What is fluid?

A **fluid** is a substance which is capable of flowing and offers no resistance to the change of shape or that continually deforms (flows) under an applied shear stress, or external force. **Fluids** are a phase of matter and include liquids, gases and plasmas.

- Example : Water, Benzine, milk etc. ...
- Example : Plaster, Slurries, Pastes etc

Types of Fluids

1. Ideal fluid
2. Real fluid

- **1. Ideal Fluid:** A fluid which are incompressible and have no viscosity and surface tension are called Ideal fluid. Ideal fluid is not found in actual practice but it is an imaginary fluid because all the fluid that exist in the environment have some viscosity there in no ideal fluid in reality.
- **2. Real Fluid**: A fluid which possess properties such as viscosity, surface tension and compressibility are called real fluids. The fluids actually available in nature are real fluids for example water.

Types of Real Fluid

- **Newtonian Fluid:** If a real fluid obeys the Newton's law of viscosity (i.e the shear stress is directly proportional to the shear strain) then it is known as the Newtonian fluid.

  Eg. Water, oil, gasoline, alcohol and glycerin

- **4. Non-Newtonian Fluid:** If real fluid does not obeys the Newton's law of viscosity then it is called Non-Newtonian fluid.

  Eg. Honey, toothpaste, starch suspensions, starch, paint, blood, and shampoo.

Fluid mechanics

Fluid mechanics is the branch of science which deals with the behaviour of fluids at rest as well in motion.

Hydrostatics

The study of liquid at rest is called hydrostatics

Hydrokinematics

The study of liquids in motion, when pressure forces are not considered, is called hydrokinematics.

Hydrodynamics

The study of liquids in motion, when pressure forces are considered, is called hydrokinematics.

Hydraulics

Fluid mechanics is the branch of science which deals with water at rest or in motion

Chapter -2

Properties of Fluid

Properties of Fluid

1. Mass density
2. Specific weight
3. Specific volume
4. Relative density (Specific gravity)
5. Viscosity
6. Surface tension
7. Capillarity
8. Vapour Pressure
9. Cohesion
10. Adhesion
11. Compressiblity

- **Mass density (ρ)**

Mass of fluid is defined as the mass of the fluid per unit volume Density is denoted by the symbol 'ρ'. Its unit is kg/m^3.

$$\rho = \frac{mass\ of\ fluid}{volume\ of\ fluid}\ \frac{Kg}{m3}$$

- **Specific weight (w):**

The specific weight of the fluid can be defined similarly as its weight per unit volume.

Unit- N/m3

$$w = \frac{\textbf{weight of fluid}}{\textbf{volume of fluid}}$$

- **Specific volume** : - Specific volume of a fluid is volume per unit mass *i.e.* the reciprocal of mass density.

$$\mathbf{v} = \frac{\mathbf{volume\ of\ fluid}\ \boldsymbol{m3}}{\mathbf{mass\ of\ fluid}\quad \boldsymbol{Kg}}$$

- **Relative density** (Specific gravity), ***S*** :-

Specific gravity is the ratio of fluid density (specific weight) to the fluid density (specific weight) of a standard reference fluid. For liquids water at is considered as standard fluid.

$$= \frac{\text{specific weight (mass density) of fluid}}{\text{specific weight (mass density) of standard fluid (water}}$$

It has no unit.

Sp weight of water = 9.81 KN/m3

Sp weight of water = 9810 N/m3

Mass density of water 1g/cc

Mass density of water 1000Kg/m3

Viscosity

It is the property of the fluid due to which the fluid offers resistance to flow of one layer of the fluid over another adjacent layer.
SI unit is N-sec/m2

In CGS system unit is dyne-sec/m2

Newton 's Viscosity Law

Newton's viscosity law's states that, the shear stress between adjacent fluid layers is proportional to the velocity gradients between the two layers. The ratio of shear stress to shear rate is a constant, for a given temperature and pressure, and is defined as the **viscosity** or coefficient of **viscosity**.

- **Kinematic viscosity (v)**

Kinematic viscosity is defined as the ratio of dynamic viscosity to mass density

- **Surface Tension**

The property of liquid by virtue of which the free surface of the liquid act as a stretched membrane capable of bearing small amount of tension is called surface tension.

Surface tension is defined as the tensile force acting on the surface of a liquid in contact with a gas

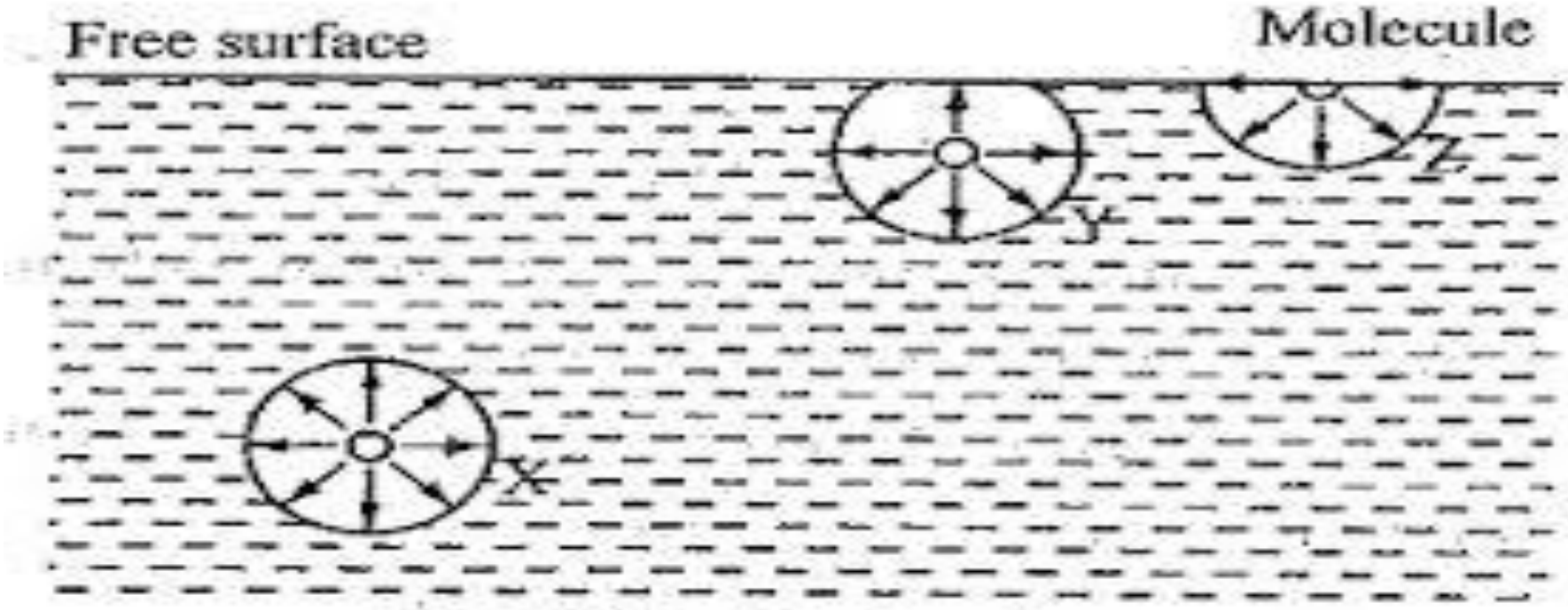
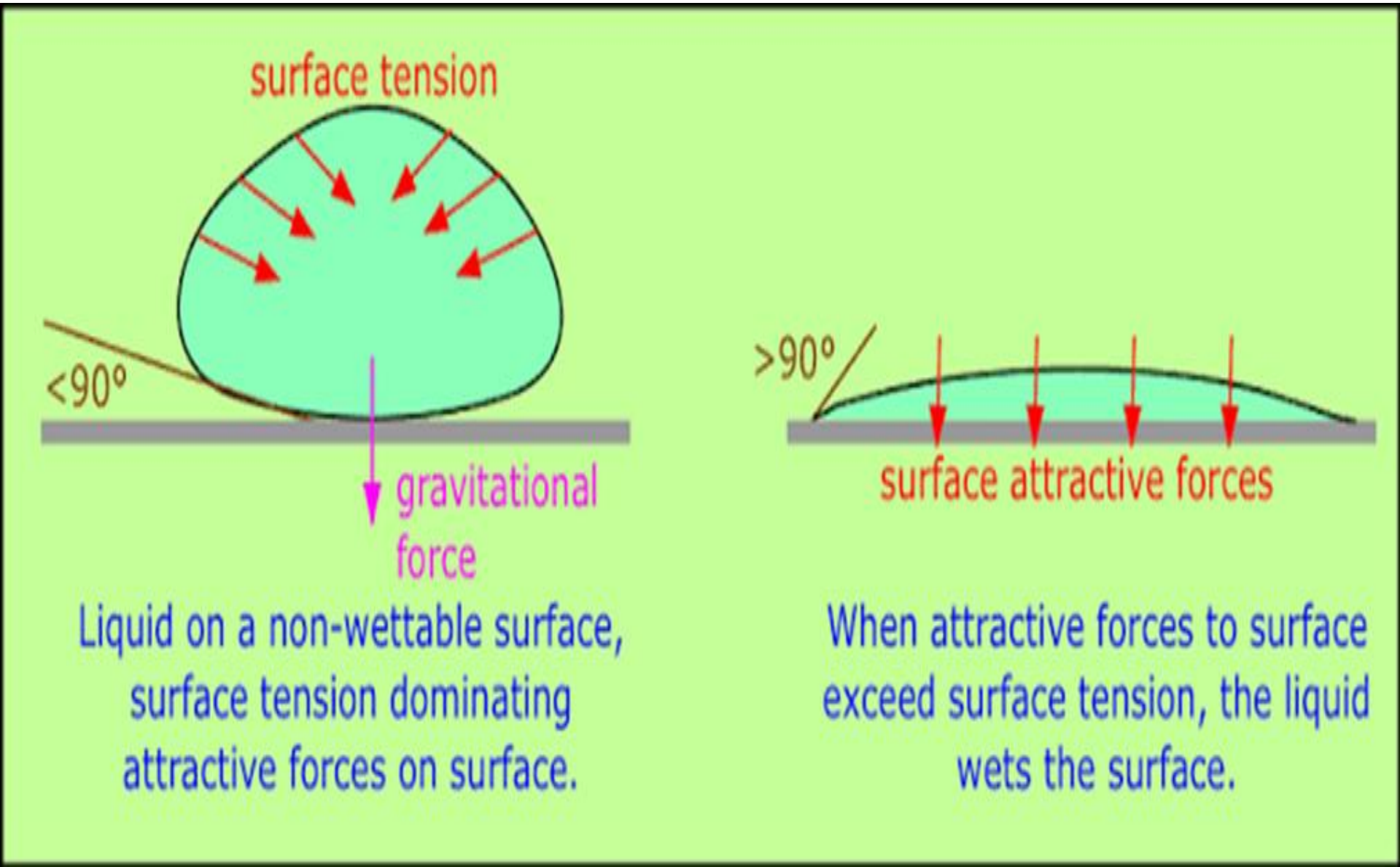


Fig 1.3 Surface tension

SI unit of surface tension is N/m



Example-

- **Bubbles are round**
- **Floating a needle** Small insects such as the water strider can walk on water because their weight is not enough to penetrate the surface.

