AKTU

B. Tech I-Year

Gateway Classes

Semester -I & II

Common to All Branches

Fundamentals of Mech. Engg.(BME101/201)

Unit-5 P-1 : ONE SHOT- Measurement & Mechatronics

Gateway Series for Engineering

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- Long - Short Questions Covered
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Gateway Classes

Fundamentals of Mech. Engg.(BME101/201)

Unit-5

Introduction to Measurement & Mechatronics

Syallbus

Introduction to Measurement: Concept of Measurement, Error in measurements, Calibration, measurements of pressure(Bourdon Tube Pressure and U-Tube Manometer), temperature(Thermocouple and Optical Pyrometer), mass flow rate(Venturi Meter and Orifice Meter), strain(Bonded and Unbonded Strain Gauge), force (Proving Ring) and torques(Prony Brake Dynamometer); Concepts of accuracy, precision and resolution.

Introduction to Mechatronic Systems: Evolution, Scope, Advantages and disadvantages of Mechatronics, Industrial applications of Mechatronics, Introduction to autotronics, bionics, and avionics and their applications. Sensors and Transducers: Types of sensors, types of transducers and their characteristics.

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B. TECH 1-YEAR

MECHANICAL ENGG.

ONE SHOT UNIT-V

MEASUREMENT AND MECHATRONICS

GATEWAY CLASSES

Unit-5: Introduction to Measurement and Mechatronics

Introduction to Measurement: Concept of Measurement, Error in measurements, Calibration, measurements of pressure(Bourdon Tube Pressure and U-Tube Manometer), temperature(Thermocouple and Optical Pyrometer), mass flow rate(Venturi Meter and Orifice Meter), strain(Bonded and Unbonded Strain Gauge), force (Proving Ring) and torques(Prony Brake Dynamometer); Concepts of accuracy, precision and resolution.

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Overview of Mechanical Actuation System – Kinematic Chains, Cam, Ratchet Mechanism, Gears and its type, Belt, Bearing.

Hydraulic and Pneumatic Actuation Systems: Overview: Pressure Control Valves, Direction Control Valves, Rotary Actuators, Accumulators and Pneumatic Sequencing Problems.

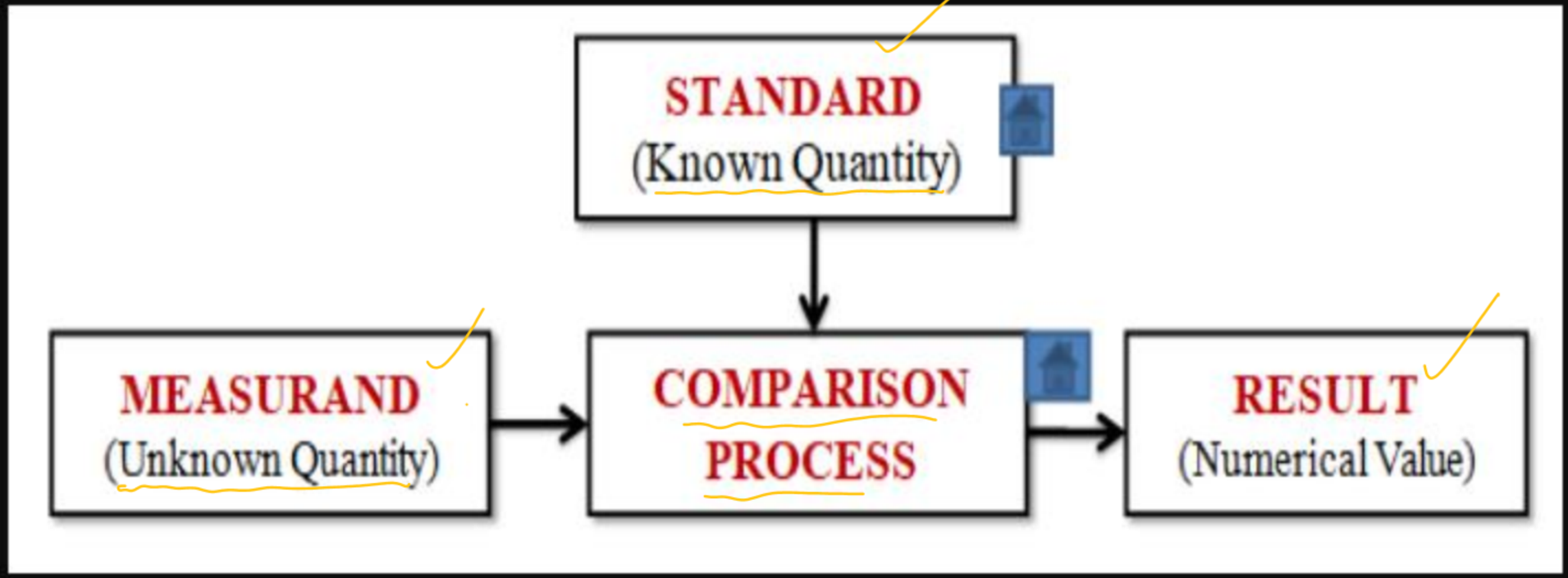
MEASUREMENT ?

The measurement is the result of comparison between a quantity whose magnitude is unknown(known as measurand), with a similar quantity whose magnitude is known (known as standard) .

OR

It is the process of obtaining a quantitative comparison between a predefined standard and measurand (i.e the quantity being measured)

6 cm



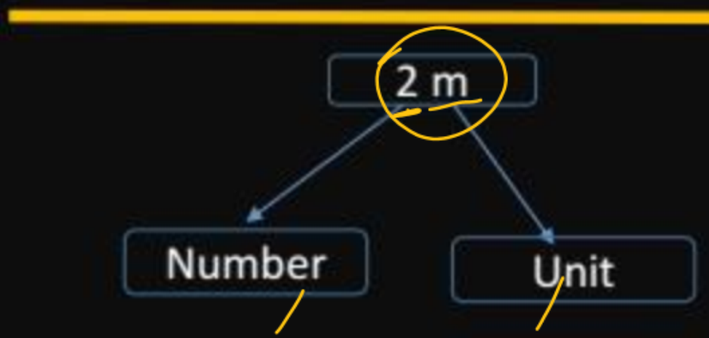
Measurand : A physical quantity such as length, weight, and angle to be measured.

Standard/Reference: A physical quantity to which quantitative comparisons are to be made, which is internationally accepted.

- Measurements are always made using an instrument of some kind.
- Although the basic objective of a measurement is to provide the required accuracy at a minimum cost.

Result of measurement consist of two parts:

1. Number of measurement
2. Unit of measurement



In order for the results of measurements to be meaningful, there are some requirements

- The standard used for comparison purposes must be accurately defined and should be commonly acceptable.
- The standard must be of the same character as the measurement.
- The apparatus used and the method adopted for comparison must be Justifiable.

