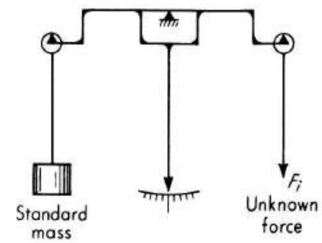
Force, Motion & Sound Measurement

Prof. Dr. M. Zahurul Haq
zahurul@me.buet.ac.bd
http://teacher.buet.ac.bd/zahurul/

Department of Mechanical Engineering
Bangladesh University of Engineering & Technology

ME 361: Instrumentation & Measurement

Analytical Balance

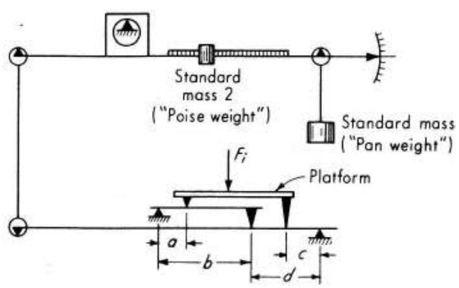


e681.eps

⇝ *Homework: Example 8.1 (Holman)*

- Exclusively used for weighing objects or chemical samples.
- Beam c.g. is slightly below knife-edge pivot for higher sensitivity.
- At the lower end range of the instrument, beam deflection may be used for output reading directly rather than attempting:
  - to *null* by adding masses, and/or
  - to adjust the arm length of a *poise-weight*.
- For very accurate measurements *buoyancy effect* must be considered, specially for lower density samples.

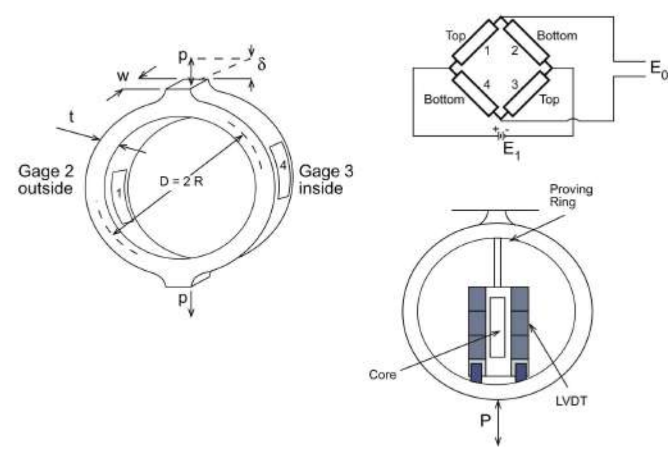
Platform Scale



e682.eps

- Utilizes a system of levers to allow measurements of large forces in terms of much smaller standard weights.
- Null is achieved by combination of *pan-weights* and adjustment of the poise-weight lever arm along its calibrated scale.
- If $a/b = c/d$, the scale reading is independent of the location of F_i. ... ... → Homework: Prove this statement.

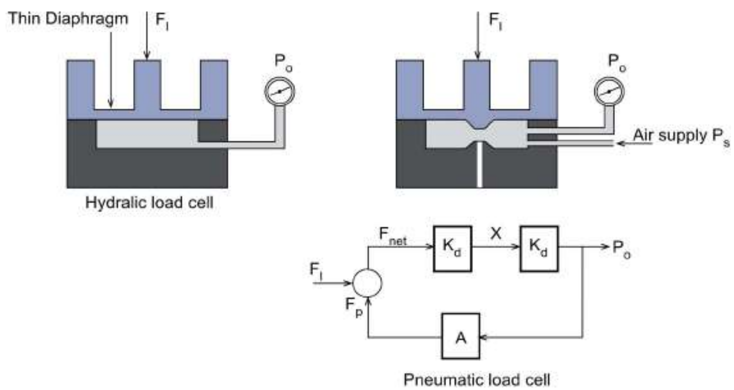
Proving Ring



e691.eps

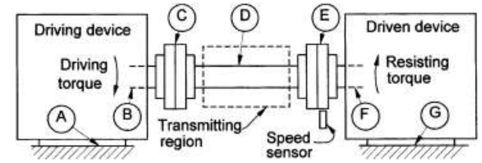
It is a ring of known physical dimensions & mechanical properties. An external tensile or compressive force causes a proportional distortion. It is used as a calibration standard for large tensile-testing machines.

