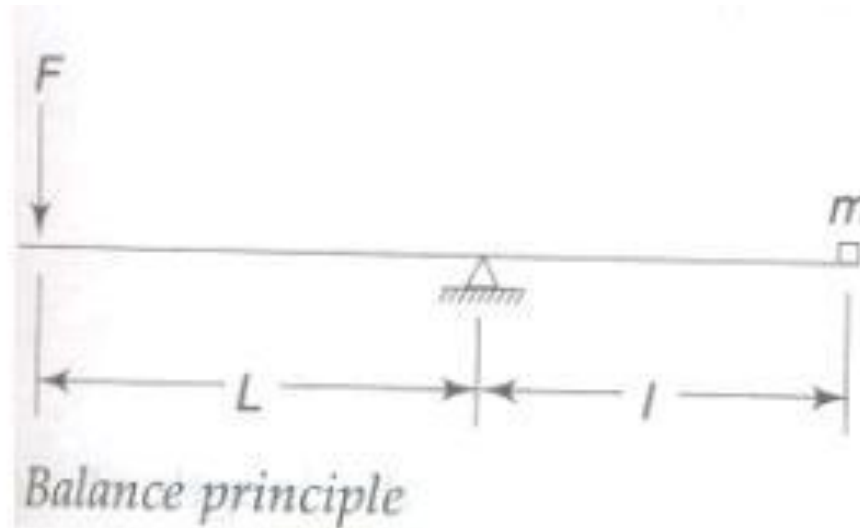# Force Measurement

Types of force measuring devices

- Balance

- Hydraulic Load Cell

- Pneumatic Load Cell

- Elastic Force Devices
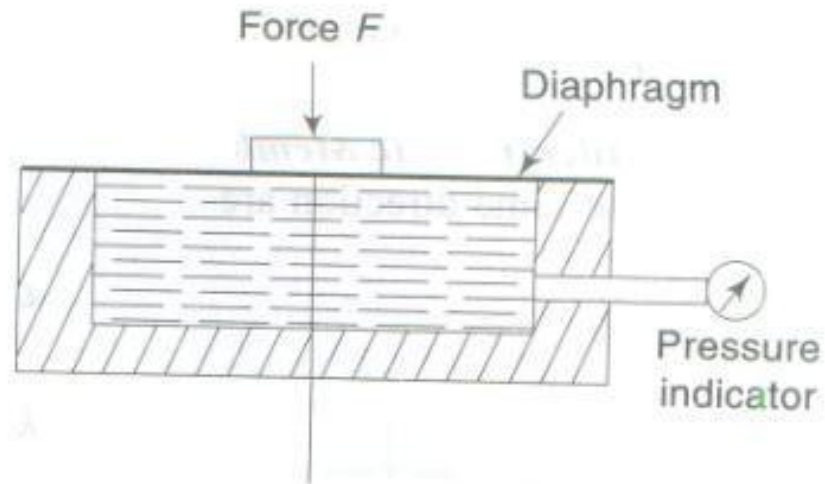
BALANCE

The system is in equilibrium
when FL = mgl

Balance principle

HYDRAULIC LOAD CELL

- Hydraulic pressure is used to indicate the force F, applied to a diaphragm

- Normally oil is used.

- Used to measure very large forces of the order of millions of Newtons.

