

GUJARAT TECHNOLOGICAL UNIVERSITY

BE-4 SEMESTER – OLD PAPER – S22 TO W25 – QUESTION BANK SOLUTION

Subject Name & Code:

Mechanical Measurement and Metrology- 3141901

Unit 5: Force, Torque, Pressure, Strain and Temperature Measurement

Repeated Questions:

1. Explain the construction and working of a Rope Brake Dynamometer. List its advantages and limitations. / Write a short note on Rope Brake Dynamometer.

Appeared in: W25 (Q2c OR, 07 marks), W23 (Q3c, 07 marks), S25 (Q5c OR, 07 marks), W22 (Q5c OR, 07 marks)

Answer:

- **Purpose:** Measures brake power (torque and speed) of an engine.
- **Construction:**
 - Engine shaft coupled to a pulley.
 - Two ropes (or belt) wound around pulley, one fixed to a spring balance, other to a dead weight or another spring balance.
 - Water cooling system to absorb heat.
 - Speed sensor (tachometer).
- **Working:**
 - Engine runs, pulley rotates.
 - Ropes create friction, load applied via weights.
 - Net force = $(S_1 - S_2)$ where S_1 and S_2 are spring balance readings.
 - Torque $T = (S_1 - S_2) \times R$ (R = pulley radius).
 - Brake power $BP = \frac{2\pi N}{60}$ watts (N in rpm).
 - Cooling water prevents rope burning.
- **Advantages:** Simple, cheap, suitable for lab.
- **Limitations:** Cools required, not for very high speeds, rope slip.
- **[DG]**

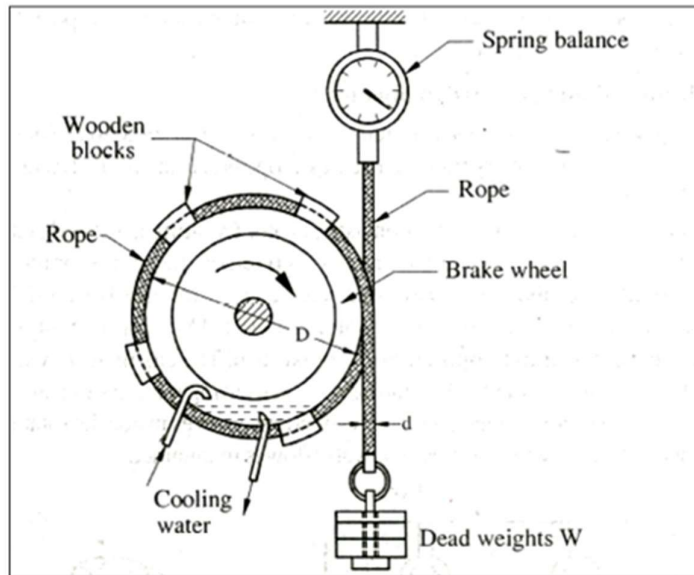


Fig.5.14 - Rope brake dynamometer

(Highest weightage: 7 marks – appears in 4+ papers)

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2. Explain the construction and working of a Bourdon Tube Pressure Gauge.
Appeared in: W25 (Q5b OR, 04 marks)

Answer:

- **Construction:**
 - C-shaped hollow tube of elliptical cross-section, closed at one end (free) and connected to pressure source at other (fixed).
 - Free end linked via linkage and sector gear to pointer.
 - Case with calibrated dial.
- **Working:**
 - Pressurized fluid enters tube.
 - Tube tends to straighten because internal pressure acts on larger area on outer wall.
 - Free end moves outward → link rotates sector gear → pointer moves over scale.
 - Calibrated in pressure units (bar, psi).
- **Types:** C-type, spiral, helical for higher ranges.
- **Applications:** Steam, air, hydraulic systems.
- [DG]

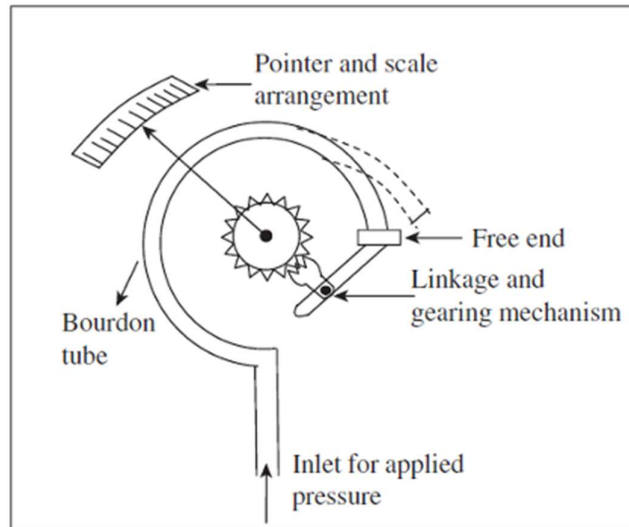


Fig.5.54 - Bourdon tube

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3. **Classify instruments for pressure measurement. / Give the classification of instruments for pressure measurement.**

