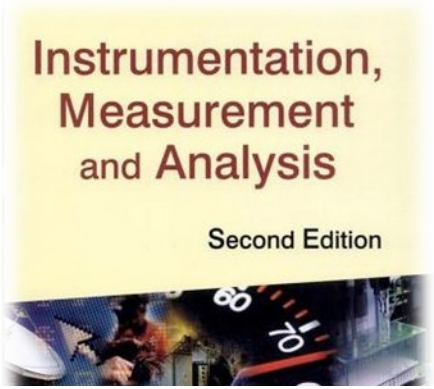
US06CPHY06

Instrumentation and Sensors

UNIT 2 Part 2

Pressure Measurements



UNIT– II Transducer Elements, Pressure Measurements

Transducer Elements: Ionization Transducers, Mechno-Electronic Transducer, Opto-Electrical Transducer, Photo-emissive Transducer, Photo-conductive Transducer, Photo-voltaic Transducer

Pressure Measurements: Introduction, Moderate Pressure Measurements, Manometers, High Pressure Measurements, Low Pressure (Vacuum) measurements, McLeod Gauge, Thermal conductivity or Pirani Gauge, Ionization Gauge, Knudsen Gauge

Pressure Measurements

What is 'Pressure' ?

Pressure: Force exerted by a fluid on unit surface area of a container i.e. P = F/A.

Units

- N/m^2 = Pascal (Pa)
- lb/in^2 = psi
- atm
- mm of Hg
- Torr

At sea level pressure is of:

1 atm = 760 mm of Hg

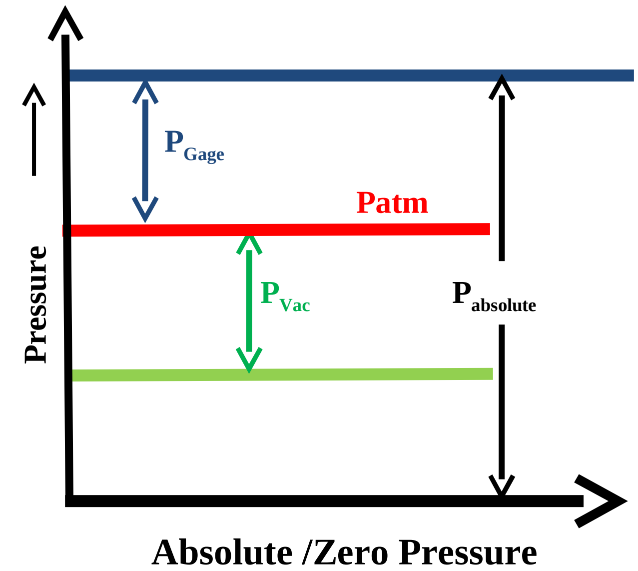
= 760 Torr

= 1.013×10^5 Pa

= 14.7 psi

Types

- Static
- Dynamic
- Gage
- Absolute
- Vacuum



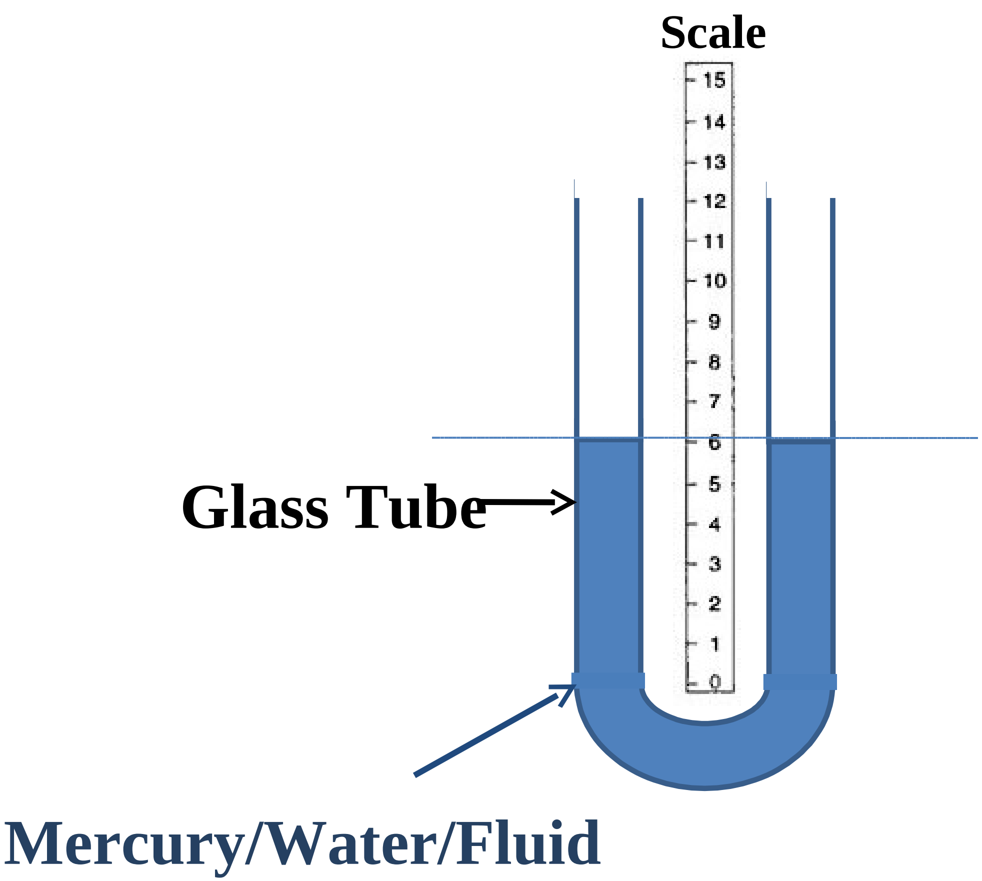
Pressure Measurement : Range &Techniques

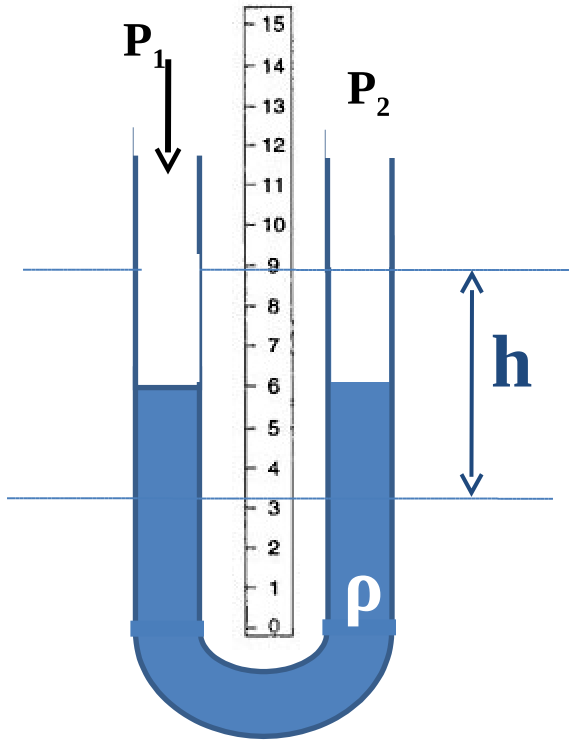
- **Very High > 1000 atm**
- **Moderate**
- **Very Low < 1mm of Hg (Torr)**

Static OR Dynamic e.g. compressors of engine.

- Moderate Pressure Measurements: Manometers : Static Pressure
- Other devices using elastic elements: For both Static and Dynamic Pressure

Manometers: Static Pressure Measurements

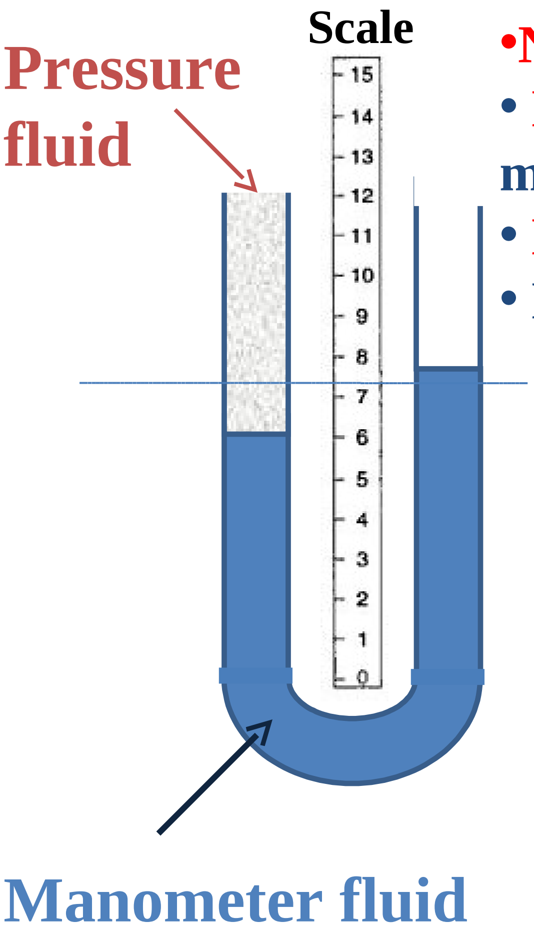




$$P_1 - P_2 = h \rho g$$

If P_2 is P_{atm} then, $(P_1 - P_2)$ gives gage pressure (applied).