Force F

Diaphragm

Pressure indicator

PNEUMATIC LOAD CELL

- For any force F, pressure P_2 gives an indication
- Used upto 20 kN.
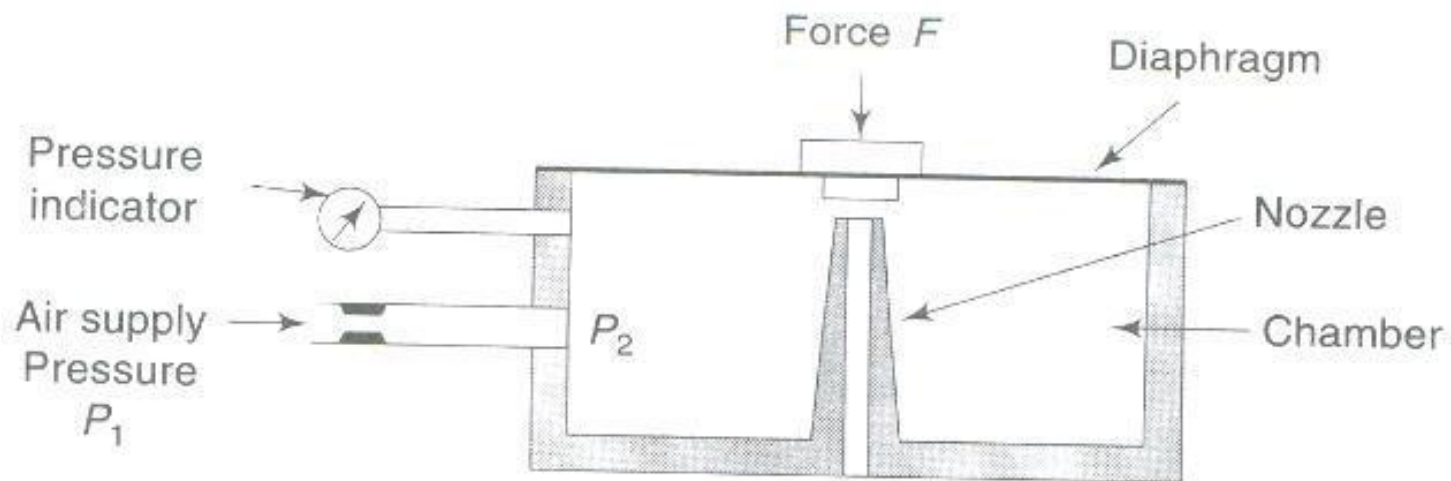
ELASTIC FORCE DEVICES

- Used for both static & dynamic force measurement.

- Force applied to elastic member results in displacement or strain which is sensed by mechanical or electromechanical means.

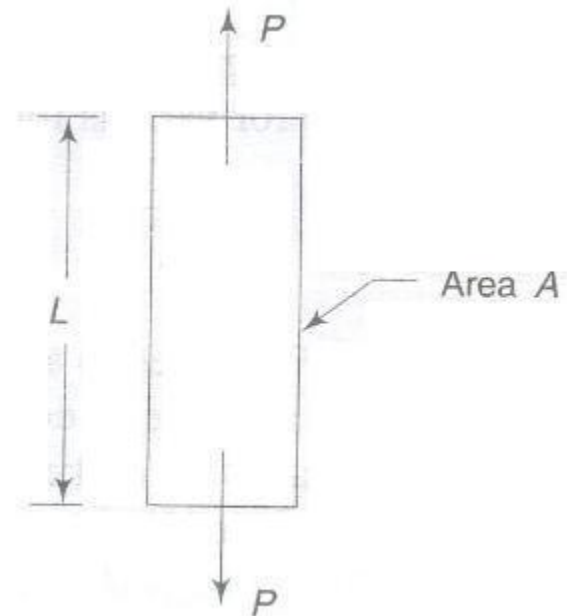- Elastic member may be in form of rings, diaphragm, strips, cylinders etc.

1. Axially loaded elastic member –

   $\varepsilon = P / AE \quad k = EA / L$
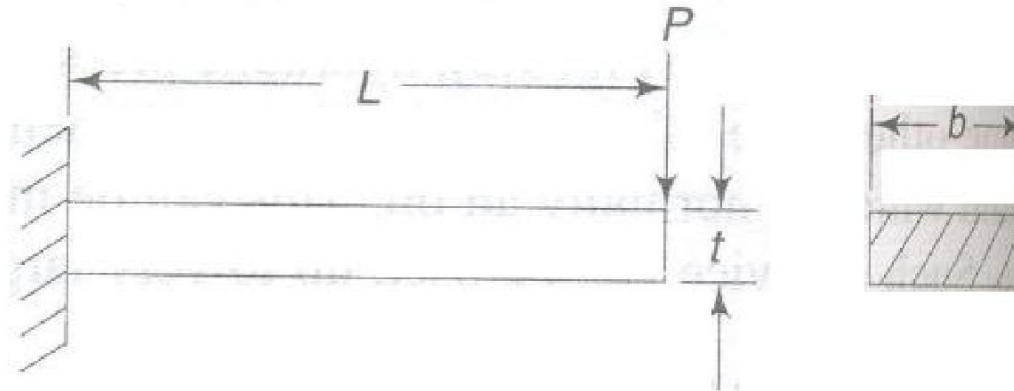
ε = strain in axial
direction k = stiffness