Capillarity

The rise and fall of a liquid surface in a small thin tube, when it is immersed vertically in a liquid is called **capillarity.**

The rise of the liquid surface in the tube is called as capillary rise and the fall of the liquid surface is called as capillary depression

- Examples Based on What is Capillarity or Capillary Action
- In plants the rise of water from the roots to all its parts takes place because of capillary action.
- The capillary action draws ink to the tips of a fountain pen from cartridge (reservoir) inside the pen.
- The towels that we use after taking bath, absorb water from our body because of capillary action.
- Sponge which has larger number of small pores acts as small capillaries and absorbs a large amount of water.
- The cotton clothes that we wear in hot summer day shows capillary action and absorbs all our body sweat and maintains the temperature of the body to normal.

1. Capillary Rise

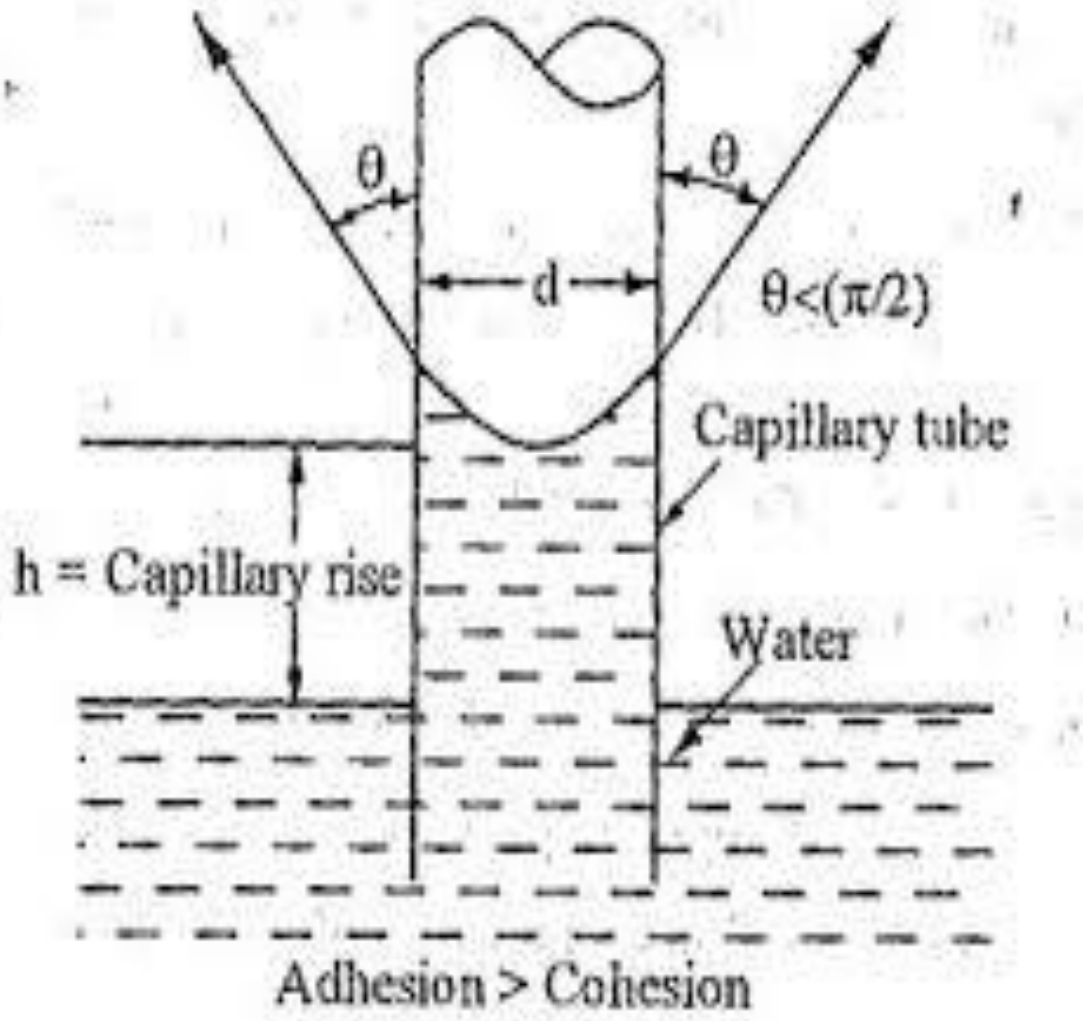


Fig 1.7 Capillary rise and depression

Radius of Capillary be = r

Density of the liquid = ρ

Height of the liquid = h

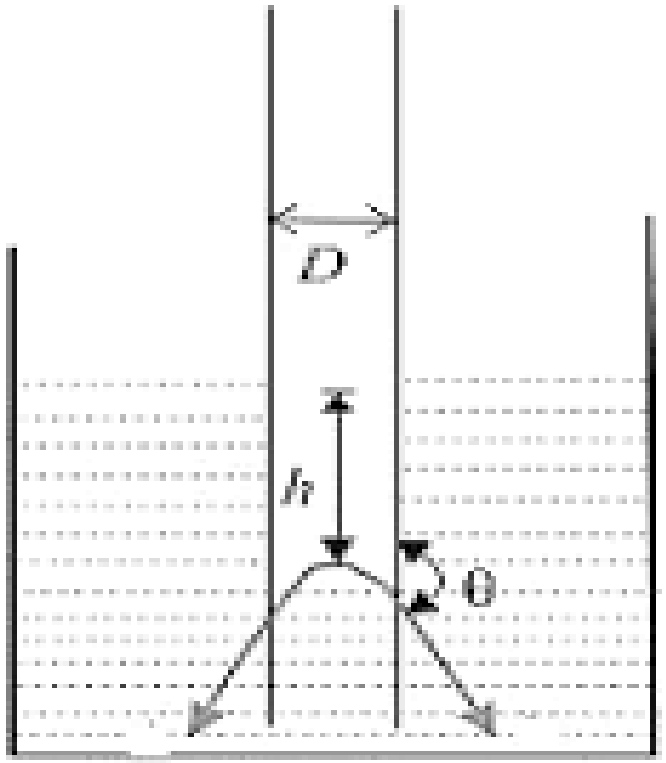
Surface Tension of Liquid be

Contact angle between liquid and glass tube =θ

$$H = \frac{4\sigma cos\theta}{\rho g d}$$

2. Capillary Rise

- $H = \frac{4\sigma cos\theta}{\rho g d}$



- **Cohesion**

It is defined as force of attraction between molecules of same type of a liquid

- **Adhesion**

It is defined as force of attraction between molecules of liquid and molecules of solid body.

Compressibility

Compressibility of a fluid may be defined as the property by virtue of which the fluid undergoes a change in volume under the action of external pressure.

Compressibility of fluid may be expressed as the reciprocal of bulk modulus of elasticity (K)

Compressibility = $\frac{1}{K}$

SI unit is m2/N

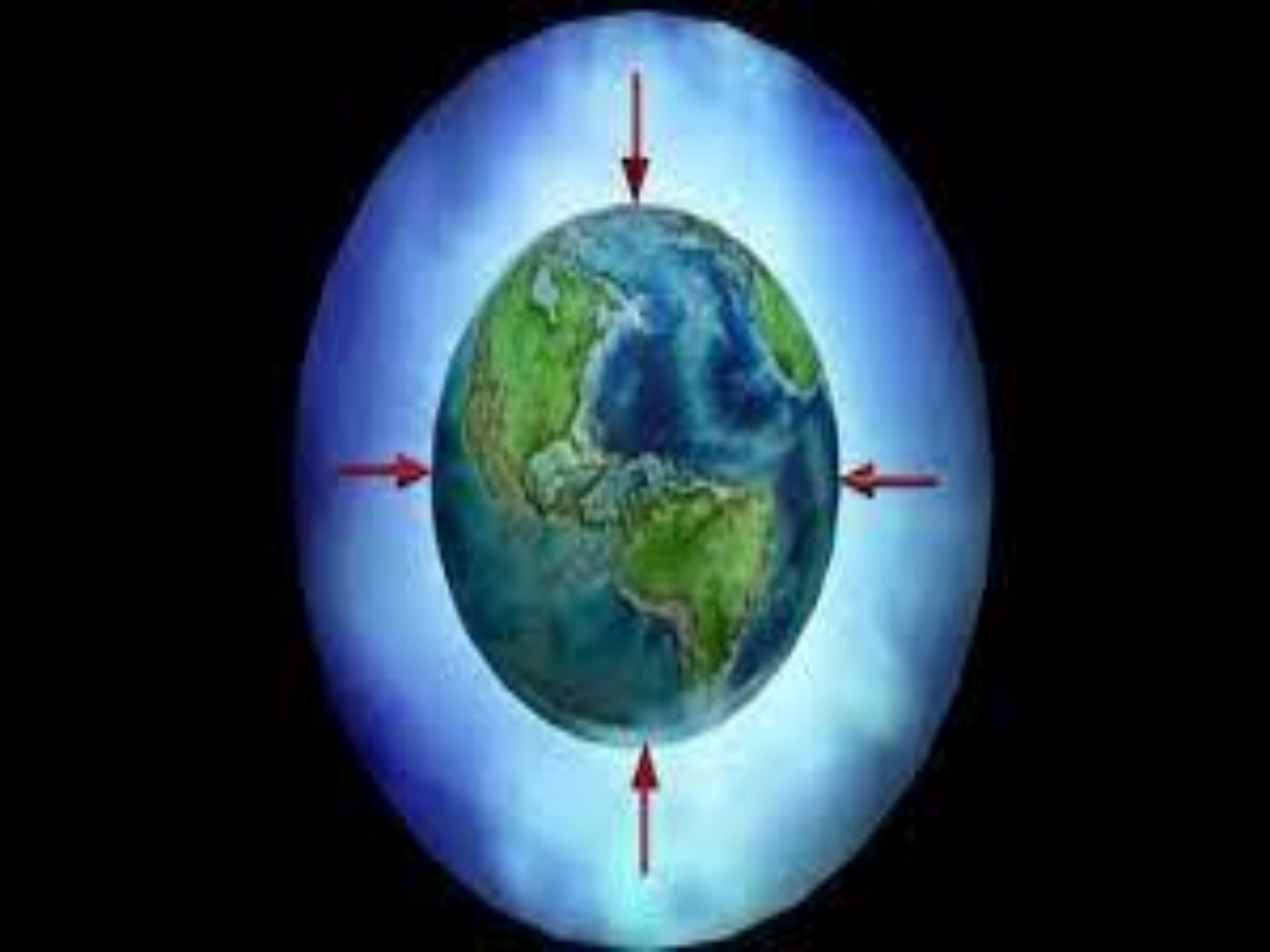
Chapter- 4

Measurement of pressure

Atmospheric Pressure

This is the pressure exerted by the envelope of air surrounding by the earth surface. This pressure act in normal direction. It is measured with the help of barometer.