Appeared in: W23 (Q3a, 03 marks), S25 (Q5a OR, 03 marks)

Answer:

1. **Mechanical:**

- Bourdon tube
- Diaphragm
- Bellows

2. **Liquid column:**

- U-tube manometer
- Well type
- Inclined tube

3. **Electrical / Electronic:**

- Strain gauge pressure transducer
- LVDT diaphragm
- Capacitance pressure cell
- Piezoelectric pressure sensor

4. **High vacuum:**

- McLeod gauge
- Pirani gauge
- Ionization gauge

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4. **Explain the construction and working of a Proving Ring type Load Cell. / Write a short note on proving ring type load cell.**

Appeared in: W24 (Q5b OR, 04 marks)

Answer:

- **Proving ring type load cell** (most common in GTU syllabus)
- **Construction:**
 - Heat-treated steel ring with two bosses for load application.

- Precision micrometer or dial indicator mounted across a diameter.
- **Working:**
 - Force applied along the ring diameter.
 - Ring deflects (flattens) proportionally to force.
 - Dial indicator measures diametral compression.
 - Calibration curve: force vs deflection.
- **Advantages:** High accuracy ($\pm 0.1\%$), rugged, portable.
- **Limitations:** Limited to static force, range up to 500 kN typically.
- [DG]

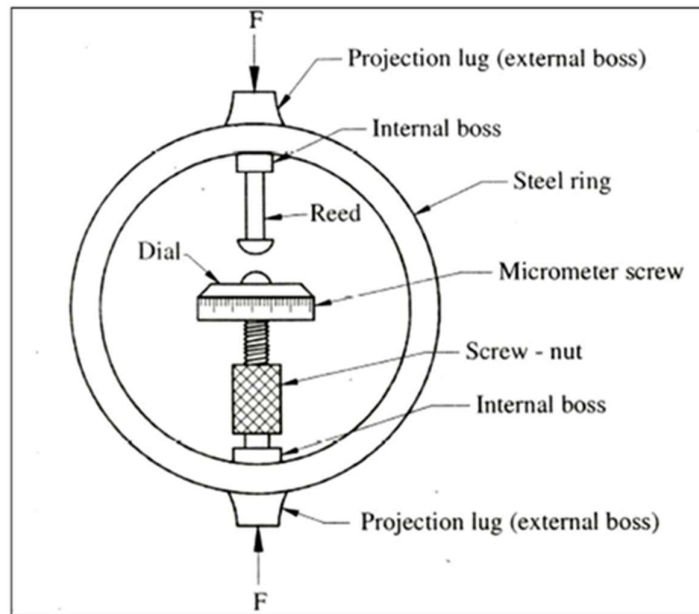


Fig.5.7 - Proving ring

(Also can explain hydraulic load cell, strain gauge load cell)

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- 5. Explain Prony Brake Dynamometer. / Write a short note on Prony Brake Dynamometer.

Appeared in: S22 (Q5b OR, 04 marks)

Answer:

- **Construction:**
 - Wooden brake blocks clamped around a pulley (shaft).
 - Levers and weights to apply load.
 - Spring balance to measure tangential force.
- **Working:**
 - Tighten brake blocks via handwheel to create friction.
 - Torque $T = W \times L$ (W = weight, L = lever arm).
 - Speed measured by tachometer.
 - Power $BP = (W \times L \times 2\pi N)/60$.
- **Limitations:** Brake wear, heat, not precise.

(Less common than rope brake in GTU)

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Other Important Questions:

1. **What is the function of Dynamometers? Enlist different types of Dynamometers and explain any one.**

Appeared in: S23 (Q3c OR, 07 marks)

Answer:

- **Function:** A dynamometer measures torque (T) and rotational speed (N) of an engine/motor to compute power ($BP = 2\pi NT/60$).

Types:

1. **Absorption dynamometers** (measuring brake power): Rope brake, Prony brake, Eddy current, Hydraulic.
2. **Transmission dynamometers** (for torque in rotating shafts): Torsion bar, Strain gauge torque meter.

Explain any one (Rope brake dynamometer) – already covered in Unit 5 (7 marks answer). Provide summary.

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2. **Explain the working of an Eddy Current Dynamometer with a neat sketch.**

Appeared in: W22 (Q5b OR, 04 marks)

Answer:

- **Construction:**
 - Rotor (disc or drum) made of conductive metal, mounted on engine shaft.
 - Stator (electromagnets) surrounding rotor.
 - Cooling system (water jacket).
- **Working:**
 - Engine rotates rotor in magnetic field created by stator current.
 - Eddy currents induced in rotor; they generate opposing torque proportional to field strength and speed.
 - Torque measured by load cell or spring balance on stator housing (stator tends to rotate).
 - Field current varied to change load.
- **Advantages:** Smooth, no mechanical contact, remote control, high power capacity.
- **Limitations:** Requires DC power, cooling needed.