E = Young's Modulus

Axially loaded elastic member

2. Cantilever–type Elastic Member

$$\varepsilon = \frac{6PL}{Ebt^2}$$

$$\text{stiffness } k = \frac{\text{Force } P}{\text{Deflection at free end}}$$

$$= \frac{Ebt^3}{4L^3}$$

3. Ring Type Elastic Member

Due to the forces V and H, strain ε at $\theta = 90°$ is given by
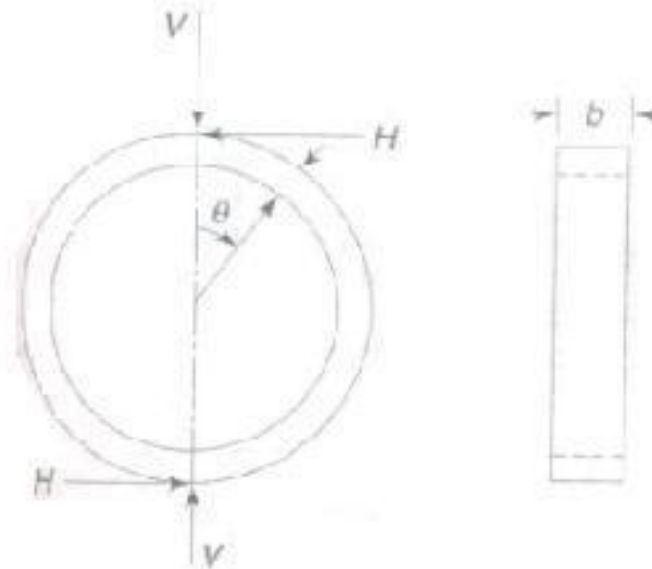
$$\varepsilon_{90°} = 1.09 \frac{Vr}{Ebt^2}$$

at $\theta = 39.6°$,

$$\varepsilon_{39.6°} = 2.31 \frac{Hr}{Ebt^2} \qquad r = \text{mean radius of the ring.}$$

Expressions for deflections in the directions of V and H are:
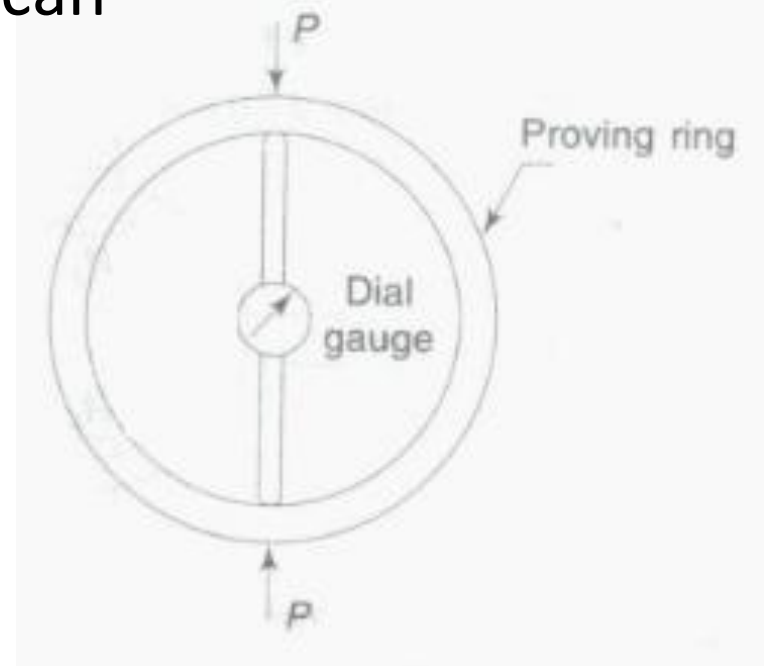
$$\delta_V = 9.42 \frac{Vr^3}{Ebt^3}$$