Example of measuring instrument or tool:

- Ruler
- Thermometer
- Stop watch or watch
- Weighing Machine etc

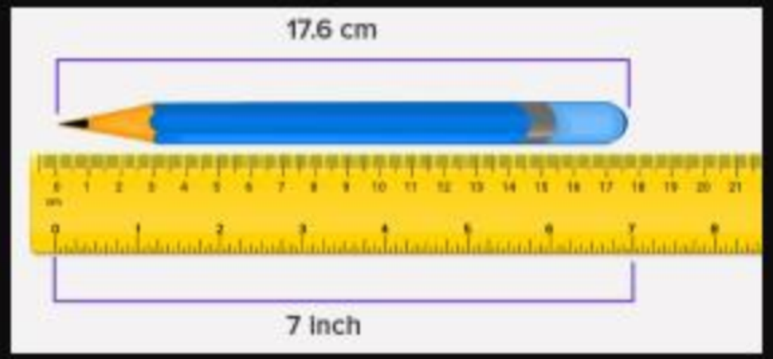
Methods of Measurement:

In precision measurement various methods of measurement are adopted depending upon the accuracy required and the amount of permissible error.

1. Direct Measurement Method

In this method the value of the physical parameter(measurand) is determined by comparing it directly with reference standards.

Example: Measurement of length with the help of scale



2. In-Direct Measurement Method

In this method the value of the physical parameter(measurand) is determined by indirect comparison with secondary standards through calibration.

The measurand is converted into an analogous signal which is subsequently processed and fed to end device that presents the result of measurement.

ERROR IN MEASUREMENT

7 Marks

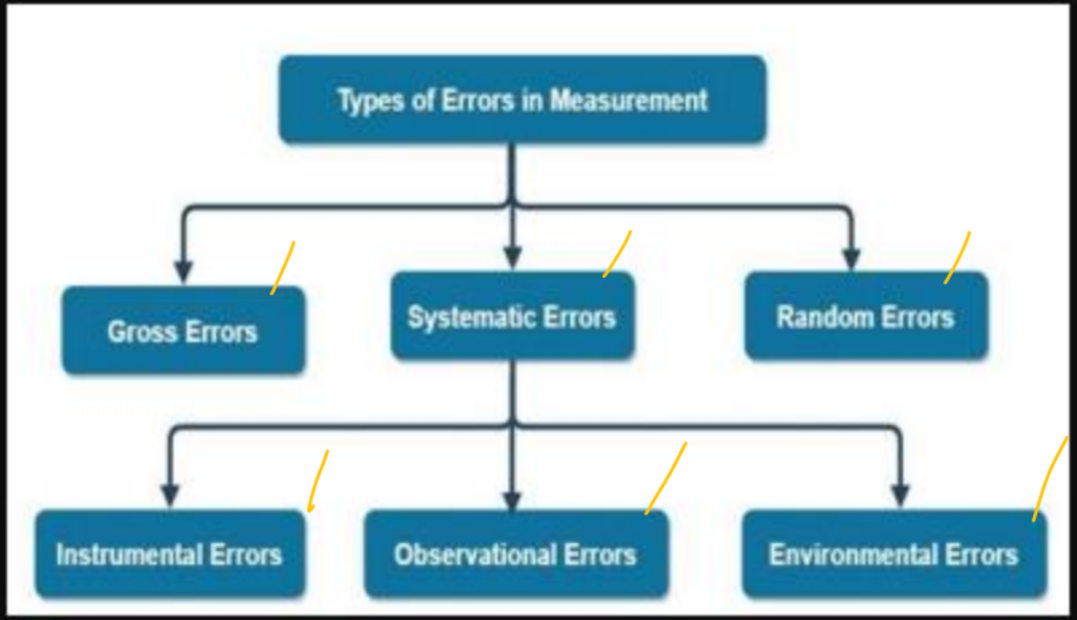
It is defined as a difference between indicated or measured value and true value.

10.01 cm

10 cm — 9.99 cm

ERROR = TRUE VALUE – MEASURED VALUE

- No measurement can be made with perfect accuracy but it is important to find out what accuracy actually is and how different errors have entered in to measurement.
- A study of errors is a first step in finding ways to reduce them.
- Errors may arise from different sources and are usually classified as under.



Gross Error:

- It mainly covers human mistakes in reading instruments and recording and calculating measurement results.

Gross errors can be avoided by using two suitable measures, and they are written below:

1. Proper care should be taken in reading, recording the data. Also, the calculation of error should be done accurately.

2. By increasing the number of experiments, we can reduce the gross error. If each experimenter takes different points, then by taking the average of more readings we can reduce the gross

Systematic Error:

Systematic errors can be better understood if we divide them into subgroups.

(i) **Instrumental Error:** These errors arise due to three main reasons:

(a) **Due to inherent shortcomings in the instruments:** These errors arise due to faulty construction and calibration of the measuring instruments. These errors may cause the instrument to read too low or too high.

(b)Due to misuse of the instruments

(c)Due to the loading effects of instruments

(ii) Environmental Errors: This type of error arises in the measurement due to the effect of the external conditions includes temperature, pressure, and humidity and can also include an external magnetic field.

(iii) Observational Errors: These are the errors that arise due to:

(a) An individual's bias, lack of proper setting of the apparatus, or an individual's carelessness in taking observations.

(b)The measurement errors also include wrong readings due to Parallax errors.

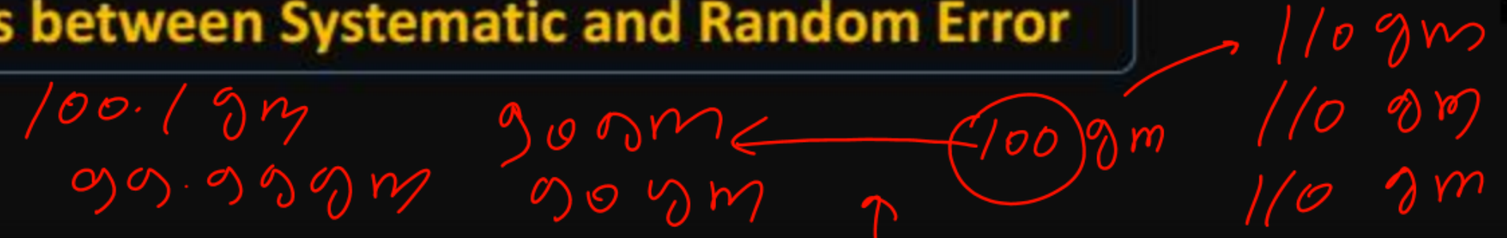
Random Error:

(a) The random errors are those errors, which occur irregularly and hence are random.

(b) The random errors are accidental, small and independent.

(c) They vary in an unpredictable manner.

