IV/IV B.Tech Regular Degree Examination
NOVEMBER, 2019
(First Semester)
ENGINEERING METROLOGY& MECHANICAL MEASUREMENTS
(MECHANICAL ENGINEERING)

SCHEME OF EVALUATION

1. **Answer all the questions. (12 X 1 =12 M)**

a) Minimum clearance:
The difference between LL of Hole and UL of shaft is called minimum clearance.

b) Selective Assembly:
Parts are mass-produced to specific tolerance and allowance, then sorted manually or through an automatic gauge.

c)

Ring Gauges	Plug Gauges
Used for checking sizes of shafts	Used for checking sizes of holes
They are in the form of holes	They are in the form of shaft
Their GO gauge id designed at UL of shaft	Their GO gauge id designed at LL of hole
NO-GO gauge is designed at LL of shaft	NO-GO gauge is designed at UL of hole

d) Function of Bore gauge:
Bore gauge is used to check the diameters of bores.

e) Any two quantitative parameters to measure surface roughness:
Roughness value, lay direction, sampling length, machining allowance and machining method

f) Thread Angle:
This is the angle between the flanks or slopes of the thread measured in an axial plane.

g) Span:
Span represents the algebraic difference between the upper and lower range value of the instrument.

h) Gauge factor:
Gauge factor is the fractional change in resistance divider by the unit strain.

i) Orifice:
An orifice plate is a device used for measuring flow rate, for reducing pressure or for restricting flow (in the latter two cases it is often called a restriction plate).

j) Principle of McLeod gauge:
In McLeod gauge, the pressure is measured through the volume of gas trapped in the manometer.

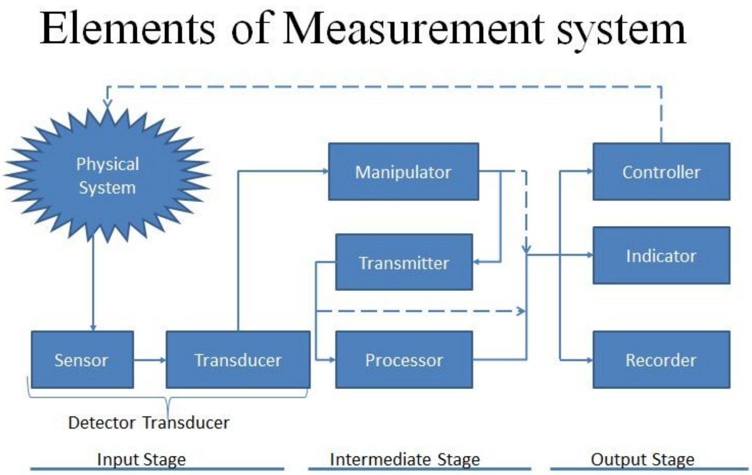
k) Principle of thermocouple:
Thermocouple is a temperature measuring device which works on Seebeck effect. When two conductors of dissimilar metals M_1 and M_2 are joined together to form a loop (a

thermocouple) and two unequal temperatures T_1 and T_2 are imposed at the two interface connections, an electric current flow through the loop.

l) Function of load cell:
It is a device which converts the force acting on it into another form of physical quantity for measuring the intensity of load.

UNIT – I

2 a). Elements of Engineering Measurements:



- Sensor: An element that is sensitive to the measured variable. The sensing elements sense the condition, state or value of the process variable by extracting small part of energy from the measurand and then produce the output which reflects this condition, state or value of the measurand.

- Transducer : An element that converts the signal from one physical form into another without changing the information content of the signal. The signal after transduction is more suitable for purposes of measurement and control.

- Manipulator: An element that operates on the signal according to some mechanical rule without changing the physical nature of the variable.

  [Input] X Constant = Output

- Data Transmission Element: An element that transmits the signal from one location to another without changing its information content.

- Data Processing Element: An element that processes the data before it is displayed or finally recorded.

- Data Presentation Element: An element that provides a record or indication of the output from the data processing element.

b). Distinguish between line standard and end standard.