Atmospheric pressure at sea level is 103 KN/m2



Gauge Pressure

The pressure which is more than the atmospheric pressure is known as gauge pressure or positive pressure.

Vacuum Pressure

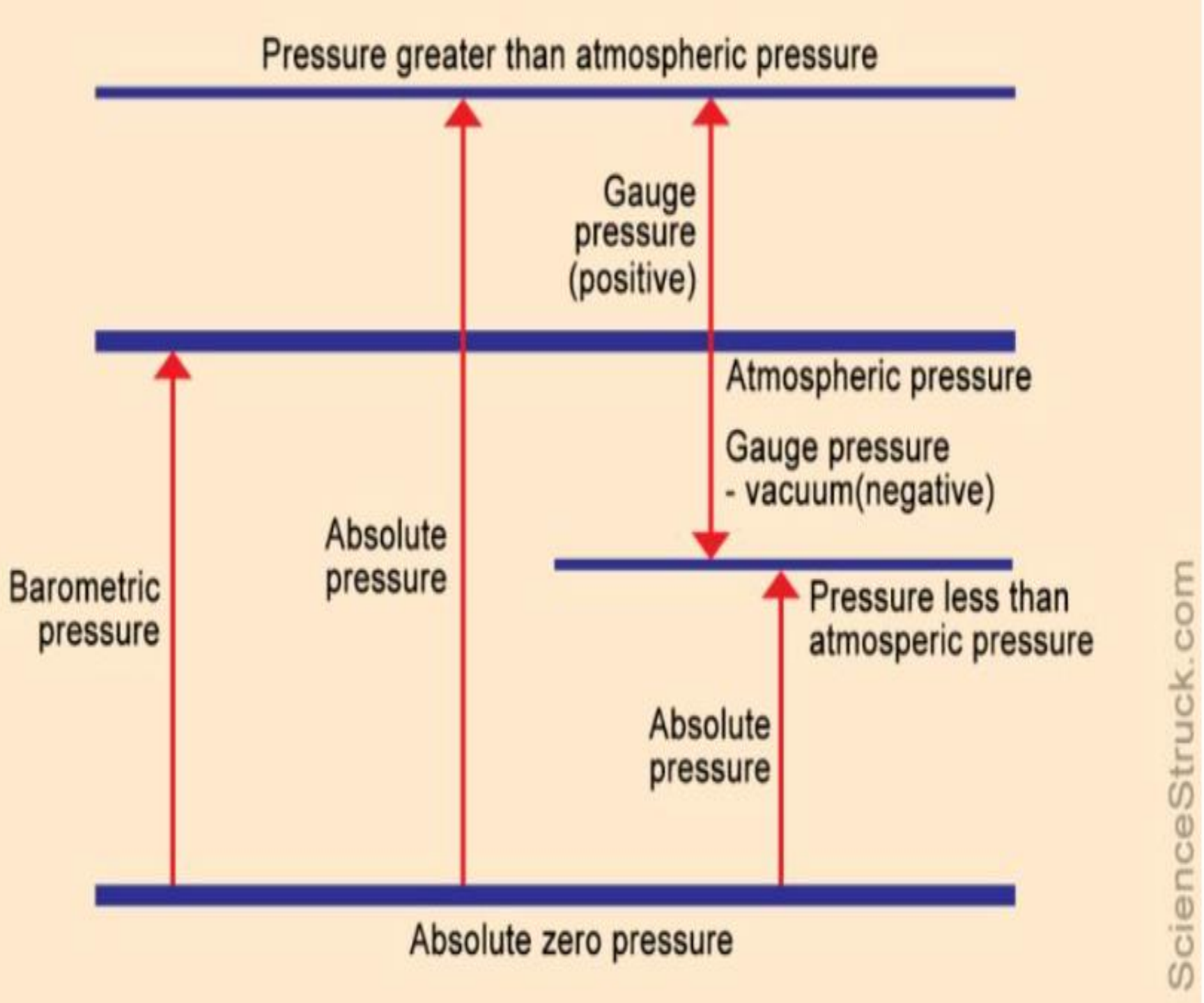
If the pressure of liquid is below the atmospheric pressure is called vacuum pressure.

Absolute Pressure

It is the pressure which is equal to the algebraic sum of atmospheric pressure and gauge pressure.

$$P_{abs} = P_{atm} + P_{gauge}$$

$$P_{abs} = P_{atm} - P_{vacuum}$$


Pressure greater than atmospheric pressure
Gauge pressure (positive)
Atmospheric pressure
Gauge pressure - vacuum(negative)
Absolute pressure
Barometric pressure
Pressure less than atmosperic pressure
Absolute pressure
Absolute zero pressure
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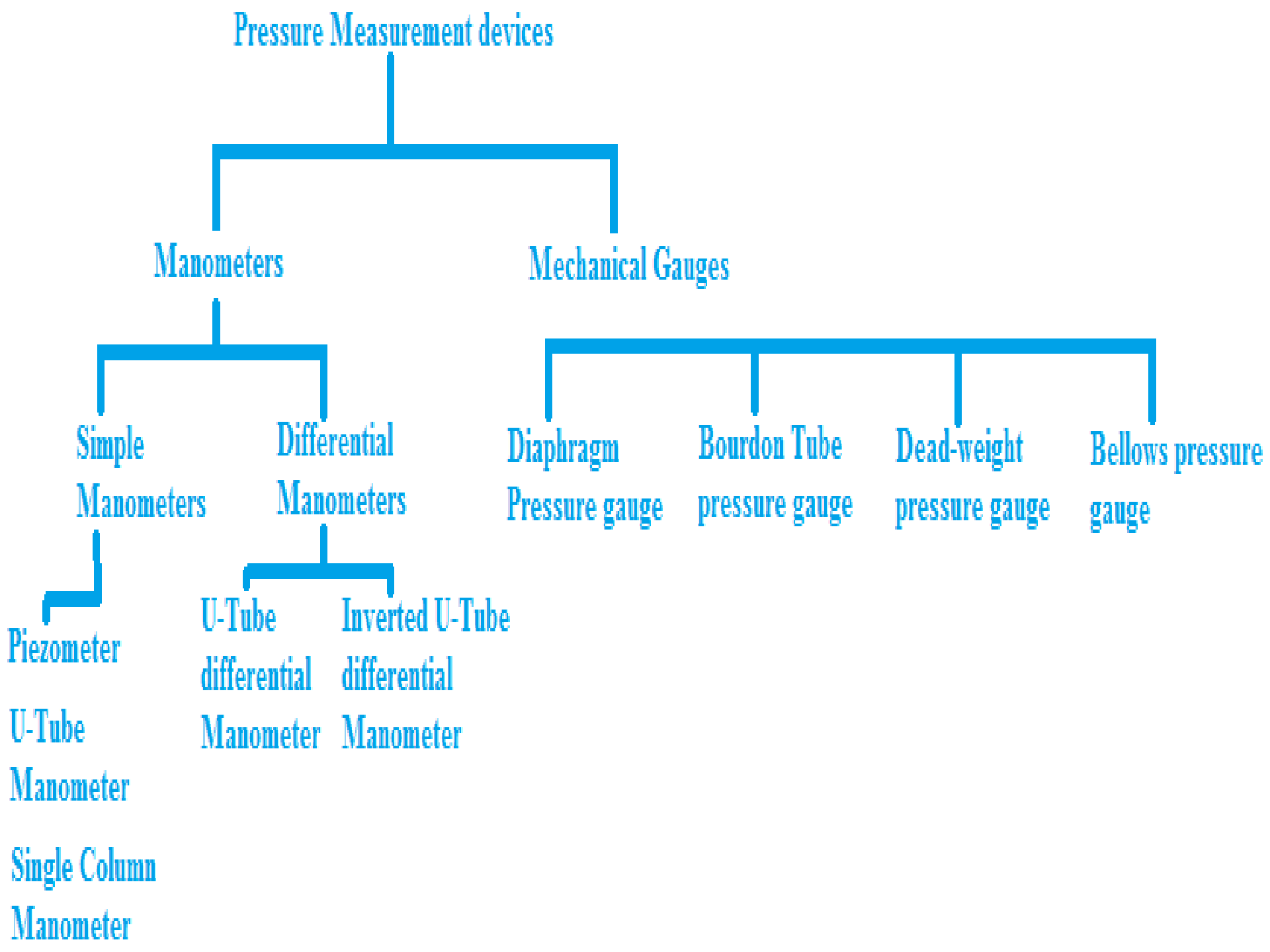
Measurement of pressure

The pressure of a liquid is measure by the following devices.

