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Affiliated to MSBTE Mumbai, Approved by AICTE New Delhi, DTE Mumbai & Govt. of Maharashtra, Mumbai.

MECHANICAL ENGINEERING MEASUREMENTS

UNIT 3: MEASUREMENT OF PRESSURE & TEMPERATURE

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INTRODUCTION

- **Pressure Definition:**

✓ The action of force against some opposite force. OR

✓ A force in the nature of thrust distributed over a surface. OR

✓ The force acting against a surface within a closed container.

- **Units:-**

✓ Some of the commonly used pressure units are:

✓ 1bar = 10^5 N/mm^2= 1.0197 kgf/cm^2 = 750.06 mm of Hg.

✓ 1 micron = 1M = 10^{-3} mm of Hg.

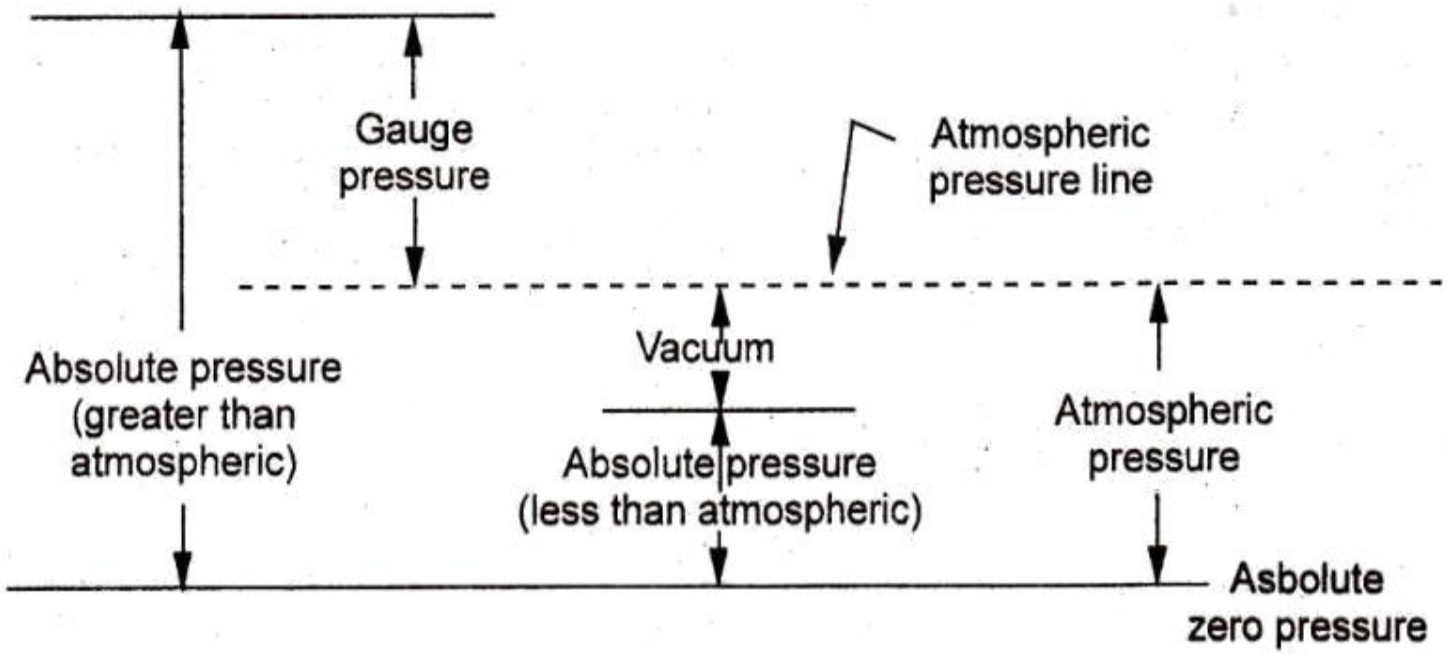
✓ 1 torr = 1 mm of Hg.

✓ 1 bar = 1 dyne/cm^2

✓ Pa = N/mm^2

INTRODUCTION

- ✓ Following terms are generally associated with pressure and its measurement.



Relation between absolute, gauge and atmospheric pressure

INTRODUCTION

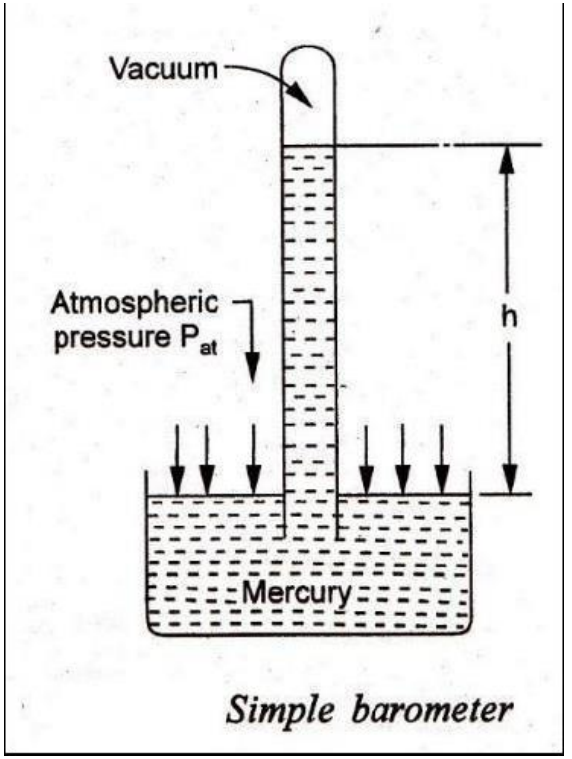
- **Atmospheric pressure (P_{at}):-**

✓ This is the pressure exerted by the envelope of air surrounding the earth surface.

✓ Atmospheric pressure is usually determined by a mercury column barometer

✓ Atmospheric pressure varies with altitude, because the air nearer the earth's surface is compressed by air above.

At sea level, value of atmospheric pressure is close to 1.01325 bar or 760 mm of Hg column.



Simple barometer

INTRODUCTION

- **Absolute pressure (P_a):-**

✓ It is defined as the force per unit area due to the interaction of fluid particles amongst themselves.

✓ A zero pressure intensity will occur when molecular momentum is zero.

✓ Such a situation can occur only when there is a perfect vacuum, i.e., a vanishingly small population of gas molecules or of molecular velocity.

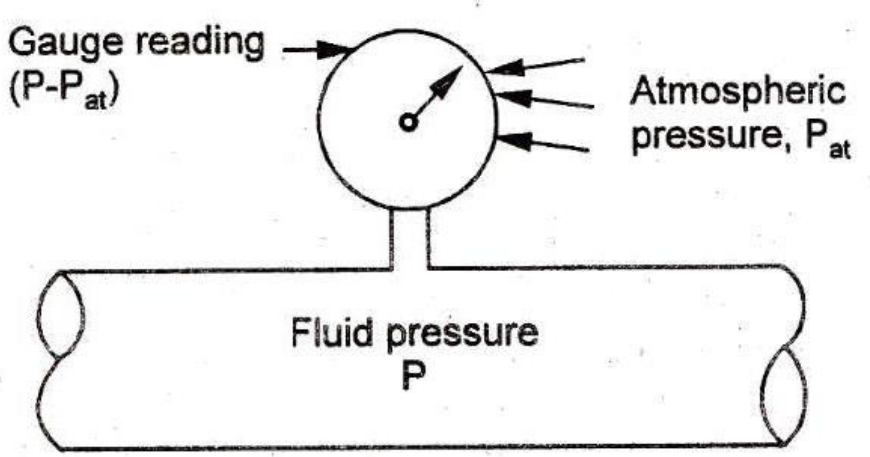
✓ Pressure intensity measured from this state of vacuum or zero pressure is called absolute pressure.

INTRODUCTION

- **Gauge Pressure (P_g):-**

✓ Instruments and gauges used to measure fluid pressure generally measures the difference between the unknown pressure ‘P’ and the existing atmospheric pressure ‘P_{at}’.

✓ When the unknown pressure is more than the atmospheric pressure the pressure is recorded by the instrument is called gauge pressure



INTRODUCTION

- **Vacuum Pressure:-**

✓ Pressure reading below the atmospheric pressure is known as vacuum pressure or negative pressure.

✓ Actual absolute pressure is the sum of gauge pressure indication and the atmospheric pressure.