$$\delta_H = 1.79 \frac{Hr^3}{Ebt^3}$$

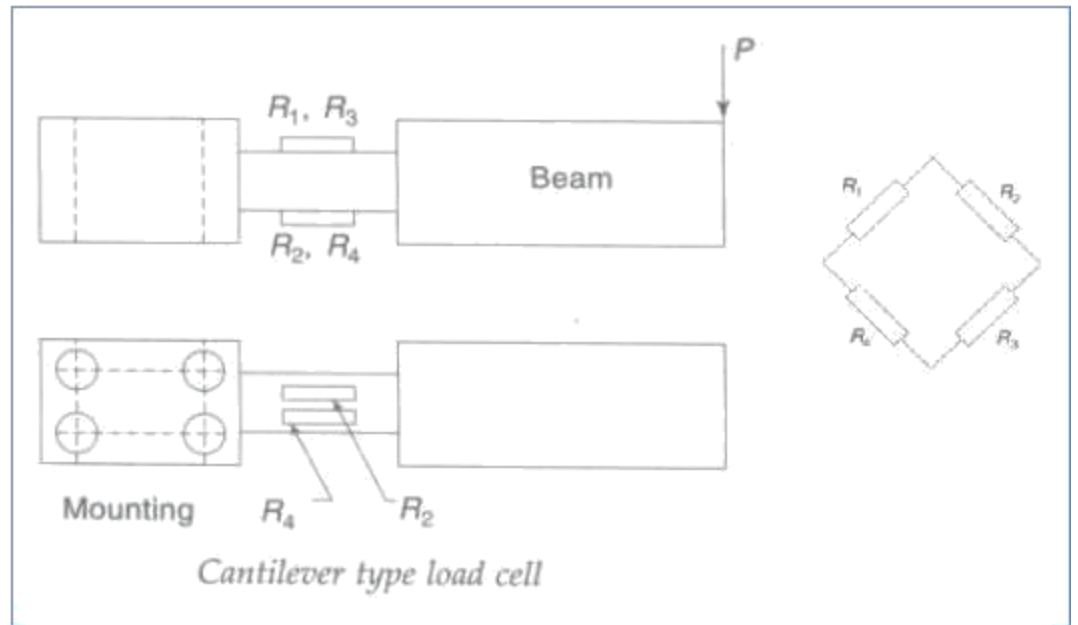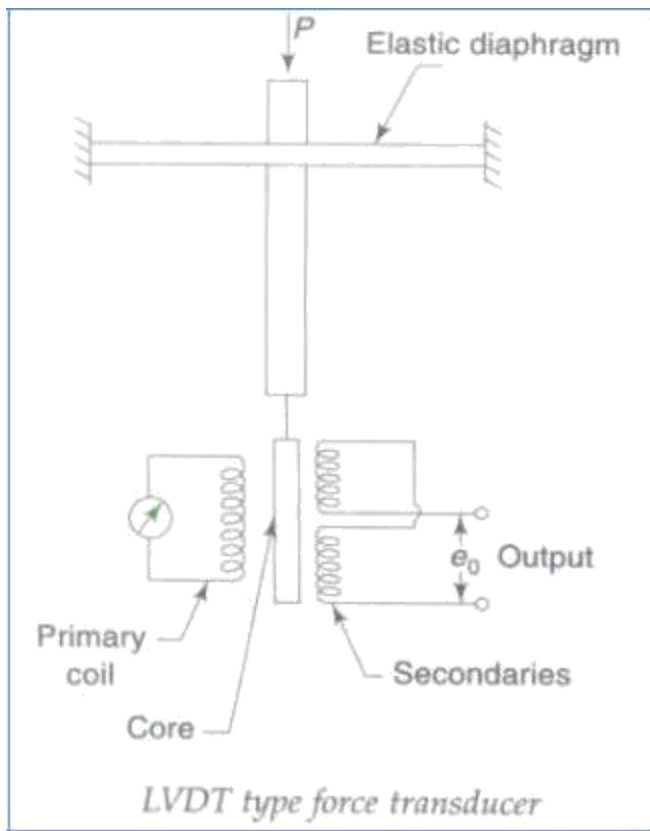# Methods to measure deflection of elastic member
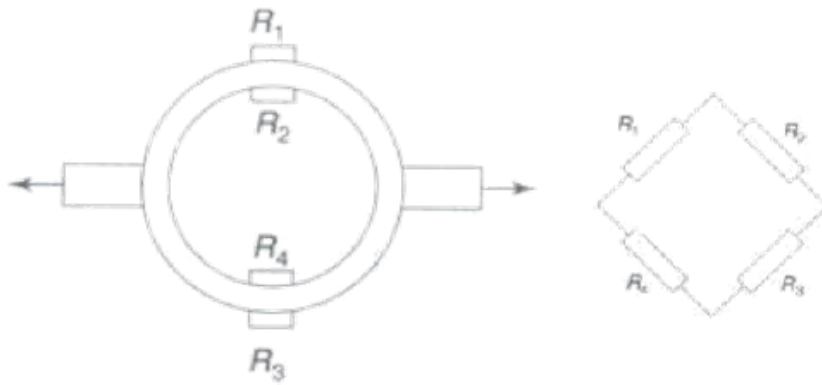
1. Mechanical method:

