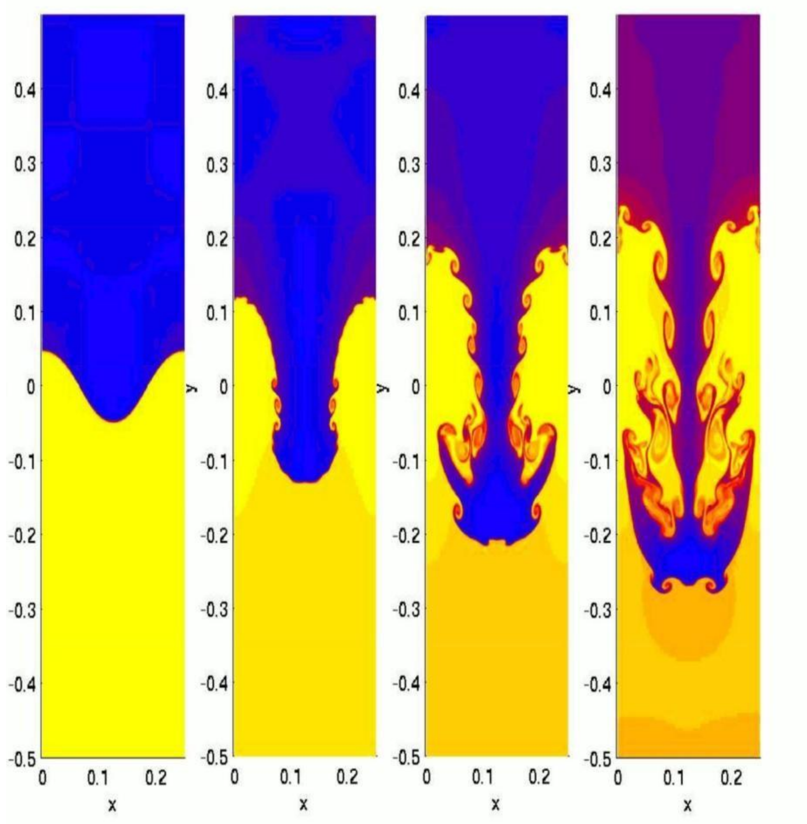
FLOW OF FLUIDS



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Syllabus

	crystals.	
6	**Flow of Fluids:** Fluid statics- pressure, pressure measurement-manometers & pressure guage, fluid dynamics, mechanism of fluid flow, material & energy balance, pressure differential flow meter-principle, orifice meter, pitot tube; Variable area flow meter-principle, rotameter orifice & plug meter, quantity flow meters.	**07**
7	**Distillation:** Vapour liquid equilibrium, distillation of miscibile systems, boiling	**06**

Contens

- Fluid properties
- Reynolds experiment
- Manometer
- Orificemeter
- Venturimeter
- Pitot tube
- Rotameter
- Current flow meter

Fluid Flow

- Mention fluid **properties** such as viscosity, compressibility and surface tension of fluids.
- Hydrostatics **(Fluidstatics)** influencing fluid flow.
- **Fluid dynamics**- Bernoulli's theorem, flow of fluids in pipes, laminar and turbulent flow.

THE PROPERTIES OF FLUIDS

- VISCOSITY
- SURFACE TENSION
- COMPRESSIBILITY

VISCOSITY

- Viscosity is a measure of a fluid's resistance to flow.
- It describes the internal friction of a moving fluid.
- A fluid with large viscosity resists motion because its molecular makeup gives it a lot of internal friction.
- A fluid with low viscosity flows easily because its molecular makeup results in very little friction when it is in motion.

SURFACE TENSION

SURFACE TENSION

"Surface tension is a contractive tendency of the surface of a fluid that allows it to resist an external force."

