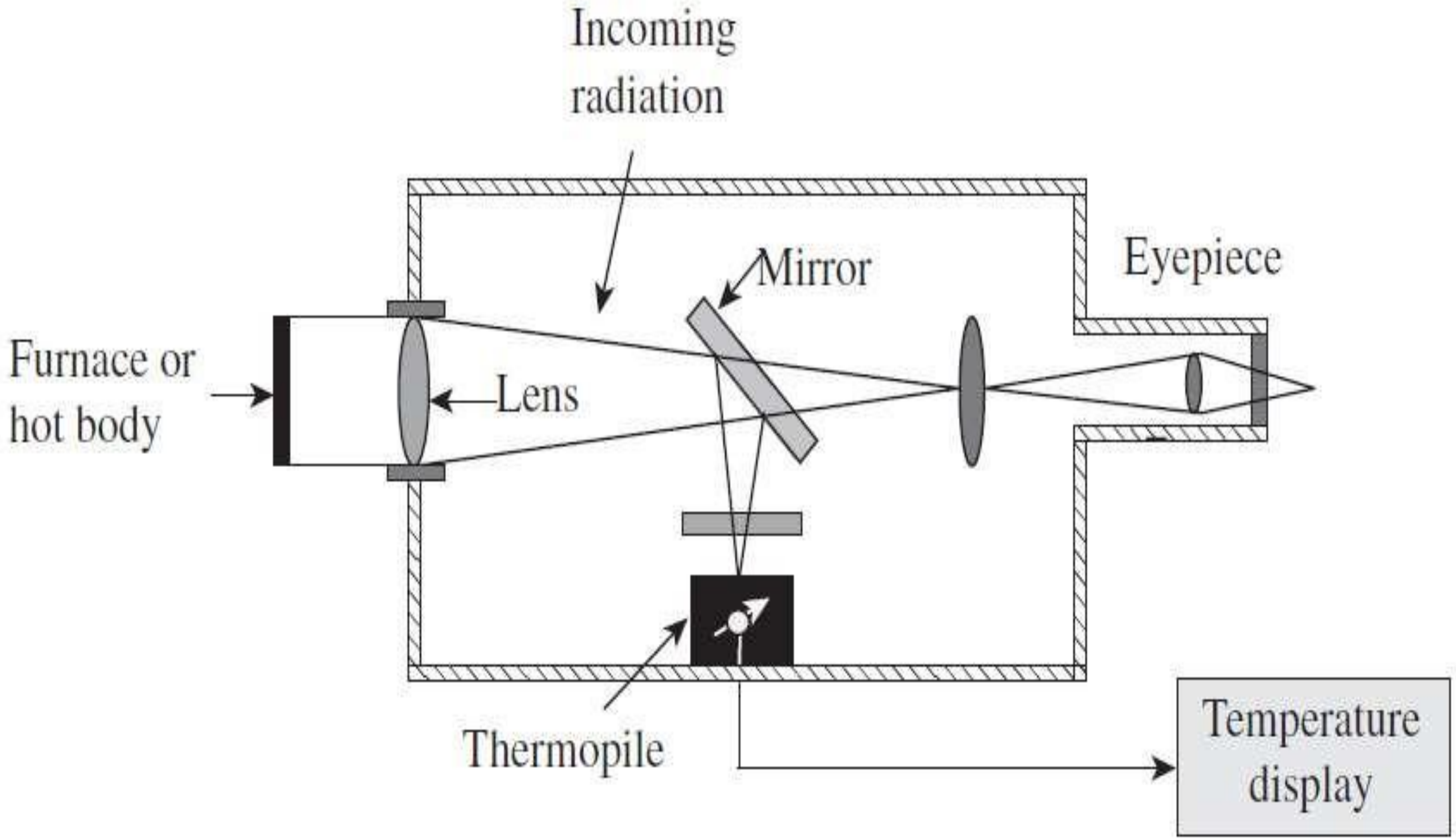


Fig. 15.13 Total radiation pyrometer

Advantages and disadvantages

- It is non- contact type device.
- It gives a very quick response.
- High temperature measurement can be accomplished.