Hydraulic & Pneumatic Load Cell

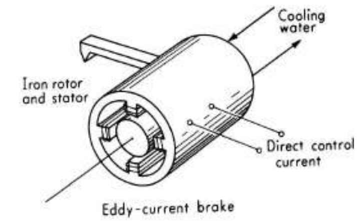


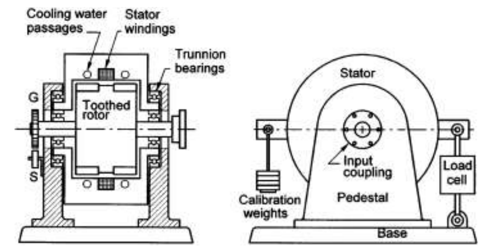
e673.eps If a force is applied to one side of a piston or diaphragm, and a pressure, either hydraulic or pneumatic, is applied to the other side, some particular value of pressure will be necessary to exactly balance the force. This is the working principle of these instruments.

Power/Torque Measurement (Absorption type)

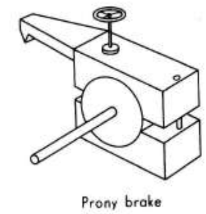


e686.eps

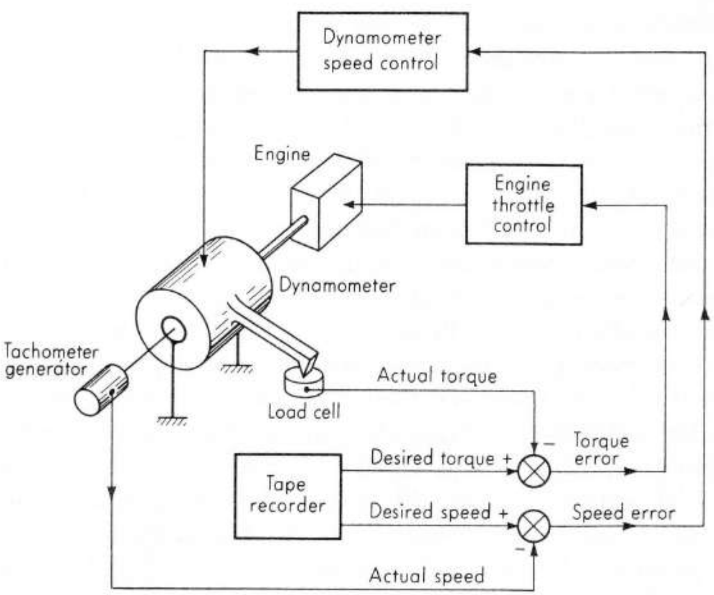




e685.eps



e687.eps

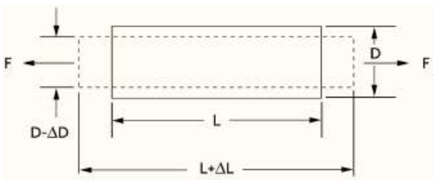


e684.eps

Measurement of Strain

- **Grid Method:** Some grid markings are placed on the work-piece under zero-load conditions. The deformation of the grid is used to measure the strain when the work-piece is subjected to a load. The grid may be scribed on the surface, drawn with a fine ink pen, or photoetched. The grid deformation may be measured by using: ⊙ Micrometer microscope, ⊙ Photography & ⊙ Extensometer.
- **Brittle Coating Method:** Work-piece is coated with some special coating with very brittle properties. When subjected to a load, small cracks appear in the coating. These cracks are used as an indication of the local stress level higher than some critical value. Very suitable method to determine the stresses at stress concentration points that are too small or inconveniently located for installation of strain gauges.
- **Resistance Strain Gauges:** ⊙ Metallic & ⊙ Semiconductor. Operation is based on principle that the electrical resistance of a conductor changes when it is subjected to mechanical deformation.

