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# Fourth Semester B.E. Degree Examination, July/August 2022
## Mechanical Measurements and Metrology

Time: 3 hrs. Max. Marks: 100

*Note: Answer any FIVE full questions, choosing ONE full question from each module.*

### Module-1

1 a. Explain international prototype meter with a neat sketch. **(06 Marks)**

b. Four length bars A, B, C and D each having a basic length 125 mm are to be calibrated using a calibrated length bar of 500 mm basic length. The 500 mm bar has an actual length of 499.9991 mm. Also, it was found that

$L_B = L_A + 0.0001$ mm

$L_C = L_A + 0.0005$ mm

$L_D = L_A - 0.0002$ mm

and $L_A + L_B + L_C + L_D = L + 0.0003$ mm

Determine $L_A$, $L_B$, $L_C$ and $L_D$ **(08 Mark**

c. Define a standard. Write a note on wavelength standards. **(06 Mar**

OR

2 a. Explain sine centre with a neat sketch. **(06 Ma**

b. Explain the principle and construction of Auto collimator with a neat diagram. **(14 Ma**

### Module-2

3 a. Define the terms :

(i) Limits (ii) Fits (iii) Fundamental deviation (iv) Toleran

(v) Allowance (vi) Basic size **(06 M**

b. Determine the actual dimensions to be provided for a shaft and hole of 90 mm size for I type clearance fit. Given Diameter steps are 80 mm and 100 mm,

$i = 0.45\sqrt[3]{D} + 0.001D$,

Value of tolerances for IT8 = 25i and for IT9 = 40i

and Fundamental Deviation for 'C' type shaft $F.D = -11\,D^{0.41}$

and also design the GO and NOGO gauges, considering wear allowance. **(14 M**

OR

4 a. Explain the construction and working of Sigma Comparator with a neat sketch. **(10 M**

b. Explain Solex Pneumatic Comparator with a neat sketch. **(10 M**

### Module-3

5 a. Explain Toolmaker's microscope with a neat sketch. **(14 M**

b. Define Best Size Wire. Derive an expression for the same. **(06 M**

OR

6 a. Explain the measurement of gear tooth thickness using constant chord method. **(10 M**

b. Explain the Gear tooth Vernier Caliper with a neat sketch. **(10 M**

## Module-4

7 a. Explain Generalized measurement system with a Block Diagram. (12 Marks)
b. Define : (i) Accuracy (ii) Precision (iii) Threshold (iv) Hysteresis (08 Marks)

**OR**

8 a. Define Transfer Efficiency. Explain Ionisation transducer with a neat sketch. (07 Marks)
b. Classify Transducers. Explain Resistive transducers with a neat sketch. (13 Marks)

## Module-5

9 a. Explain Equal arm balance for force measurement. (12 Marks)
b. Explain Prony brake dynamometer with a neat sketch. (08 Marks)

**OR**

10 a. Explain Mc Leod gauge with a neat sketch. (10 Marks)
b. Define thermocouple. State the laws of thermocouple and explain. (06 Marks)
c. Explain the theory of strain gauges and define gauge factor. (04 Marks)

* * * * *

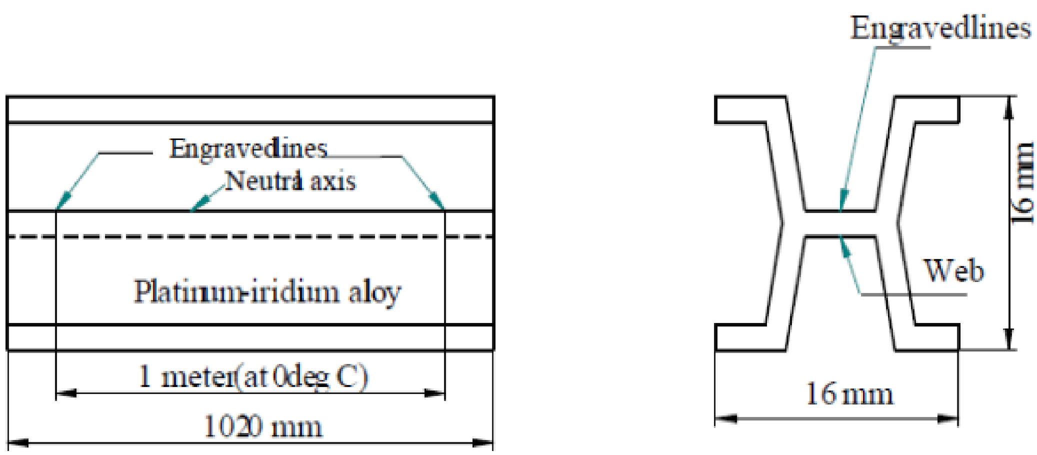
# Scheme and Solution

## Module-1

**1a.** **2 sketch+4 Explanation =6M**

### International Prototype meter

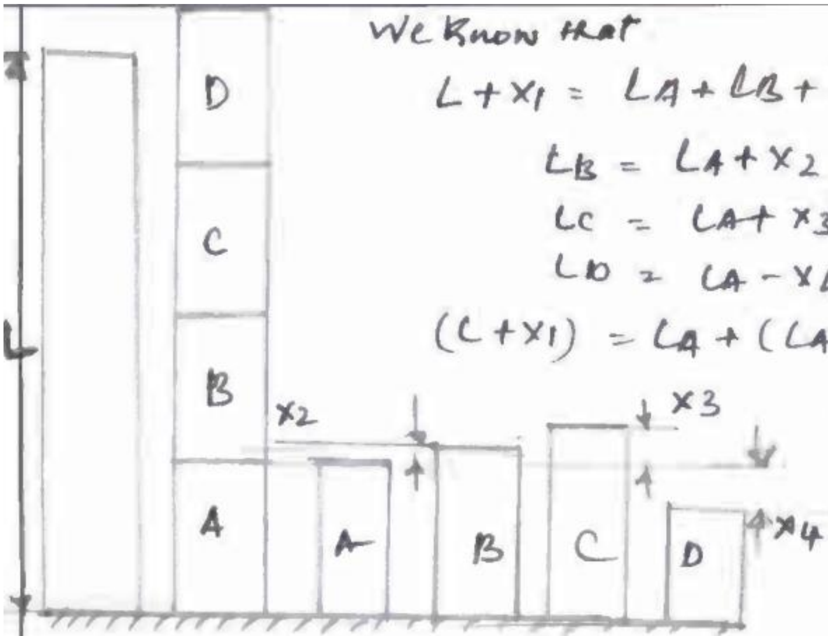
It is defined as the straight line distance, at 0°C, between the engraved lines of pure platinum-iridium alloy (90% platinum & 10% iridium) of 1020 mm total length and having a 'tresca' cross section as shown in fig. The graduations are on the upper surface of the web which coincides with the neutral axis of the section.