1. Manometers
2. Mechanical gauges

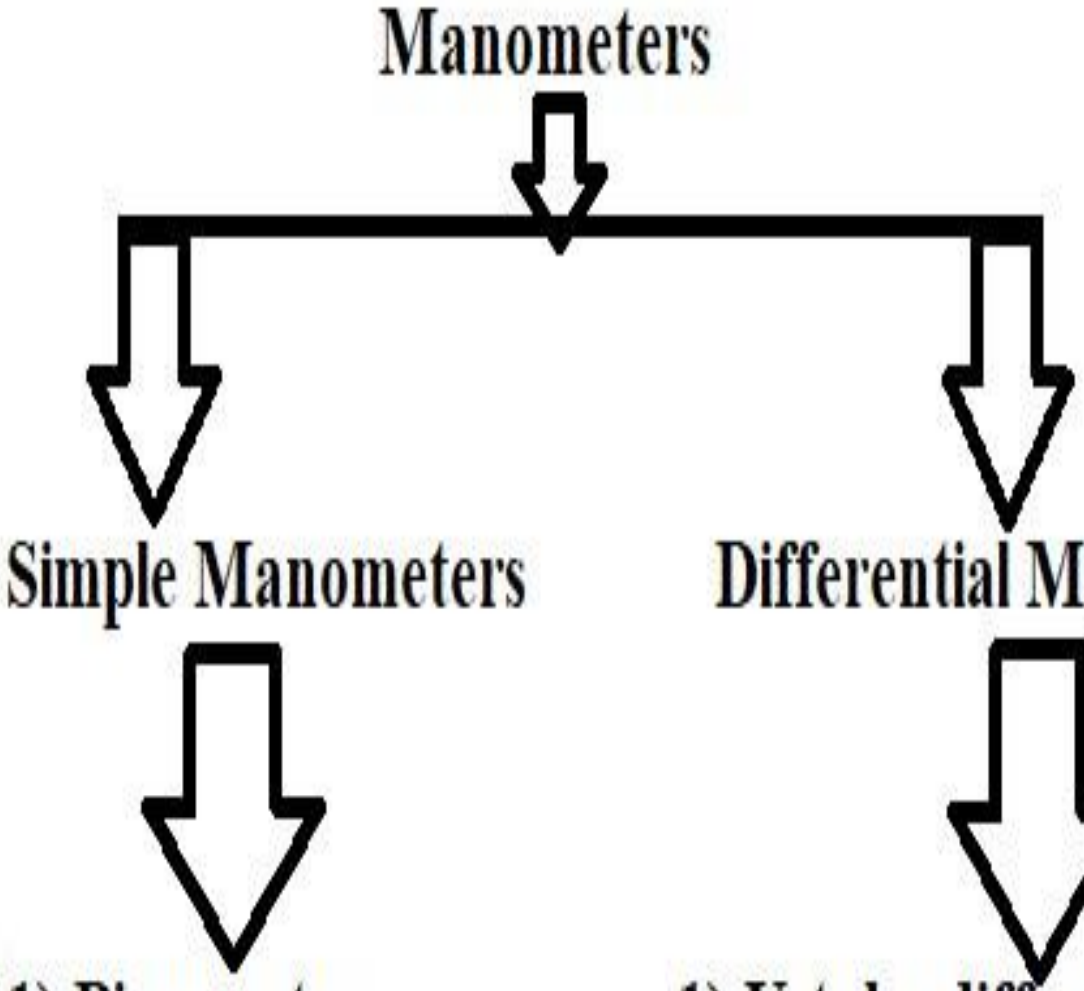

Pressure Measurement devices
Manometers
Mechanical Gauges
Simple Manometers
Differential Manometers
Diaphragm Pressure gauge
Bourdon Tube pressure gauge
Dead-weight pressure gauge
Bellows pressure gauge
Piezometer
U-Tube Manometer
Single Column Manometer
U-Tube differential Manometer
Inverted U-Tube differential Manometer

Manometers

Manometers are the devices used for measuring the pressure at a point in a fluid by balancing the column of fluid by the same or another column of the fluid. These are further classified as follows.

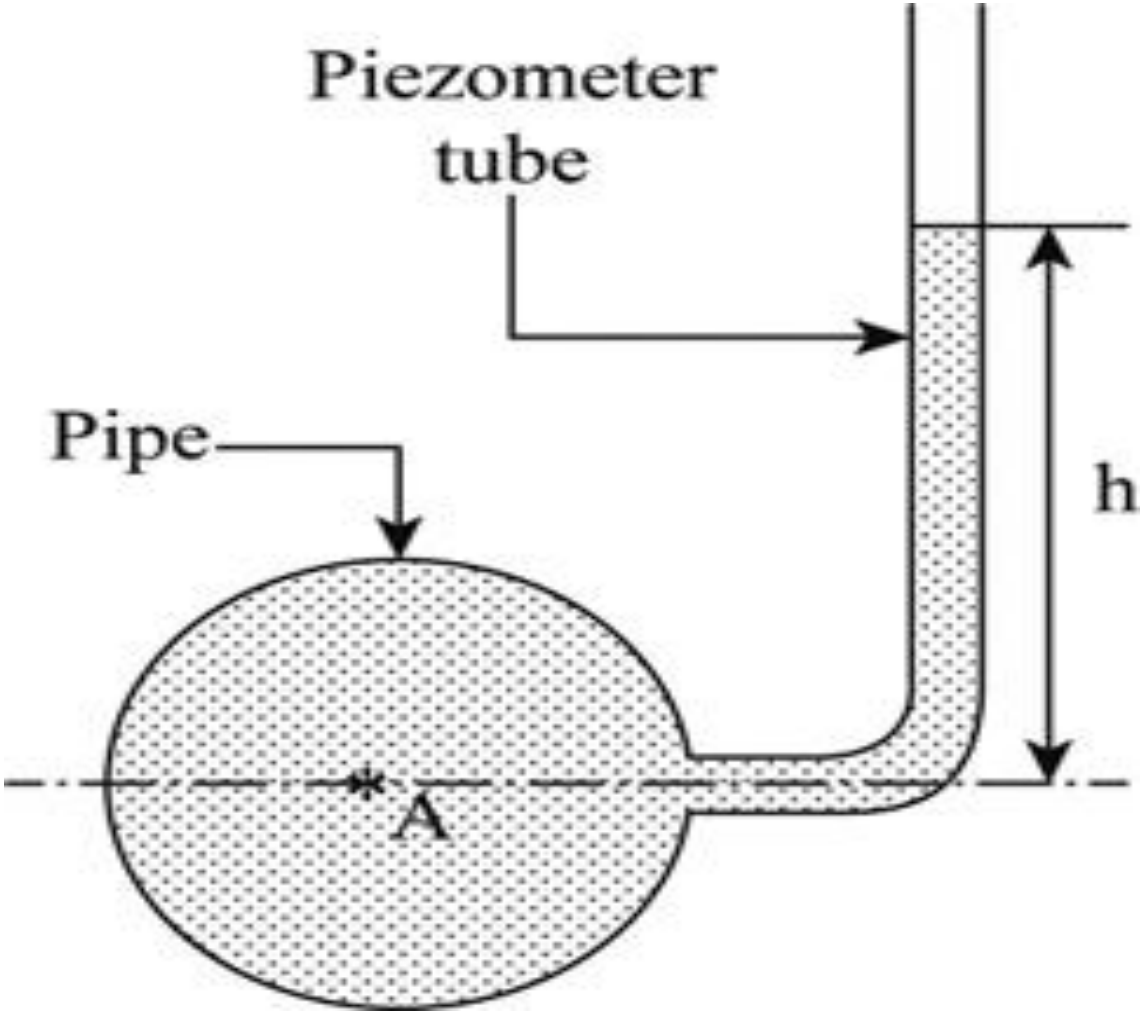
a) Simple Manometers

b) Differential Manometers


Manometers
Simple Manometers
Differential Manoeters
1) Piezometer
2) U - tube Manometer
3) Single column Manometer
1) U-tube differetial Manometer
2) Inverted U-tube differential Manometers

Piezometer

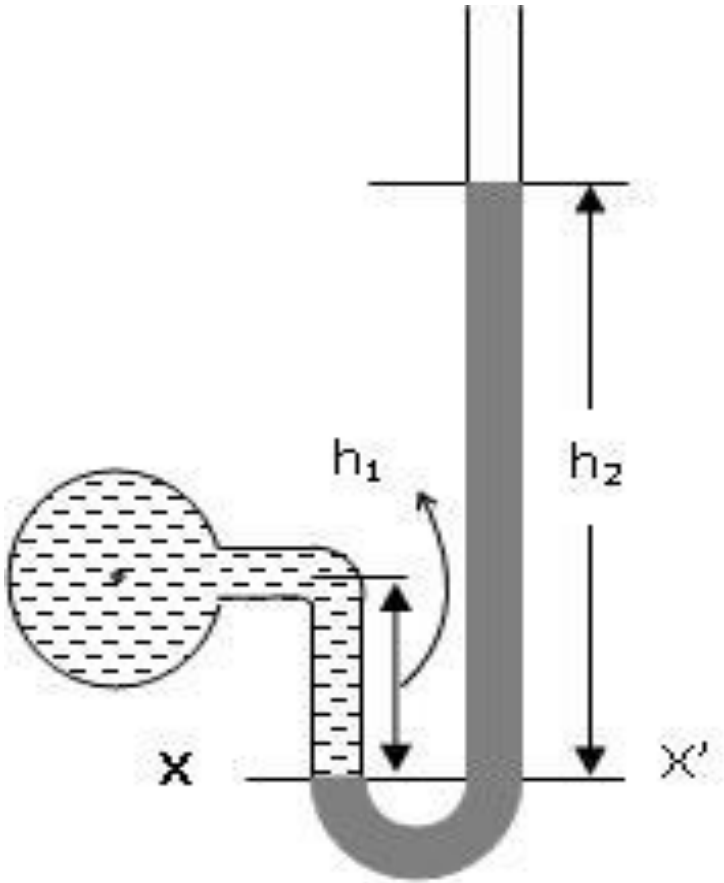
It is simplest form of manometer which can be used for measuring pressure of moderate range.



U-Tube Manometer

It consist of glass tube bent in U-shape. One end is open to the atmosphere and other end connected to a point at which pressure is to be measured.

For gauge pressure-



S_1 = Specific gravity of liquid for which pressure has to be determined

S_2 = Specific gravity of manometer liquid (assume mercury)