Manometers:



Manometer fluid Characteristics

- **Non-Corrosive**
- **No chemical reaction with fluid whose pressure is to be measured**
- **Low viscosity for quick adjustment with pressure change**
- **Negligible surface tension and capillary effects**

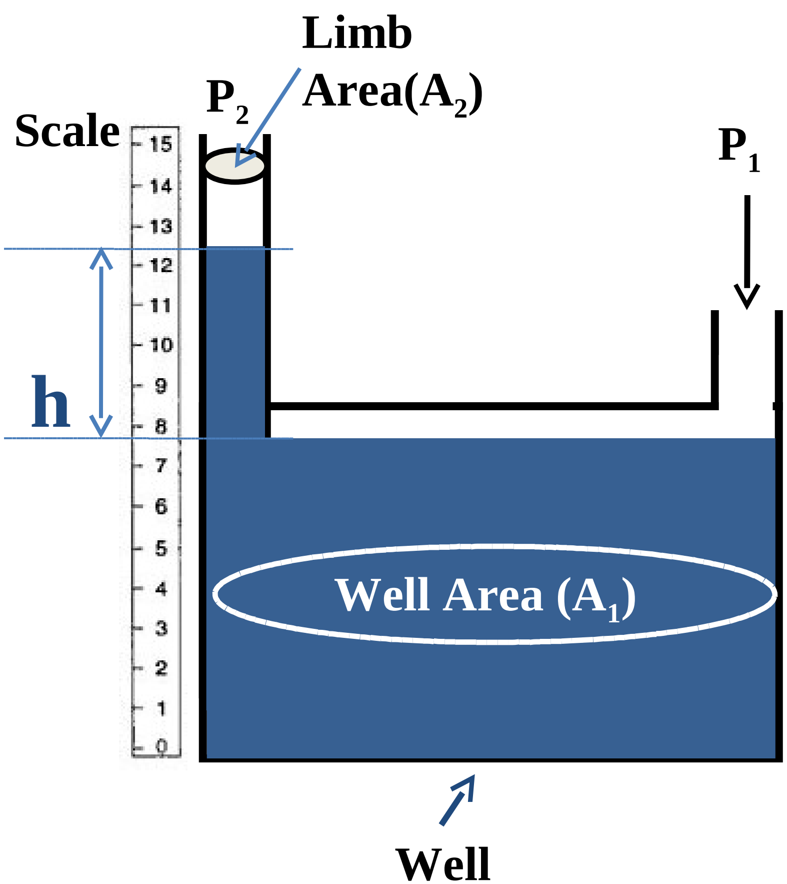
Why manometers are modified ?

- **For ease in use**
- **To increase sensitivity**

Types of Modified Manometers

- Cistern or Well Type
- Inclined Tube Type
- Movable Tube Type
- Micrometer Type
- Micro manometer with motor drive and digital read out.

Cistern or Well type Manometer



Since A_1 >> A_2,

Change in limb level >> Change in well level

So, Change in well level is ignored and reading of only one limb (h) is recorded.

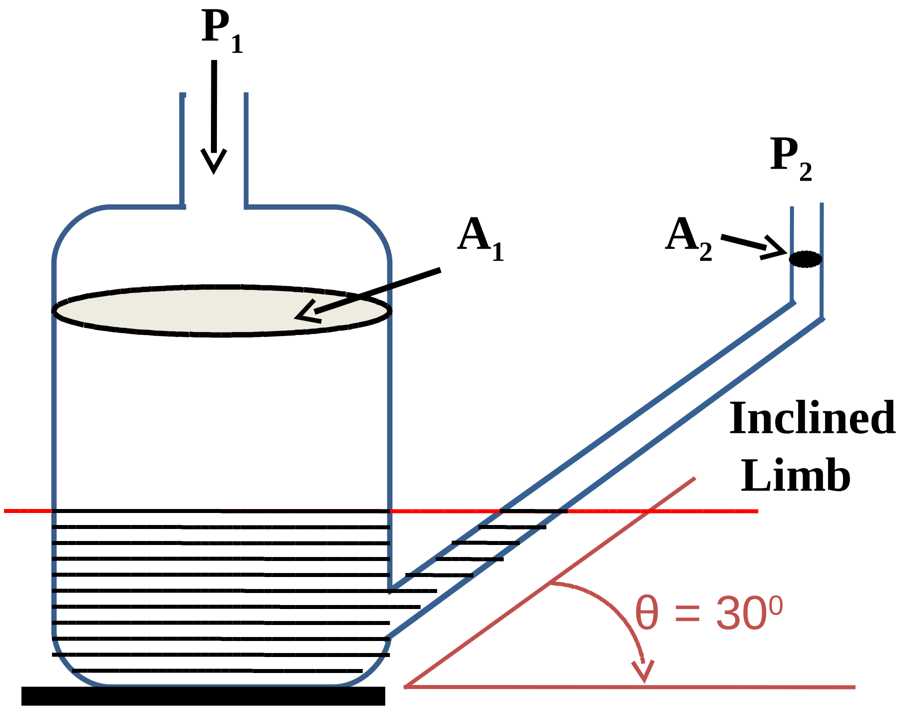
If P_1 and P_2 are absolute pressure, then force equilibrium gives

$P_1A - P_2A = A h\rho g$ (since P=F/A)

i.e. $P_1 - P_2 = h \rho g$

If P_2 is P_{atm} then, $(P_1 - P_2)$ gives Gage pressure (applied).

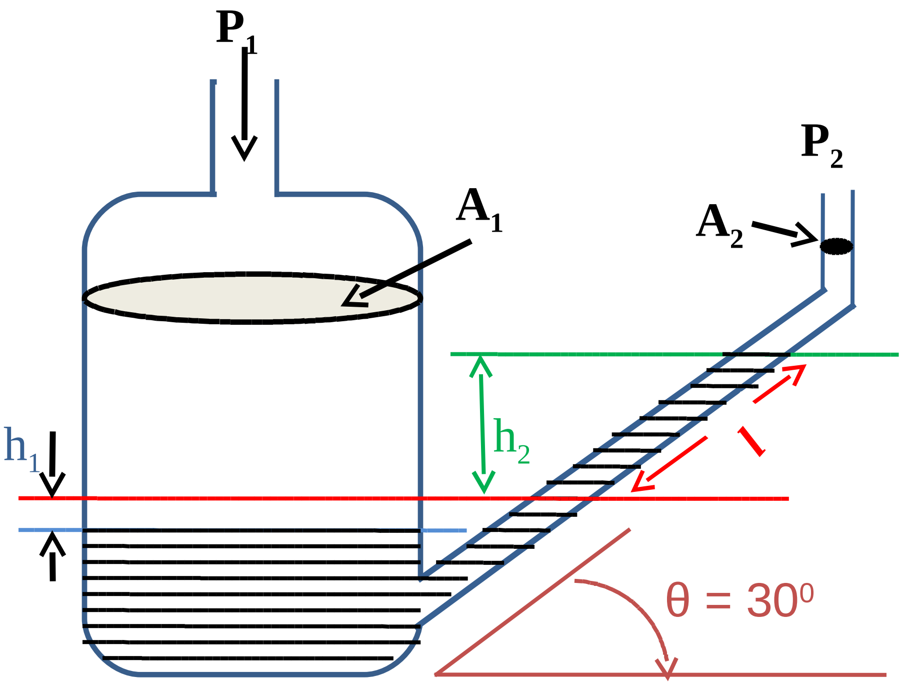
Inclined Tube Manometer



When $P_1 = P_2$

i.e. equilibrium

Inclined Tube Manometer



$$(h_1 + h_2)\,\rho g = P_1 - P_2 \quad \ldots (1)$$

$$\therefore\; h_1 + h_2 = \frac{P_1 - P_2}{\rho g} \quad \ldots (2)$$

$$Also, \quad A_1 h_1 = A_2 l$$

$$\therefore\; h_1 = \frac{A_2}{A_1} l \quad \ldots (3)$$

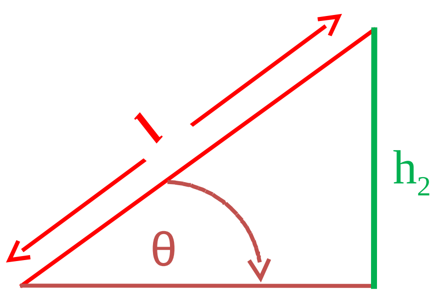
From the geometry of the system,

$$\sin\theta = \frac{h_2}{l} \qquad \therefore\; h_2 = l \sin\theta \quad \ldots (4)$$