Differences between Systematic and Random Error



Basis for Comparison	Random Error	Systematic Error
Definition	Random error occurs in the experiment because of the uncertain changes in the environment	It is a constant error which remains same for all measurements
Causes	Environment, limitation of the instrument, etc.	Incorrect calibration and incorrectly using the apparatus
Minimize	By repeatedly taking the reading.	By improving the design of the apparatus
Magnitude of Error	vary	Constant
Direction of Error	occur in both the direction	occur only in one direction
Types	Do not have any type	Three

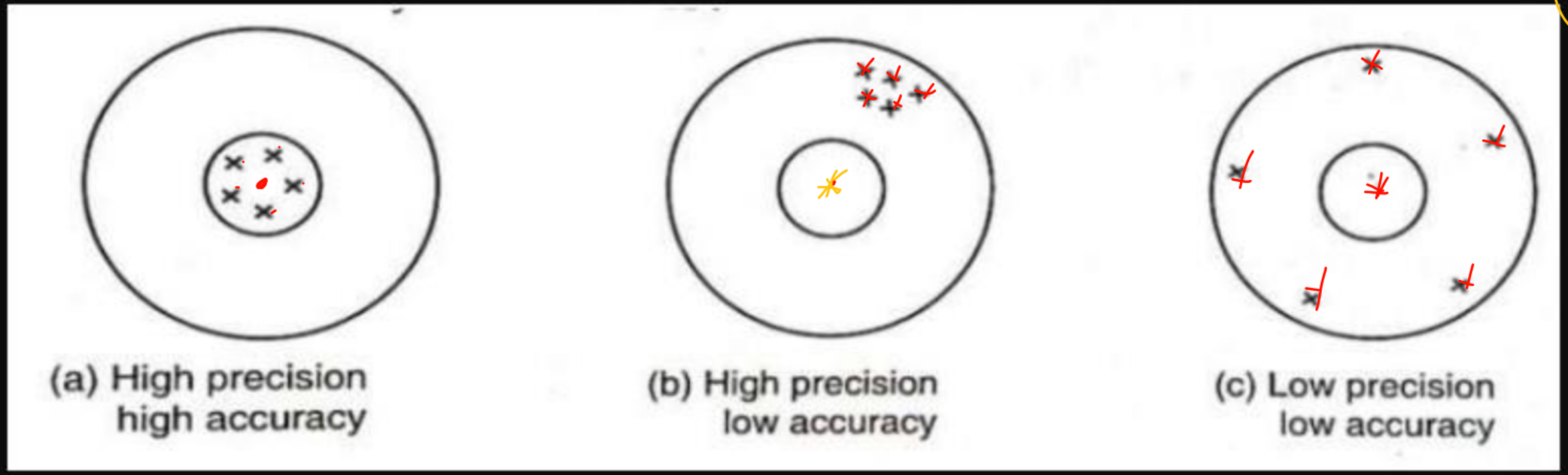
Accuracy and Precision

2m

10 cm → 1 → 10.1 cm
2 → 10.2 cm
3 → 9.9 cm

- In a set of measurements, accuracy is the closeness of the measurements to a true value.
- In a set of measurements precision is the closeness of the measurements to each other.

20 cm → 1 → 15.01 cm
2 → 15.02 cm
3 → 19.90 cm



(a) High precision high accuracy

(b) High precision low accuracy

(c) Low precision low accuracy

Calibration in Measurement

- Instrument calibration is one of the primary processes used to maintain instrument accuracy.

Or

- Calibration is the process of comparing the measurements of an instrument or device to a known standard or reference to determine any deviation from accuracy and to make necessary adjustments to correct these deviations.
- The goal of calibration is to ensure that the instrument provides accurate and reliable measurements within specified tolerances.

- Calibration provides consistency in readings and reduces errors, thus validating the measurement universally.

Measurement of Pressure

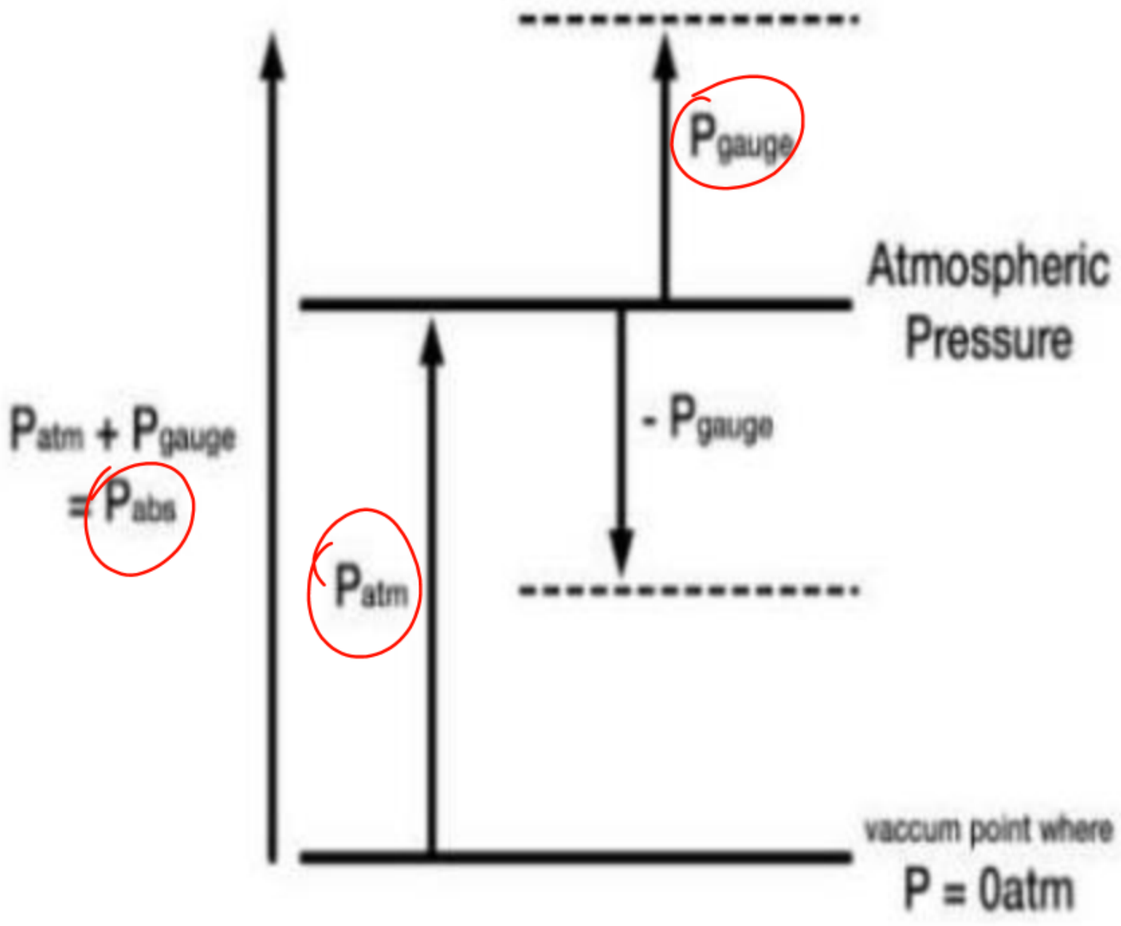
❖"It is defined as normal force per unit area."

$$P = \frac{F}{A}$$

❖It is a scalar quantity.

❖Units of Pressure :

- N/m^2
- Pascal (Pa) (1 Pa = 1 N/m^2)
- atm (1 atm = 101325 Pa = 101.325 kPa)
- Bar (1 bar = 10^5 Pa = 10^5 N/m^2



Measurement of Pressure

1. U-tube Manometer
2. Bourdon Tube Pressure Gauge

Manometer

- It is an instrument used for measuring the pressure at a point in a fluid by balancing the column of fluid by same or another fluid column.