The tresca cross section gives greater rigidity for the amount of material involved and is therefore economic in the use of an expensive metal. The platinum-iridium alloy is used because it is non oxidizable and retains good polished surface required for engraving good quality lines.

**1.b** **sketch-2+ Solution each 2 M = 8M**

Actual length of bar 499.9991mm.
Basic length of length bar = 500 mm.
Basic length of each bar = 125mm
$X_2$ = 0.0001mm, $X_3$ = 0.0005mm, $X_4$ = −0.0002mm
$X_1$ = 0.0003 mm.




We know that

$$L + x_1 = L_A + L_B + L_C + L_D$$

$$L_B = L_A + x_2 = L_A + 0.0001\ mm$$

$$L_C = L_A + x_3 = L_A + 0.0005\ mm$$

$$L_D = L_A - x_4 = L_A - 0.0002\ mm$$

$$(L + x_1) = L_A + (L_A + x_2) + (L_A + x_3) + (L_A - x_4)$$

$$L + x_1 = 4L_A + x_2 + x_3 - x_4$$

$$4L_A = L + x_1 - x_2 - x_3 + x_4$$

$$L_A = 124.9997\ mm$$

$$L_B = L_A + x_2 = 124.9997 + 0.0001 = 124.9998$$

$$L_C = L_A + x_3 = 124.9997 + 0.0005 = 125.0002\ mm$$

$$L_D = L_A - x_4 = 124.9997 - 0.0002 = 124.9995\ mm$$

**1c.** **Definition -2 + Explanation 4 Marks = 6M**

## Definition of Standards

A standard is defined as "something that is set up and established by an authority as rule of the measure of quantity, weight, extent, value or quality".

For example: a meter is a standard established by an international organization for measurement of length. Industry, commerce, international trade in modern civilization would be impossible without a good system of standards.

## Light (Optical) wave Length Standard

Because of the problems of variation in length of material length standards, the possibility of using light as a basic unit to define primary standard has been considered. The wavelength of a selected radiation of light and is used as the basic unit of length. Since the wavelength is not a physical one, it need not be preserved & can be easily reproducible without considerable error.

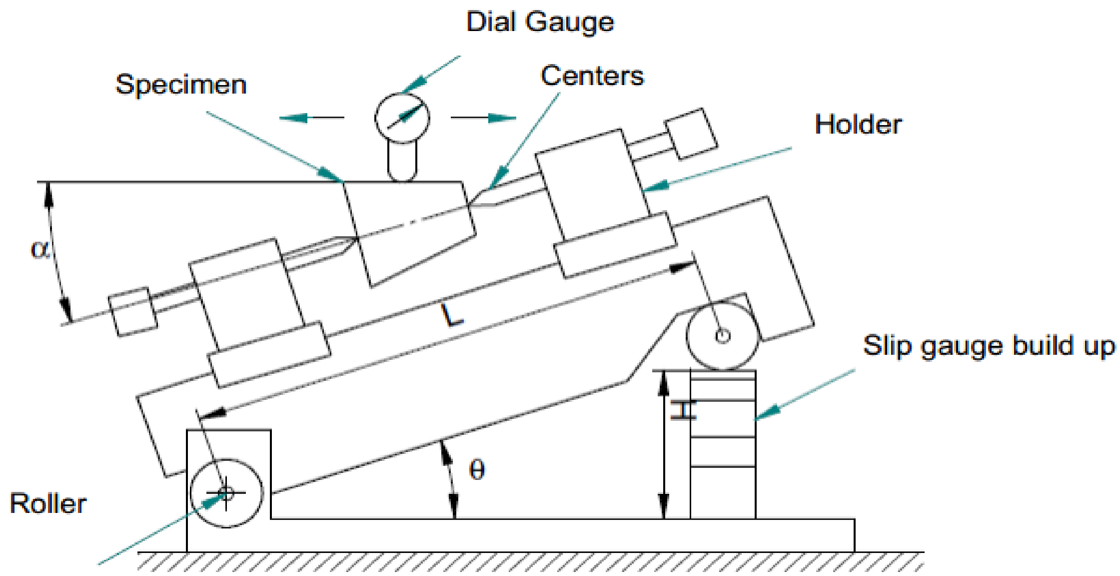
A krypton-filled discharge tube in the shape of the element's atomic symbol. A colorless, odorless, tasteless noble gas, krypton occurs in trace amounts in the atmosphere, is isolated by fractionally distilling liquefied air. The high power and relative ease of operation of krypton discharge tubes caused (from 1960 to 1983) the official meter to be defined in terms of one orange-red spectral line of krypton-86.

**[OR]**

**2a.** **Definition -2 + Explanation 4 Marks = 6M**

**Sine Centers**

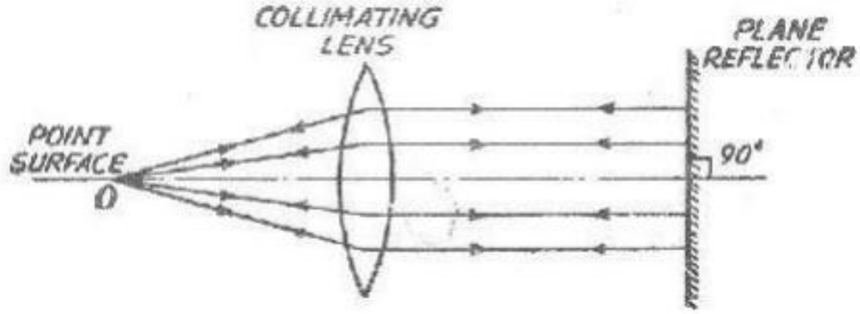
It is the extension of sine bars where two ends are provided on which centers can be clamped, as shown in Figure. These are useful for testing of conical work centered at each end, up to 60°. The centers ensure correct alignment of the work piece. The procedure of setting is the same as for sine bar. The dial indicator is moved on to the job till the reading is same at the extreme position. The necessary arrangement is made in the slip gauge height and the angle is calculated as θ = Sin-1 (h/L).