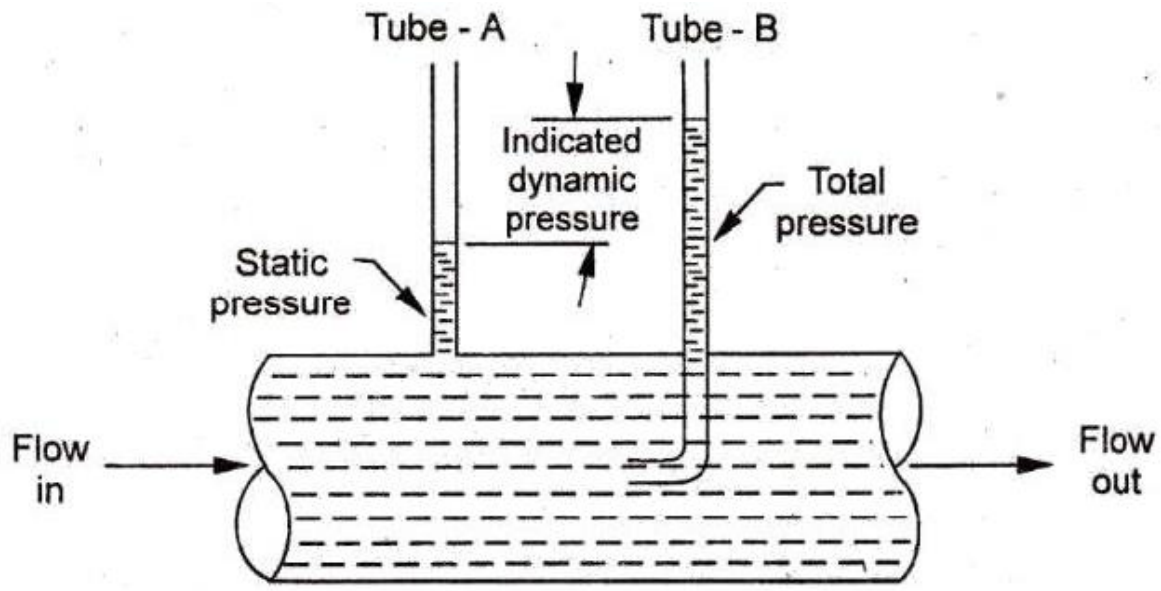
$$Pa = Pg + Pat$$

INTRODUCTION

- **Static Pressure And Total Pressure :-**

✓ Static pressure of a moving fluid is measured with an instrument which is at rest relative to the fluid.

Velocity pressure = total pressure – static pressure.



Static and total pressure

- **Pressure Measurement Groups:-**

A. Instruments for measuring low pressure (below 1 mm of Hg): - manometers and low pressure gauges.

B. Instruments for medium and low pressures (below 1 mm of Hg to 1000 atmospheres):- Bourdon tube and diaphragm gauges.

C. Instruments for measuring low vacuum and ultra high vacuum (760 torr to 10−9 torr and beyond):- McLeod thermal conductivity and ionization gauges.

- **Pressure Measurement Groups:-**

D. Instruments for measuring very high pressure (1000 atmospheres and above):- bourdon tube, diaphragm and electrical resistance pressure gauges.

E. Instruments for measuring varying pressure:- engine Indicator and CRO (cathode ray oscilloscope).

- **Classification of Pressure Measuring Devices:-**

1. Gravitational transducer.
    a) A dead weight tester.
    b) Manometer.
2. Electrical transducers.
    a) Bourdon tube pressure gauges.
    b) Elastic diaphragm pressure.
    c) Bellows gauges.
3. Strain gauge pressure cells.
    a) Pinched tubes.
    b) Cylindrical tube pressure cell.

- **Classification of Pressure Measuring Devices:-**

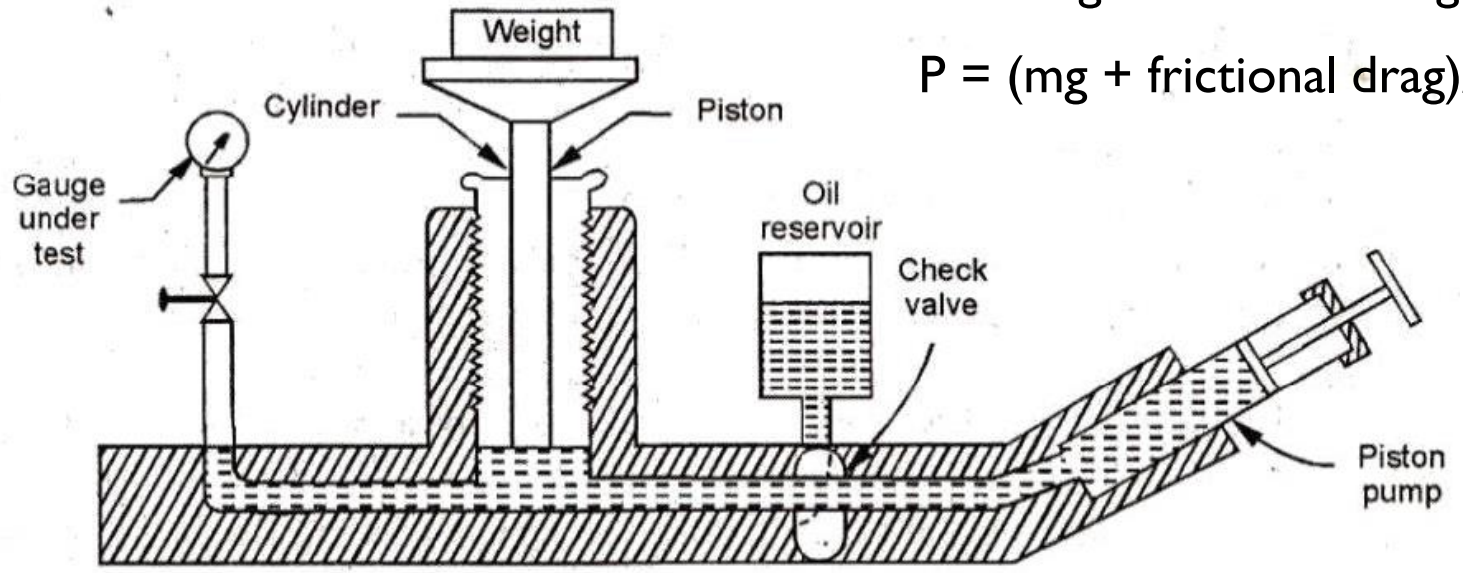
4. McLeod gauge.
5. Thermal conductivity gauges.
    a) Thermocouple gauge
    b) Pirani gauge
6. Ionization gauge.
7. Electrical resistance pressure gauge.

Dead Weight Piston Gauge

- ✓ The dead weight tester is a primary standard for pressure measurement, and it offers a good calibration facility over a wide pressure range (700 N/mm^2 to 70 MN/mm^2 gauge in steps as small as 0.01% of range with a calibration uncertainly of 0.01-0.05% of the reading).

PA = mg + frictional drag.

P = (mg + frictional drag)/A



Dead weight piston gauge

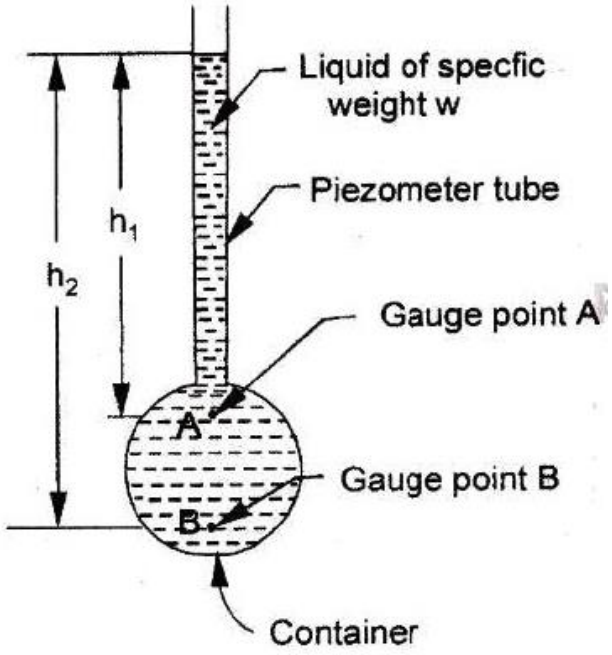
Manometers

- ✓ Manometers measure pressure by balancing a column of liquid against the pressure to measured. Height of column so balanced is noted and then converted to the desired units.
- ✓ Manometers can be used to measure gauge, differential, atmospheric, and absolute pressure.
  i. Piezo meter
  ii. U- tube manometer
  iii. Single column manometer