- They are classified as

1. Simple Manometers

(a) Piezometers
(b) U-tube monomer
(c) Single column manometer

2. Differential manometers

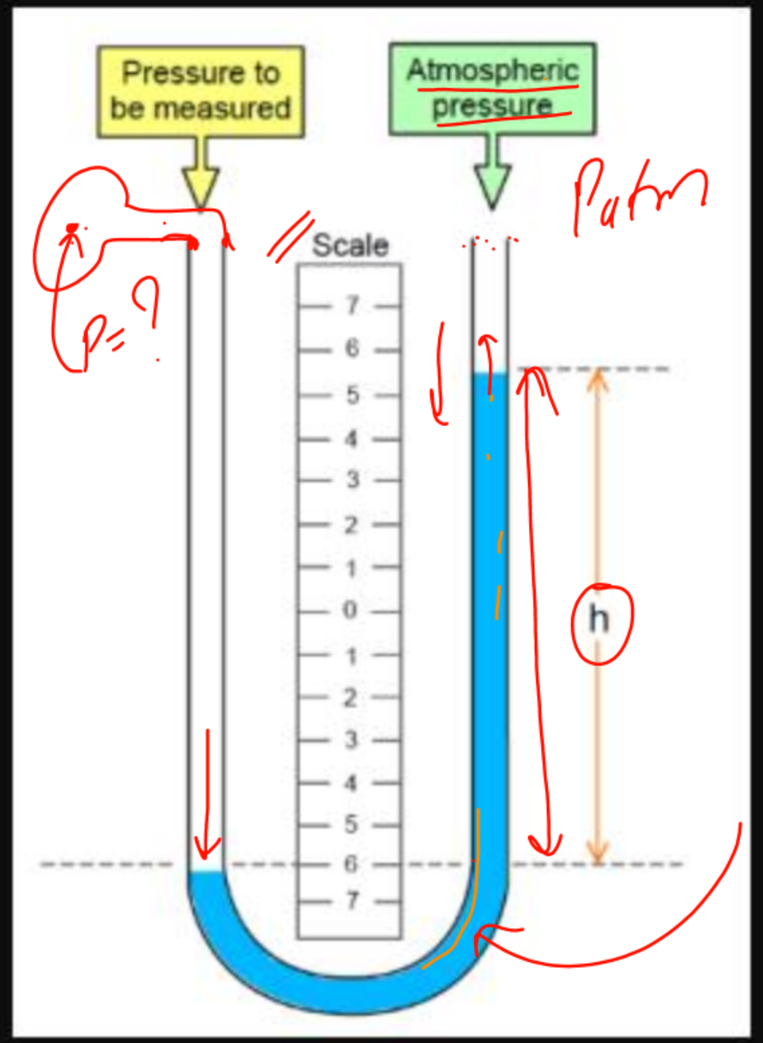
(a) U-Tube differential manometer
(b) Inverted U-Tube differential manometer

U-Tube Manometer

- This manometer consists of U- shaped glass-tube as shown in figure.

- One end of the U-tube is connected to the point where pressure has to be measured while other end remains open to the atmospheric pressure.

- Water and mercury are used as a manometric fluid.



Advantages of Manometer

- Simple in construction
- High accuracy & sensitivity

Disadvantages of Manometer

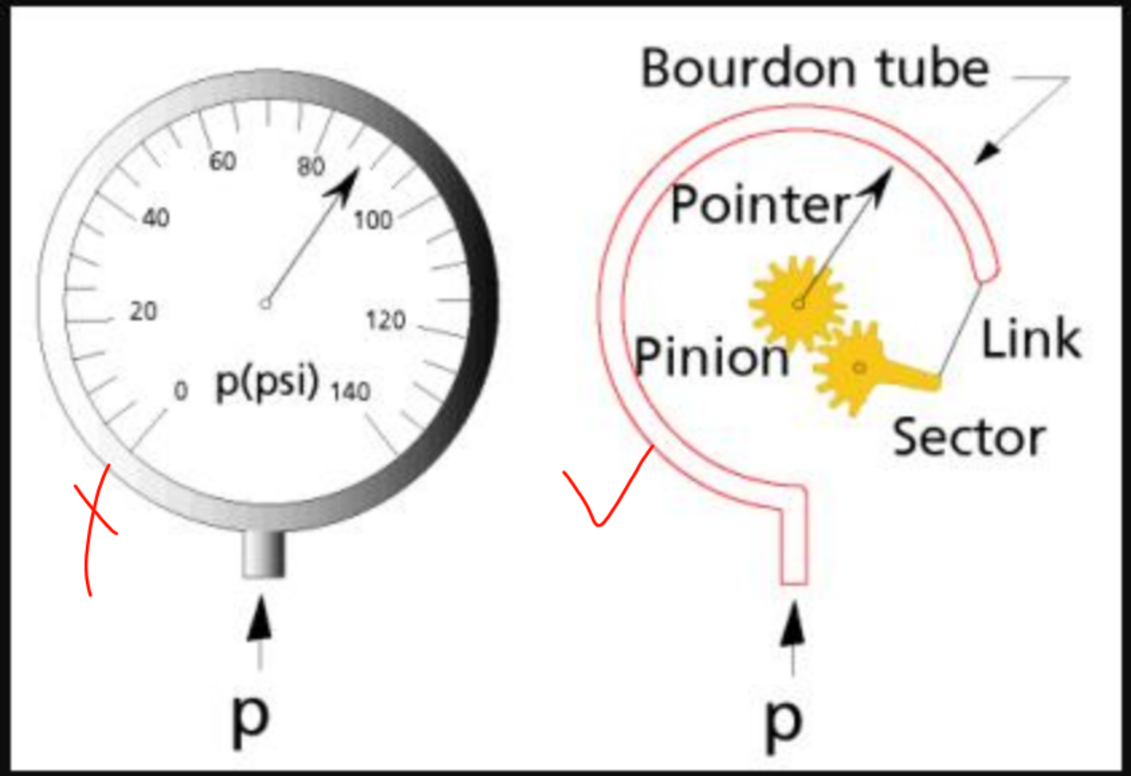
- Large & bulky
- Measured fluids must be compatible with the manometer fluids
- Need for leveling

Bourdon Tube Pressure Gauge

- Bourdon tube pressure gauge is used to measure the pressure from 0.6 bar to 7000 bar.
- It is a mechanical pressure-measuring instrument.
- It operates without any electric power.

- When the bourdon tube is subjected to applied pressure then it deflects.
- This deflection is proportional to applied pressure.
- C-type bourdon tube consists of a long thin wall cylinder that is sealed at one end.
- The other end of the tube is fixed and open at the application where pressure is measured.