S. No.	**Characteristics**	**Line**	**End**
1	Principle	Length is expressed as distance between two lines.	Length is expressed as distance between two parallel faces.
2	Accuracy	Limited to ±0.2 mm	High accuracy of about ± 0.0001 mm
3	Ease and Time of measurement	Quick and easy	Requires skill and time consuming

4	Effect of wear	Less	Subjected to wear on measuring faces
5	Alignment	Not easily aligned with the axis of measurement	Can be easily aligned with the axis of measurement
6	Manufacture and cost	Simple to manufacture at low cost	Manufacturing process is complex and high cost
7	Parallax error	Yes	No
8	Example	Scale	Slip gauges, V. Calipers

(OR)

3. a) Interchangeable manufacturing and Selective assembly:

Interchangeable Assembly: The mating parts are made with in the tolerance limits so as to get the required fit by any one of the component selected at random will assemble with the other, selected at random.
Advantages:
Time is reduced considerably.
Increased output with reduced production cost.
Division of labour.
Facilitated the production of mating parts at different places by different operators.
The replacement of defective and worn-out parts becomes very easy.
Cost of maintenance and shut down period is also reduced to minimum.
Selective Assembly: Parts are mass-produced to specific tolerance and allowance, then sorted manually or through an automatic gauge. All parts are inspected and sorted into various size grades according to size. Parts are then selectively assembled.

b) Basic size = 45 mm, D = 38.7298 mm (1M)

i = 1.5612 microns

IT7 = 24.979 microns = 0.024 mm

IT8 = 39.031microns = 0.039 mm,

Hole-type: H7.

Limits of H hole: **(2M)**

LL of hole = Basic size = **45mm**
UL of hole = LL of hole + IT7
= 45 + 0.024
= **45.024 mm**

Limits of 'f' shaft: (2M)

F.D of 'f' shaft = $-5.5^{0.44}$ = -27.485 microns = **-0.0274mm**

UL of shaft = Basic size + F.D = 45 – 0.0274= **mm = 44.9726 mm**

LL of shaft = UL of shaft – Tolerance

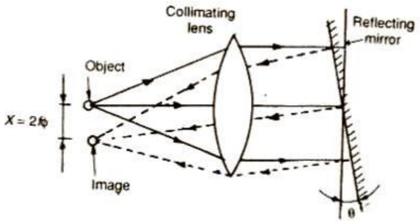
= 44.9726 – 0.039 = **44.9336 mm**

Allowance = LL of hole – UL of shaft

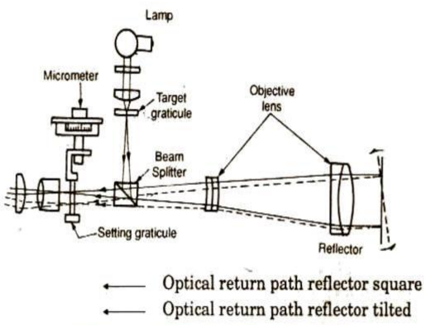
= 45 – 44.9726 = **0.0274 mm (1M)**

UNIT – II

4. a) Describe with neat sketch, the principle of working of an Autocollimator.
(Diagram 3M +Principle and Working 3M)



Principle of auto-collimator



Line diagram of an injected graticule autocollimator

Principle: If a light source is placed in the focus of a collimating lens, it is projected as a parallel beam of light. If this beam is made to strike on a plane reflector, kept normal to the optical axis, it is reflected back along its own path and is brought to the same focus. If the reflector is tilted through a small angle ‘θ’, the parallel beam is deflected twice that angle and is brought to a focus in the same plane as the light source, but to one side at a distance x= 2.f.θ.

Working:

→ Consists of 3 parts *viz.* micrometer microscope, lighting unit and collimating lens.

→ A 45° transparent beam splitter reflects the light from the graticule towards the objective (collimating lens).

→ The image seen after the reflection in the external reflector, whose angular variations are being measured is formed by light from the objective lens.

→ The light passes through the beam splitter and the image is picked up by the microscope.

→ For simultaneous measurements in two planes at right angles, a micrometer is fitted to the largest graticule, optically at right angles to that on the eye piece graticule.

b). Methods of measuring primary texture of a surface (Roughness)

1. Inspection by Comparison (3M)
2. Direct instrument measurement (3M)

(OR)

5. a) Two Wire method of measuring effective diameter of screw threads.

- The effective diameter of a screw thread may be ascertained by placing the two wires or rods of identical diameter between the flanks of the thread and measuring the distance outside of these wires.