Manometers

i. Piezo meter:

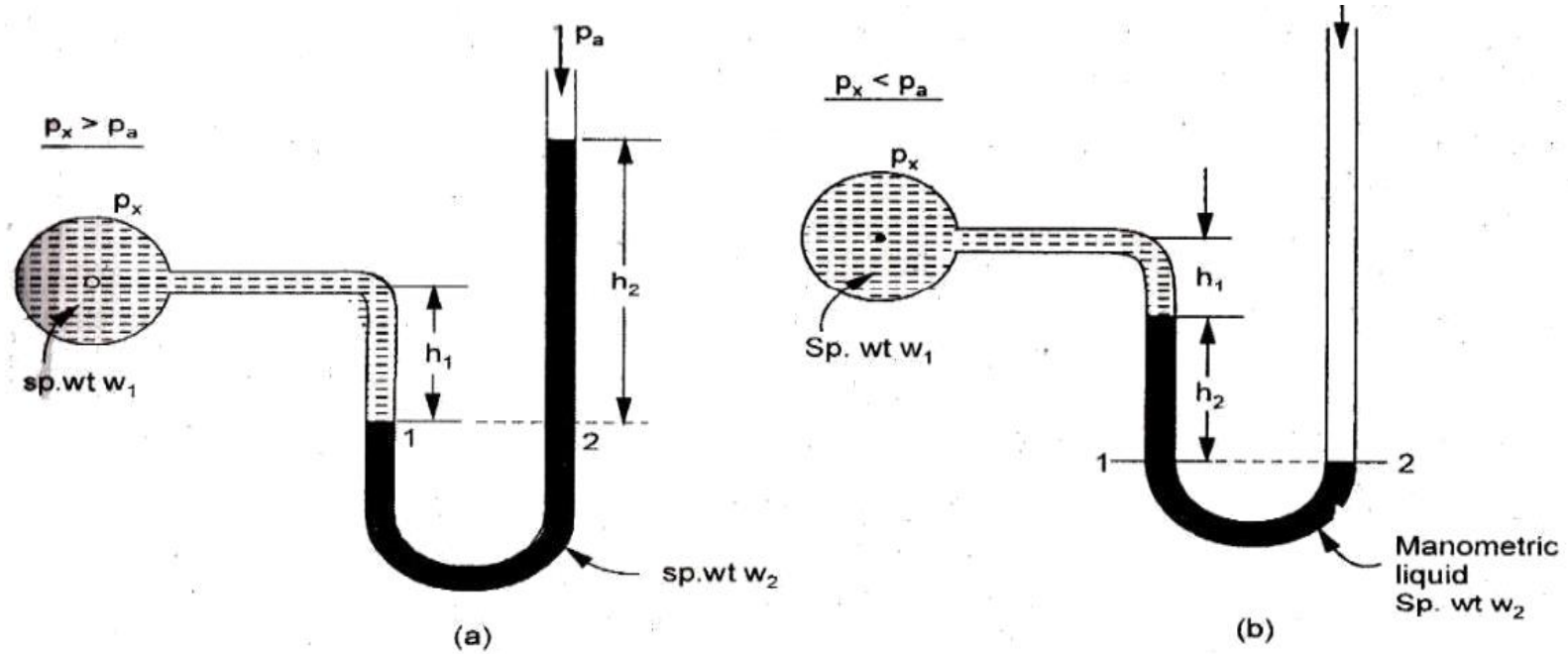
- ✓ lt is a vertical transparent glass tube, the upper end of which is open to atmosphere and the lower end is in communication with the gauge point.
- ✓ A point in the fluid container at which pressure is to be measured.
- ✓ Rise of fluid in the tube above a certain gauge point is a measure of the pressure at that point.



Manometers

ii. U- Tube Manometer:

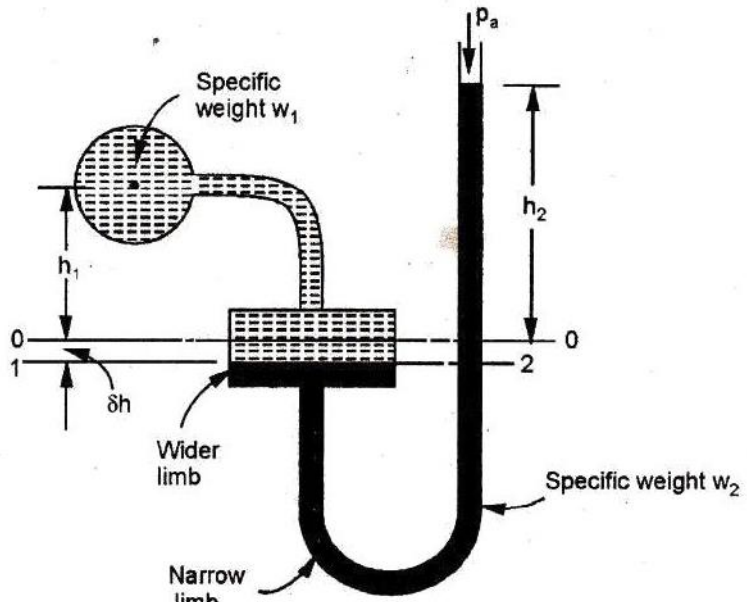
- ✓ This simplest and useful pressure measuring consists of a transparent tube bent in the form of letter U and filled with a particular liquid whose density is known.



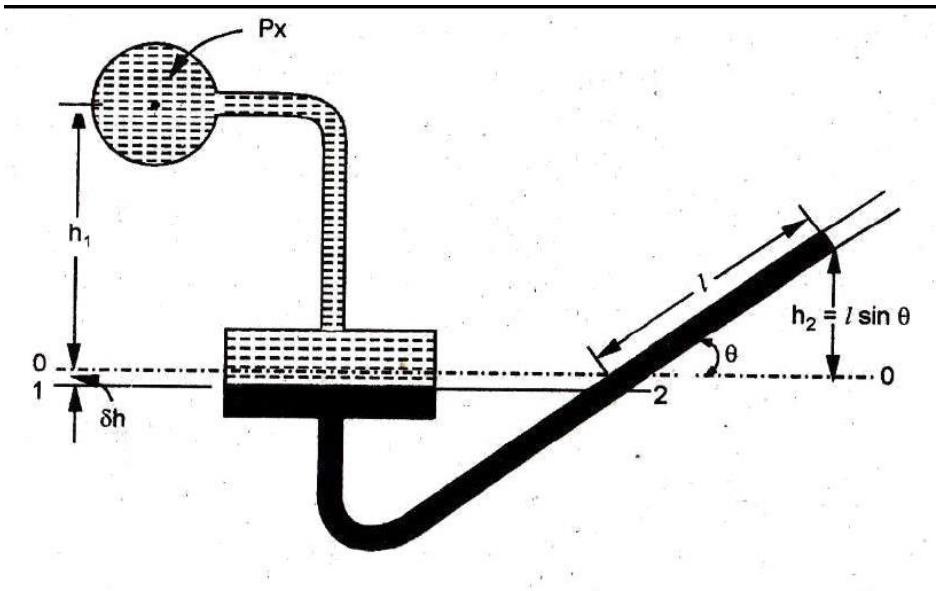
Manometers

iii. Single Column Manometer:

- ✓ This simplest and useful pressure measuring consists of a transparent tube bent in the form of letter U and filled with a particular liquid whose density is known.