**2 b.** **Sketch-6 + Explanation 8 Marks = 14M**

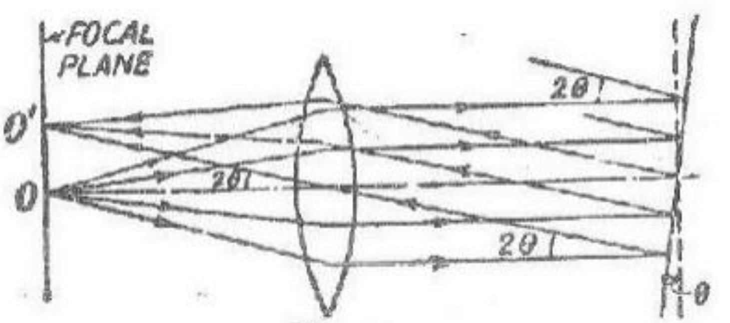
**Autocollimators**

This is an optical instrument used for the measurement of small angular differences. For small angular measurements, autocollimator provides a very sensitive and accurate approach. Auto-collimator is essentially an infinity telescope and a collimator combined into one instrument. The principle on which this instrument works is given below. O is a point source of light placed at the principal focus of a collimating lens in Fig. 8.30. The rays of light from O incident on the lens will now travel as a parallel beam of light. If this beam now strikes a plane reflector which is normal to the optical axis, it will be reflected back along its own path and refocused at the same point O. If the plane reflector be now tilted through a small angle 0, [Refer Fig] then parallel beam will be deflected through twice this angle and will be brought to focus at O' in the same plane at a distance x from O. Obviously $OO'=x=2\theta.f$, where $f$ is the focal length of the lens.




There are certain important points to appreciate here:

The position of the final image does not depend upon the distance of reflector from the lens, i.e. separation x is independent of the position of reflector from the lens. But if reflector is moved too much back then reflected rays will completely miss the lens and no image will be formed. Thus for full range of readings of instrument to be used, the maximum remoteness of the reflector is limited.




For high sensitivity, i.e., for large value of x for a small angular deviation θ, a long focal length is required.

## MODULE-2

**3. a** **Definition each -1 Mark= 6M**

**Limits**

The maximum and minimum permissible sizes within which the actual size of a component lies are called Limits.

**Tolerance:**

It is impossible to make anything to an exact size, therefore it is essential to allow a definite tolerance or permissible variation on every specified dimension.

**Fundamental Deviation:** It is the deviation, either upper or lower deviation, which is nearest to the zero line for either a hole or a shaft. It fixes the position of the tolerance zone in relation to the zero line.

***Fit*** is an assembly condition between 'Hole' & 'Shaft'

**Allowance:** It is the intentional difference between the hole dimensions and shaft dimension for any type of fit.

**3b.** **14Marks**

Given data's :

Shaft and hole size = 90H8 eq. Diameter 80 to 10

$i = 0.45\sqrt[3]{D} + 0.001D$, $IT8 = 25i$, $IT9 = 40i$,

$f = -11D^{0.41}$

Calculate the tolerance unit (i)

As diameter step is 80 to 100 mm the minimum and maximum diameter are 80 mm and 100 mm respectively.

$D = \sqrt{D_{min} \times D_{max}} = \sqrt{80 \times 100}$

$D = 89.4427$ mm.

We have $i = 0.45\sqrt[3]{D} + 0.001D$

$i = 0.45\sqrt[3]{89.4427} + 0.001 \times 89.4427$

$i = 2.109$ microns. $= 0.002102$ mm

For hole:

Fundamental deviations for hole

The fundamental deviation for a hole of 'H' Type is equal to zero.

$(f)\ hole = 0$

Calculate the upper and lower limit for hole

we know that Lower limit (LL)

$(LL) =$ Basic size $+$ Fundamental deviation

$90 + 0 = 90$ mm.

Standard tolerance for hole.

Standard tolerance grade $IT8 = 25i$

$= 25 \times 0.002102 = 0.05255$ mm

Upper limit $=$ LL $+$ Standard tolerance

$= 90 + 0.05255 = 90.05255$ mm

for a Shaft:

The fundamental deviation for shaft is given by, $f = -11 D^{0.41} = -11 (89.4427)^{0.41}$

$f = -69.4266$ microns. $= -0.0694$

Upper limit (UL) = Basic size + FD.

$90 + (-0.06942) = 89.9306$ mm

Standard tolerance grade IT8 = 25i

$= 25 \times 0.002102 = 0.05255$ mm.

lower limit = Upper limit − Standard tolerance

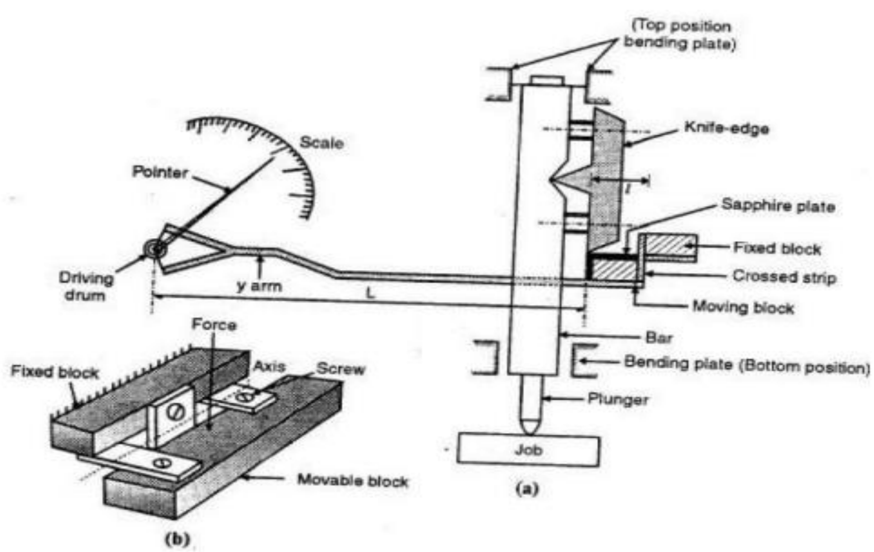
$= 89.9306 - 0.05255 = 89.878$

**[OR]**

**4.a.** **Sketch -4 + Explanation-6 =10 Marks**

**Sigma Comparator:**

The plunger is attached to a bar which is supported between the bending plates at thetop and bottom portion




The bar is restricted to move in the vertical direction. A knife edge is fixed to the bar.

The knife edge is attached to the sapphire plate which is attached to the moving block. The knife edge extorts a force on the moving block through sapphire plate. Moving block is attached to the fixed block with the help of crossed strips as shown in Figure (b). When the force is applied on the moving block, it will give an angular deflection. A Y-arm which is attached to the moving block transmits the rotary motion to the driving drum of radius r. This deflects the pointer and then the reading is noted.