- The effective diameter E is then calculated as

E= T+P,

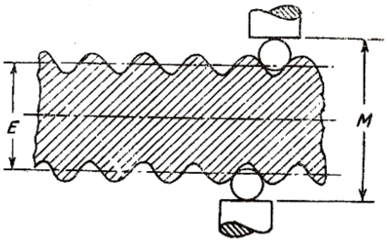
where T=Dimension under wires = M-2*d*

M= Dimension over wires,

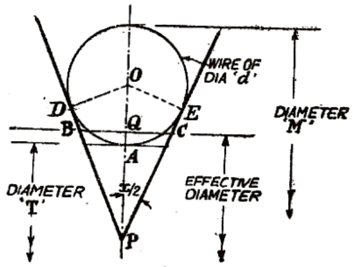
d= diameter of each wire.

P= It is a value which depends on the dia. of the wire and pitch of the thread.

- The dimension T can also be determined by placing wires over a standard cylinder of diameter greater than the diameter under the wires and noting the reading R_1 and taking the reading over the gauge, R_2 .
- Then, $T=S-(R_1-R_2)$.
- If *p* is the pitch of the thread, then $P=0.9605p-1.1657d$ (Whitworth thread), $P= 0.866p-d$ (Metric thread)
- Actually P is a constant value that has to be added to T to give the effective diameter.
- The expression for the value of P in terms of *p*, *d* and *x* can be derived as follows:
- Since BC lies on the effective diameter line, BC= ½ Pitch=½.p



(*a*)



(*b*)

$$OP = \frac{d * \operatorname{cosec}\left(x/2\right)}{2}$$

$$PA = \frac{d\left(\operatorname{cosec}\left(x/2\right) - 1\right)}{2}$$

$$PQ = QC \cdot \cot x/2 = \frac{p}{4} \cdot \cot x/2$$

$$AQ = PQ - AP = \frac{p.\cot x/2}{4} - \frac{d\left(\operatorname{cosec} x/2 - 1\right)}{2}$$

- AQ is half the value of P, P value= 2AQ, $P = \frac{p}{2}.\cot x/2 - d\left(\operatorname{cosec}\frac{x}{2} - 1\right)$
- Two wire method can be carried out only on the diameter measuring machine because the alignment is not possible two wires and can be provided only by the floating carriage machine.

b) Alignment Tests on machines:

- Quality and accuracy of the finished work depends on the accuracy of the machine tools used in their production.
- The machine tools must be able to produce the work piece of given accuracy with in prescribed limits consistently.

- The machine tools are tested at various stages, during assembly, after assembly, erection, repairs or overhauls as per accuracy test chart in order to determine whether it meets the requirement of specification or not.
- Alignment test is carried out to check the grade of the manufacturing accuracy of the machine tool.
- It consists of checking the relationship between the various machine elements (such as bed, table, spindle etc.) when machine tool is idle and unloaded.
- In addition to the manufacturing accuracy, the working accuracy of the machine is influenced by the following factors:
    - Geometry of the cutting tool
    - Material of the cutting tool, shape and rigidity
    - Material of the work piece, its size, shape and rigidity
    - Cutting speed, feed and depth of cut
    - Work holding and clamping equipment
    - Skill of the operator
    - Working conditions etc.

UNIT- III

6. a) Explain the terms

1. Precision (2M): Precision is defined as ability of the instrument to reproduce the same output value again and again. It is possible to obtain high precision with poor accuracy, but not high accuracy with low precision.

2. Resolution (1M): Resolution defines the smallest change of input for which there will be a change of output.

3. Calibration (1M): The entire procedure laid down for making, adjusting, or checking a scale so that readings of an instrument or measurement system conform to an accepted standard is called *Calibration*.

4. Sensitivity (2M): Sensitivity of an instrument is the ratio of the magnitude of the response (output signal) to the magnitude of the quantity being measured (input signal).

$$K = \frac{Change\ of\ \ Output\ Signal}{Change\ of\ \ Input\ Signal}$$

b). Temperature Compensation in strain gauges:

i. The strain gauge resistance changes both with strain and temperature.

ii. The temperature then constitutes an interfering input and brings about a change in the gauge resistance in two ways:

   a. Resistance change in the wire filament or grid due to change in its volume and resistivity.

   b. Resistance change due to differential expansion existing between the gauge and the test surface to which the gauge is bonded.

iii. The resistance change in the gauge resulting from above factors can be evaluated.