Single column manometer



Inclined manometer

Manometers

Advantages and limitations of manometers:

- ✓ Relatively inexpensive and easy to fabricate
- ✓ Good accuracy and sensitivity
- ✓ Requires little maintenance; are not affected by vibrations
- ✓ Particularly suitable to low pressures and low differential pressures
- ✓ Sensitivity can be altered easily by affecting a change in the quantity of manometric liquid in the manometer
- ✓ Generally large and bulky, fragile and gets easily broken

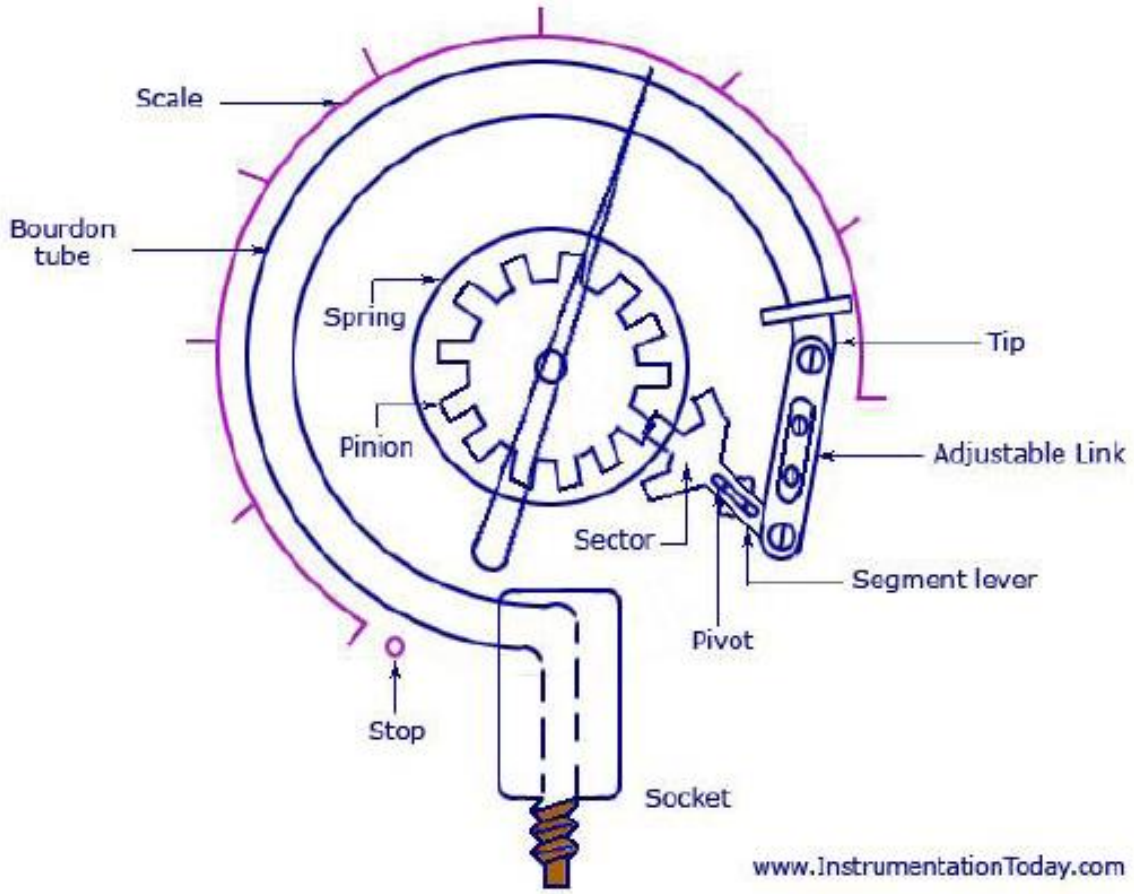
Manometers

Advantages and limitations of manometers:

- ✓ Measured medium has to be compatible with the manometric fluid used.
- ✓ Readings are affected by changes in gravity, temperature and altitude
- ✓ Surface tension of manometric fluid creates a capillary affect and possible hysteresis
- ✓ Meniscus height, has to be determined by accurate means to ensure improved accuracy.

Mechanical Gauges

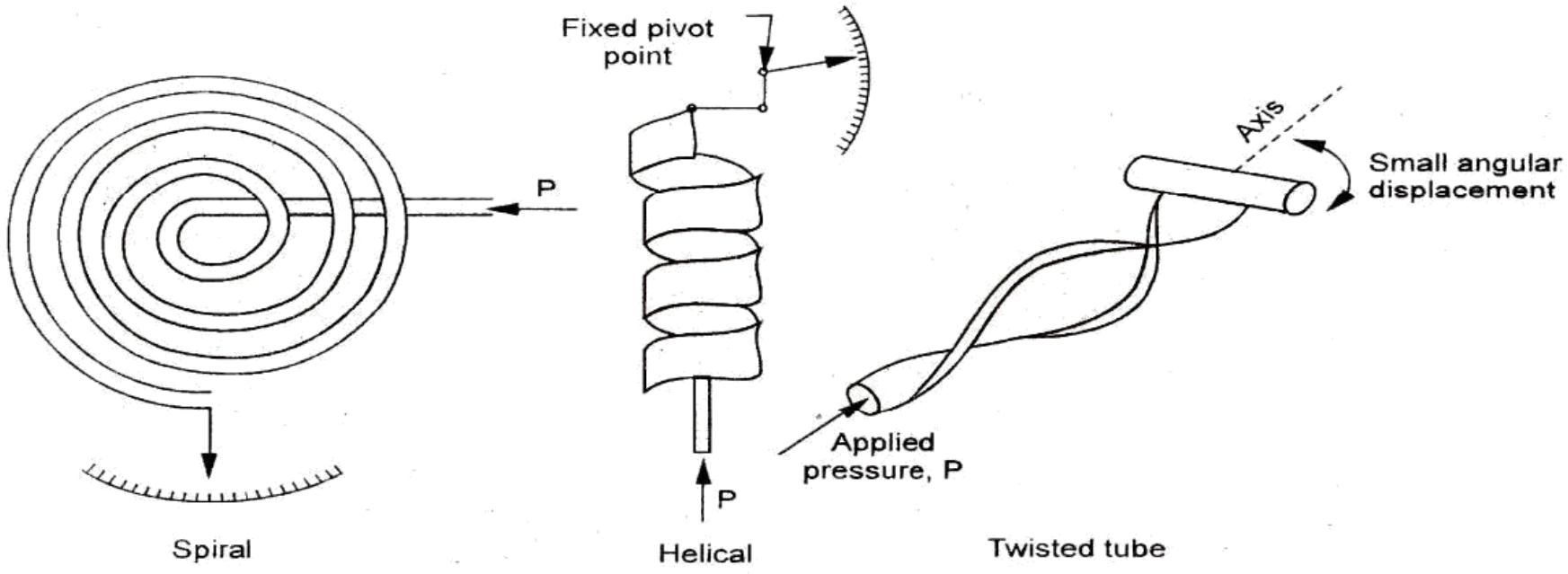
Bourdon Gauge:-



Bourdon Tube Pressure Gauge

Mechanical Gauges

Bourdon Gauge:-



Bourdon tube configurations

Mechanical Gauges

Bourdon Gauge:-

- **Materials:**

✓ Pressure 100 to 700 KN/m^2 (tubes are made of phosphor bronze)

✓ For high pressure P=7000 to 63000 KN/m^2 (tubes are made of alloy steel or k-monel)

- **Advantages:**

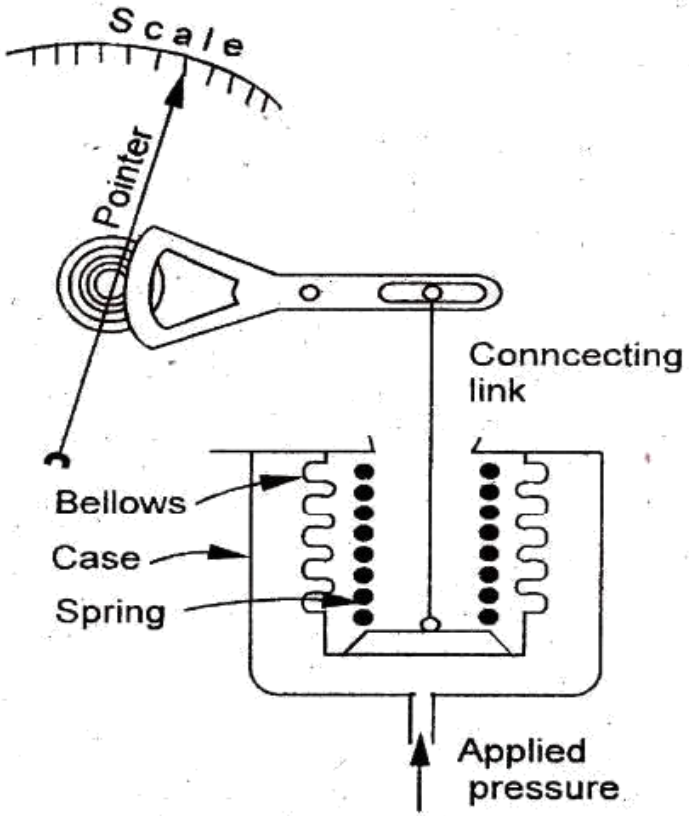
✓ Low cost and simple in construction.

✓ Capability to measure gauge absolute and differential pressure.