- The tip of the tube is connected to a segmental liver through an adjustable link.
- The segmental liver is provided with a rack that meshes with a suitable pinion.
- This pinion is mounted on a spindle.
- This spindle holds a pointer.
- The resulting movement of the free end of the tube causes the pointer to move over a scale



.....Bourdon Tube Pressure Gauge

Advantages of Bourdon Tube

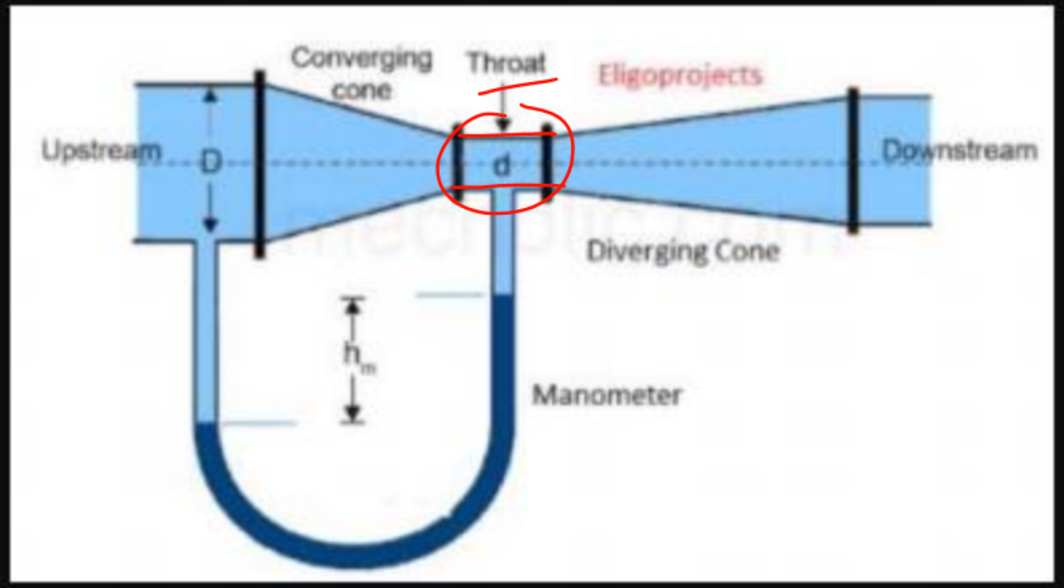
- Low cost
- Simple in construction
- Wide rangeability
- Good accuracy
- Adaptable to transducer designs

Disadvantages of Bourdon Tube

- Subject to Hysteresis
- Susceptible to shock & vibration

Measurement of mass flow rate : Venturi Meter

- It is a gradually converging-diverging device that is used to measure the discharge of fluid flow.
- Venturi meter is work on Bernoulli's equation.
- It is one of the costlier device to measure discharge.
- Accuracy is high.
- Losses are less.
- Value of C_d is high (0.94 to 0.98) [Coefficient of discharge ,$C_d = Q_{act}/Q_{th}$



Main parts of Venturimeter:-

1. Converging part
2. Throat
3. Diverging Part

$$Q = \frac{A_1 A_2 \sqrt{2gh}}{\sqrt{A^2_1 - A^2_2}}$$

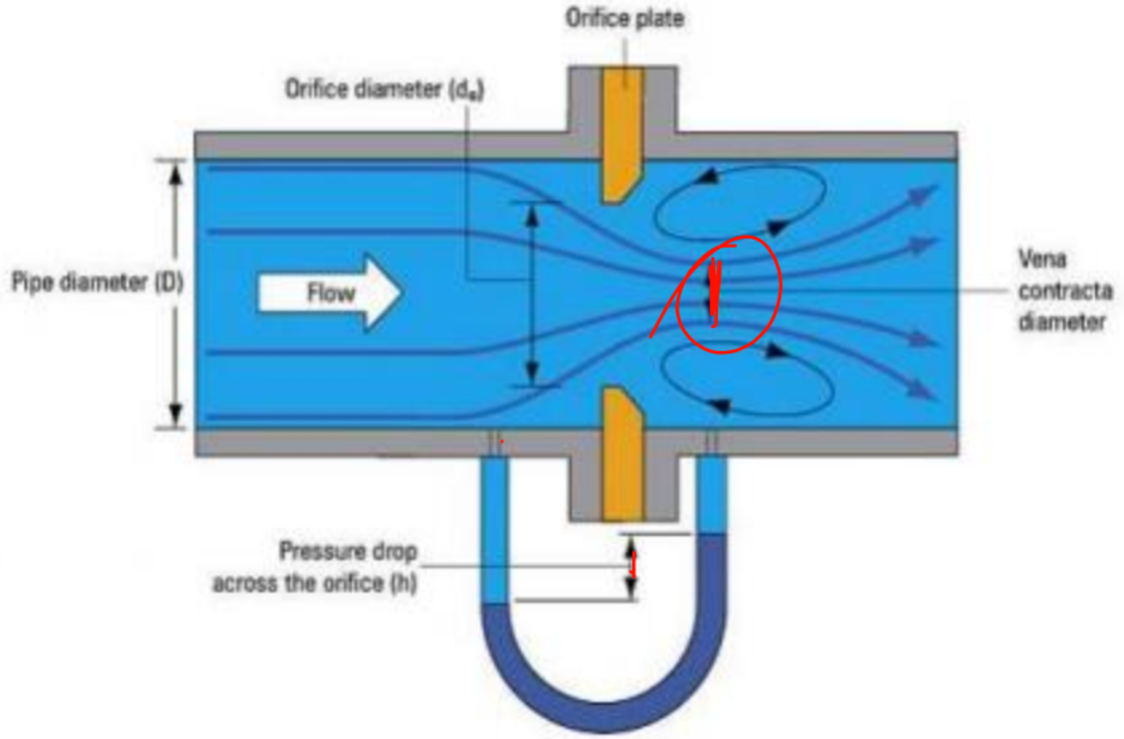
- Cross cross-sectional area of the throat section is smaller than the inlet section due to this the velocity of flow at the throat section is higher than the velocity at the inlet section, this happens according to the continuity equation.
- The increases in velocity at the throat result in decreases in pressure at this section, due to this pressure difference is developed between the inlet valve and throat of the venturi-meter.
- This pressure difference is measured by a manometer by placing this between the inlet section and the throat.
- Using the pressure difference value, we can easily calculate the flow rate through the pipe.

Measurement of mass flow rate : Orifice Meter

$$Q = C_c A_0 \frac{\sqrt{2gh}}{\sqrt{1 - C^2_c \left(\frac{A_0}{A_1}\right)^2}}$$

- Orifice Meter is a cheapest device to measure **discharge**.
- Losses are high.
- Value of C_d is low (0.60 to 0.65) [Coefficient of discharge , $Cd = \frac{Q_{act}}{Q_{th}}$]

- Orifice meter is device used to determine the rate of flow through pipe.
- It consist of flat circular plate which has a sharp edged circular hole called orifice.
- It is fixed concentric to pipe.
- The orifice diameter is generally kept half of the diameter of the pipe.
- It is based on the same principle as explained in venturimeter.
- The value of Cd varies between 0.60 to 0.65.
- It is a economical and less space is requred for fitting.