FLUID FLOW

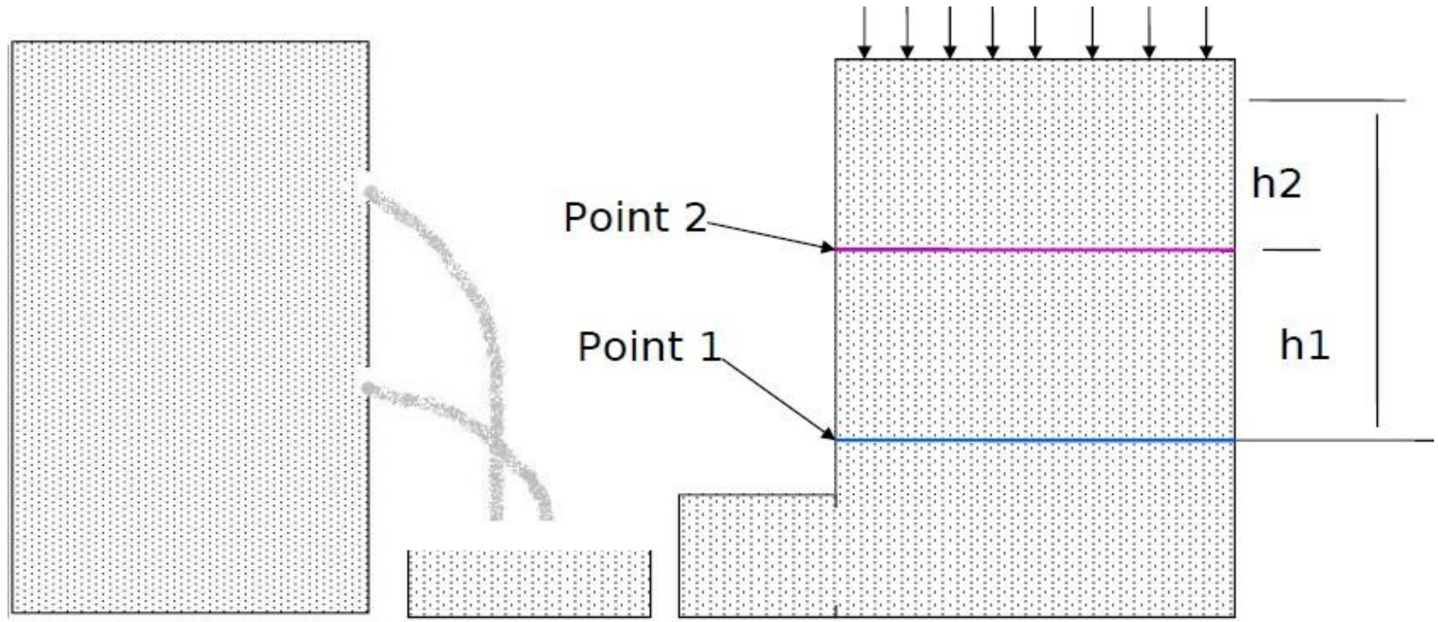
FLUID FLOW

- A fluid is a substance that continually deforms (flows) under an applied shear stress.
- Fluids are a subset of the phases of matter and include liquids, gases.
- Fluid flow may be defined as the flow of substances that do not permanently resist distortion.
- The subject of fluid flow can be divided into fluid static's and fluid dynamics.

FLUID STATICS

FLUID STATICS

- Fluid static's deals with the fluids at rest in equilibrium.
- Behaviour of liquid at rest.
- Nature of pressure it exerts and the variation of pressure at different layers.
- Pressure differences between layers of liquids.



- Consider a column of liquid with two openings Which are provided at the wall of the vessel at different height
- The rate of flow through these openings are different due to the **pressure exerted at the different heights are different**
- Consider a **stationary column** the pressure P is acting on the surface of the fluid, column is maintained at constant pressure by applying pressure
- The force acting below and above the point 1 are evaluated
- **Substituting the force with pressure** x area of cross section in the above equation

Force acting on the liquid At **point 1** = **Force on the surface** + **Force excreted by the liquid Above point 1**

Pressure at point 2 x Area= (Pressure on the surface area x surface area)