If l = Distance from hinge pivot to the knife edge

L = Length of y-arm

R = Driving drum radius

D Length of the pointer

Then the total magnification = (L/l) *(D/R)

**4b.** **Sketch -4 + Explanation-6 =10 Marks**

## Pneumatic Comparators (Solex Gauge):

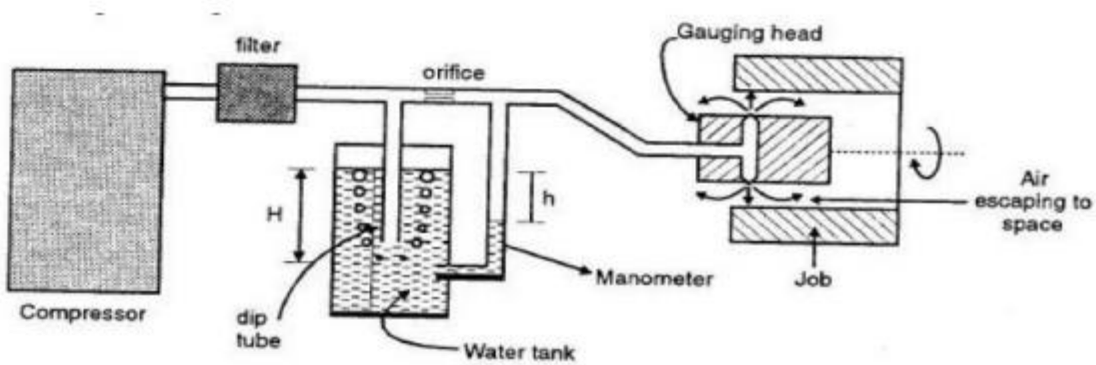
**Principle:**

It works on the principle of pressure difference generated by the air flow. Air issupplied at constant pressure through the orifice and the air escapes in the form of jetsthrough a restricted space which exerts a back pressure. The variation in the back pressure isthen used to find the dimensions of a component.

**Working:**

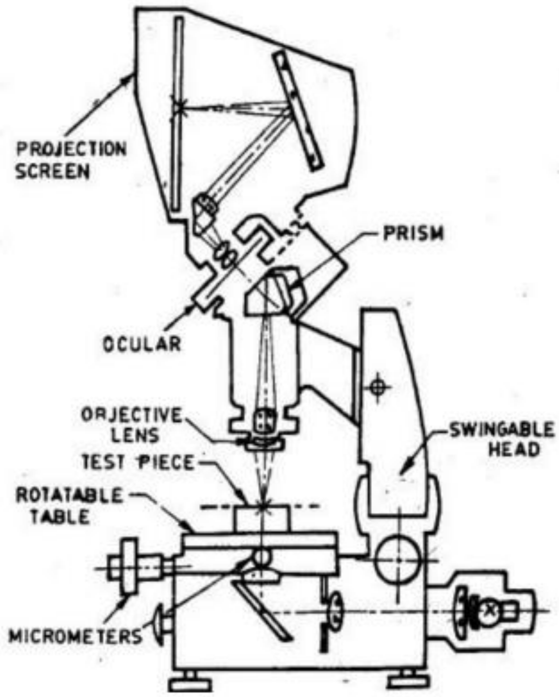
The air is compressed in the compressor at high pressure whichis equal to Water head H. The excess air escapes in the form of bubbles. Then the metric amount of air is passed through the orifice at the constant pressure. Due to restricted area, atA1 position, the back pressure is generated by the head of water displaced in the manometer tube. To determine the roundness of the job, the job is rotated along the jet axis, if no variation in the pressure reading is obtained then we can say that the job is perfectly circular at position A1.

Then the same procedure is repeated at various positions A2, A3, A4, position and variation in the pressure reading is found out. Also the diameter is measured at position A1corresponding to the portion against two jets and diameter is also measured at various position along the length of the bore.




**MODULE-3**

**5.a.** **Sketch -6 + Explanation-8 =14Marks**




The microscope consists of a rigid stand on which a swingable head is mounted. The measuring stage moves on ball guideways by actuating two measuring micrometersarranged perpendicular to each other in the length. and the cross-sections. The measuring range of each micrometer is 25 mm and the measuring capacity can be increased using slip gauges. A rotatable table is provided over the stage, on which the workpiece can be fixed either directly or between centers. This table can be rotated though 3600 and the angular rotation can be read by a fixed vernier to a scale value of 3'.

**Working:**

The component being measured is illuminated by the through light method. A parallel beam of light illuminates the lower side of workpiece which is then received by the objective lens in its way to a prism that deflects the light rays in the direction of the measuring ocular and the projection screen. Incident illumination can also be provided by an extra attachment. Exchangeable objective lens having magnification1X, 1.5X, 3X and 5X are available so that a total magnification of l0X,15X, 30 X and 50X can be achieved with an ocular of l0X. The direction of illumination can be tilted with respect to the workpiece by tilting the measuring head and the whole optical system. This inclined illumination is necessary in some cases as in screw thread measurements.

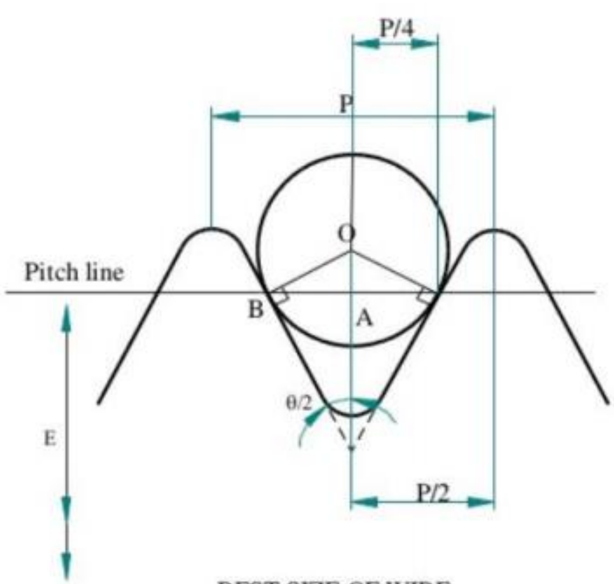
The scale value of this microscope:

- 0.01 mm for length measurement.
- 3' for angle measurement with rotatable table.
- 1' for angle measurement with the angle measuring ocular.

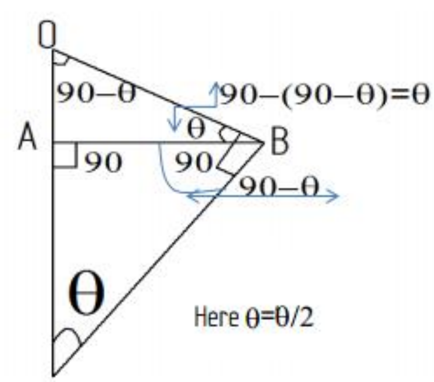
**5.b** **Sketch-2 M + Derivation 4 M=6Marks**

## BEST SIZE WIRE ($D_b$)

Best size wire is the standard wire used for measurement of effective diameter using floating carriage micrometer.
Figure shows the wire placed on a screw thread.

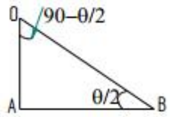



BEST SIZE OF WIRE



The best size wire is the one which makes contact at the pitch line or effective diameter of the screw thread. In other words, as shown in fig OB is perpendicular to flank portion of the thread at the pitch line.