Measurement of Temperature: 1. Thermocouple Thermometer , 2. Optical Pyrometers

Temperature of a body is defined as degree of hotness or coldness of the body measured on a definite scale.

The commonly used scales for measuring temperature are:

- Kelvin scale (K)
- Centigrade scale (^{O}C)
- Fahrenheit scale (^{O}F)
- Rankine scale (R)

- The principle of temperature measurement is based on Zeroth's law of thermodynamics.
- The instrument which is used for measuring temperature is a thermometer.

Note: For a higher range of temperatures, i.e. above 650 ^{O}C, filled thermometers are unsuitable.

for the higher range of temperatures, thermocouples and pyrometers are used.

Thermocouple Thermometer

➢It is the most popular electrical method for temperature measurement in industrial applications.

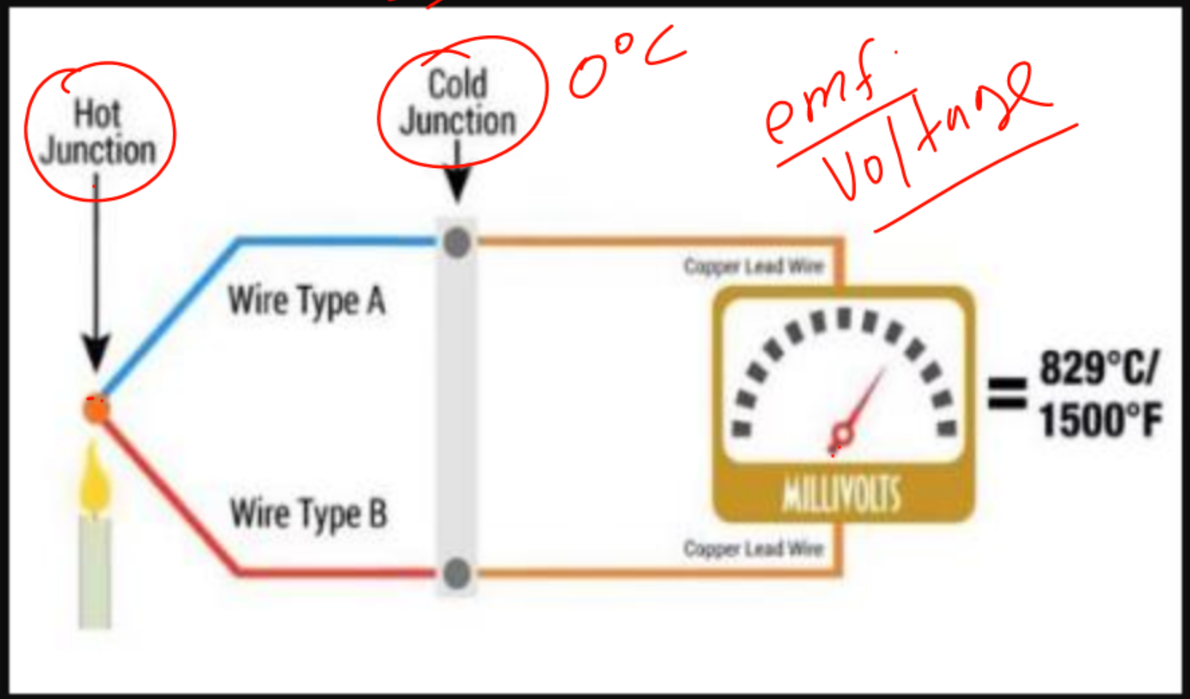
➢The temperature range of this instrument depends upon the type of thermocouple materials used.

The major reasons behind their popularity are :

(i) Readings are consistent

(ii) They can measure over a wide range of temperatures.

(iii) Their characteristics are almost linear with an accuracy of about 0.05%.



Thermocouple Thermometer

The working of thermocouples is based on the principle of the Seeback Effect.

- When two junctions of a pair of dissimilar metals are maintained at different temperatures, e.m.f. is generated. This phenomenon of generation of em.f. is called the Seebeck effect.
- A sensitive voltmeter connected to the circuit will indicate a voltage (emf) which is correlated to the difference in temperature between the hot junction and the cold junction.
- The reference junction or cold junction is usually maintained at some constant temperature, such as 0^{o} C.

Optical Pyrometers

Principle of Optical Pyrometers :

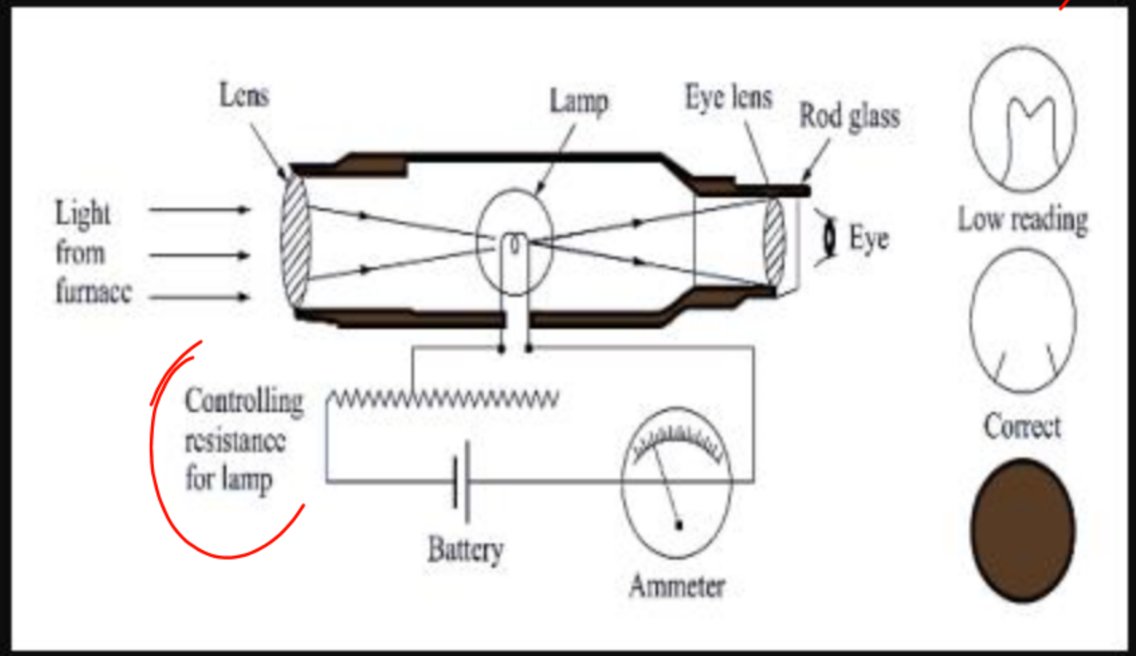
- It is a device which measures the temperature as a change in brightness of a colour.
- Acording to Planck's law, energy levels in the radiation emitted by a hot body are are distributed in different wavelengths.
- As the temperature of hot body rises,the emissive power shifts towards shorter wavelengths.
- The radiations from a hot body at high temperature fall within the visible region of electromagnetic spectrum.
- If we can measure brightness of the light of a given emitted by a hot source , we can estimate its temperature.
- This is the principle of optical pyrometers.
- It can be used to measure temperature in the range of 800 °C to 1200 °C.