Pressure at point 1 x Area (Pressure on the surface area x surface area)

$P_1S = P_2S$ + height x volume x density x g

$P_1S = P_2S + \text{volume x density x g}$

$\quad = P_2S + \text{height x area x density x g}$

$P_1S = P_2S + h_1\, S\, \rho\, g$

Since surface area is same

$$P_1 = P + h_1 \rho g$$

Pressure acting on point 2 may be written as

$$P_2 = P + h_2 \rho g$$

Difference in the pressure is --

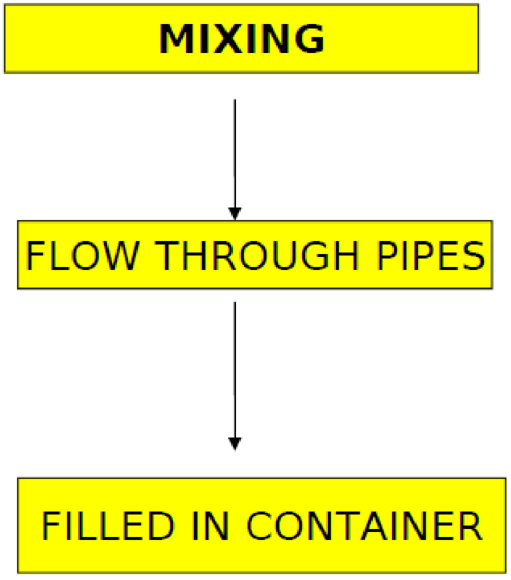
$P_2 - P_1 = g\,(Ps + h_2\, \rho\,) - (\,Ps + h_1\, \rho)\, g$

$\Delta P = (\cancel{Ps} + h_2\, \rho - \cancel{Ps} - h_1\, \rho\,)\, g$

$\Delta P = \Delta\, h\, \rho\, g$ [F=Volume.ρ g]

FLUID DYNAMICS

- Fluid dynamics deals with the study of fluids in motion
- This knowledge is important for liquids, gels, ointments which will change their flow behaviour when exposed to different stress conditions



Importanc e

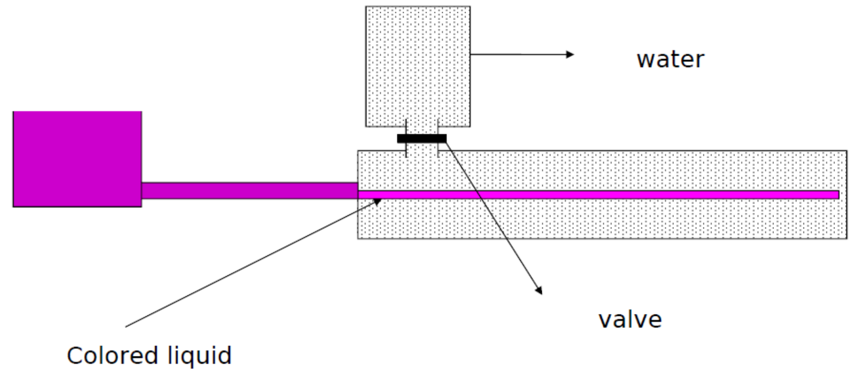
Identification of type of flow is important in

- Manufacture of dosage forms
- Handling of drugs for administration

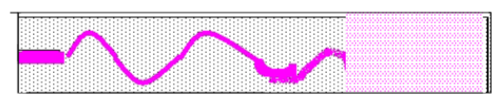
The flow of fluid through a pipe can be *viscous* or *turbulent* and it can be determined by **Reynolds number** Reynolds number have no unit