The elastic ring called proving ring, has on its inside an accurate dial gauge that can

be calibrated in terms of the force.

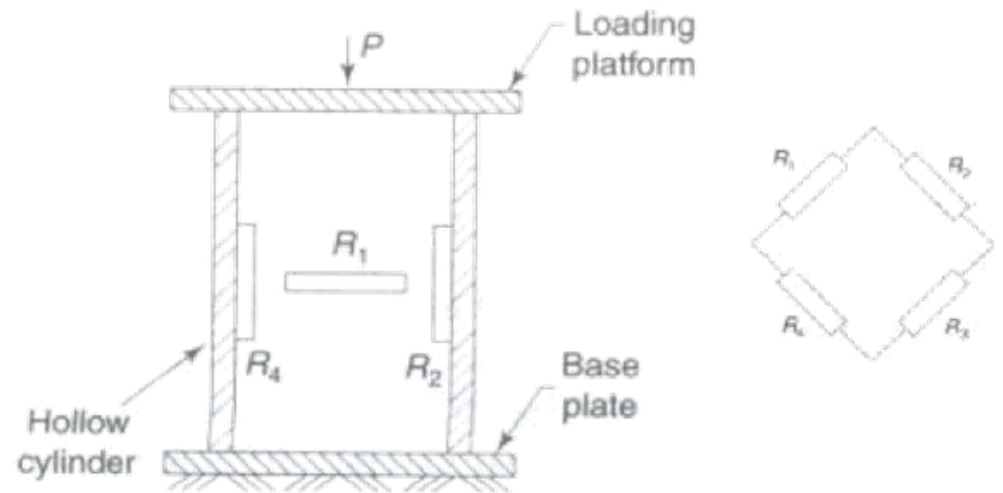2. Electromechanical methods:

- Piezo-electric transducer – dynamic force meas.