Using (3) & (4) *in* (1)

$$\therefore\; P_1 - P_2 = \left(\frac{A_2}{A_1} l + l\sin\theta\right)\rho g$$

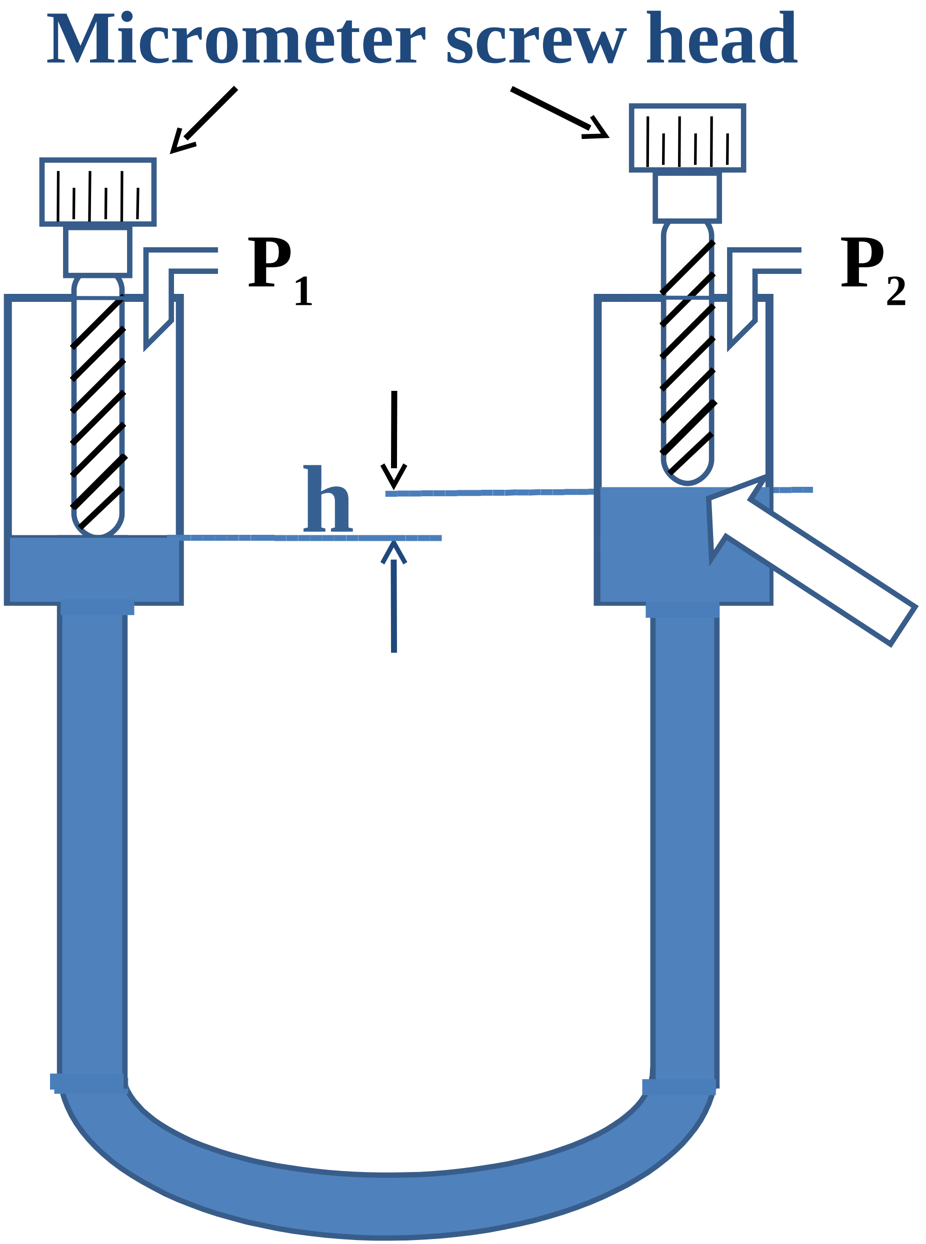
$$\therefore\; P_1 - P_2 = \left(\frac{A_2}{A_1} + \sin\theta\right) l\rho g$$



$$Since\ A_1 \gg A_2, \quad P_1 - P_2 = \rho g l \sin\theta = \rho g\, h_2$$

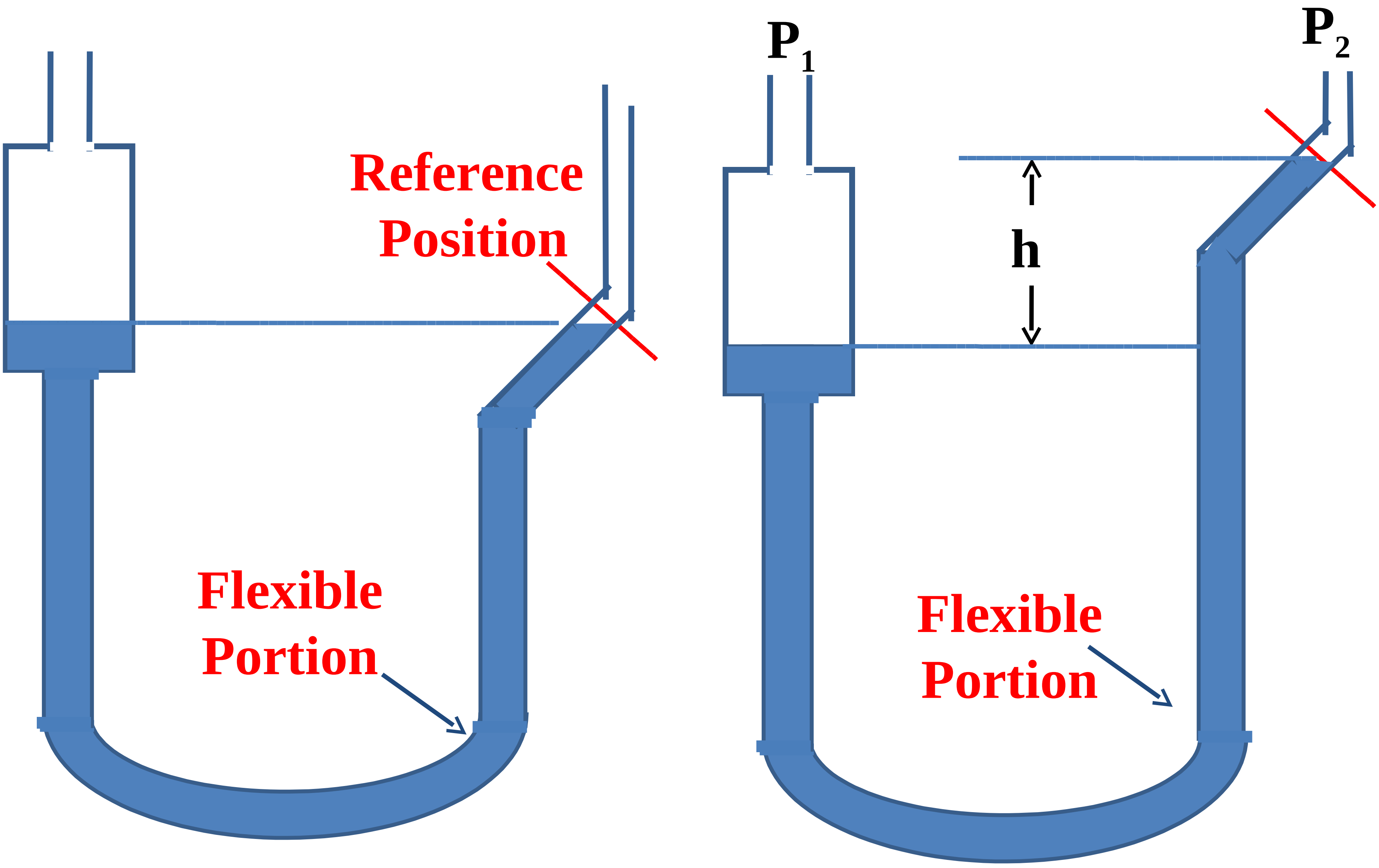
$$if\ \theta = 30^0\ then, \quad h_2 = l\sin\theta = \frac{l}{2} \quad and\ so\ l = 2h_2$$