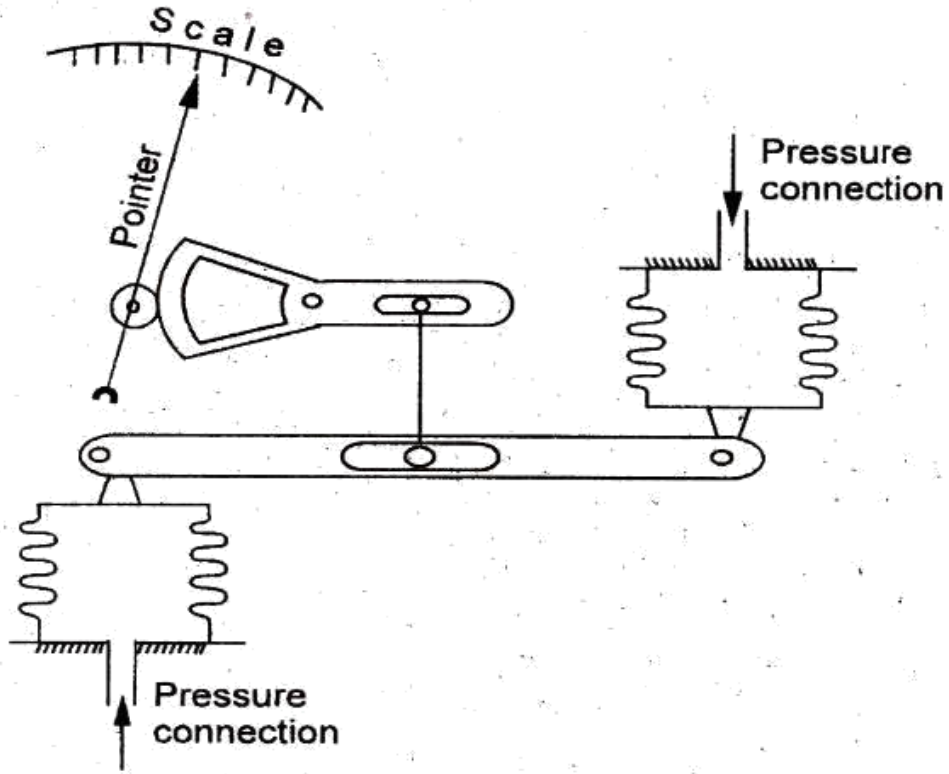
✓ Availability in several ranges.

Mechanical Gauges

Bellow Gauges:



Bellows pressure gauge



Differential bellows gauge

Mechanical Gauges

Bellow Gauge:-

- **Advantages:**

✓ Simple in construction.

✓ Good for low to moderate pressures.

✓ Available for gauge, differential and absolute pressure measurements.

✓ Moderate cost.

- **Disadvantages:**

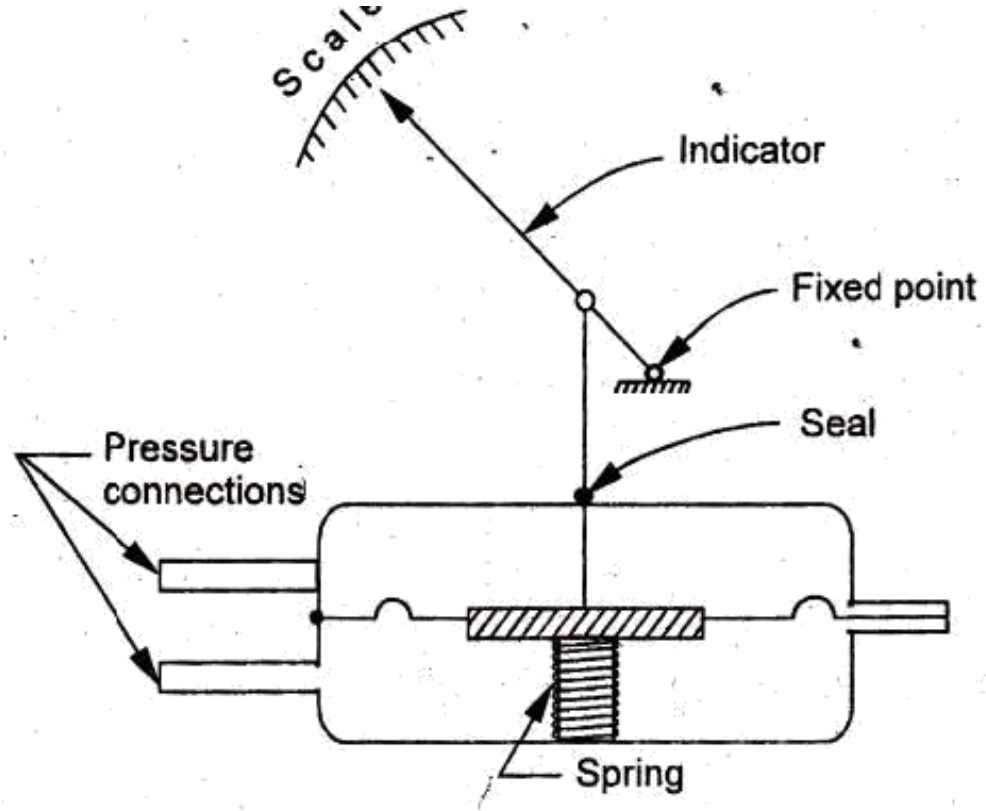
✓ Zero shift problems.

✓ Needs spring for accurate characterization.

✓ Requires compensation for temperature ambient changes.

Mechanical Gauges

Diaphragm Gauges:-



Slack diaphragm pressure gauge


Dish


Flat


Corrugated


Capsule

Mechanical Gauges

Diaphragm Gauges:-

- **Advantages:**

✓ Relatively small size and moderate cost.

✓ Capability to with stand high over pressures and maintain good linearity over a wide range.

✓ Availability of gauge for absolute and differential pressure measurement.

✓ Minimum of hysteresis and no permanent zero shift.

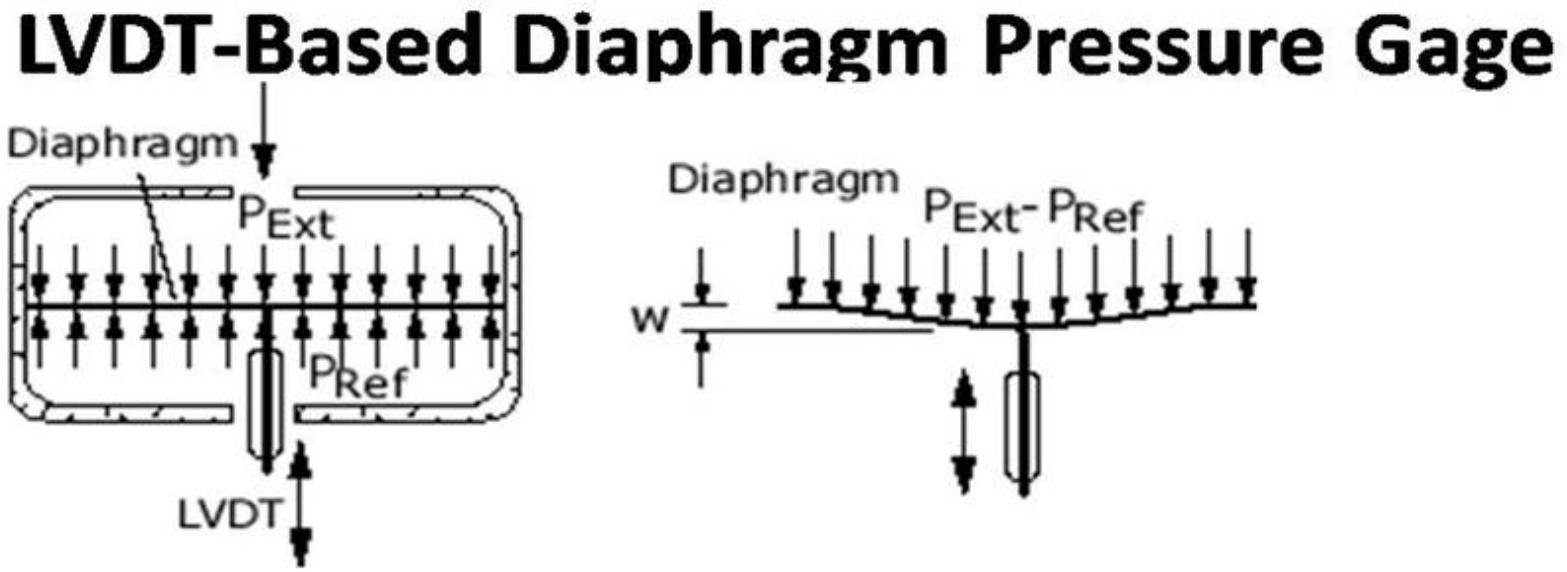
- **Limitations:-**

✓ Needs protection from shocks and vibrations.