Resistance Strain Gauge



e689.eps

$$\text{Axial strain, } \epsilon_a = \frac{\Delta L}{L}$$

$$\text{Traverse strain, } \epsilon_t = \frac{\Delta D}{D} = \frac{1}{2}\frac{\Delta A}{A}$$

$$\text{Poission's Ratio, } \mu = -\frac{\epsilon_t}{\epsilon_a}$$

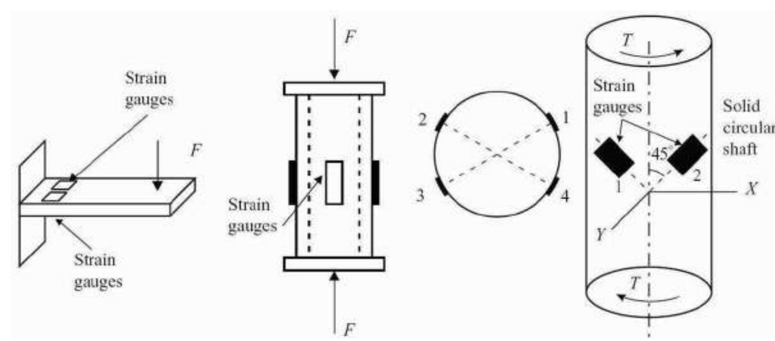
- $R = \rho \frac{L}{A}$: ρ = resistivity of material, R = resistance
- $\frac{dR}{R} = \frac{d\rho}{\rho} + \frac{dL}{L} - \frac{dA}{A} = \frac{d\rho}{\rho} + \epsilon_a(1 + 2\mu)$
- $\boxed{F \equiv \frac{dR/R}{\epsilon_a} = 1 + 2\mu + \frac{d\rho/\rho}{\epsilon_a}}$: F = Gauge Factor

Resistance change due to:
→ Length change
→ Area change
→ *Piezoresistance* effect.

- The value of F & R are usually specified by the manufacturer. For most commercial gauges, F is the same for both compressive & tensile strains.
- ⊙ *Bonded-wire gauge* employs wire sizes varying from 12 to 25 micron. ⊙ *Foil gauge* usually employs a foil less than 25 micron in thickness & is available in a wide variety of configurations. It is the most widely used gauge. ⊙ *Semiconductor gauge* employs a silicon base material that is strain sensitive & has the advantage that very large values of F may be obtained ($F \sim 100$). They have very high temperature coefficient of resistance.
- The surface should be absolutely clean. Cleaning with emery cloth followed by acetone is usually satisfactory. Sufficient time should be allowed for to dry & harden completely.
- **Bonding Materials:** cellulose, phenolic, epoxy or ceramics. Desirable properties are: ⊙ High mechanical strength ⊙ High creep resistance ⊙ Good adherence ⊙ Minimum moisture attraction.

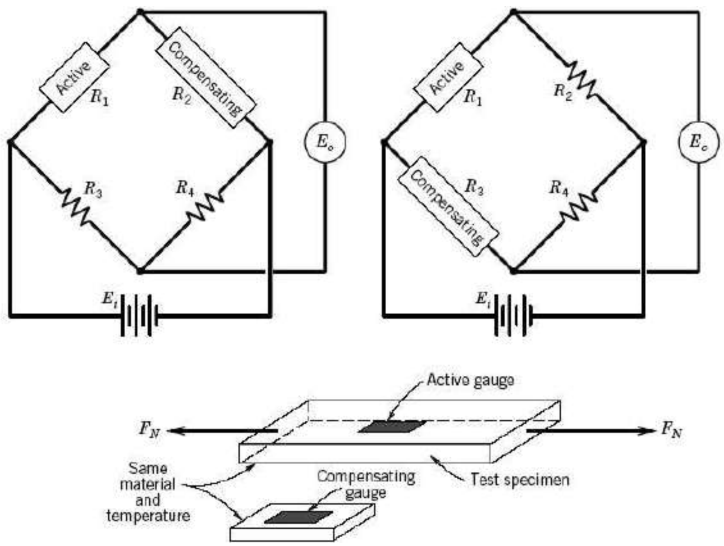
e470.eps

Various load cells using strain gauges for force and torque measurements



e680.eps

Force & Torque measurement on a shaft or beam using strain gauges directly mounted on the part