Pressure head in left limb at X-X = $h + h_1S_1$

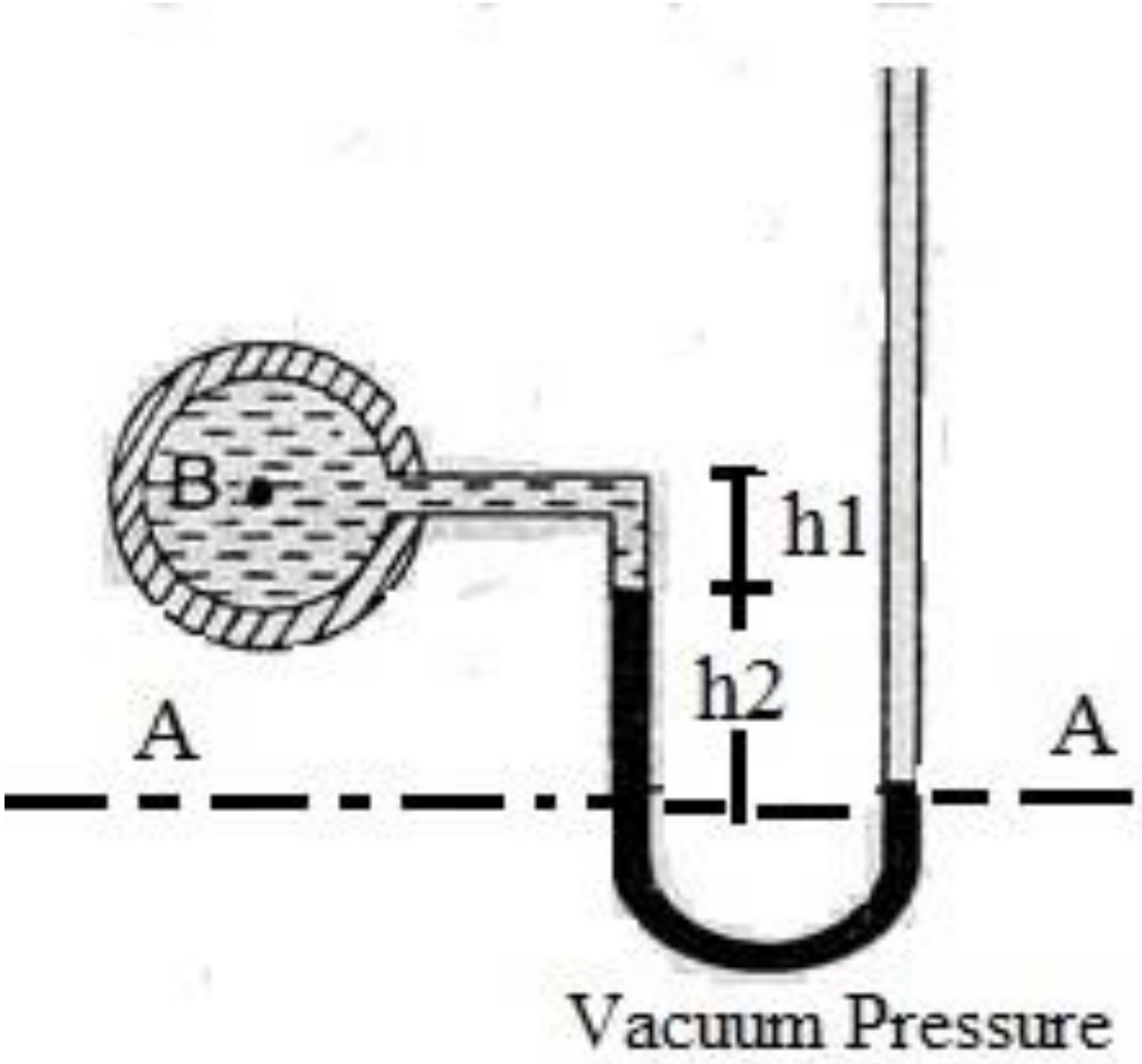
Pressure head in right limb at X-X = h_2S_2

Equating pressure head at X-X as the pressure at datum line would be equal.

$$h + h_1S_1 = h_2S_2$$

$$h = h_2S_2 - h_1S_1$$

For vacuum pressure-



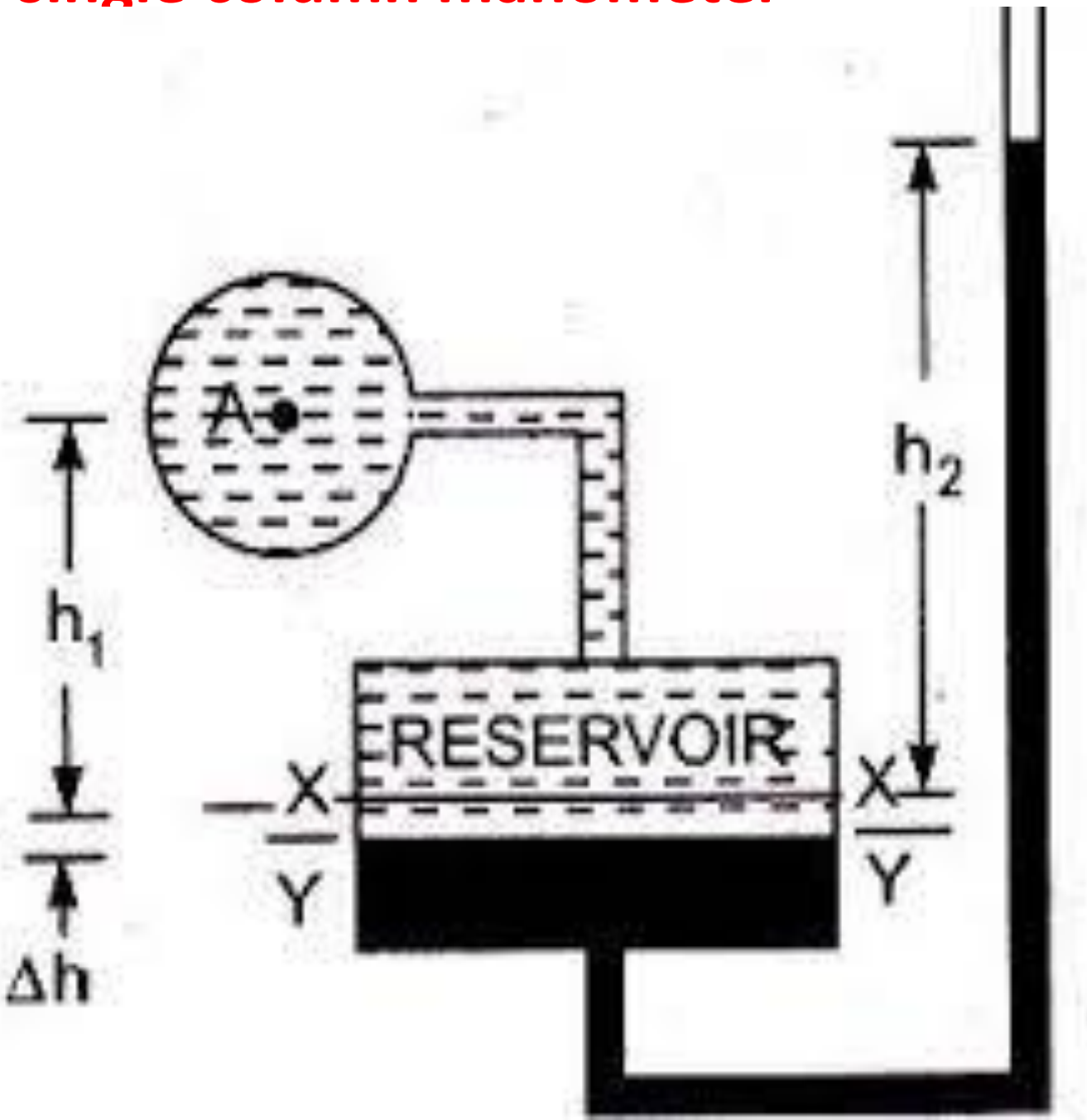
Single Column Manometer

Single column manometer is a **modified form of a U-tube manometer in which one side is a large reservoir** and the other side is a small tube, open to the atmosphere. There are two types of single column manometer:

1- Vertical single column manometer.

2- Inclined single column manometer.

Vertical single column manometer



Let us consider that container, filled with a liquid whose pressure is to be measured, is connected now with vertical single column manometer.

XX is the datum line between in the reservoir and in the right limb of manometer

h_1 = Height of lower specific gravity liquid above the datum line

h_2 = Height of higher specific gravity liquid above the datum line

Δh = Fall of heavy liquid in the reservoir

S_1 = Specific gravity of the light liquid i.e. specific gravity of liquid in container

S_2 = Specific gravity of the heavy liquid

A = Cross-sectional area of the reservoir

a = Cross-sectional area of the right limb

YY = Datum line after connecting the manometer with reservoir

Fall of heavy liquid in reservoir will cause a rise of heavy liquid in right limb

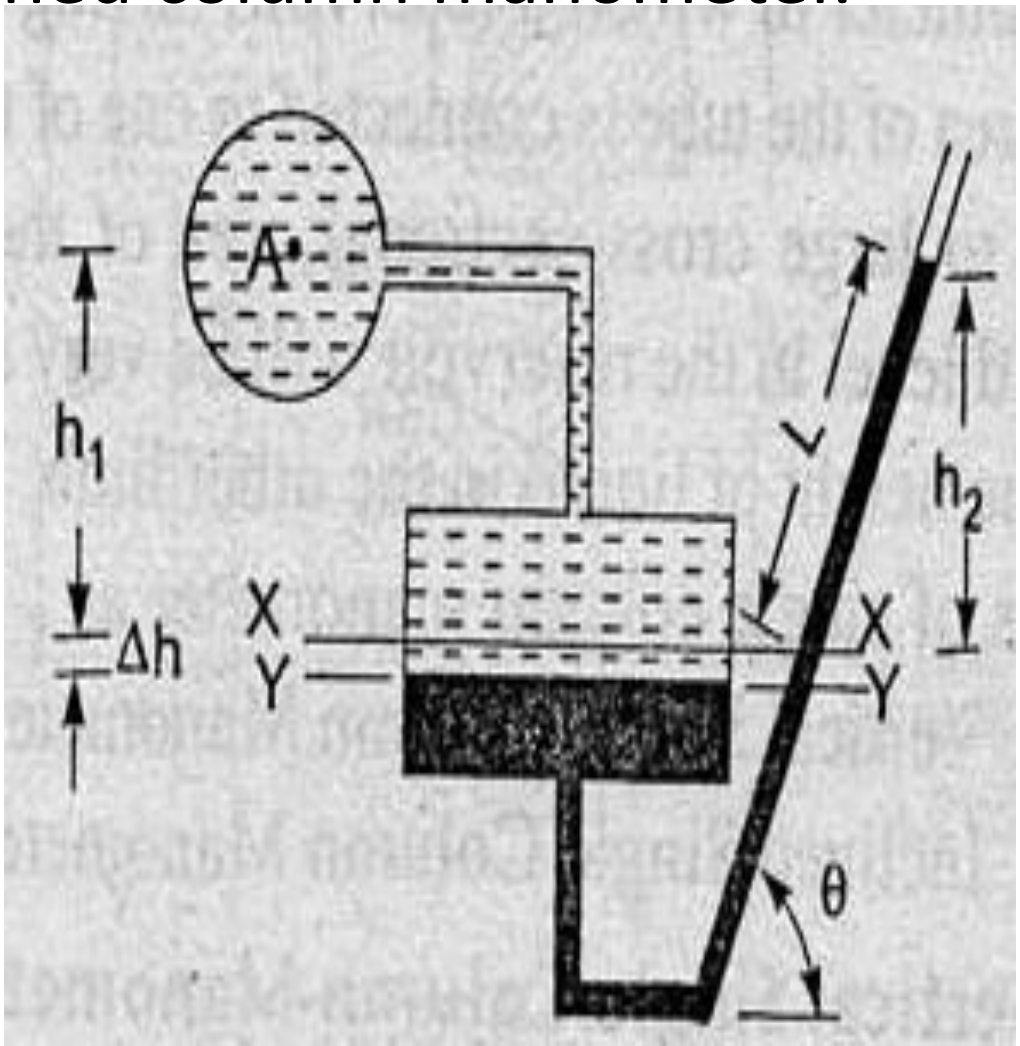
$$A \times \Delta h = a \times h_2$$

$$\Delta h = a / A \times h_2$$

Considering the datum line Y-Y

$$P + S_1\Delta h + S_1 h_1) = S_2\Delta h + S_2 h_2)$$

Inclined single column manometer – This is used for measuring small presssure. If the vertical tube of the manometer is made inclined as shown in figure then it is called inclined column manometer.