Micrometer Type Manometer

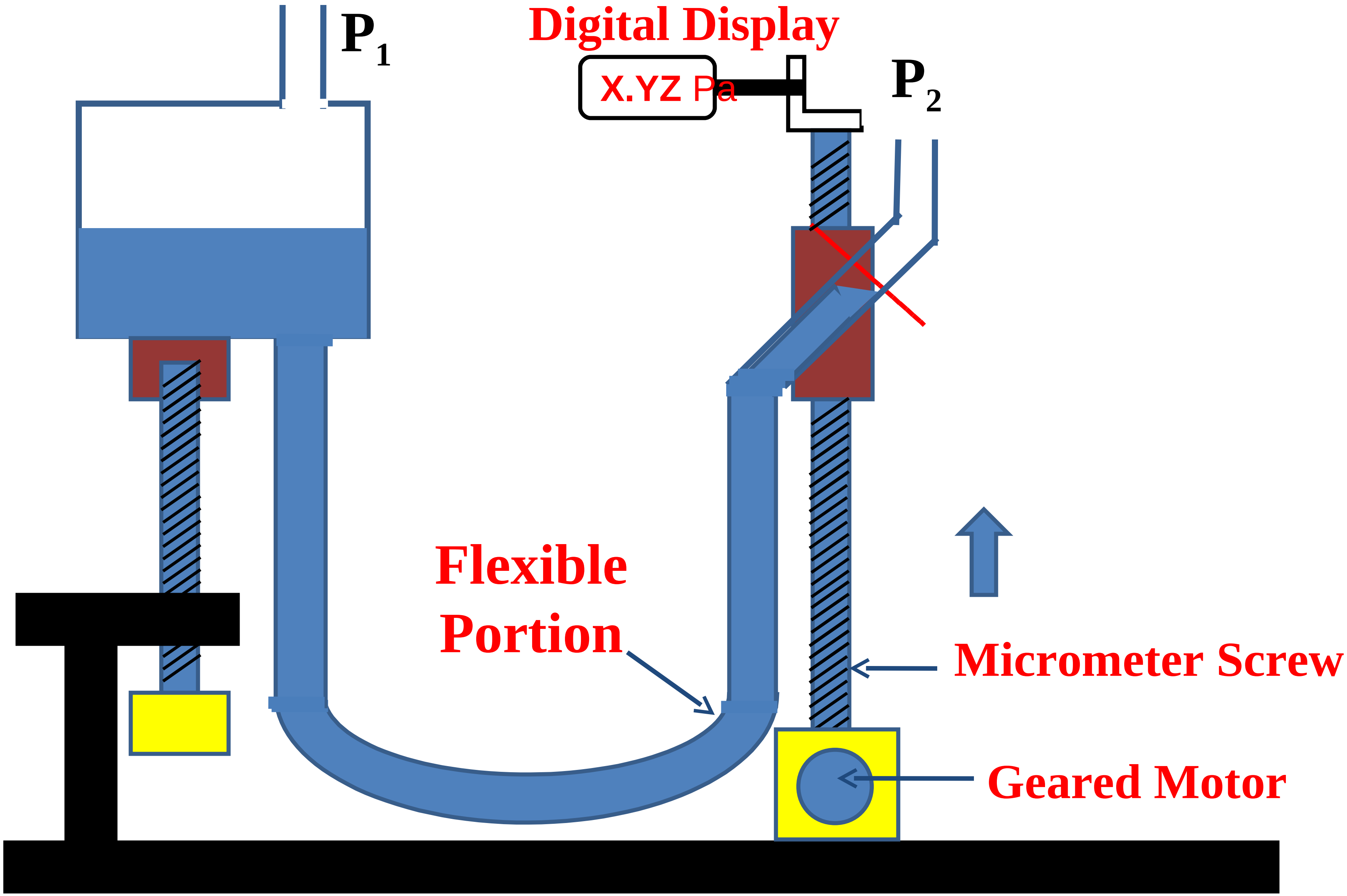


- Increased accuracy in reading of he output of manometer i.e. liquid displacement.
- Contact between micrometer screw and liquid level can be sensed <u>electrically</u> for more accuracy

Movable Tube Type Manometer

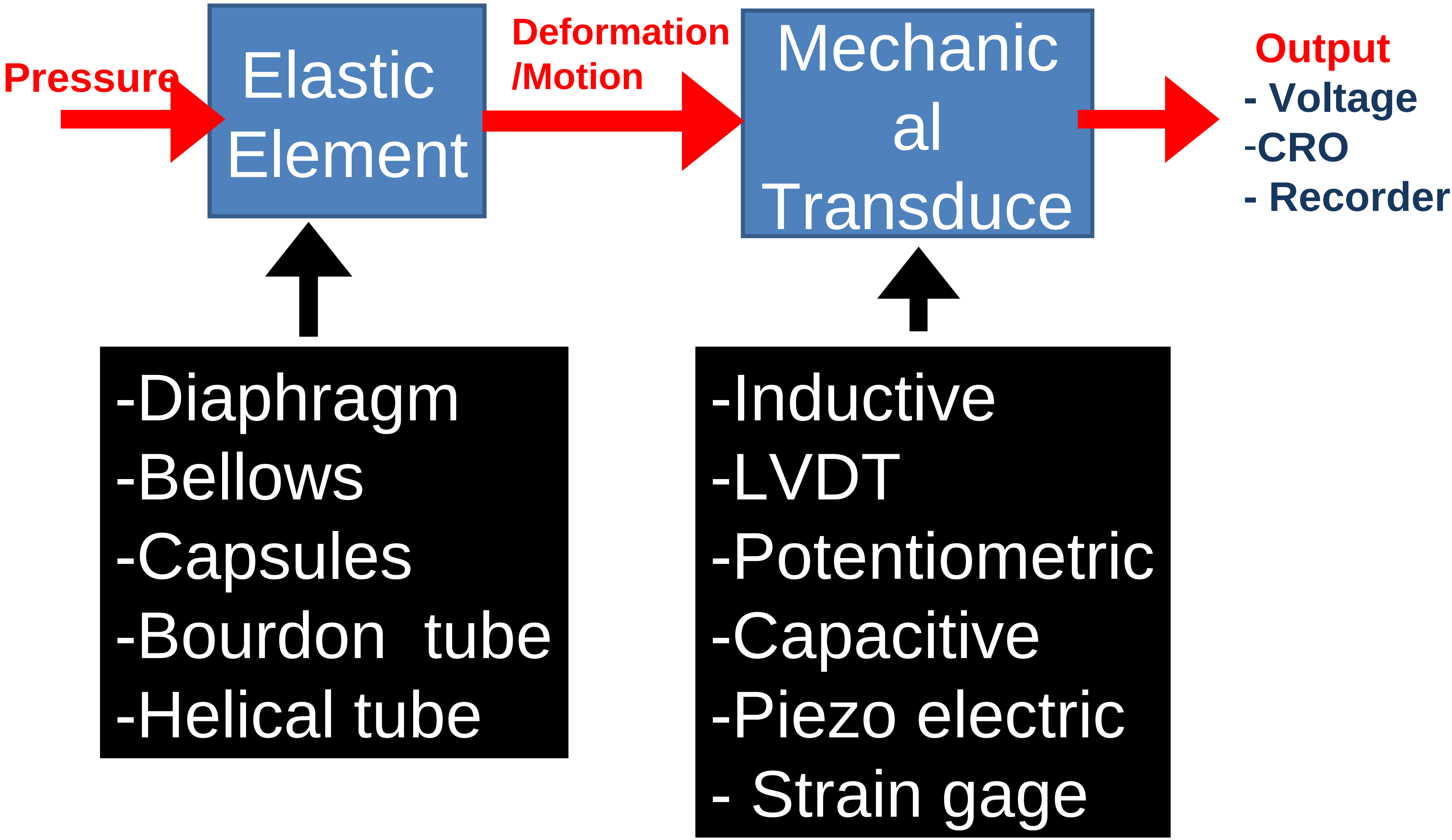


Micrometer with motor-drive Type Manometer

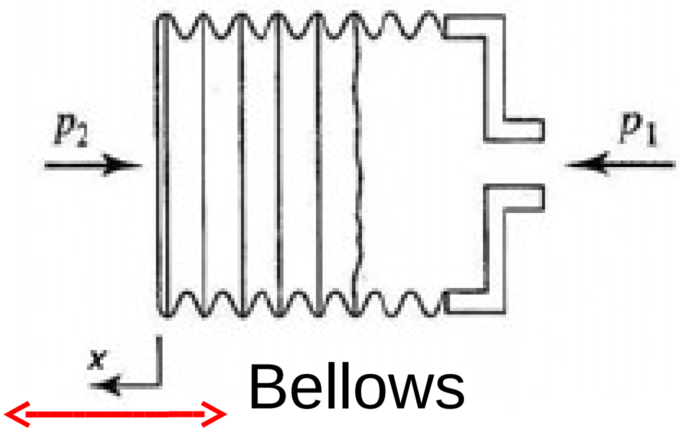


Elastic Transducers: Static/Dynamic Pressure

Principle of Working:

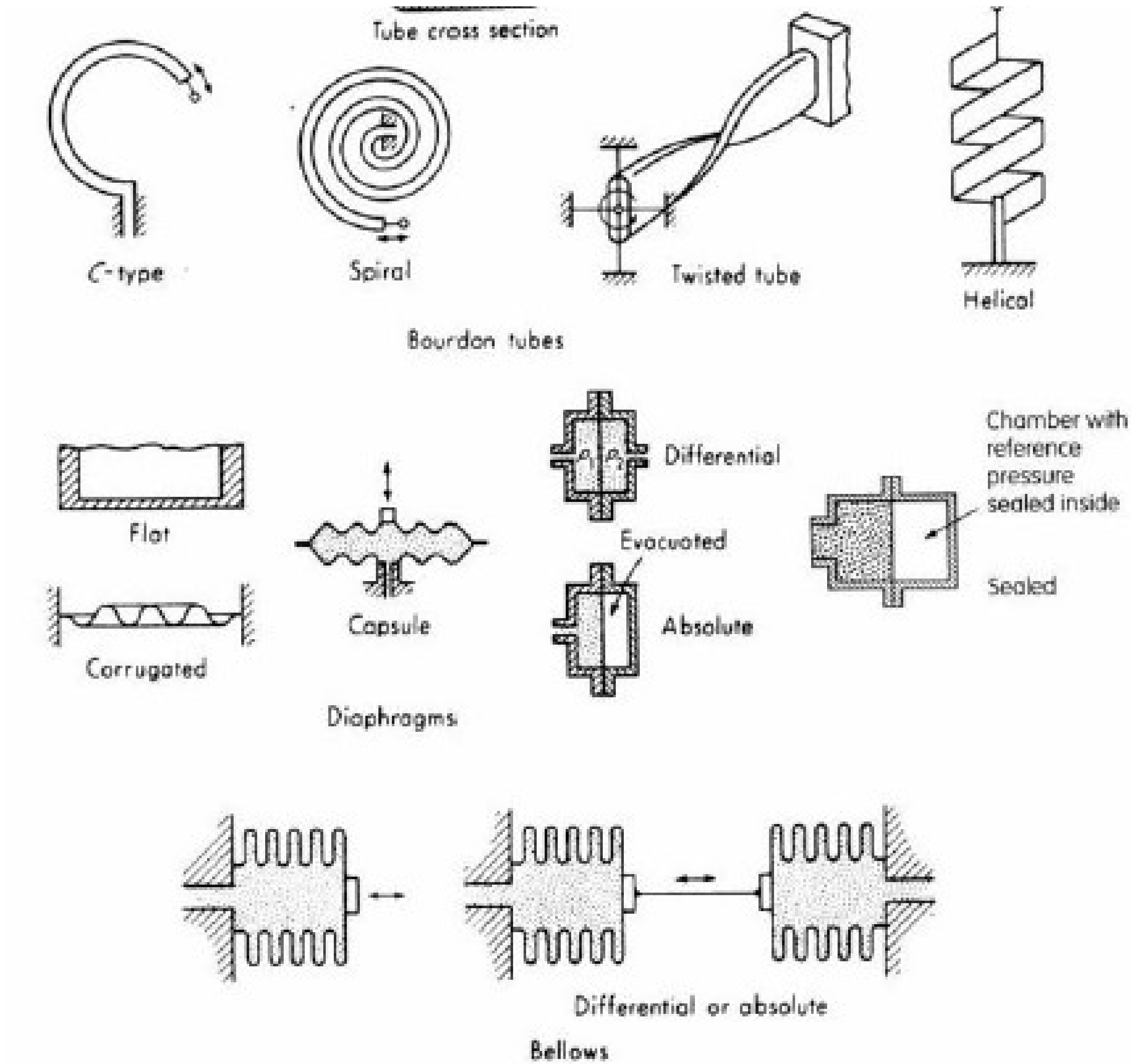


Elastic Elements:

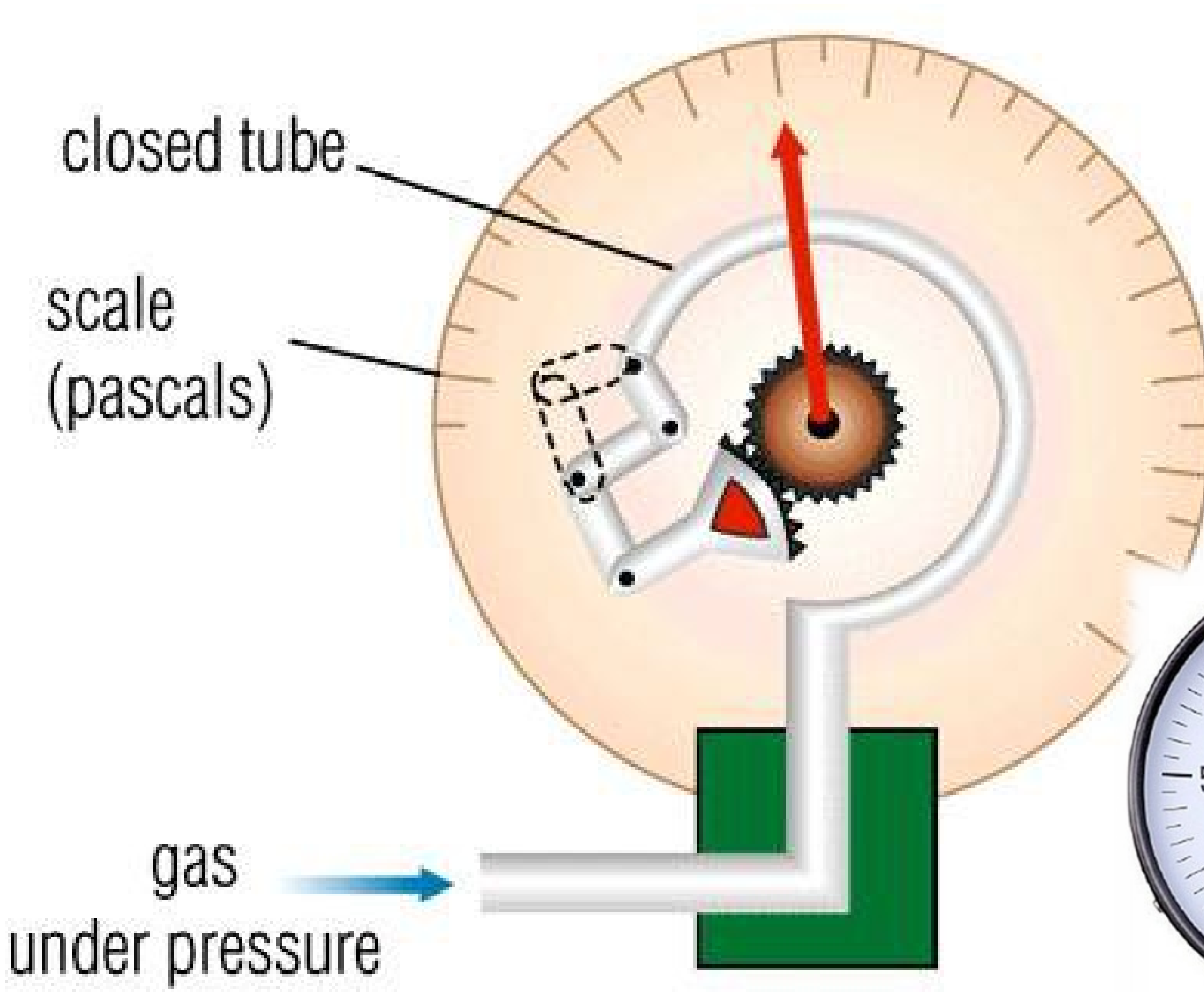


Bellows

Elastic Elements:



Bourdon Gage:



Bourdon Gage:

Bourdon Tube Gauge

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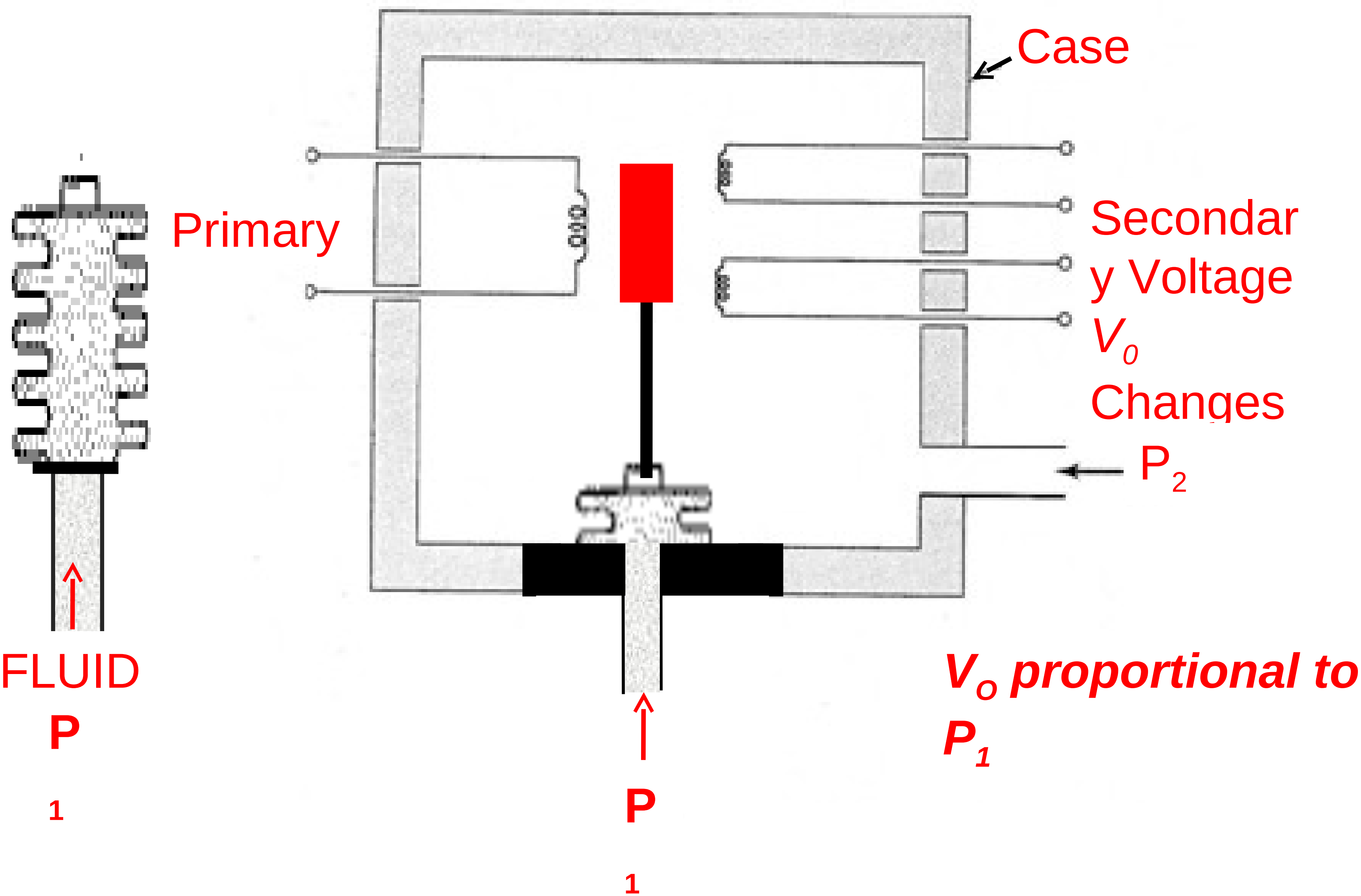
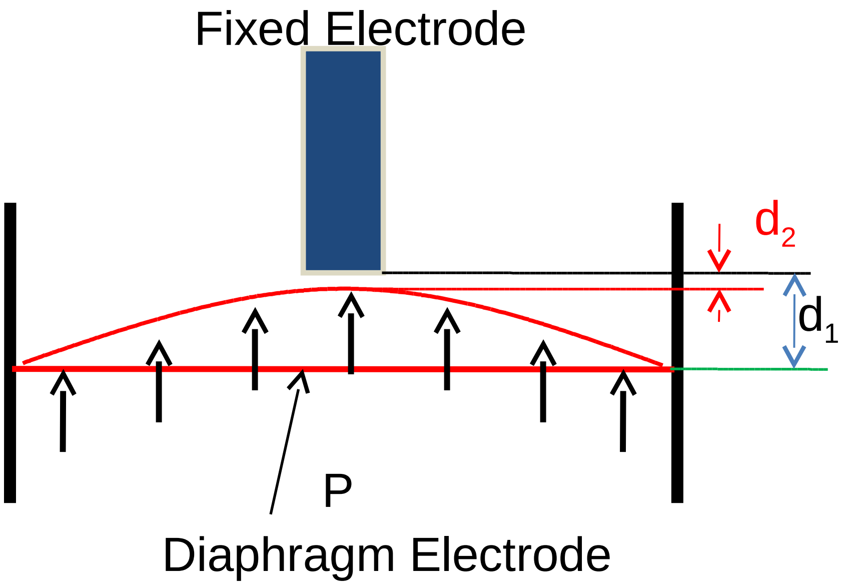
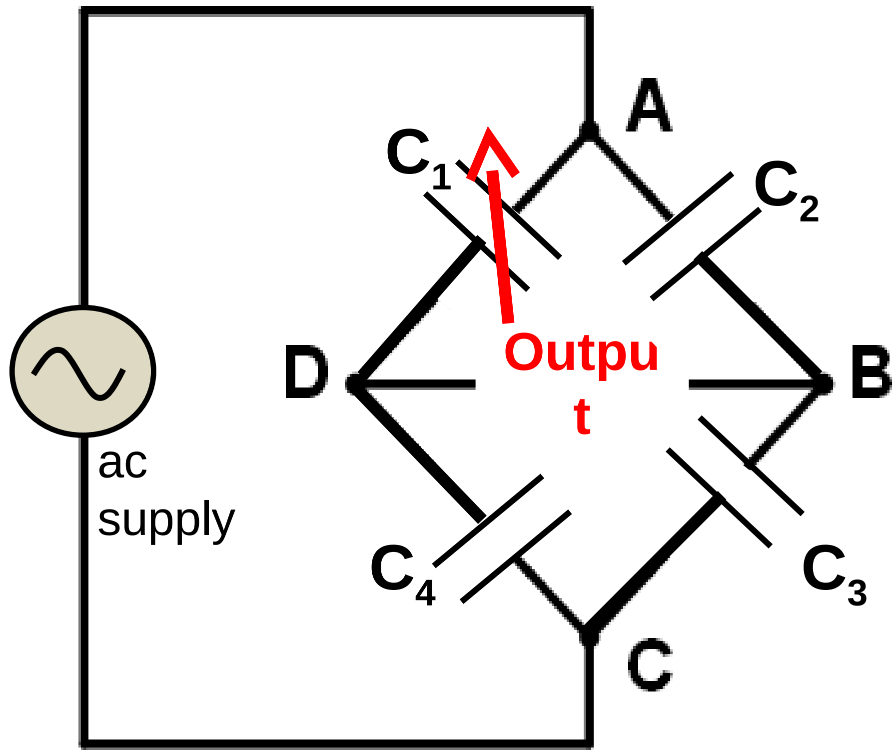
LVDT Type Pressure Transducer



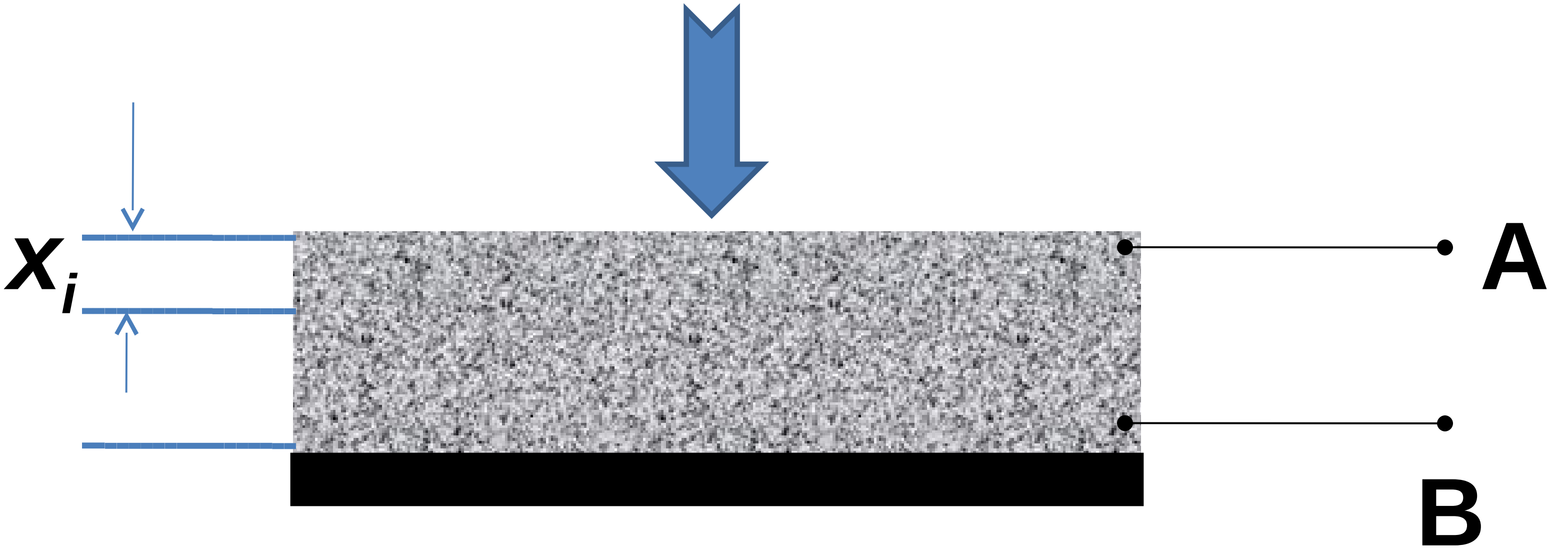
Variable capacitance Type Pressure Transducer