Disadvantages-

- Errors in temperature measurement are possible due to emission of radiations to the atmosphere.
- Emissivity errors affect measurements.

Optical pyrometer

- In order to measure temperature the brightness generated by the radiation of the unknown source or hot body whose temperature is to be determined is compared with that of the reference lamp.
- The brightness of the reference lamp is adjusted equal to the hot under consideration.
- The light intensity depends on the temperature of the object irrespective to wavelength.
- The current flowing through the filament is adjusted by means of a rheostat and ammeter is used to measure it.

Optical pyrometer

- The current passing through the circuit is proportional to the temperature of the unknown source.
- An optical pyrometer essentially consist of an eyepiece by means of which the filament and the source are focused so that they are super imposed enabling a clear view for the observer.

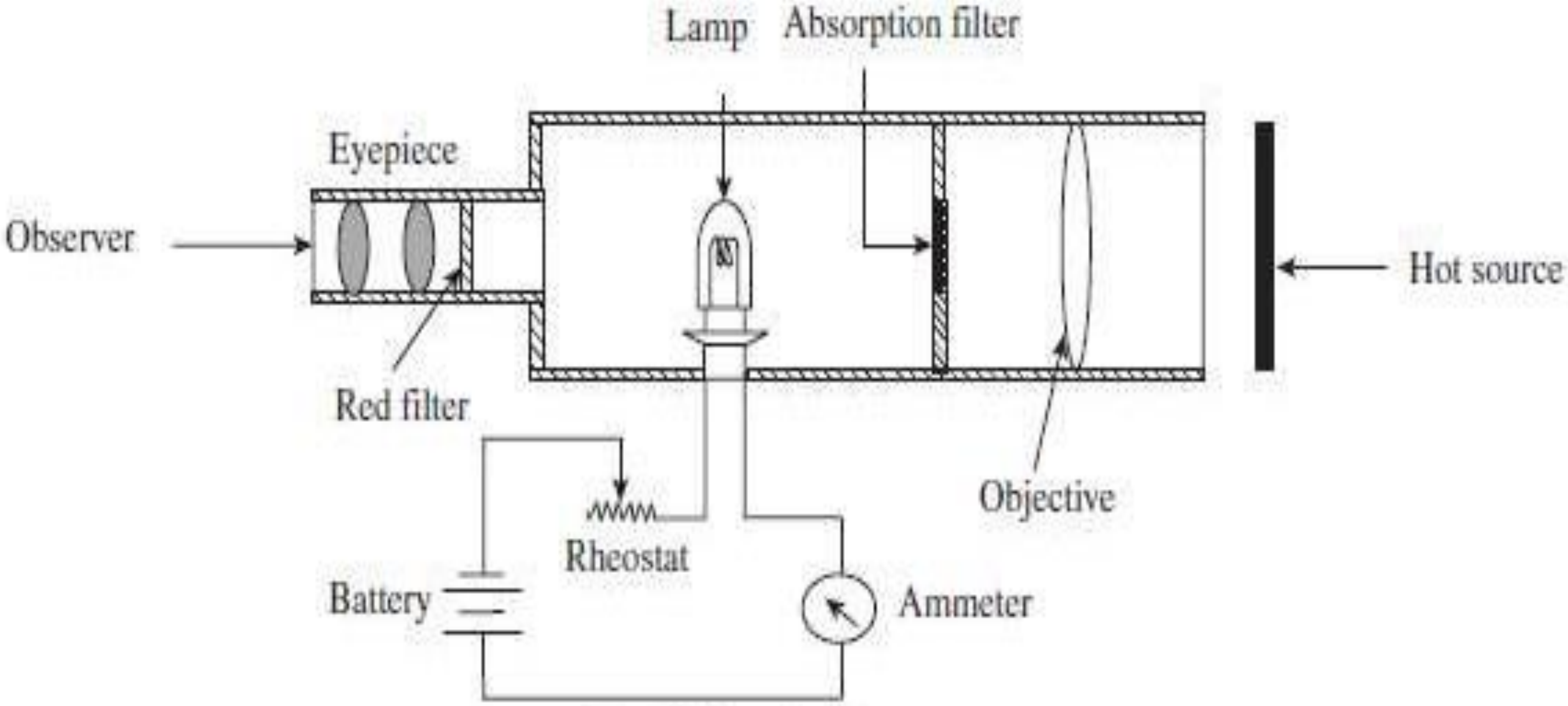


Fig. 15.14 Optical pyrometer

Image of lamp through eyepiece

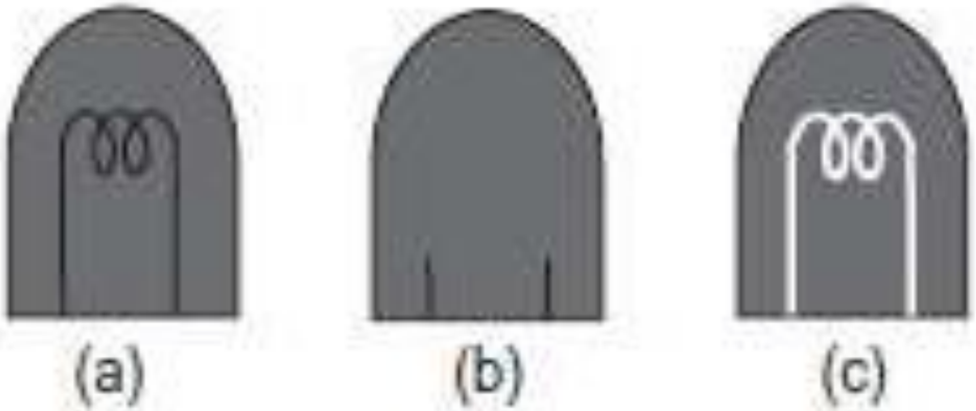


Fig. 15.15 Disappearing filament principle (a) Current passing though the filament is low (b) Current passing though the filament is exact (c) Current passing though the filament is high

advantages associated with optical pyrometers are as follows:

1. They are simple in construction and portable.
2. Optical pyrometers are flexible and easy to operate.
3. They provide very high accuracy of up to ±5 °C.
4. Since they are non-contact-type sensors, they are used for a variety of applications.
5. They can be used for remote-sensing applications, since the distance between the source and the pyrometer does not affect the temperature measurement.
6. Optical pyrometers can be employed for both temperature measurement and for viewing and measuring wavelengths that are less than 0.65 µm.

The following are the disadvantages of optical pyrometers:

1. Optical pyrometers can be employed for measurement only if the minimum temperature is around 700 °C, since it is based on intensity of light.
2. Temperature measurement at short intervals is not possible.
3. Emissivity errors may affect measurement.
4. Optical pyrometers are used for the measurement of clean gases only.

Optical pyrometers can be employed to measure temperatures of liquid metals and materials that are heated to a high temperature. This method is useful in situations where physical contact is impossible, for example, for determining the temperature of molten metals and materials that are heated to a high temperature. Temperature of furnaces can be measured easily.

Infrared pyrometer

- It is well known fact that every material or matter whose temperature is above absolute zero emits infrared radiation depending on temperature.
- **Infrared radiation are invisible to human eye and can be sensed as heat.**
- **Radiations that have longer wave lengths that visible light are known as infrared radiation, These radiations posses less energy and less harmful**.
- It can be sensed by the Infrared sensor. It essential measure the radiation of the objects.