Optical Pyrometers

Construction of Optical Pyrometers :

As shown in the fig.

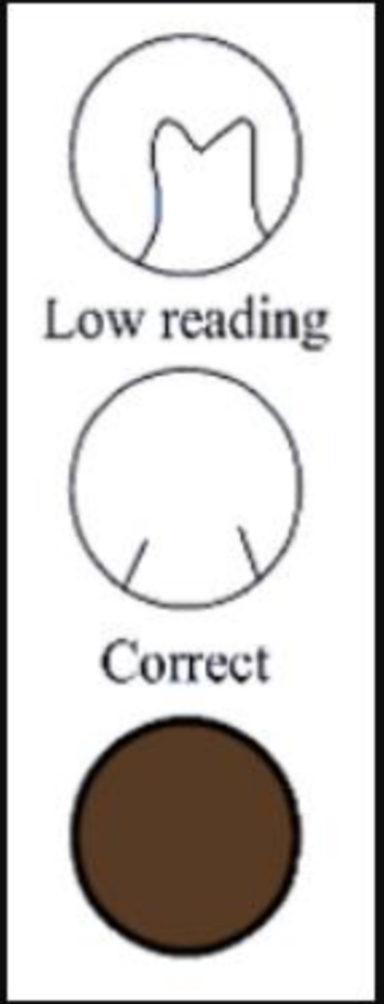
- An eye piece at the right side and an optical lens on the left.
- A reference lamp, which is powered with the help of a battery.
- A rheostat to change the current and hence the brightness intensity.
- So as to increase the temperature range which is to be measured, an absorption screen is fitted between the optical lens and the reference bulb.
- A red filter placed between the eye piece and the reference bulb helps in narrowing the band of wavelength.



Optical Pyrometers

Working of Optical Pyrometers :

- As shown in the fig. using the rheostat, current can be varied in the tungsten lamp, so as to vary the brightness of light.
- The image of the radiating source (hot body) , produced by the object lens system, is made to superimpose on the filament of electric lamp.
- The electric current through the filament is varied while being viewed through a filter and eye piece.
- The view shall appear one of the types as shown in fig.
- If the filament temperature is lower as compared to hot body temperature, it is less bright and appears darker.
- But when the brightness of filament is same as that of hot body, the filament disappears. At this state the temperature of the filament is equal to that of the hot body.
- The tungsten filament lamp is so calibrated that for known current, the temperature of the filament is also known.



Optical Pyrometers

Uses :

It is widely used for accurate measurement of temperature.

- Furnace
- Molten metal
- Steel manufacturing
- Glass production
- Ceramics manufacturing
- Furnace Monitoring
- Aerospace engineering

Advantages :

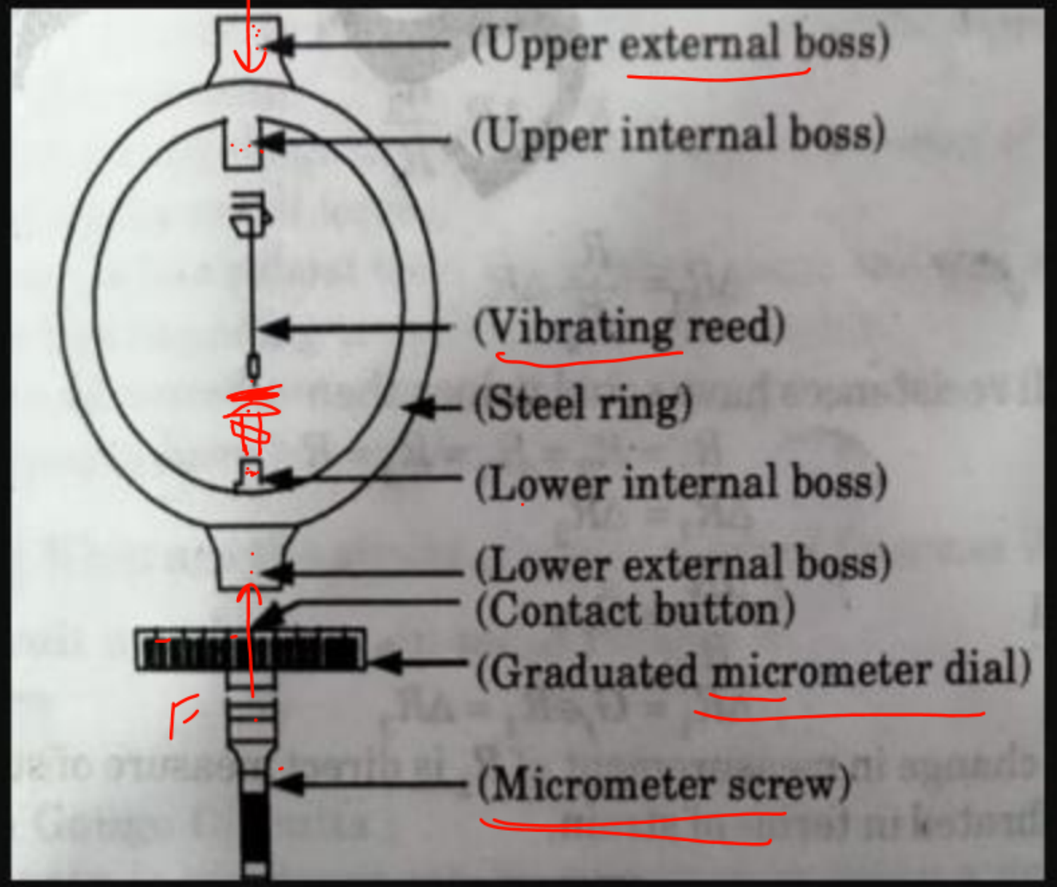
- Excellent accuracy within $\pm$ 5 °C
- No direct contact with the object whose temperature is to be measured.
- Measurement is independent of the distance between the body and the instrument.
- The semiskilled operator is required

Dis-Advantages :

- Can not measure lower temperature
- Radiation is harmful

Measurement of Force (Proving Ring)

- The proving ring is a device used to measure force.
- It consists of an elastic ring of known diameter with a measuring device located in the center of the ring.
- Proving rings come in a variety of sizes. They are made of a steel alloy.
- Proving rings can be designed to measure either compression or tension forces. Some are designed to measure both.



Construction of Proving Ring:

- The proving ring consists of two main elements, the ring itself and the diameter-measuring system.
- Forces are applied to the ring through the external bosses.
- The resulting change in diameter, referred to as the deflection of the ring, is measured with a micrometer screw and the vibrating reed mounted diametrically within the ring.
- The micrometer screw and the vibrating reed are attached to the internal bosses of the ring.