iv. Resistance change due to load induced strain ϵ is given by

$$dR_1 = \in .F.R$$

v. If α is the temperature coefficient of gauge filament and dt is the growth in ambient temperature, then the resistance variation dR_2 due to temperature growth will be

$$dR_2 = R.\alpha.dt$$

vi. If β and γ are the coefficients of expansion of grid material and test surface, then the gauge length L will change by an amount $L(\gamma - \beta).dt$ due to differential coefficient of expansion. Recalling the definition of gauge factor,

$$F = \frac{dR/R}{dL/L}$$
$$dR_3 = F\frac{dL}{L}R$$
$$dR_3 = F\frac{L(\gamma-\beta)dt}{L}R = FR(\gamma-\beta)dt$$

vii. Hence the overall change in the dR would be given by

$$dR = dR_1 + dR_2 + dR_3$$
$$dR = \in FR + R\alpha dt + FR(\gamma-\beta)dt$$
$$\therefore \frac{dR}{Rdt} = \frac{\in F}{dt} + [\alpha + F(\gamma-\beta)] = \frac{\in F}{dt} + \alpha^* \rightarrow 1$$
$$Where$$
$$\alpha^* = \alpha + F(\gamma-\beta)$$

viii. α^* is called the temperature coefficient of a strain gauge.

ix. It depends not only on the properties of the gauge but also on that of the test surface.

x. From equation 1, the effect of temperature can be nullified when α^* is made zero.

xi. As α is always positive, F is to be made negative and equal to $[\alpha/(\gamma - \beta)]$.

xii. This is possible when the grid is made up of two different materials.

Different methods of temperature compensation are Dummy gauge, Half bridge circuit, and Poisson gauge.

(OR)

7 a). Unbonded strain gauge:

→ Fine wire filaments i.e. resistance wires are stretched around rigid and electrically insulated pins on two frames A & B.

→ The frames are held close by a spring loaded mechanism.

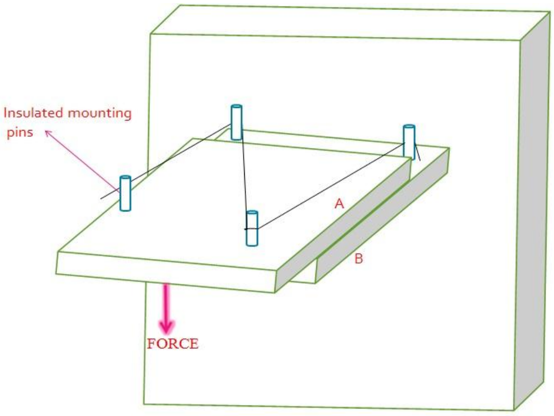
→ When frame A moves relative to frame B, the wire filaments are strained.

→ The strain can be detected through measurement of the change in resistance by an electrical circuit.

→ The range is ± 0.15 % strain with accuracies better than 0.1% and linearity within 1%.

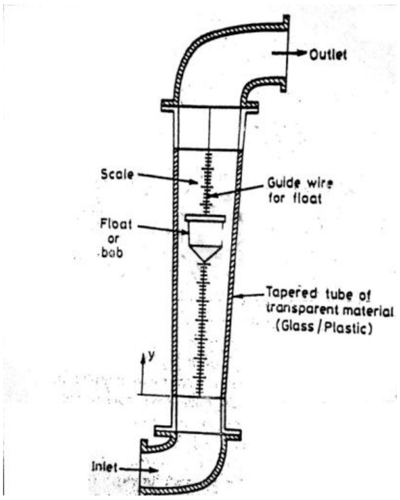
→ Since the gauges are not cemented but are simply screwed at the desired location, they can be detached and used again.

→ They are used for the measurement of force, pressure, acceleration.



b). Rotameters (Working 3M + Diagram 3M):

- Variable area flow meters are very simple yet versatile flow measurement devices for use on all types of liquids, gases and steam.
- They operate on the variable area principle, whereby a flowing fluid changes the position of a float, piston, or vane to open a larger area for the passage of the fluid.