L = Length of heavy liquid moved in the inclined limb from XX

h_1 = Height of lower specific gravity liquid above the datum line

h_2 = Height of higher specific gravity liquid above the datum line

$h_2 = L \times \sin \theta$

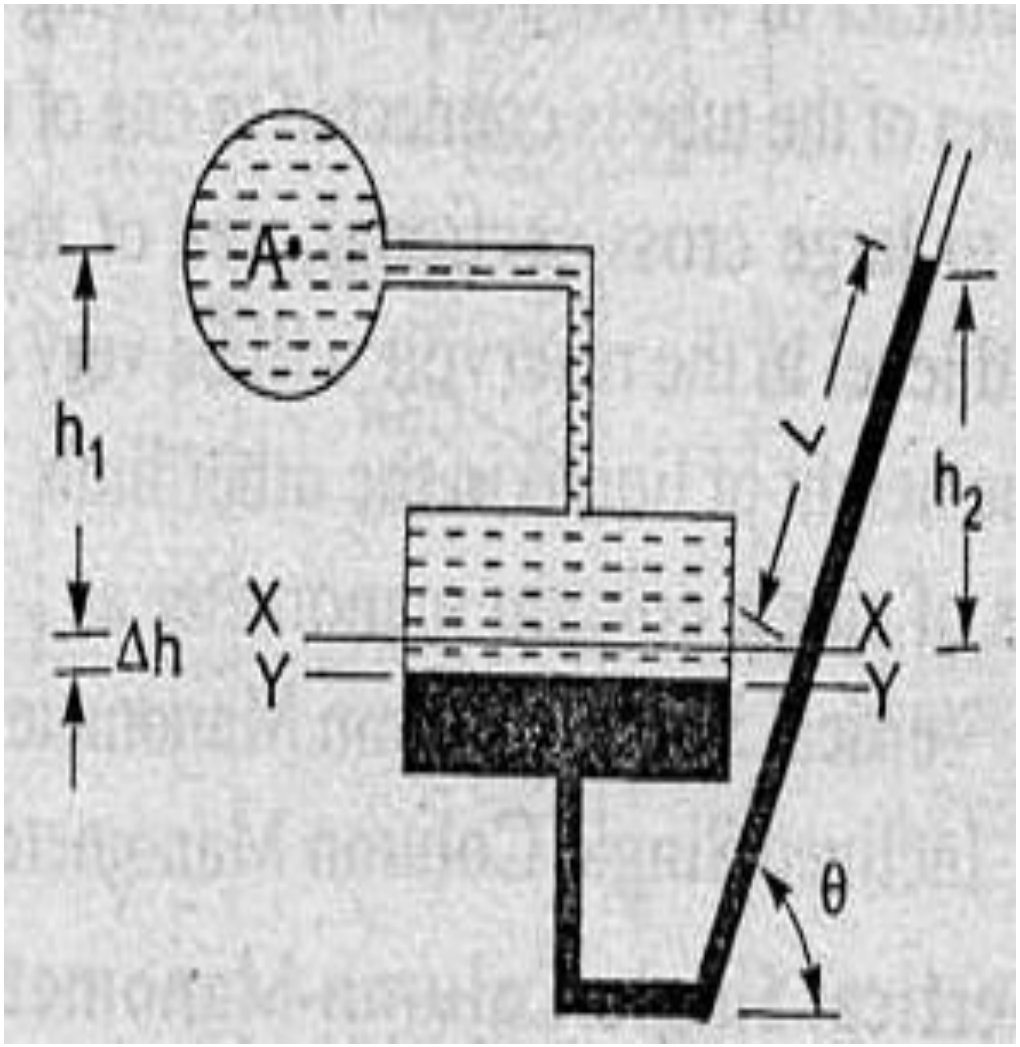
Δh = Fall of heavy liquid in the reservoir

S_1 = Specific gravity of the light liquid i.e. specific gravity of liquid in container

S_2 = Specific gravity of the heavy liquid

As pressure is same for the horizontal surface

$P = L \times \sin\theta \times S_2 - S_1 h_1$



Differential Manometer

The differential manometer is used to measure the difference in pressure between two points in a pipe or in two pipes.

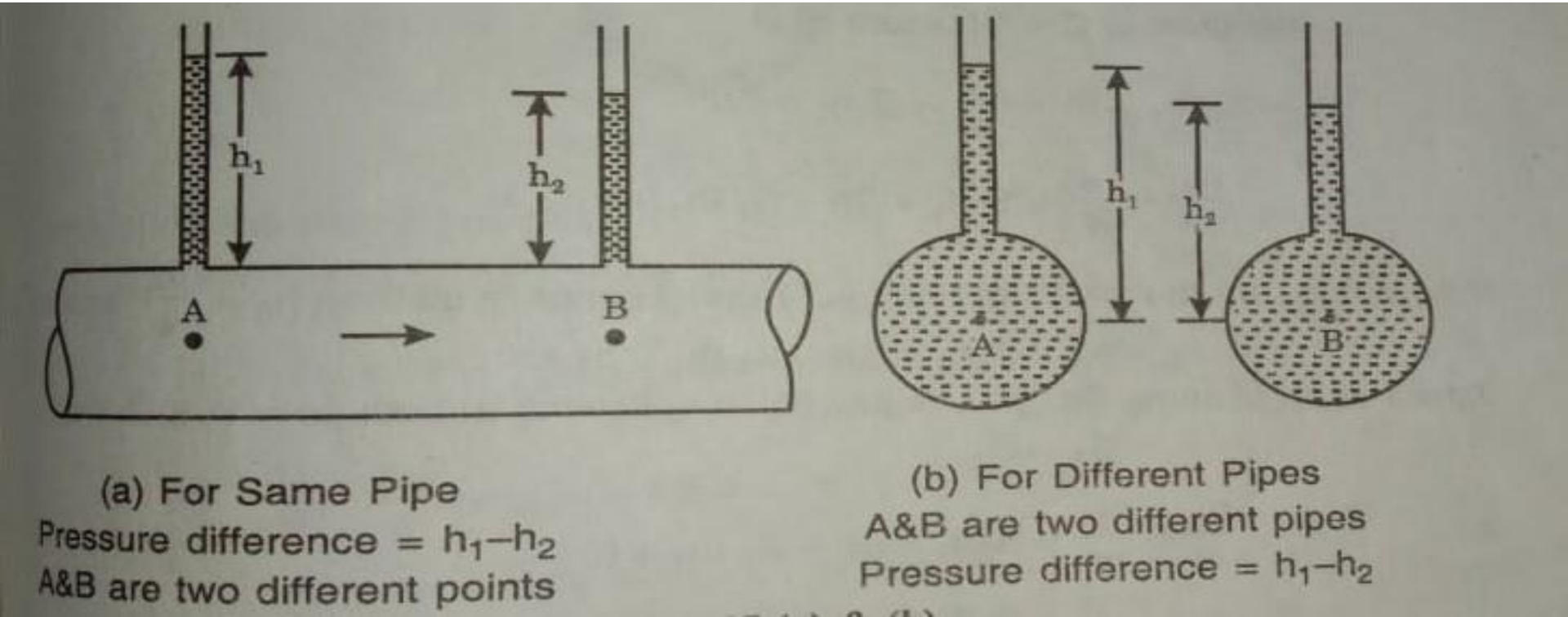
Types Of Differential Manometer

There are mainly three types of differential manometer:

- Two piezometer manometer
- U-tube differential manometer
- Inverted differential manometer

Two Piezometer Manometer

It consists of two piezometers mounted at two different gauge points where the pressure difference is to be measured. The pressure difference between two points can be simply measured by the difference in the level of liquid between the two tubes

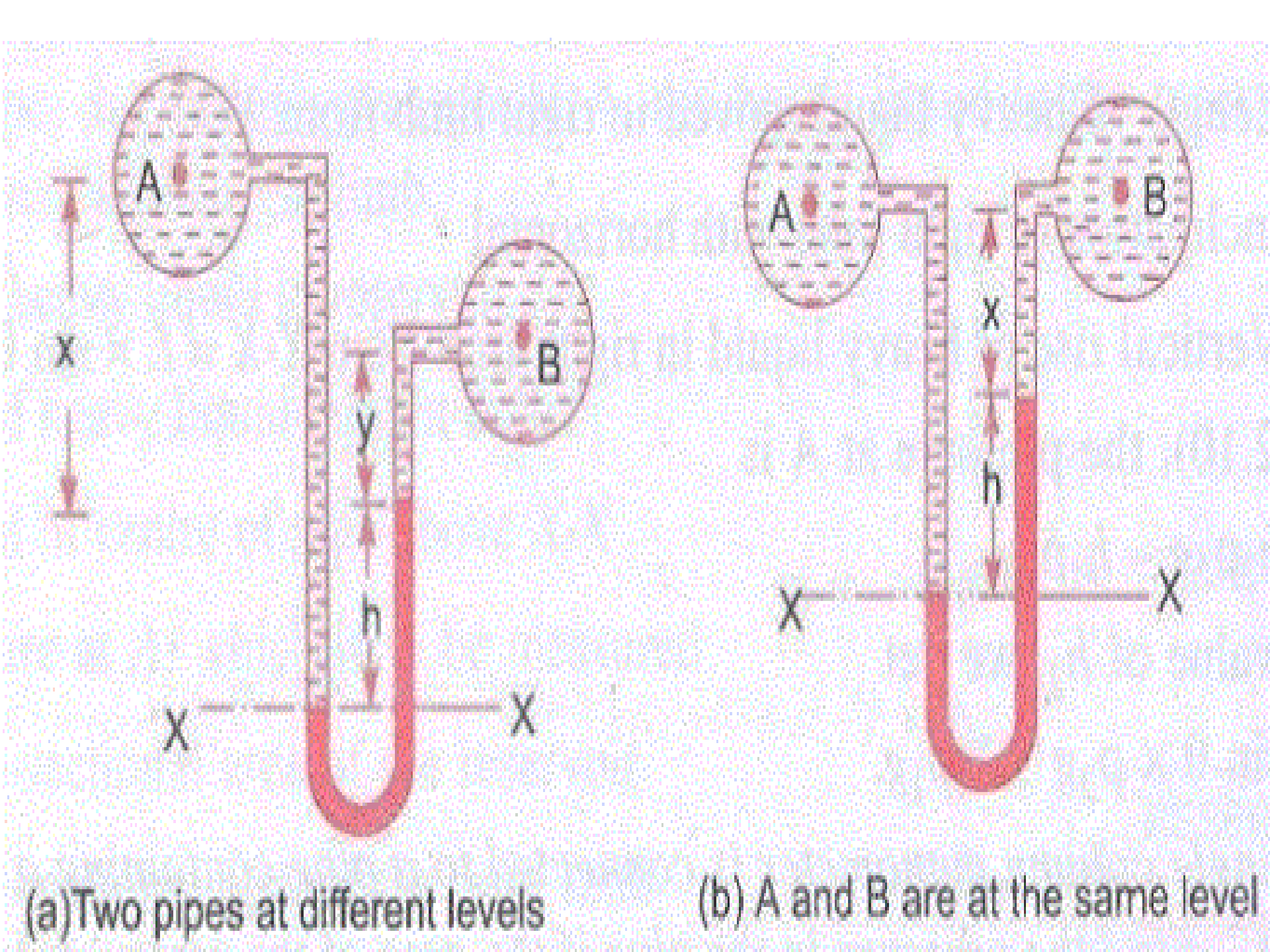


(a) For Same Pipe
Pressure difference = $h_1 - h_2$
A&B are two different points

(b) For Different Pipes
A&B are two different pipes
Pressure difference = $h_1 - h_2$

2. U-tube Differential Manometer

It is a device that is used to measure the pressure difference between two points in a pipe or between two different pipes. this manometer is consists of a U shaped tube containing a heavy liquid.