Due to pressure diaphragm displaces and Capacitance changes

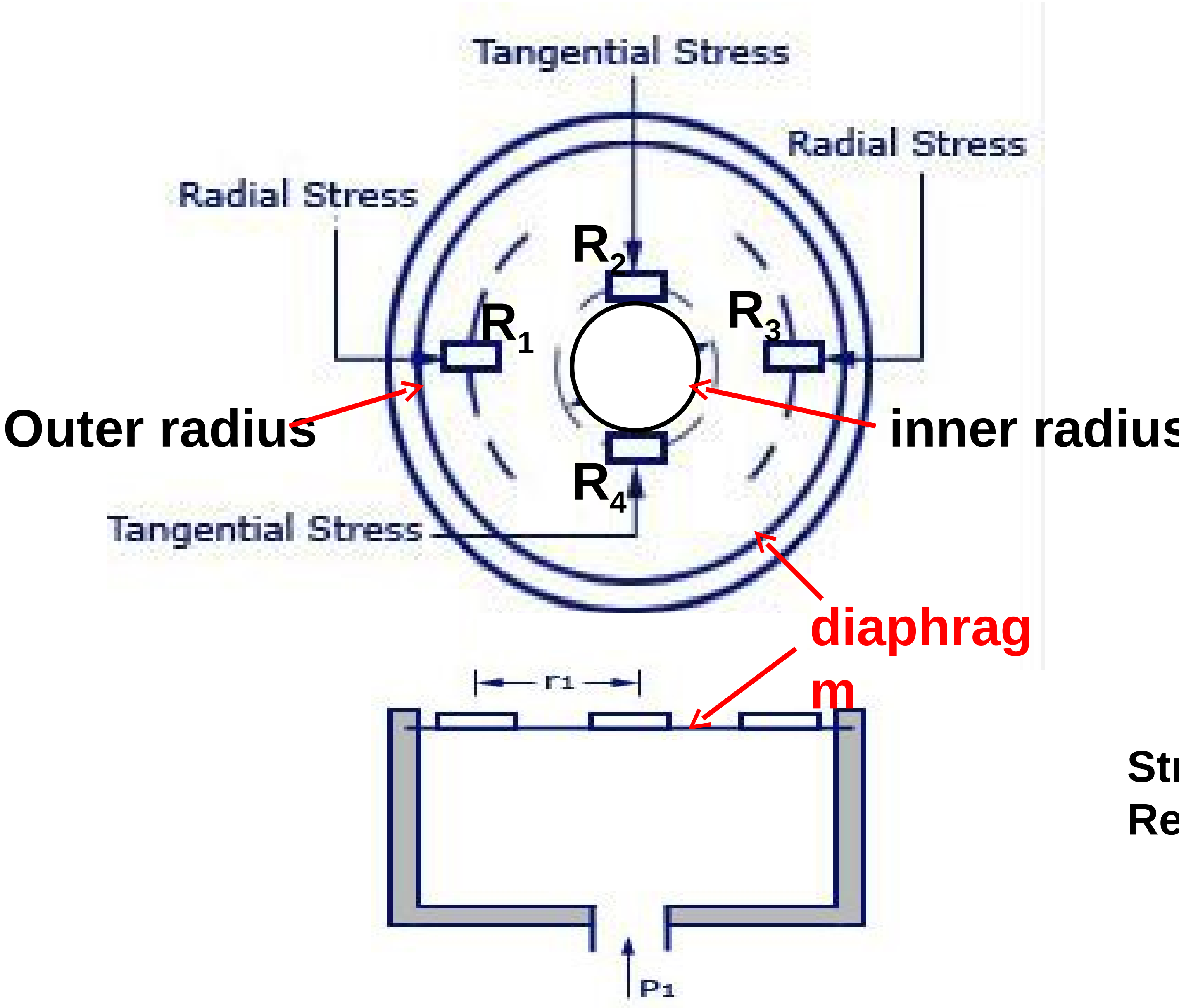
Piezo-electric Type Pressure Transducer

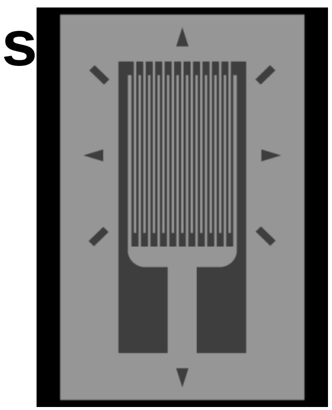


ue to pressure crystal squeezes to produce voltage between A and B .

Only dynamic pressures can be measured.

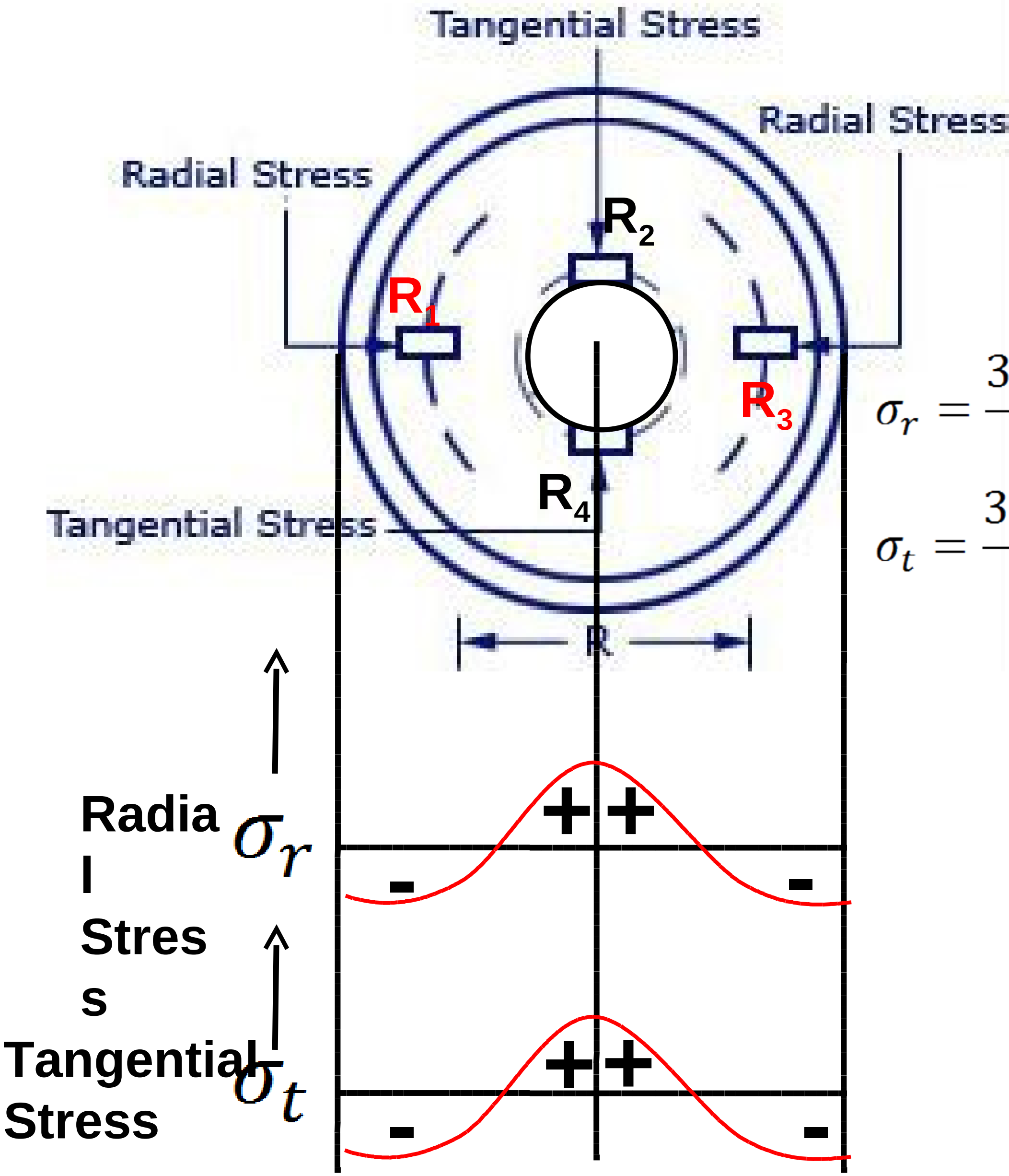
Resistance Strain-gages Pressure Transducer





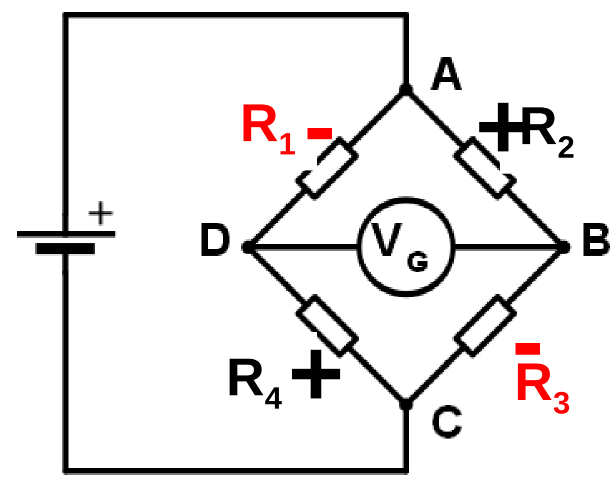
Strain gage
Resistor

Resistance Strain-gages Pressure Transducer



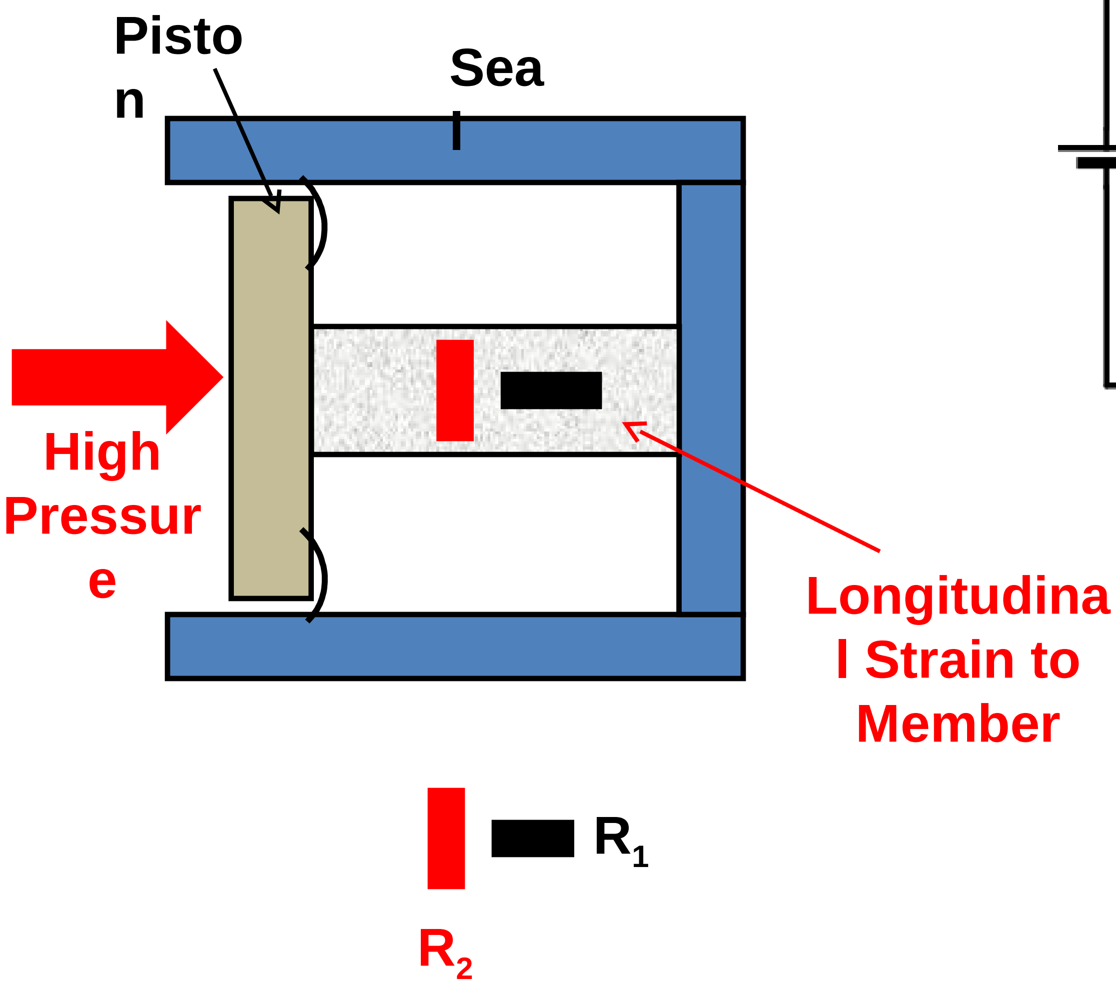
$$\sigma_r = \frac{3pR^2v}{8t^2}\left[\left(\frac{1}{v}+1\right)-\left(\frac{3}{v}+1\right)\left(\frac{r}{R}\right)^2\right]$$