✓ Cannot be used to measure high pressure.

Mechanical Gauges

Diaphragm Gauges:-



The commonly used materials for making the diaphragm are polythene, neoprene, animal membrane, silk, and synthetic materials.

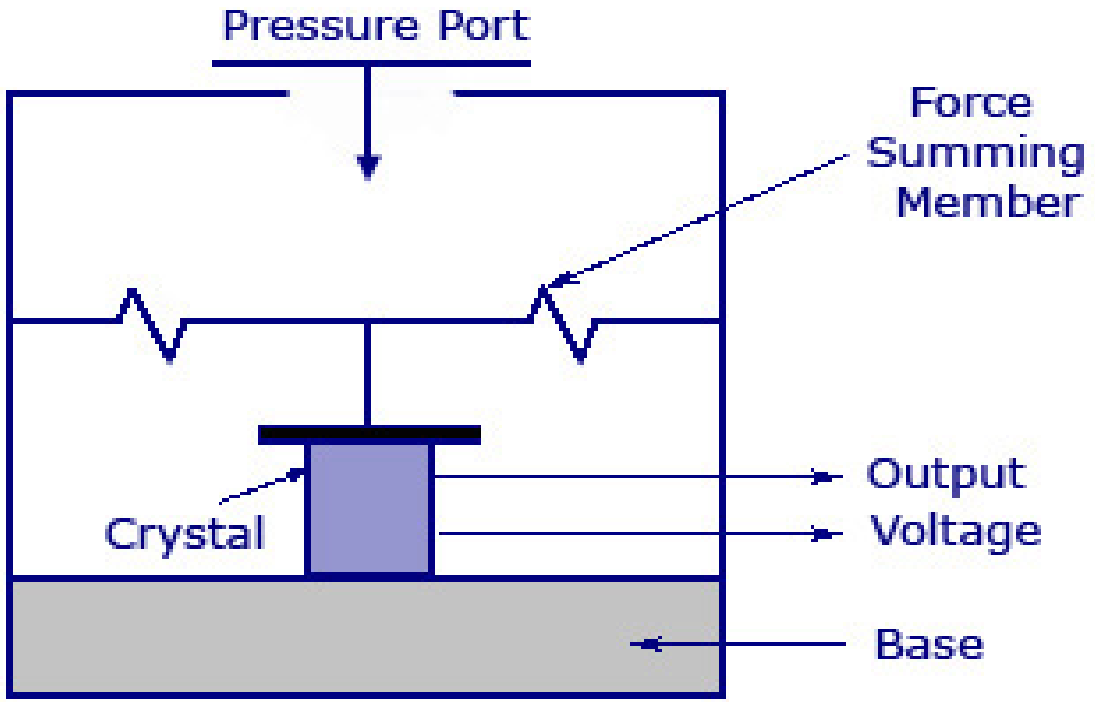
The common range for pressure measurement varies between 50 Pa to 0.1 MPa.

Difference between Diaphragm and Bellow Element

Sr.No.	Parameters	Diaphragm	Bellow
1	Working Primciple	The deflection of diaphragm is proportional to applied pressure.	A bellow gauge contains an elastic element that is convoluted unit which expands and contracts axially with changes in pressure. The pressure to be measured is applied to the outside or inside of bellow.
2	Construction	A thin member of sheet metal made to precision dimensions either in shape of membrane or circular disc.	Bellow gauges are made of brass, phosper bronze, stainless steel, beryllium copper or other metal that is suitable for the intended purpose the gauge.
3	Pressure range	0-50 N/m^2 to 0-200N/m^2	Vacuum and low pressure measurement
4	Application	Industrial process pressure measurement, Manifold pressure measurement	Abroad ship, also some type of recording device.

Piezoelectric Pressure Transducer

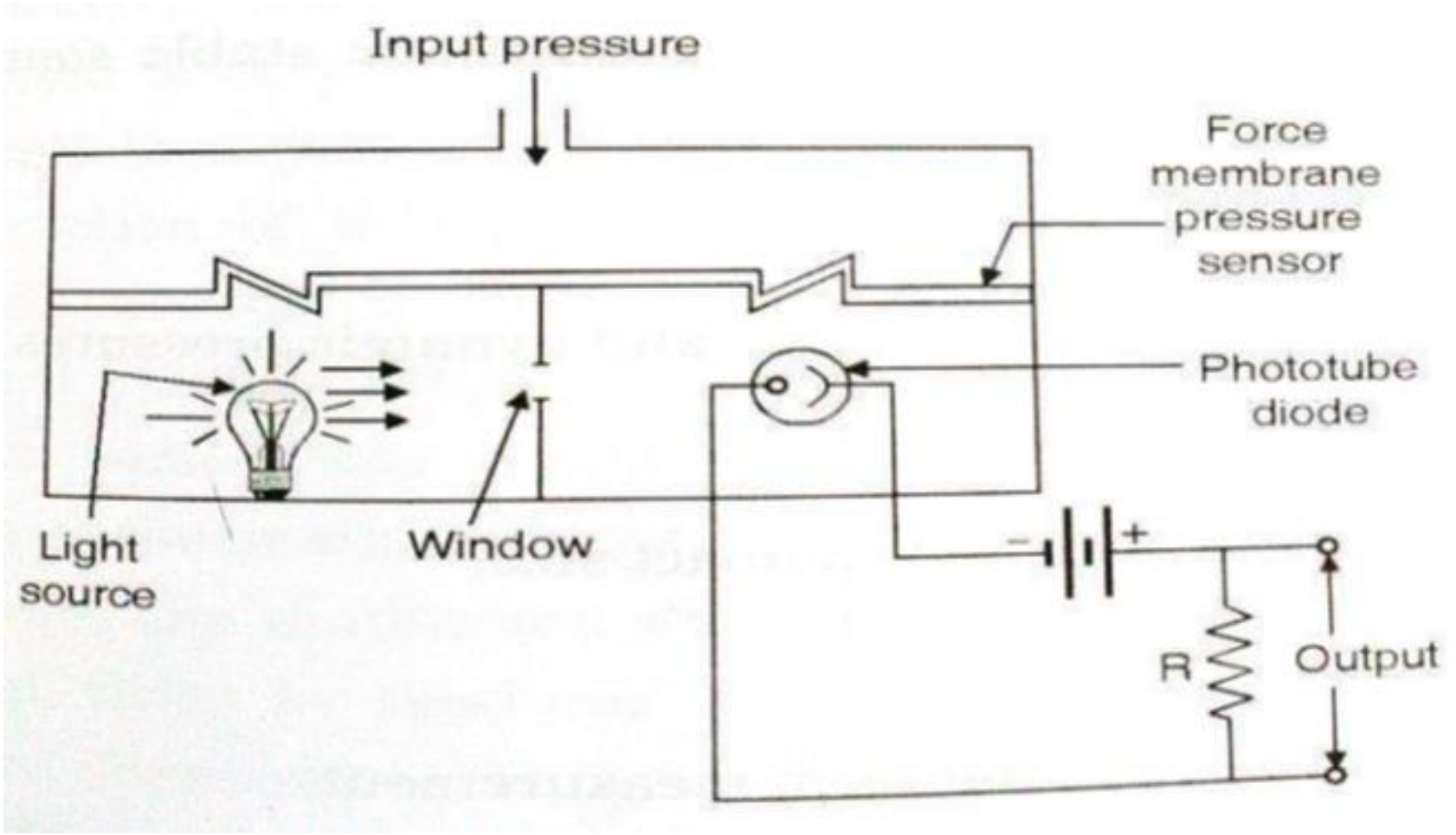
Working Principle: The main principle of a piezoelectric transducer is that a force, when applied on the quartz crystal, produces electric charges on the crystal surface.