.....Measurement of Force (Proving Ring)

Working of Proving Ring:

- **To read the diameter of the ring, the vibrating reed is set in motion by gently tapping it with a pencil.**
- **As the reed is vibrating, the micrometer screw on the spindle is adjusted until the contact-button on the spindle just touches the vibrating reed, dampening out its vibrations.**
- **When this occurs a characteristic buzzing sound is produced.**
- **At this point a reading of the micrometer dial indicates the diameter of the ring.**

Applications:

Proving rings are commonly used in various engineering and scientific fields for force measurement, including:

- Material testing
- Structural analysis
- Load monitoring in machinery and equipment
- Calibration of other force-measuring devices
- Geotechnical testing, such as soil and rock mechanics

Advantages:

- High accuracy and sensitivity
- A wide range of measurement capacities is available
- Suitable for both static and dynamic force measurements
- Robust construction for reliable performance in harsh environments

Measurement of Torques (Prony Brake Dynamometer)

Working and construction of Prony Brake Dynamometer:

- It consists of two wooden blocks, placed around a pulley of radius R as shown in fig.
- The pulley is keyed to the shaft of the engine whose power to be measured.
- The wooden blocks are clamped by two nuts and bolts.
- A helical spring is placed between the nut and the upper wooden block in order to adjust the pressure on the pulley and hence control its speed.
- The upper block also has a long lever attached to it which carries a load W at its outer end.
- A counter weight is placed on the other end of lever to balance the brake when unloaded.
- The stops limit the motion of the lever.
- To measure shaft power using prony brake dynamometer, the lever is loaded with suitable load W and nuts tightened such that the engine shaft runs at a constant speed and the lever is in a horizontal position.

Measurement of Torques (Prony Brake Dynamometer)

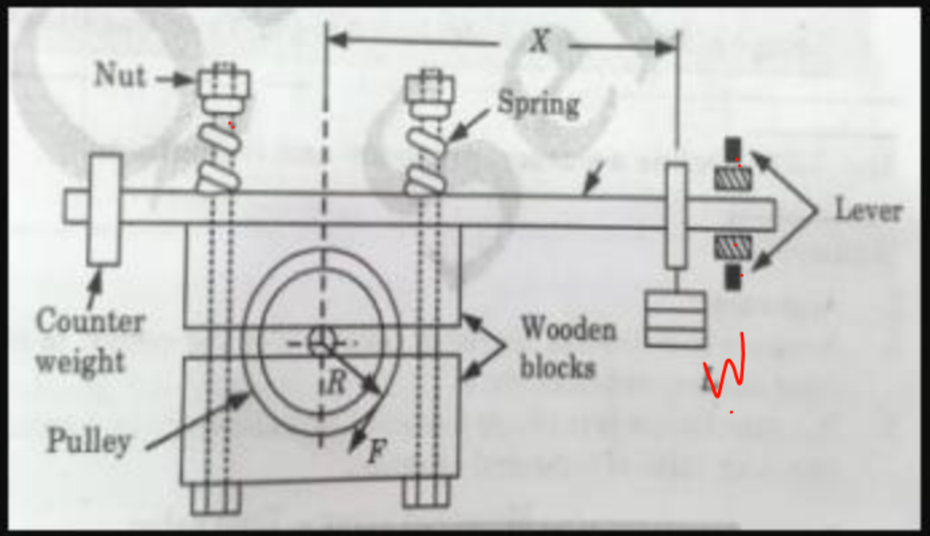
- Under such working conditions, the moment due to load W balances the moment due to frictional resistances force between wooden blocks and the pulley.

- Hence, torque(T) on the shaft is given by the relation
  $T = W \times X$ = F x R

- Brake Power(P) transmitted by the engine shaft,

$$P = \frac{2\pi NT}{60} \text{ watt.}$$

N = rpm.



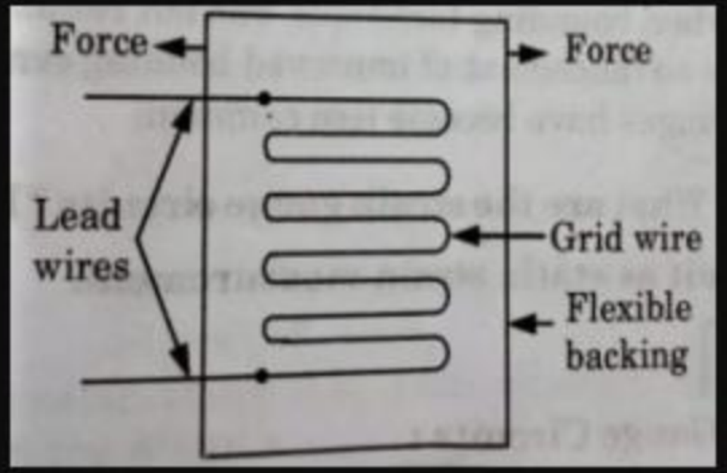
Measurement of strain(Bonded and Unbonded Strain Gauge)

Strain Gauge

- The transducers which measure the strain in the body or object are known as strain gauge.
- Strain is defined as the ratio of change in length to its original length. It is dimensionless quantity.

Bonded Strain Gauge.

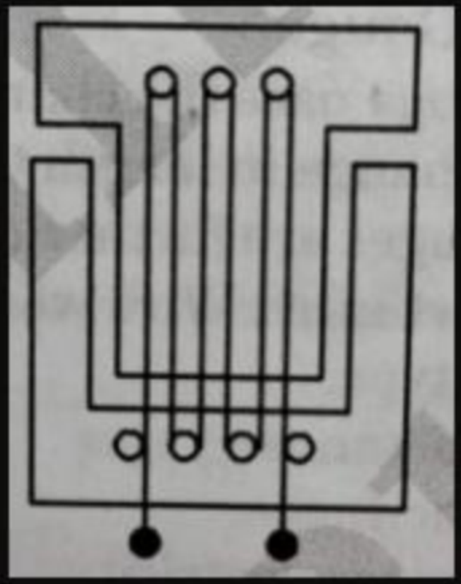
- These gauges are directly bonded (pasted) on the surface of the structure under study.
- Hence they are termed as bonded strain gauges.
- A bonded metal wire strain gauge is used for stress analysis.
- A resistance wire strain gauge has a wire of diameter 0.25mm or less.
- The grid of fine resistance wire is cemented to carrier. It can be a thin sheet of paper, Bakelite or a sheet of Teflon.
- To prevent the wire from any mechanical damage, it is covered on top with a thin sheet of material.
- The spreading of wire allows a uniform distribution of stress over the grid.
- The carrier is bonded with an adhesive material. Due to this, a good transfer of strain from carrier to a grid of wires is achieved.



Measurement of strain(Bonded and Unbonded Strain Gauge)

Unbonded Strain Gauge

- The unbonded resistance strain gauge uses a strain sensitive wire with one end fixed and the other end attached to a movable element.
- The basic design of this type of transducer is shown in Fig.
- Strain, induced on the wire by the displacement of the movable element, produces a change in resistance proportional to the displacement of the movable element.
- Unbonded strain gauge can measure very small motion of the order of 50 pm and very small forces. 4.
- The device is less robust than the bonded gauge and was developed at a time when bounding technique was not reliable.
- With the advancement of improved bonding cements, unbonded wire strain gauges have become less common.



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