In the triangle OAB, $\sin\left(B\hat{O}A\right)=\frac{AB}{OB}$, or $\sin\left(90-\frac{\theta}{2}\right)=\frac{AB}{OB}$




$$\therefore OB=\frac{AB}{\sin\left(90-\frac{\theta}{2}\right)}=\frac{AB}{\cos\frac{\theta}{2}}=AB\sec\frac{\theta}{2}.$$

But OB = radius of wire $=\frac{1}{2}\times$ dia of best size wire $(D_b)$

i.e. $D_b=2\times OB=2\times AB\sec\frac{\theta}{2}$. Also since AB lies on the pitch line, $AB=\frac{P}{4}$

where P is the pitch of the thread.

$$\therefore D_b=2\frac{P}{4}\sec\frac{\theta}{2} \qquad \boxed{D_b=\frac{P}{2}\sec\frac{\theta}{2}}$$

**[OR]**

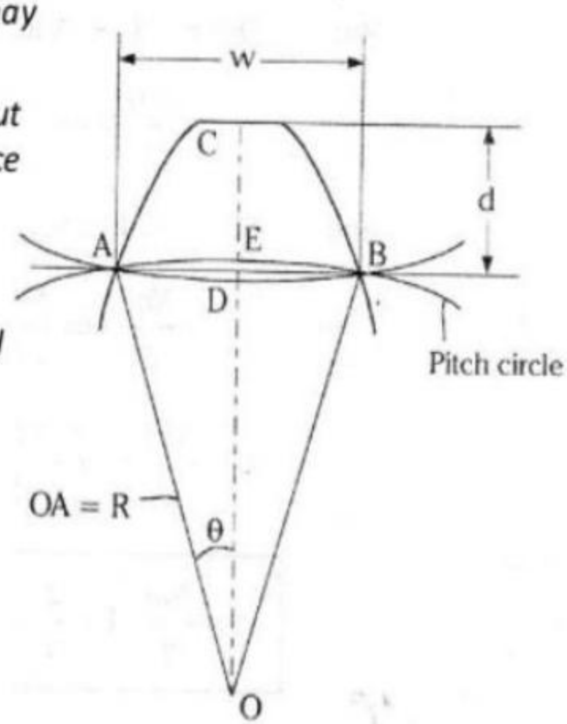
**6a.** **Sketch-4M + Derivation 6 M=10Marks**

- Considering one gear tooth, the theoretical values of *w and d can be found out which may be verified by the instrument.*
- *As shown in the figure , w is a chord ADB, but tooth thickness is specified as an arc distance AEB. Also the depth d adjusted on the instrument is slightly greater than the addendum CE", width w is therefore called chordal thickness and d is called the chordal addendum.*

  W=AB=2AD

  WKT, θ=360/4N,

  Where N= number of teeth.



In the $\Delta^{le}$ $ADO$, $\text{Sin}\theta = \frac{AD}{OA}$

$$w = 2AD = 2 \times AO \sin\theta$$

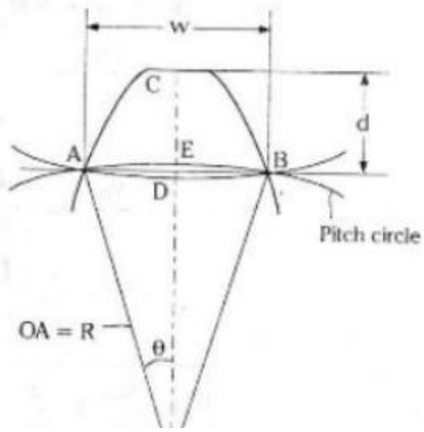
$$= 2R \sin\frac{360}{4N} \quad (\because R = \text{pitch circle radius})$$

$$\text{module } m = \frac{\text{pitch circle diameter}}{\text{Number of teeth}} = \frac{2R}{N}$$

$$\therefore \quad R = \frac{N \cdot m}{2}$$

$$\therefore \quad w = 2 \cdot \frac{Nm}{2} \cdot \sin\left(\frac{360}{4N}\right)$$

$$\boxed{w = Nm \sin\left(\frac{90}{N}\right)}$$



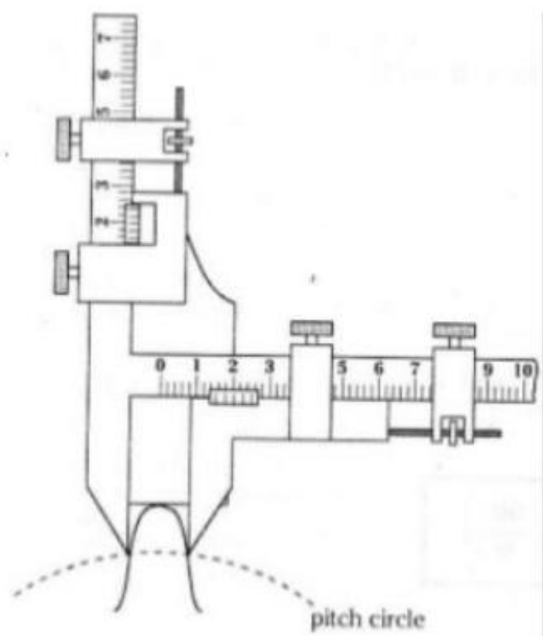

**6.b** **Sketch-4M + Expla-6=10M**

**Measurement of tooth thickness:**

Generally tooth thickness is measured at pitch circle diameter.

To measure gear tooth we use gear tooth Vernier caliper as shown in fig.

GTVC has two Vernier scales, the vertical scale is used to set depth(d) along the pitch circle from the top surface of the tooth and horizontal scale is used to measure width (w) of the teeth.



**MODULE-4**

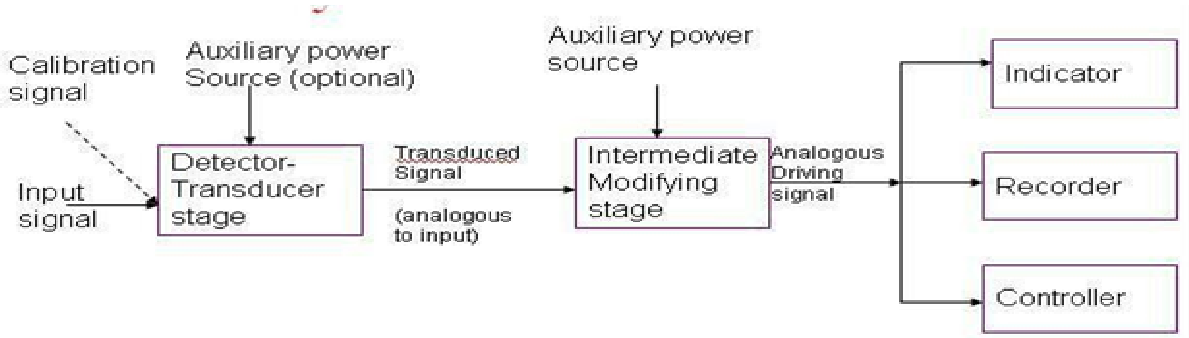
**7a.** **Block Dia-6 M + explanation – 6 M=12 Marks**

# Generalized Measurement System

It can be considered as a system that is used to measure the required quantity/parameter.