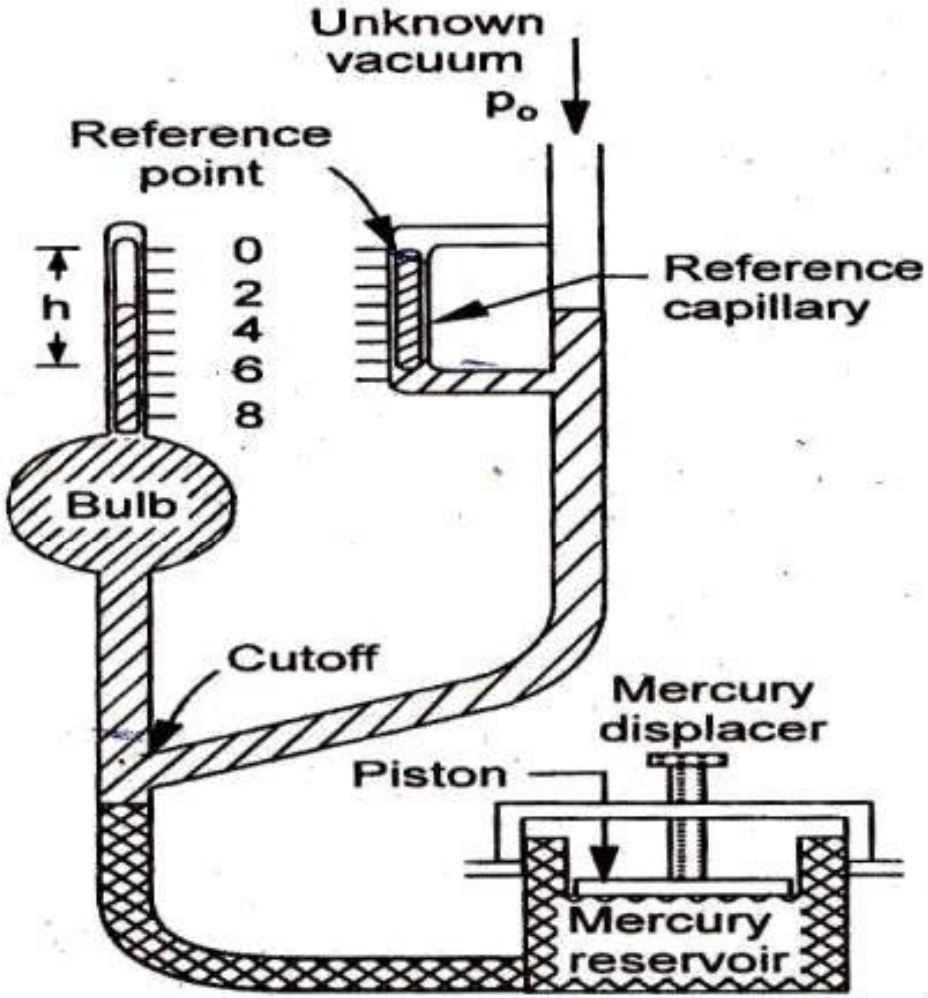
Piezo-Electric Transducer

Photoelectric Pressure Transducer

Working Principle: "Variation of window size results variation of light beams emitting on photodiode hence output reading changes."



Mcleod Gauge



Mcleod gauge

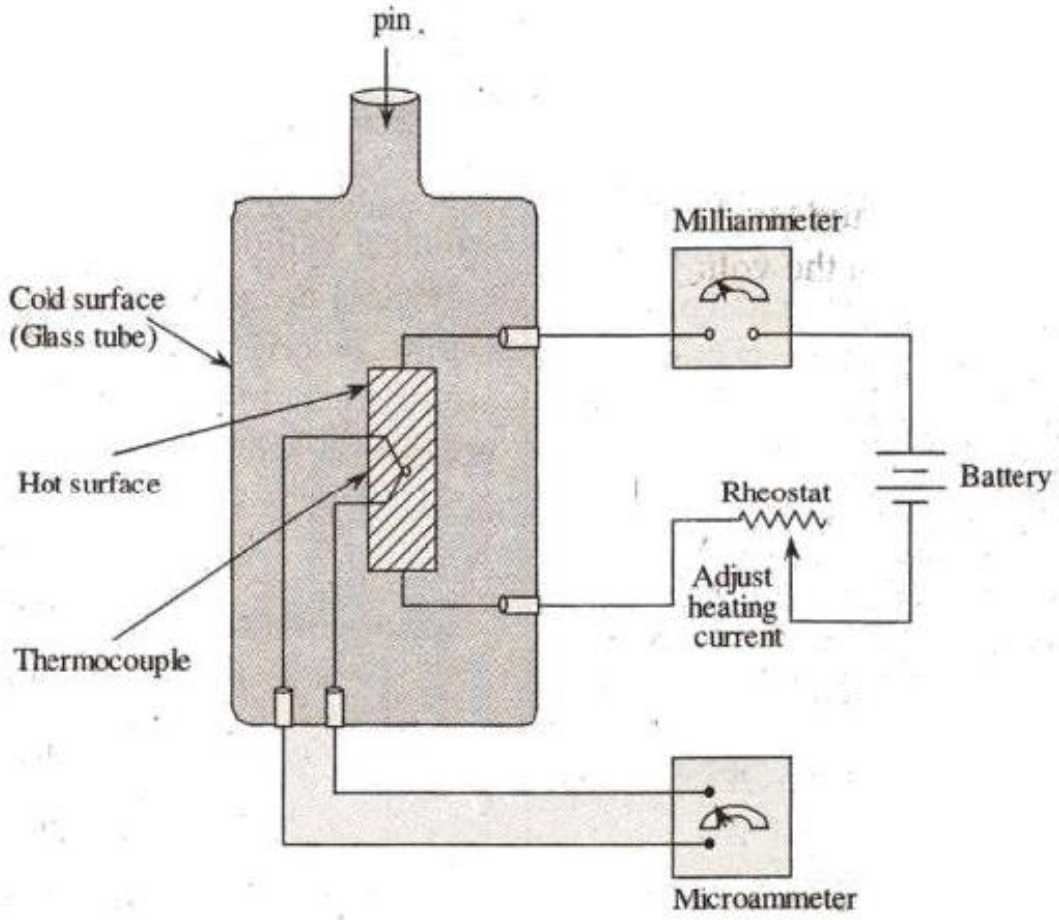
Thermal Conductivity Gauges

- ✓ These gauges measure pressure through a change in the thermal conductivity of the gas.
- ✓ Their operation is based on the thermodynamic principle that “at low pressures there is a relationship between the pressure and thermal conductivity i.e., the heat conductivity decreases with decrease in pressure”.
- ✓ There are two types of thermal gauges.
  - i. Thermocouple gauge.
  - ii. Pirani gauge.

Thermal Conductivity Gauges

1. Thermocouple gauge:

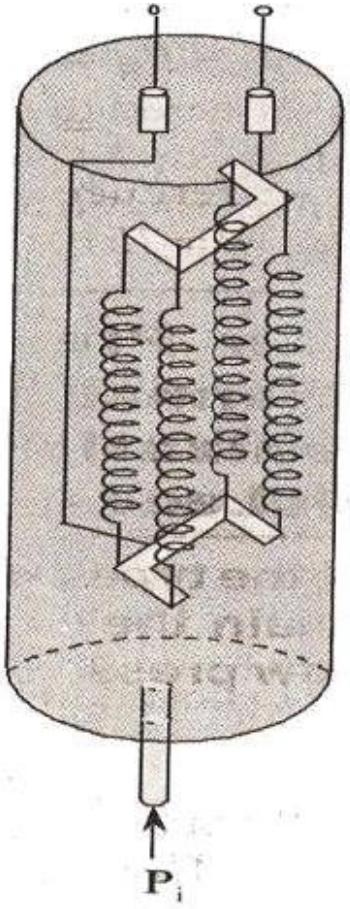
Working Principle: "As surrounding pressure changes the filament temperature and it changes thermal conductivity hence temperature and resistance."