- LVDT type force transducer

- Cantilever type load cell

- Ring type load cell

- Cylinder type load cell

P

Elastic diaphragm

e_0 Output

Primary coil

Core

Secondaries

LVDT type force transducer

R_1, R_3

Beam

P

R_2, R_4

R_1

R_2

R_4

R_3

Mounting
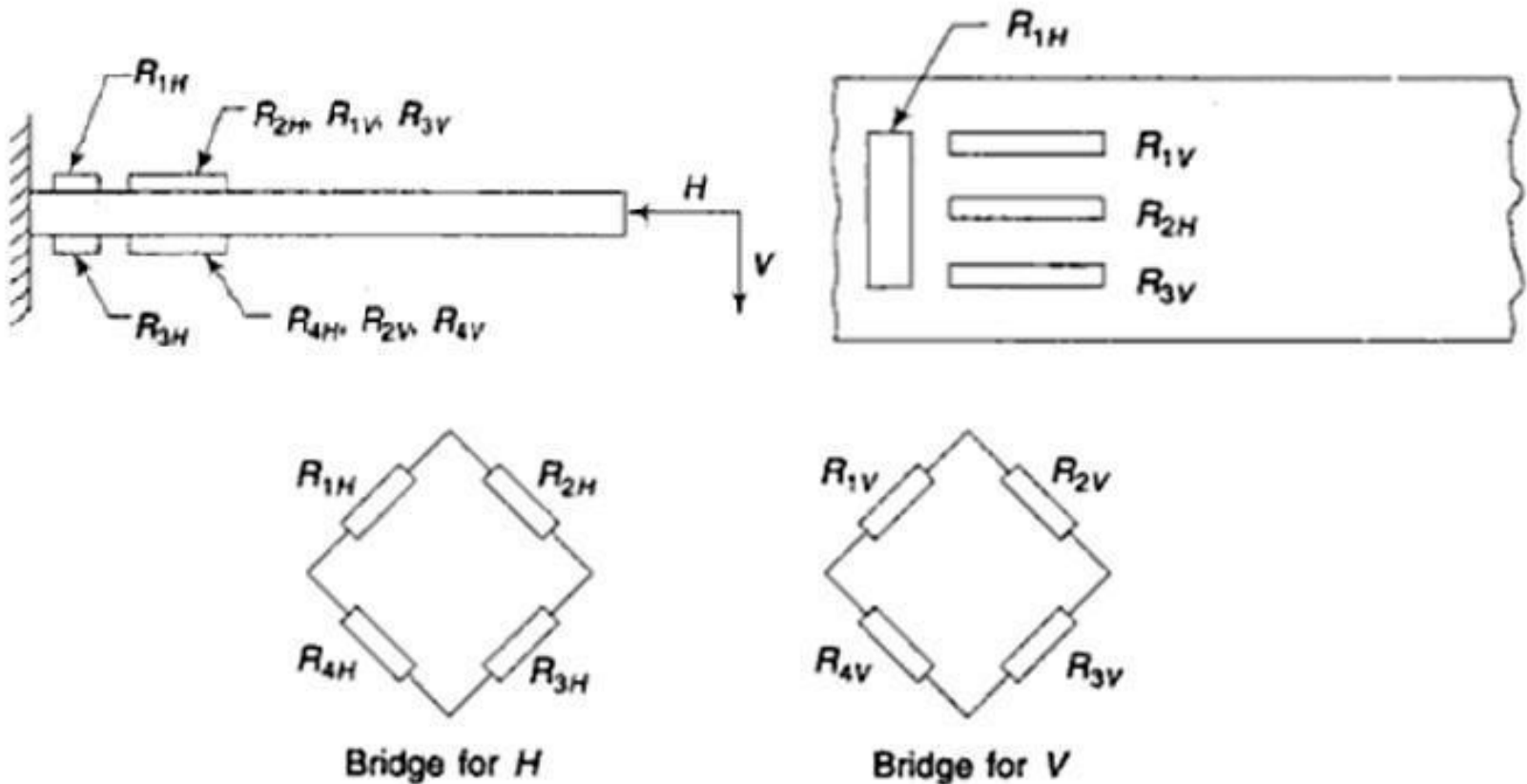
R_4

R_2

Cantilever type load cell

Force measurement-ring type cell

Force measurement-cylindrical type cell

Separation of Force Components

- To find the components of force along specified axes, elastic force transducers, especially strain gauge types are used.

Bridge for H

Bridge for V

Calibration

1. Static calibration

- For static calibration, dead weights are used.

- For very large forces, a known force may be applied by hydraulic pressure.

2. Dynamic Calibration

- Electrodynamic shaker provides dynamic force of harmonic type.

- Frequency can be varied by the oscillator

- Force can be varied by power amplifier.

- Mass m can be attached on the top of strip.

- The device to be calibrated is a strip with resistance gauges.

The dynamic force applied = m $\ddot{x}$

$$= - m \omega^2 x_0 \sin \omega t \text{ for } x = x_0 \sin \omega t$$

$\ddot{x}$ being the acceleration of the mass, ω the circular frequency and x_0 the amplitude of mass displacement.

Thus amplitude of harmonic force applied is m ω^2

$x_0.$ x_0 can be measured using microscope.

Dynamic force calibration