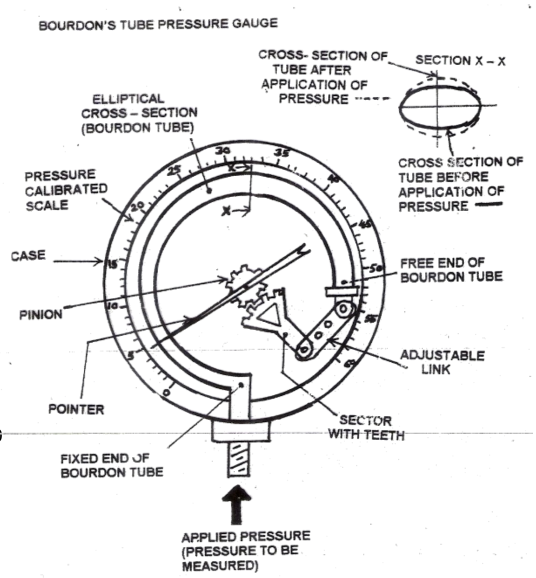


- The position of the float, piston, or vane is used to give a direct visual indication of the flow rate.
- The rotameter is an industrial flow meter used to measure the flow rate of liquids and gases.
- Its operation is based on the variable area principle: fluid flow raises a float in a tapered tube, increasing the area for passage of the fluid.
- The greater the flow, the higher the float is raised. The height of the float is directly proportional to the flow rate. With liquids, the float is raised by a combination of the buoyancy of the liquid and the velocity head of the fluid.
- With gases, buoyancy is negligible, and the float responds to the velocity head alone.
- The float moves up or down in the tube in proportion to the fluid flow rate and the annular area between the float and the tube wall.
- The float reaches a stable position in the tube when the upward force exerted by the flowing fluid equals the downward gravitational force exerted by the weight of the float.
- A change in flow rate upsets this balance of forces. The float then moves up or down, changing the annular area until it again reaches a position where the forces are in equilibrium.
- To satisfy the force equation, the rotameter float assumes a distinct position for every constant flow rate.
- However, it is important to note that because the float position is gravity dependent, rotameters must be vertically oriented and mounted.

UNIT- IV

8. a) Bourdon Tube: (Working 3M + Diagram 3M)

- → The pressure responsive element of a bourdon gauge consists of metallic tube called bourdon tube, oval in cross-section and bent to form a circular segment of approximately 200 to 300 degrees.
- → The tube is fixed but open at one end and it is through this fixed end, the pressure is to be measured is applied.
- → The other end is closed but free to allow displacement under deforming action of the pressure difference across the tube walls.
- → Tip Travel: The motion of the free end, commonly called tip travel is a function of the tube length, wall thickness, cross-sectional geometry and modulus of the tube material.
- → For a bourdon tube, deflection Δa of the tip element is expressed as:



$$\Delta a = 0.005\frac{aP}{E}\left(\frac{r}{t}\right)^{0.2} \times \left(\frac{x}{y}\right)^{0.33} \times \left(\frac{x}{t}\right)^{3.0}$$

- → Where 'a' is the total angle subtended by the tube before pressurization, P is the applied pressure difference and E is the modulus of elasticity of tube material.
- → The material chosen to fabricate a bourdon tube will relate to the instrument sensitivity, accuracy and precision.
- → For accuracy and repeatability, materials for bourdon tube must have good elastic or spring characteristics.
- → For common pressure ranges of 100 to 7000 KN/mm2, tubes are made up of phosphor bronze and are solid drawn.
- → For high pressure ranges of 7000 to 630000 KN/m2, the tubes are made of alloy steels or K-monel.
- → Where corrosion is a problem, stainless steel is employed and where stainless steel does not meet the requirement, an appropriate fluid or membrane is used to protect the gauge.

Advantages and limitations:

- ✓ Low cost and simple construction.
- ✓ Capability to measure gauge, absolute and differential pressures.
- ✓ Simple and straight forward calibration with dead weight tester.
- ✓ Availability in several ranges.
- ✓ Easily adapted to strain, capacitance, magnetic and other transducers.
- × Inherent hysteresis and slow response to pressure changes.
- × Usually required geared movement for amplification.
- × Susceptibility to shocks and observations.