Infrared pyrometer

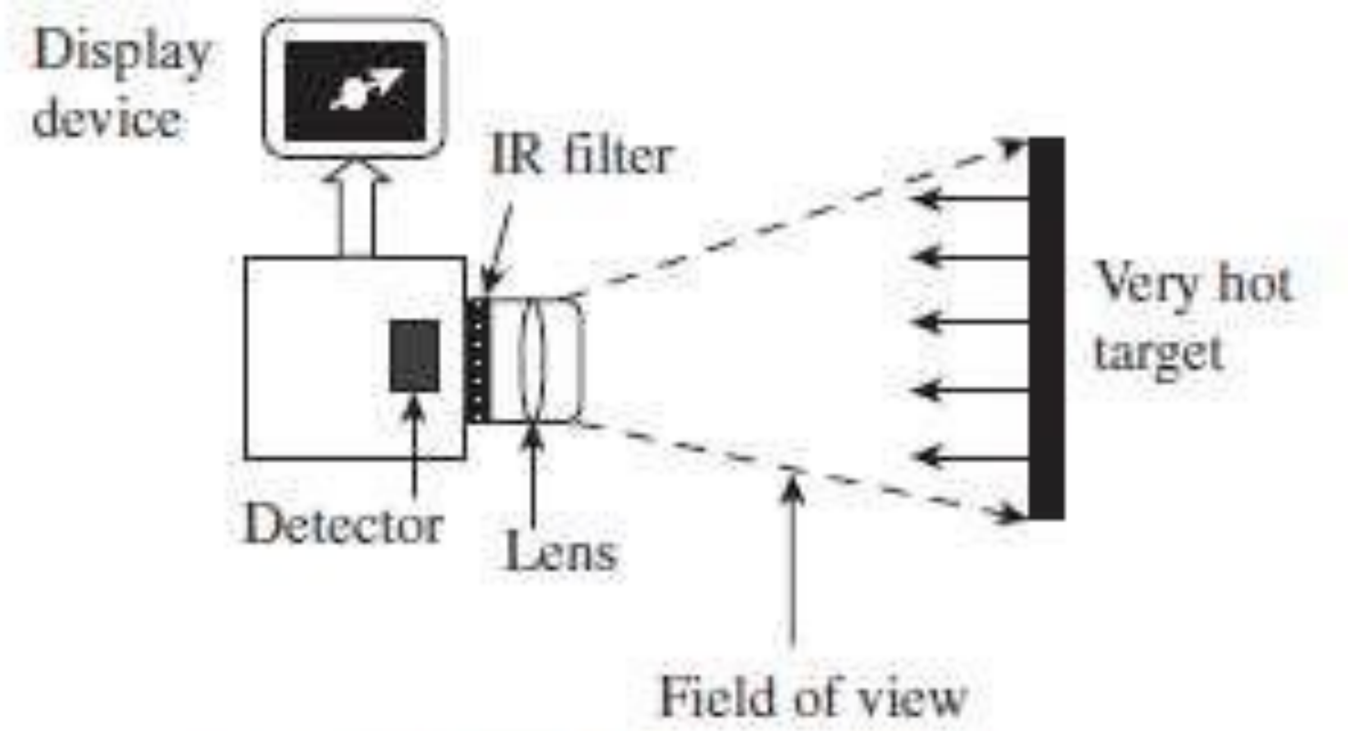


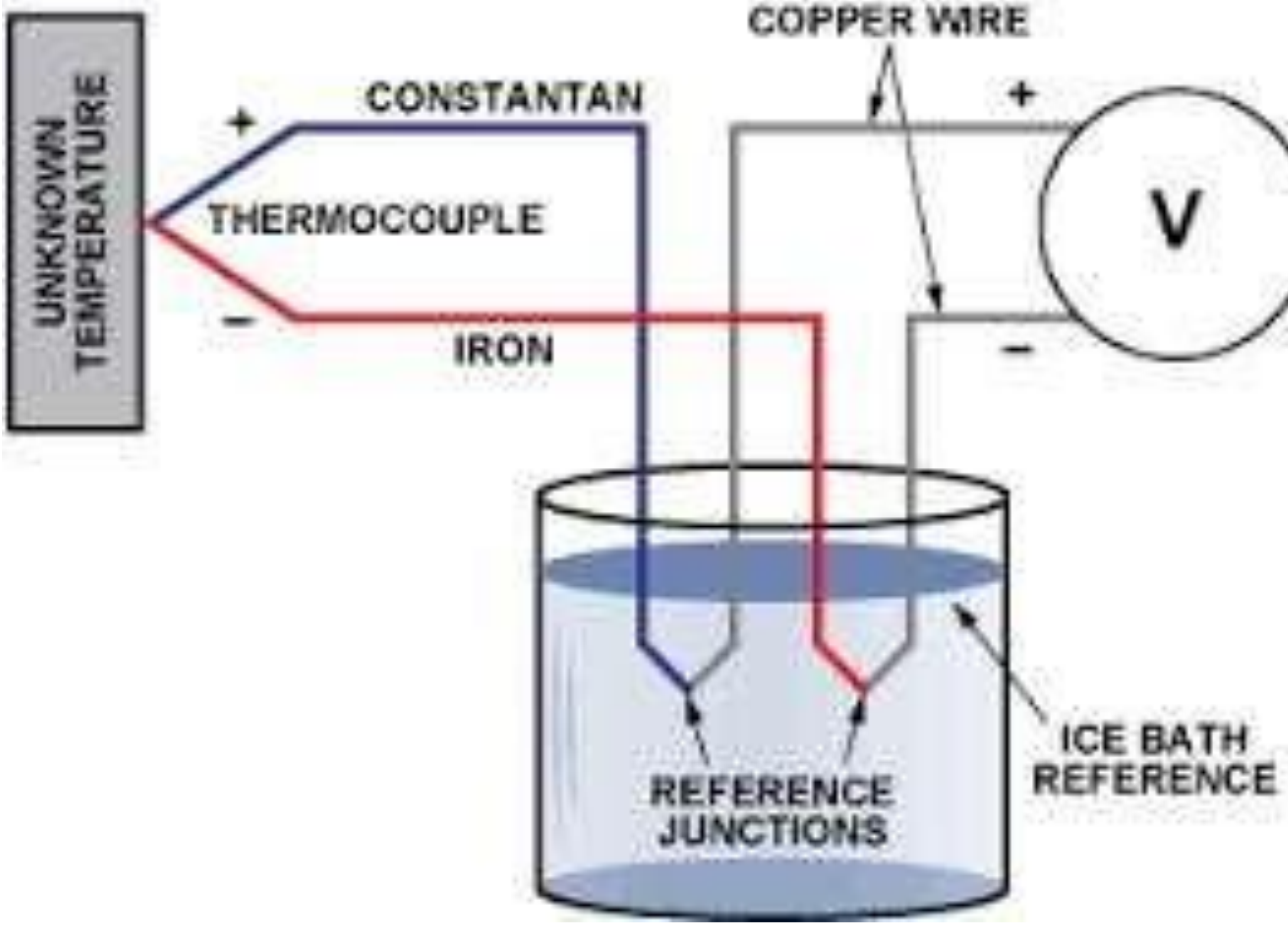
Fig. 15.16 Principle of infrared measurement

Infrared pyrometer

- **It is ideally suited for the 500-600 C. the Infrared energy increase with the temperature and decreases with temperature.**
- The wavelength of the infrared radiation is **0.7 to 20 micrometer, but normally radiation in the wavelength range 0.7-14 micrometer are employed for the measurement.**
- It usually comprises of the lens through which the infrared wave is focused on the detector.

The infrared energy is absorbed and converted into electrical signals by the detector. The amount of the radiation striking the detector determines Output signals.

Ice bath check



UNKNOWN TEMPERATURE
+
CONSTANTAN
THERMOCOUPLE
–
IRON
COPPER WIRE
+
V
–
REFERENCE JUNCTIONS
ICE BATH REFERENCE