Generalized measurement system consists of the following elements:

- Primary Sensing Element(detecting element) ( detector-transducer element)
- Variable Conversion Element-Intermediate modifying element.
- Data Processing and Data Presentation element-Terminating stage element.




**Block Diagram** – Generalized Measurement System

Generalized system Consisting Of three stages namely,

- A *detector-transducer* or *sensor* stage
- An *intermediate modifying* stage or *signal conditioning* stage
- A *terminating* or *read-out* stage, as shown in the block diagram above.

**Stage-I-Detector Transducer stage:**

In this stage it detects or sense the input signal.

At the same time, it should be insensitive to every other possible input signals.

For ex, if it is a pressure signal, it should be insensitive to acceleration.

In the measurement of strain, the strain gauges should be insensitive to temperature.

If you take an **example of bourdon tube pressure gauge-** Bourdon tube acts as detector transducer which detects the input pressure.

### Stage-II-Intermediate modifying stage:

In this stage, the received input signal or transduced signal will be modify with the help of auxiliary power source. i.e., increases amplitude and power so that the modified signal will be used in a required form at the last stage.

**Example**: Link-Gear and Pinion in Burdon tube pressure gauge acts as intermediate modifying device.

### Stage III-Terminating stage:

This stage provides an indication or a recording of the signal in a form which can be understood by a human being or a control system.

**Example:** Pointer and a scale in Burdon tube pressure gauge acts as terminating stage or read out.

**7.b.** **Definitions – 2 Marks each =8Marks**

**[OR]**

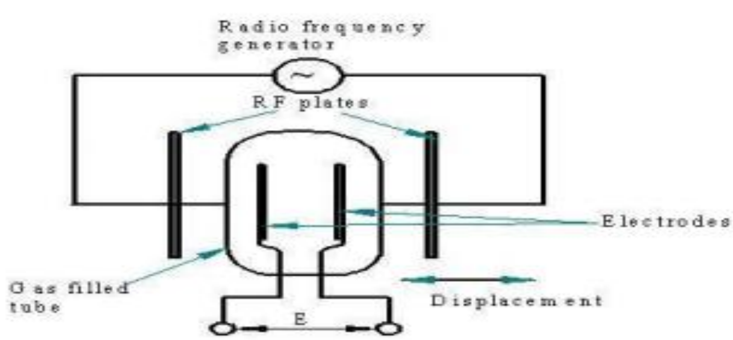
**8a.** **3 M + 4 M= 7 marks**

**Transfer efficiency:** It is the ratio of output information delivered by the pick up (Sensor) to the information received by the pick up.

Transfer efficiency $\square \square \frac{I_{out}}{I_{in}}$

Where Iout=the information delivered by the unit, Iin=information received by the unit

**Ionization Transducer**



- The fig shows the schematic diagram of an *Electronic transducer* element which is basically an electronic tube in which some of the elements are movable.
- Here, the plates are mounted on an arm which extends through a flexible diaphragm in the end of the tube.
- A mechanical movement applied to the external end of the rod is transferred to the plates within the tube thereby changing the characteristics of the tube.

**8.b** **Classification -6 + Explanation -7 =13 Marks**

Electrical
Mechanical and
Electronic Transducers
Active and Passive transducer and
Primary and secondary transducers

## Resistive Transducers

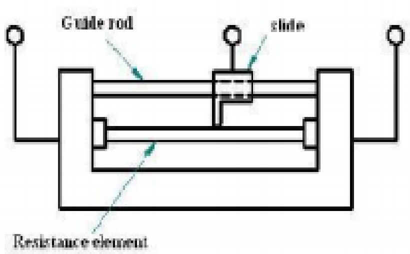
The resistance of an electrical conductor varies according to the relation,

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

where R= resistance in ohms, r= Resistivity of the material in ohm-cm, L= length of the conductor in cm, A= cross sectional area in cm2. Any method of varying one of the quantities involved may be the design criterion for the transducer. Following are some types:

### Sliding contact devices:

Convert mechanical displacement input into either current or voltage output - Achieved by changing the effective length of the conductor - The slide or contactor maintains electrical contact with the element and the slide is a measure of the linear displacement of the slide - Such devices are used for sensing relatively large displacements.



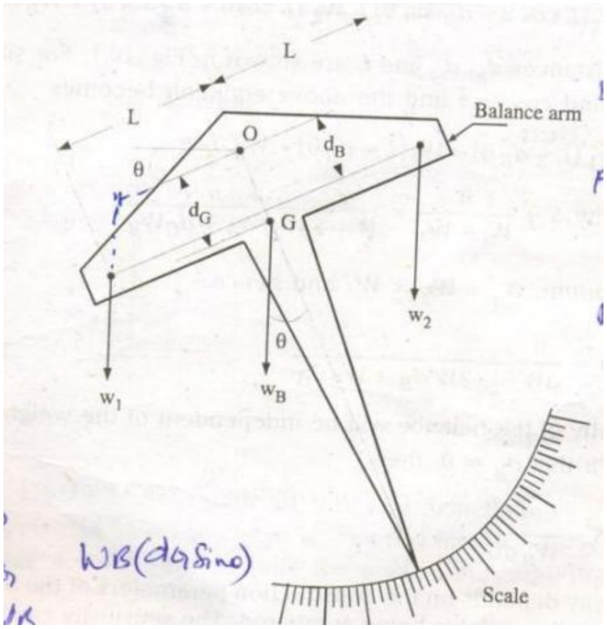

**Sliding contact Resistive Transducer**

# MODULE-5

**9a.** **Skt -4 + Derivation 8M =12Marks**

## Analytical Balance : (Equal arm balance)

Direct comparison of an unknown force with the gravitational force can be explained with the help of an analytical balance. The direction of force is parallel to that of the gravitational force, and hence only its magnitude needs to be determined. The constructional details of an analytical balance are as shown in Fig.




The balance arm rotates about the point "O" and two forces W1 and W2 are applied at the ends of the arm. W1 is an unknown force and W2 is the known force due to a standard mass. Point G is the centre of gravity of the balance arm, and WB is the weight of the balance arm and the pointer acting at G. The above figure show the balance is unbalanced position when the force W1 and W2 are unequal. This unbalance is indicated by the angle θ which the pointer makes with the vertical.

In the balanced position $W_1 = W_2$, and hence θ is zero. Therefore, the weight of the balance arm and the pointer do not influence the measurements.