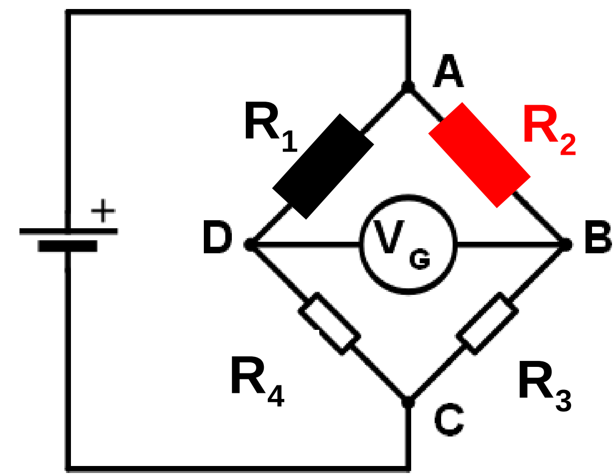
$$\sigma_t = \frac{3pR^2v}{8t^2}\left[\left(\frac{1}{v}+1\right)-\left(\frac{1}{v}+3\right)\left(\frac{r}{R}\right)^2\right]$$



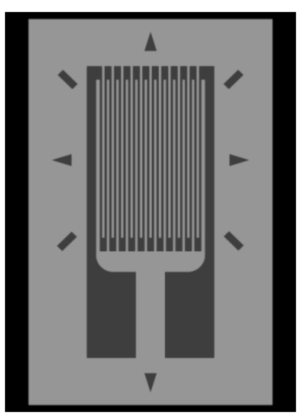
Bridge Circuit

Piston Type Strain-gages Pressure Transducer



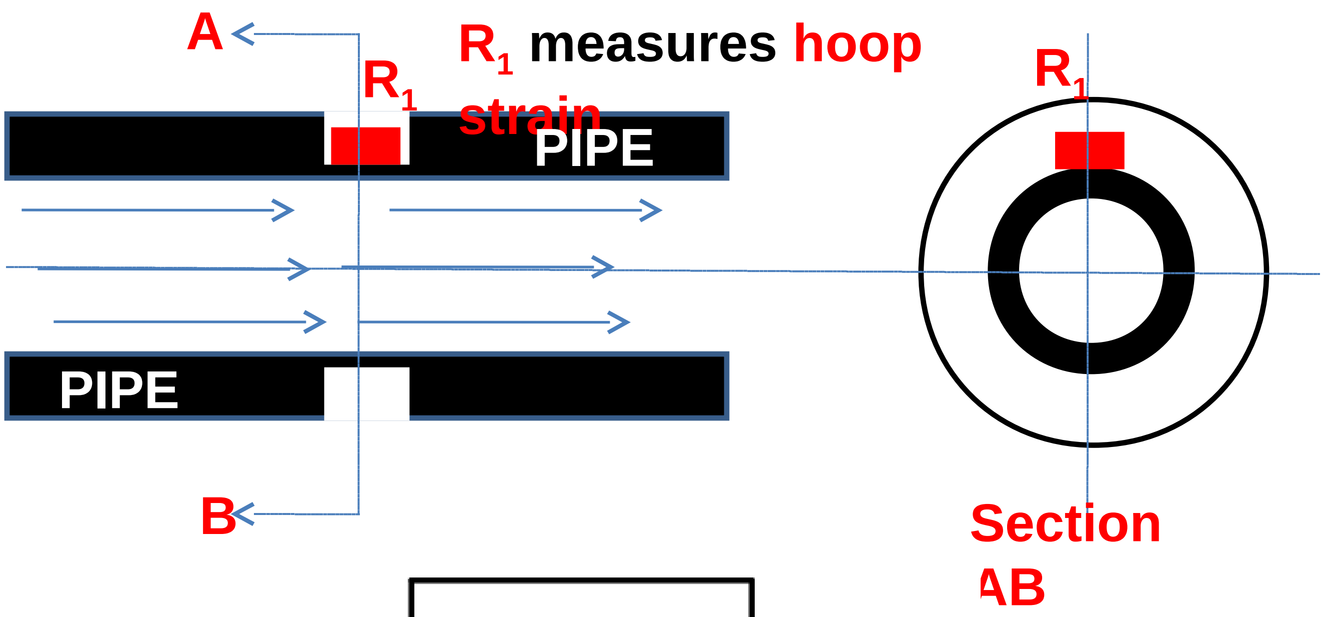


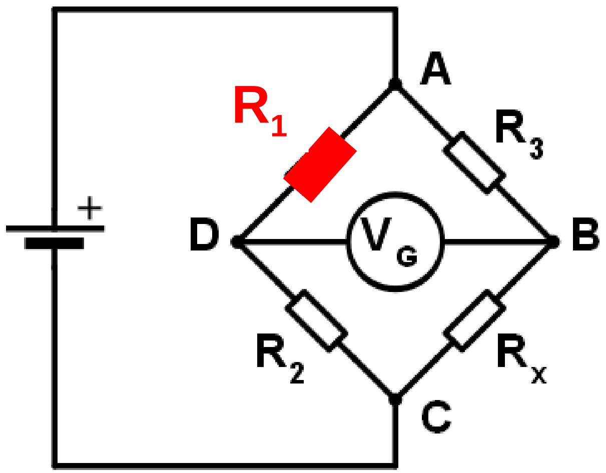
Bridge
Circuit



Strain gage
Resistor

Strain-gages Transducer-For Fluid Pressure





Bridge Circuit

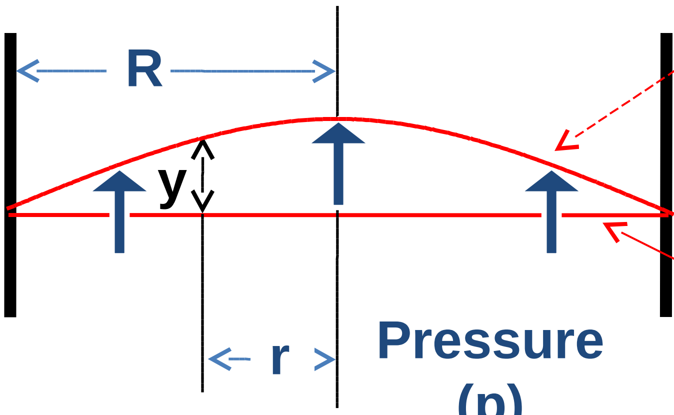
Elastic Element Characteristics

For elastic elements used in pressure transducers

- Deflection due to pressure and
- Dynamic properties are of great importance

Elastic Element Characteristics

Deflection due to pressure



$$Deflection\ at\ r,\quad y = \frac{3}{16}\, p\, \frac{(1-v^2)}{E t^3}\,(R^2 - r^2)^2$$

$p = pressure\ at\ r\ ,\ v = Poisson\ ratio$
$t = thickness\ E = Young\ Modulus$

$$y_{max}(at\ r = 0) = \frac{3}{16}\, \frac{p(1-v^2)}{E t^3}\, R^4$$

y_{max} **< t/3**

Elastic Element: Dynamic Characteristics

Fundamental frequency of vibration for a circular diaphragm of radius R, is

$$\omega_n = \frac{10.21}{R^2}\sqrt{\frac{Et^2}{12(1-v^2)\rho}}\ rad/s$$

Here ρ is the mass density of the diaphragm material

Let ω_e be the exciting frequency of vibrations of the elastic element, then

$$\omega_n \gg \omega_e$$

for dynamic considerations

Elastic Element: Dynamic Characteristics

"Points to consider"

The properties of pressure transmitting fluid & the connecting tubing are also important.

- The effective mass of the moving system depends on

  the mass of the fluid that moves with the deflected elastic diaphragm.
- The damping action depends on fluid friction.

High Pressure Measurements