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3. **Explain Hydraulic Load Cell.**

Appeared in: W23 (Q3a OR, 03 marks)

Answer:

- **Construction:**
 - Fluid-filled cylinder with piston.
 - Pressure gauge (Bourdon tube or digital) connected.
- **Working:**
 - Force applied to piston → fluid pressure rises.
 - $P = F/A \rightarrow F = P \times A$.
 - Pressure gauge calibrated in force units.
- **Advantages:** No moving parts except piston, remote reading possible.
- **Limitations:** Fluid leakage, temperature affects viscosity.

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4. **Explain any one method used for force measurement.**

Appeared in: S25 (Q5b OR, 04 marks)

Answer:

- **Proving ring type load cell** (most common in GTU syllabus)
- **Construction:**
 - Heat-treated steel ring with two bosses for load application.
 - Precision micrometer or dial indicator mounted across a diameter.
- **Working:**
 - Force applied along the ring diameter.
 - Ring deflects (flattens) proportionally to force.
 - Dial indicator measures diametral compression.
 - Calibration curve: force vs deflection.
- **Advantages:** High accuracy ($\pm 0.1\%$), rugged, portable.
- **Limitations:** Limited to static force, range up to 500 kN typically.
- **[DG- given ABOVE]**

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5. **State the operating principle of a Pressure Gauge & Pressure Transducer.**

Appeared in: W22 (Q3a, 03 marks)

Answer:

- **Pressure gauge (Bourdon):** Uses elastic deformation of tube proportional to pressure.
- **Pressure transducer:** Converts pressure into electrical signal (strain gauge bridge on diaphragm, LVDT core movement, capacitance change).

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6. **Explain the principle of a Pitot Tube.**

Appeared in: (From syllabus)

Answer:

- **Principle:** Pitot tube measures fluid velocity by converting kinetic energy into pressure (Bernoulli's theorem).
- **Construction:** A small tube with its open end facing the flow (stagnation point) and another with side holes (static pressure).
- **Working:**
 - Stagnation pressure (P_{total}) = static pressure (P_{static}) + dynamic pressure ($\frac{1}{2}\rho v^2$).
 - The difference $\Delta P = \frac{1}{2}\rho v^2 \rightarrow \text{velocity } v = \sqrt{(2\Delta P/\rho)}$.
 - ΔP measured by manometer or pressure transducer.
- **Applications:** Airspeed in aircraft, flow measurement in pipes, wind tunnels.

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7. **Explain the use of elastic members in pressure measurement (Bourdon tube, diaphragm, bellows).**

Appeared in: (From syllabus)

Answer:

Elastic member	Principle	Range	Application
Bourdon tube	Tube straightens with pressure	0.1 to 1000 bar	General industrial
Diaphragm	Deflection of flexible disc	0.001 to 10 bar	Low pressure, corrosive fluids
Bellows	Convoluteds tube expands	0.01 to 5 bar	Low-medium pressure, pneumatic

All convert pressure to displacement, further converted to mechanical pointer or electrical signal.

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8. Explain the Bridgeman Gauge.

Appeared in: (From syllabus)

Answer:

- **Bridgeman gauge** is a high-pressure measuring device (up to 10,000 bar) using a manganin wire coil.
- **Principle:** Electrical resistance of manganin changes linearly with pressure (piezoresistive effect).
- **Construction:** Manganin coil placed inside a high-pressure chamber, connected to a Wheatstone bridge.
- **Working:** Pressure change → resistance change → bridge output calibrated in pressure units.
- **Advantages:** Very high range, good linearity, stable over time. Used in hydraulic presses, deep-sea research.

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9. Explain the Pirani Gauge.

Appeared in: (From syllabus)

Answer:

- **Principle:** Thermal conductivity of gas decreases with pressure. A heated wire loses heat by conduction; its temperature (resistance) depends on pressure.
- **Construction:**
 - A thin platinum wire (temperature sensor) enclosed in a chamber connected to vacuum.
 - Wheatstone bridge circuit.
- **Working:**
 - Constant current heats the wire.
 - Pressure decreases → fewer gas molecules → less heat loss → wire temperature rises → resistance rises → bridge output changes.
 - Calibrated for pressure range 10^{-4} to 1 torr.
- **Advantages:** Simple, continuous reading.
- **Limitations:** Gas composition affects calibration.