The sensitivity S of the balance is defined as the angular deflection per unit of unbalance is between the two weight $W_1$ and $W_2$ and is given by

$$S = \frac{\theta}{w_1 - w_2} = \frac{\theta}{\Delta W}$$

where, $\Delta W$ is the difference between $W_1$ and $W_2$. The sensitivity S can be calculated by writing the moment equation at equilibrium as follows:

$$W_1 (L \cos\theta - d_B \sin\theta) = W_2 (L \cos\theta + d_B \sin\theta) + W_B d_G \sin\theta$$

where the distances $d_B$, $d_G$ and $L$ are shown in Fig. For small deflection angles $\sin\theta = \theta$ and $\cos\theta = 1$ and the above equation becomes

$$W_1 (L - d_B \theta) = W_2 (L + d_B \theta) + W_B d_G \theta$$

$$\therefore \text{ The Sensitivity } \quad S = \frac{\theta}{w_1 - w_2} = \frac{L}{(w_1 + w_2) d_B + d_G W_B}$$

Near Equilibrium, $W_1 = W_2 = W$ and hence

$$S = \frac{\theta}{\Delta w} = \frac{L}{2W d_B + W_B d_G}$$

The sensitivity of the balance will be independent of the weight W Provided it is designed such that $d_B = 0$ then

$$S = \frac{L}{W_B d_G}$$

**9b.** **Skt-4 + Expl.4=8marks**

These dynamometers are of absorption type. The most device is the prony brake as shown in Fig.

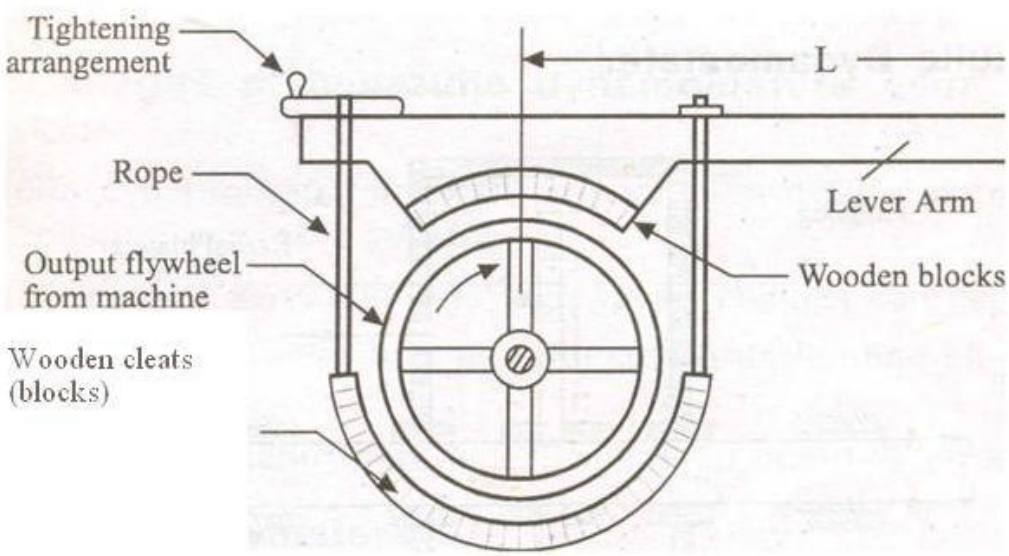



**Fig. Schematic of Prony Brake**

Two wooden blocks are mounted diametrically opposite on a flywheel attached to the rotating shaft whose power is to be measured. One block carries a lever arm, and an arrangement is provided to tighten the rope which is connected to the arm. The rope is tightened so as to increase the frictional resistance between the blocks and the flywheel. The torque exerted by the prony brake is T = F.L

where force $F$ is measured by conventional force measuring instruments, like balances or load cells etc. The power dissipated in the brake is calculated by the following equation.

$$P = \frac{2\pi\ NT}{60} = \frac{2\pi\ FLN}{60}\ Watts.$$

where force $F$ is in Newtons, $L$ is the length of lever arm in meters, $N$ is the angular speed in revolution per minute, and $P$ in watts. The prony brake is inexpensive, but it is difficult to adjust and maintain a specific load.

**[OR]**

**10.a.** **Sketching 4 + expl. -6 =10Marks**

**The Mcleod Gage**

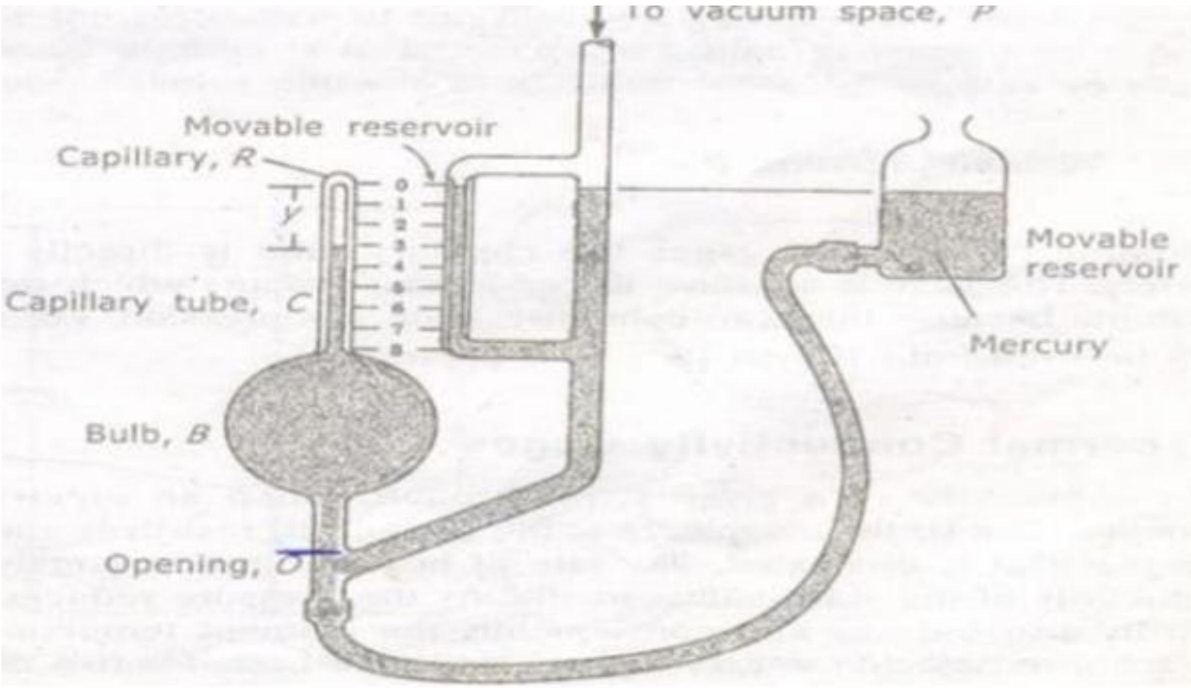
The operation of McLeod gage is based on Boyle's law.

$$p_1 = \frac{p_2\, v_2}{v_1}$$

Where, p1 andp2 are pressures at initial and conditions respectively, and v1 and v2 are volumes at the corresponding conditions. By compressing a known volume of low pressure gas to a higher pressure and measuring the resulting volume and pressure we can calculate the initial pressure.