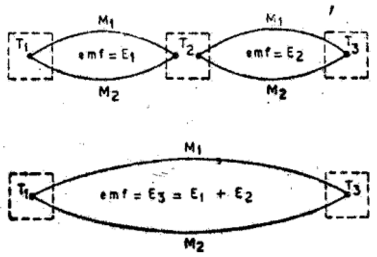
b). Laws of Thermocouples: (Each Law 2M)

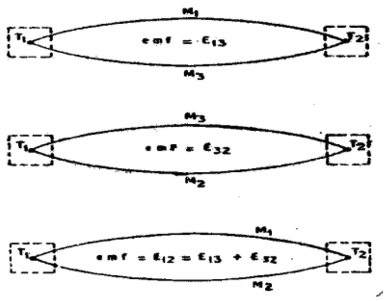
- The actual application of thermocouple to the measurement requires consideration of the following laws:

☝ *Law of the Homogenous circuit*: An electric current cannot be sustained in a circuit of a single homogenous metal by application of heat alone.

- *Law of Successive or intermediate temperatures*: The emf generated in a thermocouple with junctions at temperatures T1 and T2 is equal to the sum of emf's generated by similar thermocouples, one acting between the temperatures T1 and T2 and the other acting between T2 and T3, where T2 lies between T1 and T3.

- *Law of intermediate metals*: The introduction of third metal in to thermocouple circuit will have no effect on the emf generated as the junctions of the third metal with thermocouple metals are at the same temperature.

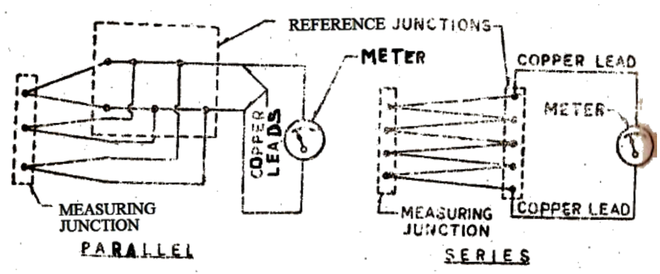




(OR)

9 a). Series and Parallel connection of Thermocouples (3M for Series connection+ 3M for Parallel connection, both with diagram and explanation)

1. Series connection (Thermopile):
   - → The total output from n thermocouples equals the sum of the individual emfs.
   - → For identical thermocouples, with all the measuring junctions at one temperature, n thermocouples give output n times greater as single thermocouple.
   - → This arrangement provides considerably more sensitivity and is frequently used where it is desired to obtain a substantially large emf for measurement of small temperature difference between the two junctions.
   - → The arrangement may not however, increase the accuracy of the measurement because of uncertainties from inhomogeneity also increases.
   - → The increase in number of junctions, the probe size and mass are increased which may cause the error due to radiation, stem conduction and time lag.



Series and parallel arrangement

   - → When thermopile is installed, the measuring junctions are carefully insulated from each other.
2. Parallel Connection:
   a. It is used to obtain the average temperature of a number of points as in determining the average temperature of gas flowing through a large area passage.
   b. Each hot junction may be at different temperature and hence will generate different emf.
   c. The total potential indicated by the potentiometer will be an average of the junction potentials.

9. b) Mechanical Load cell (Any ONE with Diagram and Explanation 3M+3M)

- Mechanical load cells work by translating the force to a fluid pressure and then measuring the resulting pressure (hydraulic and pneumatic load cell)
- It describes a variety of force transducers which may utilize the deflection or strain of elastic member, or increase in the pressure of enclosed fluids.
- The resulting fluid pressure is transmitted to some form of pressure sensing device such as a manometer or a bourdon tube pressure gauge.
- The gauge reading is identified and calibrated in units of force.

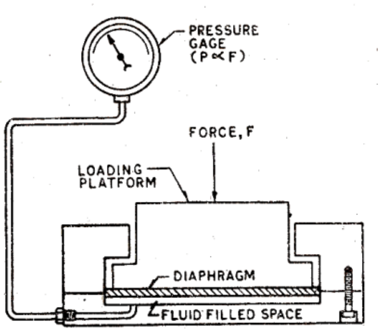


Fig 13.8 Hydraulic load cell

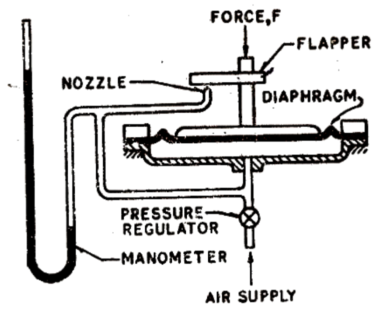


Fig. 13.9 Pneumatic load cell

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