e678.eps

Strain gauge installation for temperature compensation

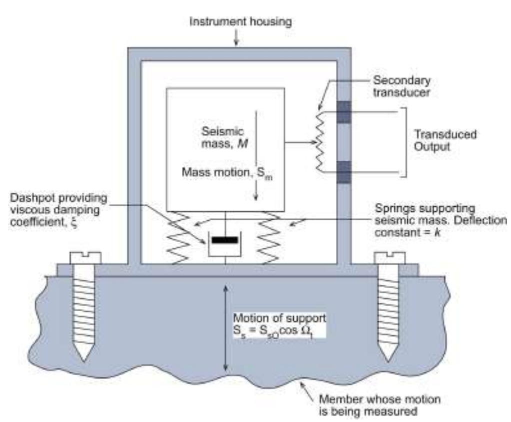
Displacement Measurement

Most common transducers can be configured to sense displacements. However, the followings are basically displacement sensitive:

1. Resistance potentiometers
2. Resistance strain gauges
3. Variable-inductance devices
4. Differential transformers
5. Capacitive transducers
6. Piezoelectric transducers

- Variable-inductance, capacitance, piezoelectric, & strain-sensitive transducers are suitable for small displacements.
- Differential transformer may be used over intermediate ranges, say a few microinches to several inches.
- Resistance potentiometers are not as sensitive to small displacements but with no limit on the maximum.
- With the exception of the piezoelectric type, all may be used for both static and dynamic displacements.

Seismic Instrument

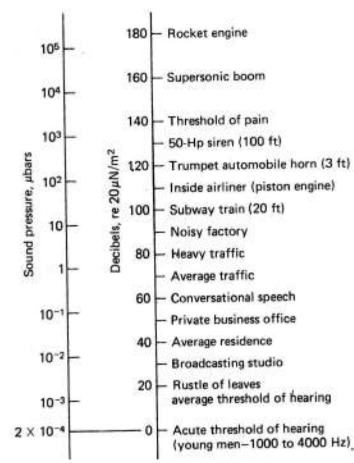


e674.eps

The action of seismic instrument is a function of acceleration through the inertia of the mass. The output is determined by the relative motion between the mass and the housing. The principle results in two varieties of seismic mass instruments: (1) vibrometer (2) accelerometer

Sound Measurements

Sound intensity or pressure level is measured in decibels (dB). It is called *Sound-pressure level*.



e683.eps

$$SPL = 10 \log \frac{I}{I_o} = 20 \log \frac{P}{P_o}$$

$$I_o = 10^{-12} \text{W/m}^2$$

$$P_o = 2 \cdot 10^{-5} \text{Pa } (0.0002\ \mu\text{bar})$$

$$SPL_{total} = 10 \log \sum_{i=1}^{n} 10^{(SPL_i/10)}$$

Example: Two sources of equal SPL are added:
$SPL_{total} = 10 \log \left[2 \cdot 10^{(SPL/10)} \right] = 10 \log 2 + SPL = 3 + SPL$

$\rightsquigarrow$ *Homework: Example 18.1 & 18.2 (Beckwith)*

$\rightsquigarrow$ *Homework: Example 11.6 & 11.7 (Holman)*

Sound level is measured by microphones which incorporates a thin diaphragm which is moved by air acting against it. The movement of the diaphragm is converted to an electrical signal by some form of secondary transducer that provides an analogous electrical signals.