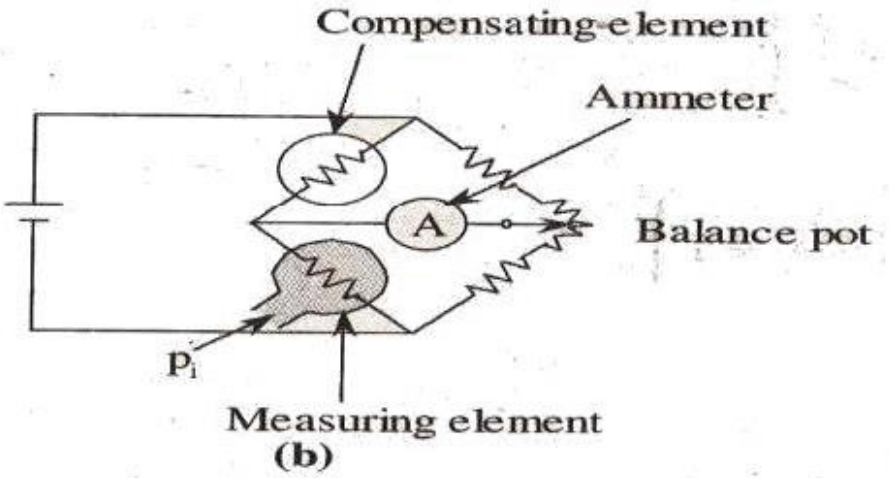


Thermal Conductivity Gauges

2. Pirani Gauge:

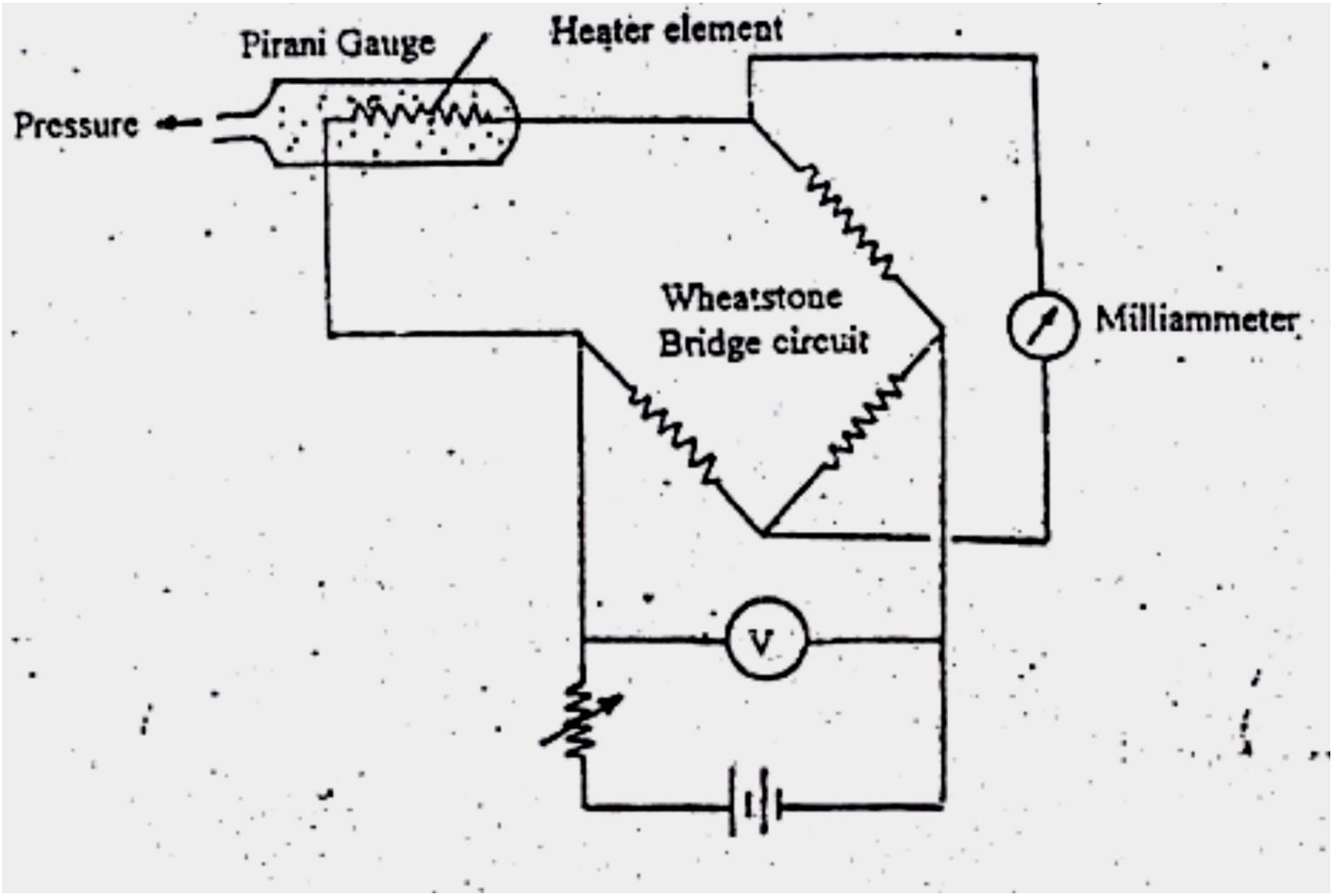
Working Principle: "As surrounding pressure changes the filament temperature and it changes thermal conductivity hence temperature and resistance."



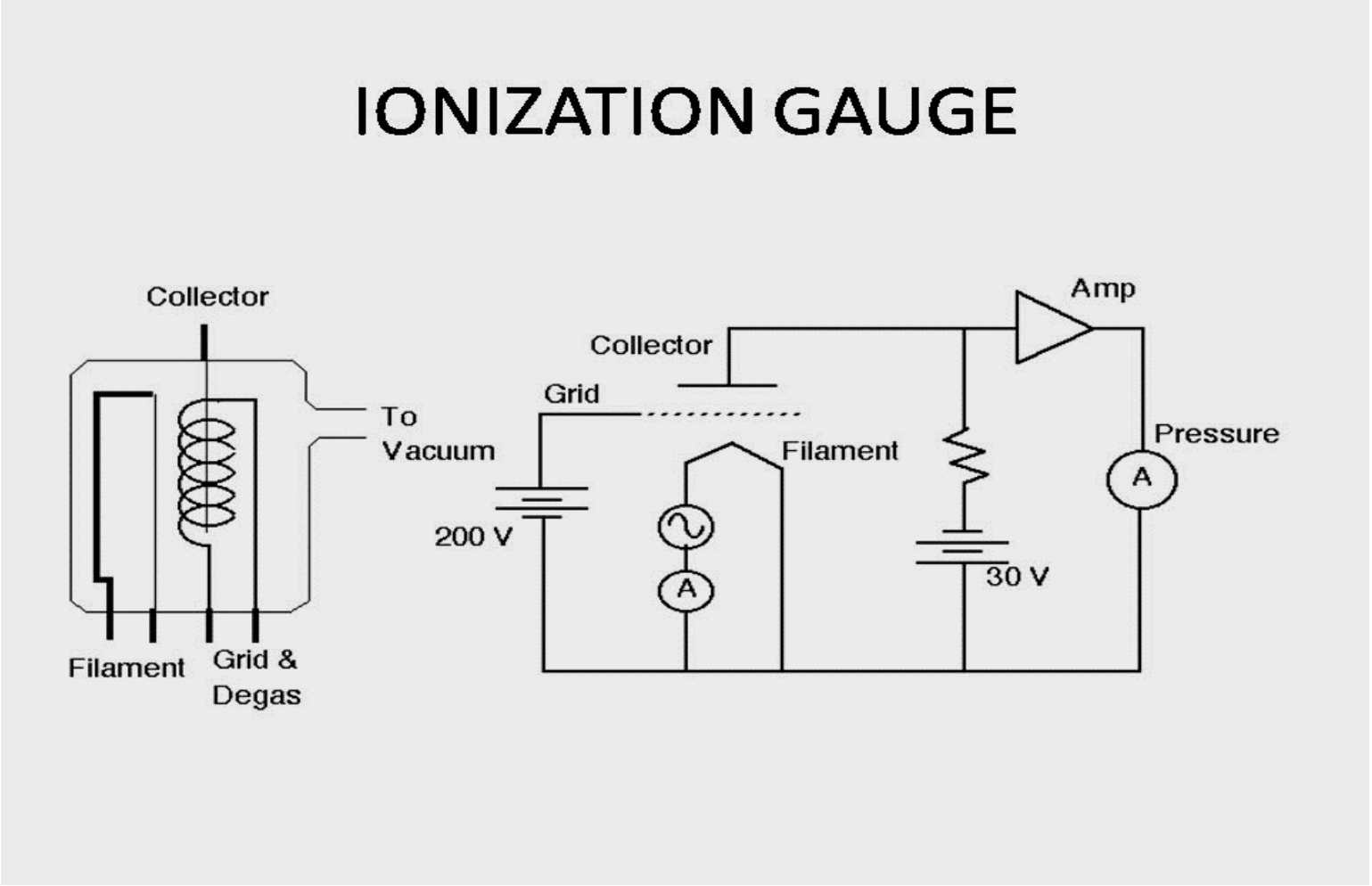


Thermal Conductivity Gauges

2. Pirani Gauge:



Ionization Gauge



Working Principle: "Flow of electrons from grid to plate or vice versa creates variation in current that is measurable at output."