10. What unit is used to measure Vacuum? Explain any one instrument used to measure vacuum.

Appeared in: S22 (Q4c OR, 07 marks)

Answer:

- **Unit of vacuum: Torr** (1 torr = 1 mm Hg), also Millibar, Pascal (1 Pa = 0.0075 torr).
 - Rough vacuum: 1 to 10^{-3} torr
 - High vacuum: 10^{-3} to 10^{-7} torr

Instrument example: Pirani gauge or McLeod gauge (explained above). For high vacuum: **Ionization gauge**.

11. Explain Temperature Compensation in strain gauges.

Appeared in: (From syllabus - Wheatstone bridge)

Answer:

- **Problem:** Strain gauges are sensitive to temperature – resistance changes due to temperature (different from strain-induced change).
- **Methods of compensation:**
 1. **Dummy gauge method:** Mount an identical gauge on an unstressed part of same material, connected in adjacent arm of Wheatstone bridge. Temperature affects both equally → bridge output null.
 2. **Self-temperature compensation (STC):** Gauge is manufactured with a metal alloy whose thermal expansion matches the test specimen – minimizes apparent strain.
 3. **Three-wire or four-wire connection** to eliminate lead-wire resistance changes.
- **Importance:** Prevents false strain readings due to ambient temperature variation.

12. Explain the orientation of strain gauges for force and torque measurement.

Appeared in: (From syllabus)

Answer:

- **For force measurement (uniaxial):** Strain gauge is oriented parallel to the direction of force. One gauge on each side of a beam – two gauges in opposite arms of bridge for bending cancellation.
- **For torque measurement on a shaft:** Gauges are oriented at $\pm 45^\circ$ to the shaft axis because maximum principal strains occur at 45° in pure torsion. Four gauges in a full bridge (two at $+45^\circ$, two at -45°) give maximum sensitivity and temperature compensation.
- **For bending beam:** Gauges on top and bottom surfaces (one in tension, one in compression) connected in opposite bridge arms.

13. Explain strain gauge-based load cells and torque sensors.

Appeared in: (From syllabus)

Answer:

Load cell:

- Converts force into strain via an elastic element (e.g., column, ring, bending beam).

- Four strain gauges bonded to the element (two in tension, two in compression) in a full Wheatstone bridge.
- Output voltage proportional to applied force. Accuracy $\pm 0.05\%$ typical. Range from few Newtons to MN.

Torque sensor (torque transducer):

- Uses a shaft with strain gauges bonded at $\pm 45^\circ$.
- Full bridge configuration. Rotating torque measured via slip rings or telemetry.
- Output proportional to torque. Common in engine test beds, electric motor testing, automotive steering.

14. **A platinum resistance thermometer has a resistance of $100\ \Omega$ at 25°C . Find its resistance at 65°C if the temperature co-efficient of platinum is $0.0039\ \text{C}^{-1}$. If the thermometer has a resistance of $150\ \Omega$, calculate the temperature.**

Appeared in: W23 (Q3b OR, 04 marks) - Numerical Question

Answer:

R_0 (reference) not given at 0°C . Assume α given with respect to 0°C ? Usually RTD formula: $R_t = R_0(1 + \alpha t)$. But here R at $25^\circ\text{C} = 100\ \Omega$. Need to find R_0 first.

Method 1: Use $R_{25} = R_0(1 + \alpha \times 25) \rightarrow 100 = R_0(1 + 0.0039 \times 25) = R_0(1.0975) \rightarrow R_0 = 100/1.0975 = 91.12\ \Omega$.

At 65°C : $R_{65} = 91.12 \times (1 + 0.0039 \times 65) = 91.12 \times (1 + 0.2535) = 91.12 \times 1.2535 = 114.27\ \Omega$.

When $R = 150\ \Omega$: $150 = 91.12(1 + 0.0039 t) \rightarrow 1 + 0.0039 t = 150/91.12 = 1.646 \rightarrow 0.0039 t = 0.646 \rightarrow t = 165.6^\circ\text{C}$.

Final Answer:

$$R_{65} = 114.27\ \Omega$$

$$t = 165.6^\circ\text{C} \text{ (when } R=150\ \Omega)$$

15. **Explain the working principle of a thermometer.**

Appeared in: S23 (Q4c OR, 07 marks)

Answer:

(for liquid-in-glass thermometer – see earlier). For electrical thermometer (RTD or thermistor):

- Principle: Change in electrical resistance with temperature, measured by bridge circuit.

16. **Enlist different types of gear measuring instruments.**

Appeared in: S23 (Q5a OR, 03 marks)

Answer:

1. Gear tooth vernier caliper
2. Constant chord method setup
3. Base tangent comparator
4. Parkinson gear tester
5. Involute profile measuring machine (Rolling gear tester)
6. Tool maker's microscope
7. Coordinate measuring machine (CMM) with gear module.