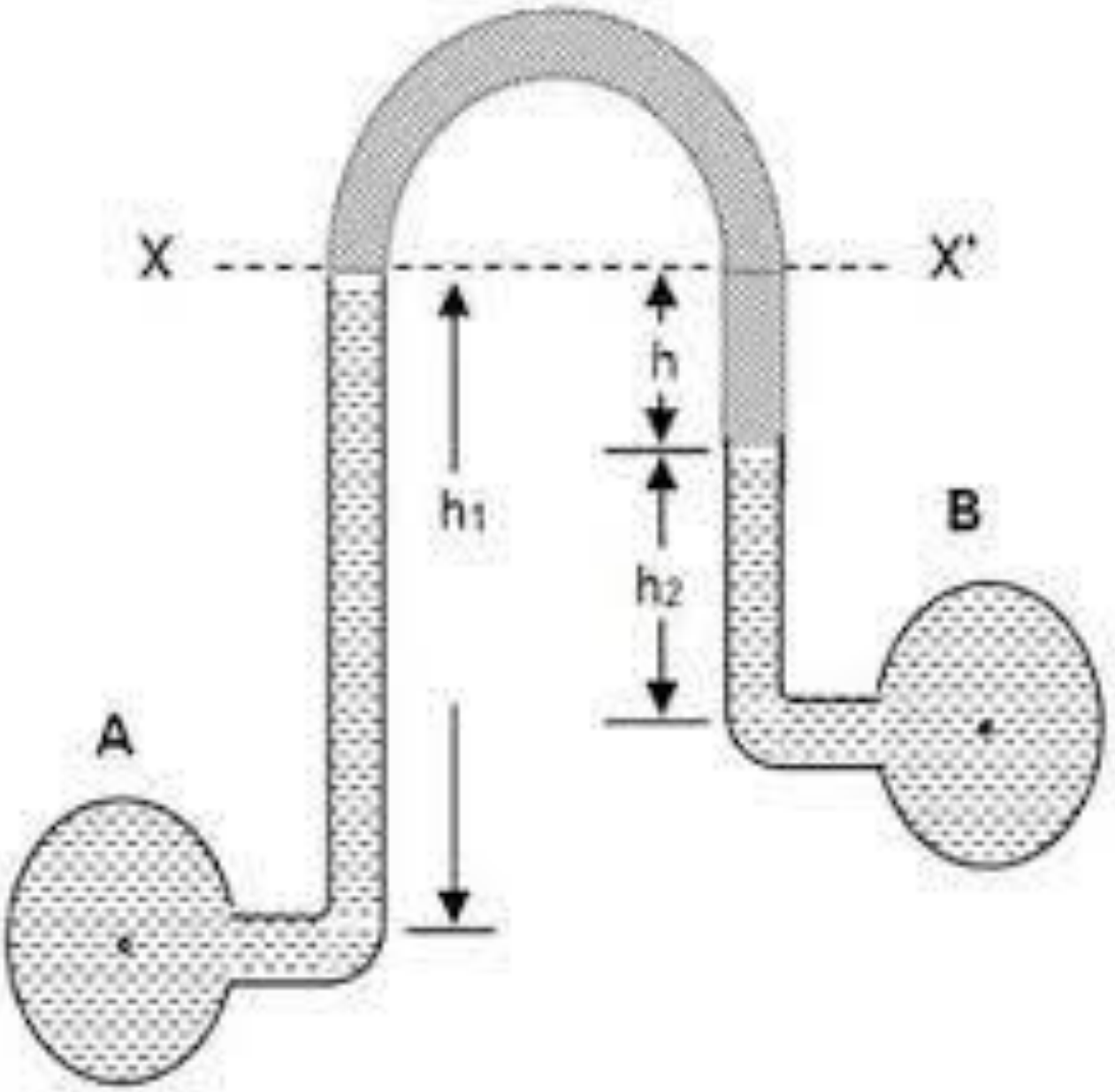


(a)Two pipes at different levels

(b) A and B are at the same level

Inverted Differential Manometer

In this type of manometer, the U-tube is inverted and contains a light liquid. The two ends of the tube are connected to the points whose pressure difference is to be measured.


X
X'
h
h1
h2
A
B

- **Advantages of manometer:**
- It has a low cost
- The manometer is suitable for low-pressure applications
- It is simple in construction
- It has better sensitivity
- It has good accuracy
- Require little maintenance
- Not affected by vibration
- The manometer is available for a large range of filling fluids of varying specific gravity

- **Disadvantages of manometer:**
- It is large in size and bulky
- It needs leveling
- In manometer, the error is introduced due to condensation
- They are fragile and hence offer less portability
- The manometric fluids density depends on temperature. Hence errors may result due to change in the temperature
- It has a slow response which makes it unsuitable for measuring fluctuating pressures

Mechanical Pressure Gauges

Mechanical gauges these are the devices used for measuring the pressure by balancing the column of fluid by spring or dead weight.

Types of Pressure Gauges

- Following are the commonly used **mechanical pressure gauges**:

I. Diaphragm pressure gauge

II. Bourdon tube pressure gauge

III. Dead-weight pressure gauge

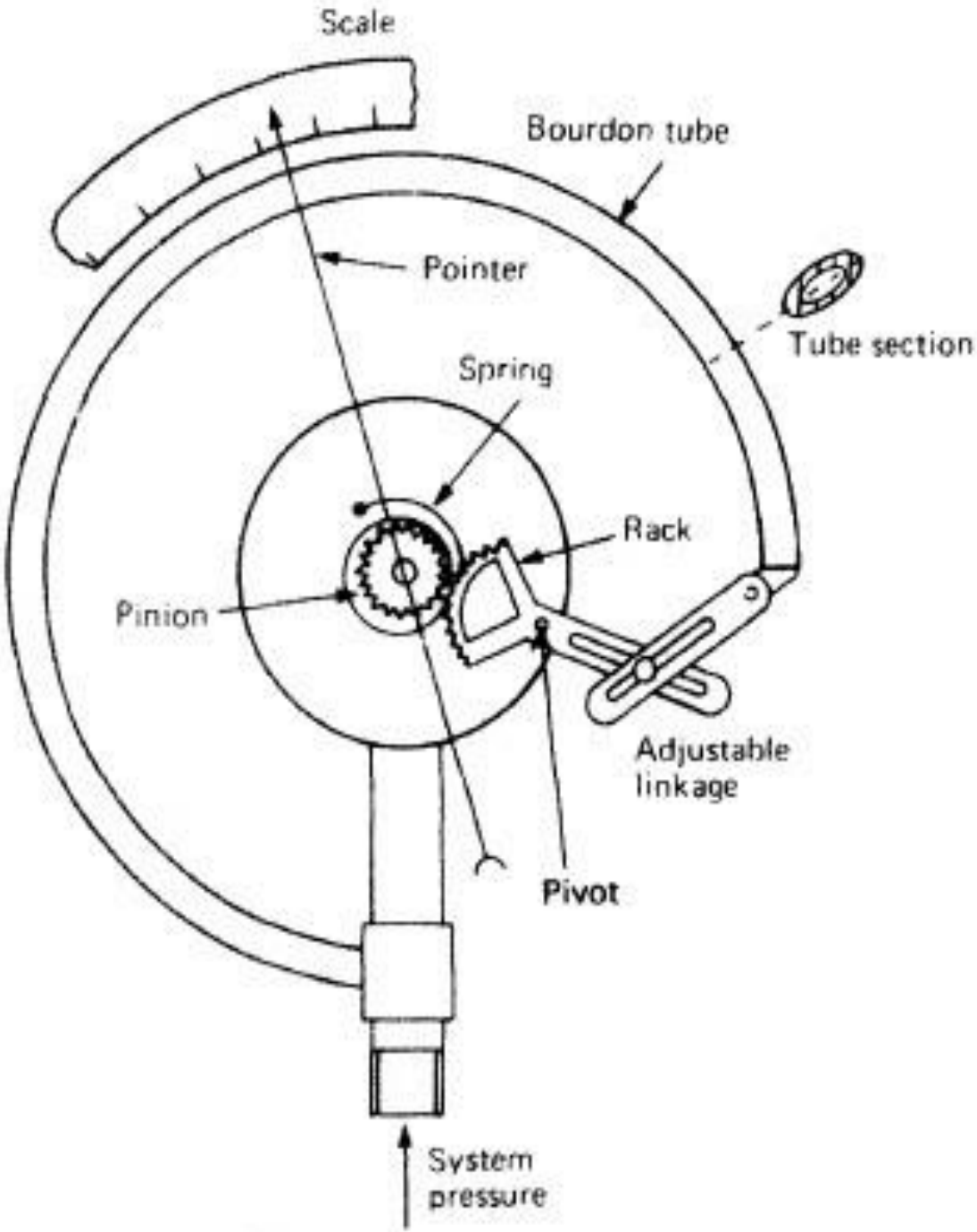
1. Diaphragm Pressure Gauge

A mechanical pressure-measuring instrument used to measure pressure above or below the atmospheric pressure. It is usually employed to measure relatively low pressures. A diaphragm pressure gauge, in its simplest form, consists of a corrugated diaphragm as shown in the figure.

The gauge is connected to the fluid which is under pressure causes some deformation to the diaphragm. With the help of pinion system, elastic deformation of the diaphragm rotates the pointer. This pointer moves over a calibrated scale, which directly gives the pressure.