The McLeod gage is a modified mercury manometer as shown in the Fig. 11.2. The movable reservoir is lowered until the mercury column drops below the opening O.

The Bulb B and capillary tube C are then at the same pressure as that of the vacuum pressure P. The reservoir is subsequently raised until the mercury fills the bulb and rises in the capillary tube to a point where the level in the reference capillary R is located at the zero point. If the volume of the capillary tube per unit length is 'a' then the volume of the gas in the capillary tube is Vc = ay----(1).




Where 'y' is the length of gas occupied in capillary tube.

If the volume of capillary tube, bulb and the tube down to the opening is VB. Assuming isothermal Compression, the pressure of the gas in the capillary tube is

$$P_C = P\frac{V_B}{V_C} \qquad \text{-------(2)}$$

The pressure indicated by the capillary tube is

Pc - P = --------(3)

Where, we are expressing the pressure in terms of the height of the mercury column. And combining equations (1), (2) and (3)

$$P = \frac{ay^2}{V_B - ay}$$

Usually ay << VB

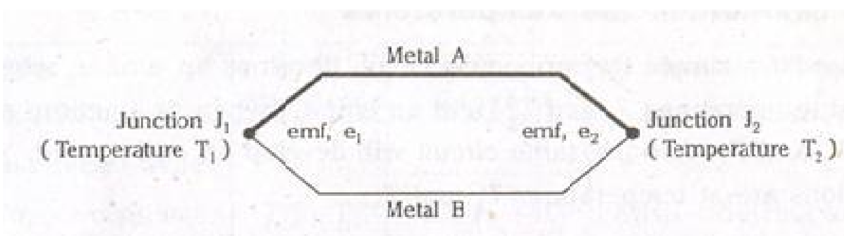
$$\therefore\ Vacuumpressur,\ P = \frac{ay^2}{V_B}$$

**10.b.** **2 + 4= 6Marks**

**Thermocouple**

If two dissimilar metals are joined an emf exists which is a function of several factors including the temperature.When junctions of this type are used to measure temperature, they are called thermocouples.

The principle of a thermocouple is that if two dissimilar metals *A* and *B are* joined to form a circuit as shown in the Fig. It is found that when the two junctions $J_1$ and $J_2$ are at two different temperatures $T_1$ and $T_2$, small emf's $e_1$ and $e_2$ are generated at the junctions. The resultant of the two emf's causes a current to flow in the circuit. If the temperatures $T_1$ and $T_2$ are equal, the two emf's will be equal but opposed, and no current will flow. The net emf is a function of the two materials used to form the circuit and the temperatures of the two junctions. The actual relations, however, are empirical and the temperature-emf data must be based on experiment. It is important that the results are reproducible and therefore provide a reliable method for measuring temperature.




**Basic Thermocouple Circuit**

It should be noted that two junctions are always required, one which senses the desired or unknown temperature is called the **hot** or **measuring** junction. The other junction maintained at a known fixed temperature is called the **cold** or **reference** junction.

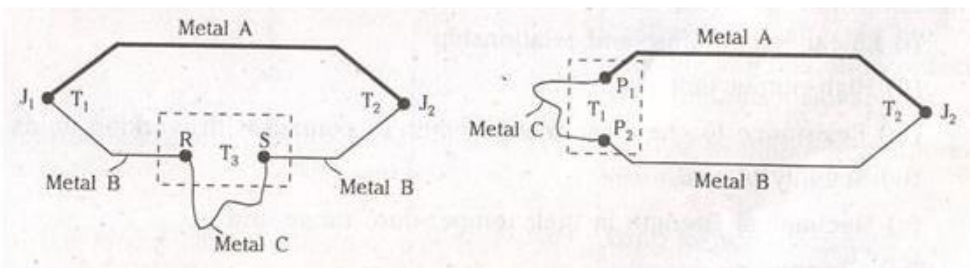
## Laws of Thermocouples

The two laws governing the functioning of thermocouples are:

### i) Law of Intermediate Metals:

It states that the insertion of an intermediate metal into a thermocouple circuit will not affect the net emf, provided the two junctions introduced by the third metal are at identical temperatures.

Application of this law is as shown in Fig. In Fig. (a), if the third metal C is introduced and the new junctions R and S are held at temperature T3, the net emf of the circuit will remain unchanged. This permits the insertion of a measuring device or circuit without affecting the temperature measurement of the thermocouple circuit




**Circuits illustrating the Law of Intermediate Metals**

In the Fig. (b) the third metal is introduced at either a measuring or reference junction. As long as junctions $P_1$ and $P_2$ are maintained at the same temperature $T_P$ the net emf of the circuit will not be altered. This permits the use of joining metals, such as solder used in fabricating the thermocouples. In addition, the thermocouple may be embedded directly into the surface or interior of a conductor without affecting the thermocouple's functioning.

### i) Law of Intermediate Temperatures:

It states that "If a simple thermocouple circuit develops an emf, $e_1$ when its junctions are at temperatures $T_1$ and $T_2$, and an emf $e_2$, when its junctions are at temperature $T_2$ and $T_3$. And the same circuit will develop an emf $e_3 = e_1 + e_2$, when its junctions are at temperatures $T_1$ and $T_3$.


**Circuits illustrating the Law of Intermediate Temperatures**

**10.c** **3 M +1 M =4 Marks**

When a system of forces or loads act on a body, it undergoes some deformation. This deformation per unit length is known as **unit strain** or simply a strain mathematically

Strain € = δl /l where, δl = change in length of the body

l= original length of the body.

If a net change in dimension is required, then the term, **total strain** will be used. Since the strain applied to most engineering materials are very small they are expressed in **"micro strain"**

Strain is the quantity used for finding the stress at any point. For measuring the strain, it is the usual practice to make measurements over shortest possible gauge lengths. This is because, the measurement of a change in given length does not give the strain at any fixed point but rather gives the average value over the length. The strain at various points might be different depending upon the strain gradient along the gauge length, then the average strain will be the point strain at the middle point of the gauge length. Since, the change in length over a small gauge length is very small, a high magnification system is required and based upon this, the strain gauges are classified as follows:

i) Mechanical strain gauges

ii) Optical strain gauges

iii) Electrical strain gauges

**Gauge factor** (GF) or strain factor of a strain gauge is *the ratio of relative change in electrical resistance R, to the mechanical strain ε.*