2. Bourdon's Tube Pressure Gauge

- A mechanical pressure-measuring instrument employing as its sensing element a curved or twisted metal tube flattened in cross-section and closed known as Bourdon tube. It is a device for measuring the pressure of gases or liquids. It consisting of a semicircular or coiled, flexible metal tube connected to a gauge, which records the degree to which the tube is straightened by the pressure of the gas or liquid inside. Generally, it is used for measuring high pressures.The instrument is connected to the fluid which is under pressure flows into the Bourdon's tube. As a result of the increased pressure, the tube tends to straighten itself. Since the tube is encased in a circular cover, therefore it tends to become circular instead of straight.
- With the help of a simple pinion and sector arrangement, the elastic deformation of the Bourdon's tube rotates the pointer. This pointer moves over a calibrated scale, which directly gives the pressure.

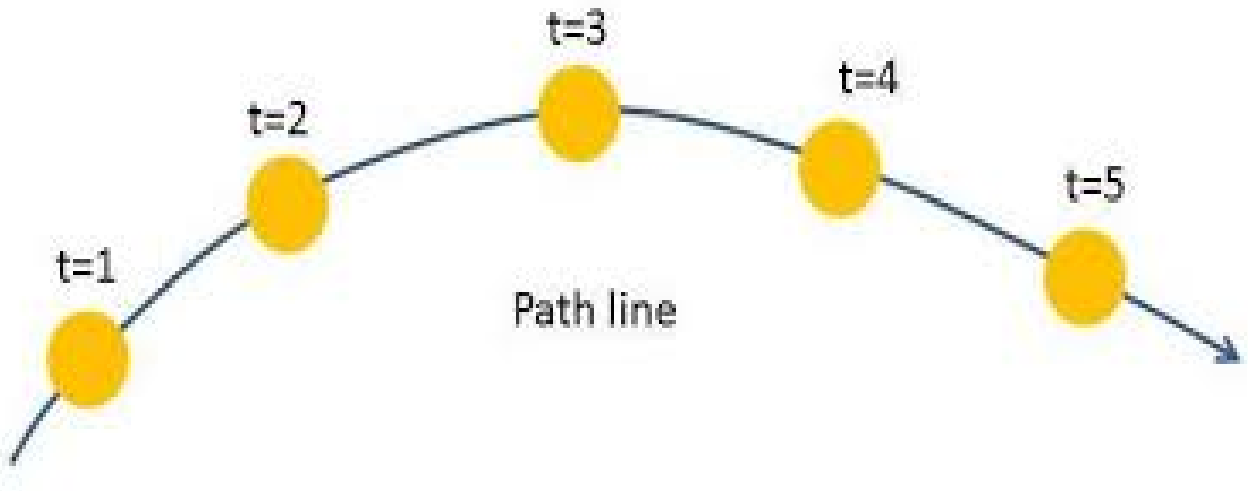

Scale
Bourdon tube
Pointer
Tube section
Spring
Rack
Pinion
Adjustable
linkage
Pivot
System
pressure

Chapter - 5

Fundamental of Fluid Flow

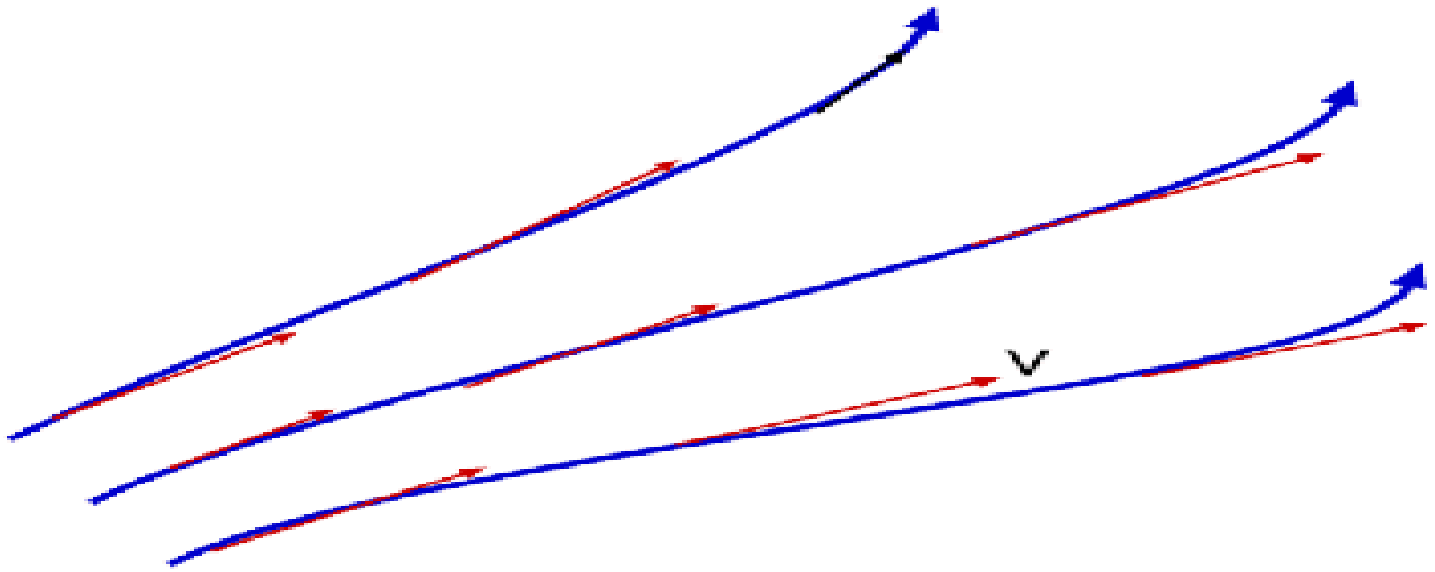
Path Line

The path followed by a fluid particle at different instant of time.



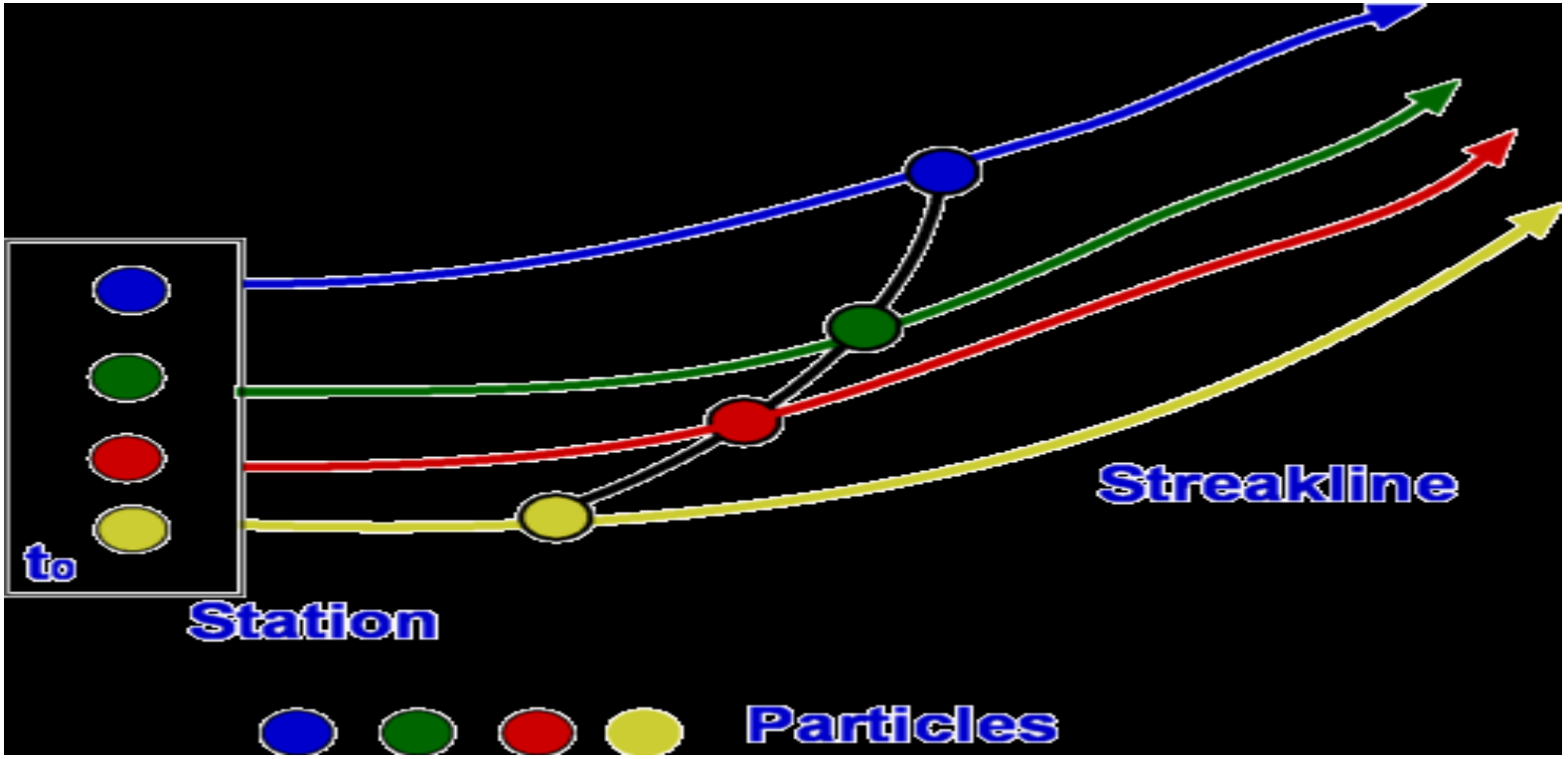
Stream line

It is an imaginary line with in the flow so that the tangent drawn at any point on it gives velocity at that point.



Streak Line

It is locus of fluid particles passing through a fixed point.



Types of Fluid Flow

I. Steady Flow
II. Unsteady Flow
III. Uniform Flow
IV. Non Uniform Flow
V. Laminar Flow
VI. Turbulent Flow

Steady Flow

The type of flow in which fluid property
Like velocity, pressure density etc at a point do not change with time at a given section.
Ex- flow through prismatic and non prismatic pipe at a constant rate

Unsteady Flow

The type of flow in which fluid property like velocity, pressure density etc at a point change with time at a given section.
Ex- Flow in a pipe whose valve is being opened or closed gradually.

Uniform Flow

The type of flow in which fluid velocity, at any given time does not change with respect to distance is called uniform flow.

Ex- Flow through a prismatic conduit

Non Uniform Flow

The type of flow in which fluid velocity, at any given time change with respect to distance is called uniform flow.

Ex- Flow through a non prismatic conduit

Laminar Flow

The type of flow in which the fluid particles move in layers and do not cross the path of other particles is called laminar flow.

Ex- Flow through a capillary tube, ground water flow

Turbulent Flow

The type of flow in which the fluid particles do not move in layers and cross the path of other particles is called turbulent flow.

Ex- High velocity flow in conduit of large size