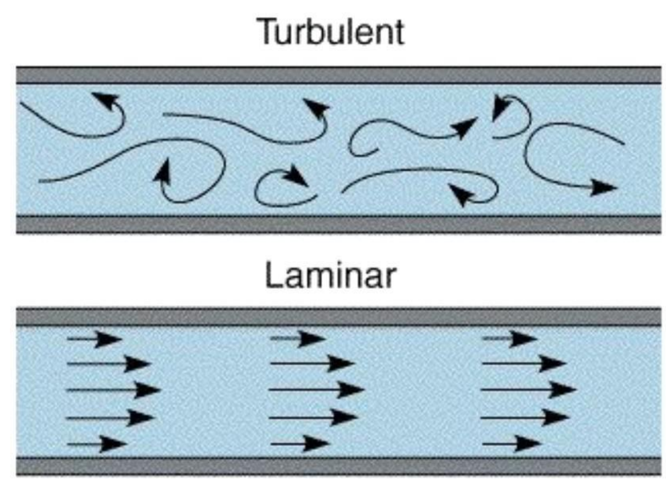
Reynolds Experiment

- Glass tube is connected to reservoir of water, rate of flow of water is adjusted by a valve.
- A reservoir of colored solution is connected to one end of the glass tube with help of nozzle.
- Colored solution is introduced into the nozzle as fine stream through jet tube.



LAMINAR OR VISCOUS FLOW


TURBULENT FLOW



TYPES OF FLOW

- **Laminar flow** is one in which the fluid particles move in layers or laminar with one layer sliding with other
- There is no exchange of fluid particles from one layer to other
- Avg velocity = 0.5Vmax
- Re < 2000

- When velocity of the water is increased the thread of the colored water disappears and mass of the water gets uniformly colored
- There is complete mixing of the solution and the flow of the fluid is called as **Turbulent flow**
- Avg velocity = 0.8Vmax
- Re >4000

The velocity at which the fluid changes from laminar flow to turbulent flow that velocity is called as **critical velocity**

REYNOLDS NUMBER

In Reynolds experiment the flow conditions are affected by

- Diameter of pipe
- Average velocity
- Density of liquid
- Viscosity of the fluid

This four factors are combined in one way as Reynolds number

$$Re = \frac{D\,u\,\rho}{\eta} = \frac{\text{INERTIAL FORCES}}{\text{VISCOUS FORCES}}$$

- Inertial forces are due to mass and the velocity of the fluid particles trying to diffuse the fluid particles

- viscous force if the frictional force due to the viscosity of the fluid which make the motion of the fluid in parallel.

- At low velocities the inertial forces are less when compared to the frictional forces

- Resulting flow will be viscous in nature

- Other hand when inertial forces are predominant the fluid layers break up due to the increase in velocity hence turbulent flow takes place.

  - If Re < 2000 the flow is said to be laminar

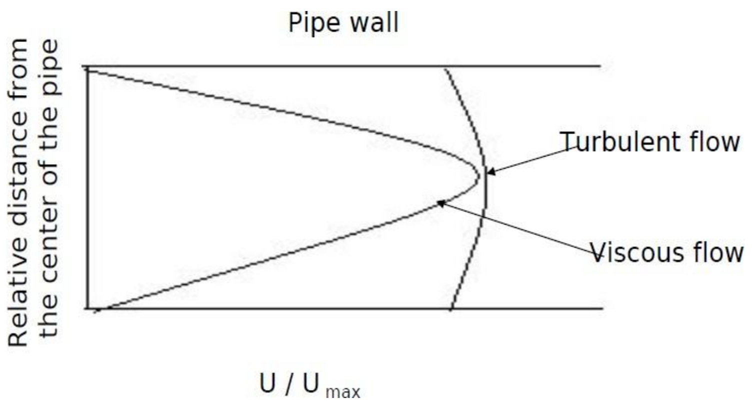
  - If Re > 4000 the flow is said to be turbulent

  - If Re lies between 2000 to 4000 the flow change between laminar to turbulent

APPLICATIONS

- Reynolds number is used to predict the nature of the flow
- Stocks law equation is modified to include Reynolds number to study the rate of sedimentation in suspension

When velocity is plotted against the distance from the wall following conclusions can be drawn



- The flow of fluid in the middle of the pipe is faster then the fluid near to the wall
- At the actual surface of the pipe - wall the velocity of the fluid is zero

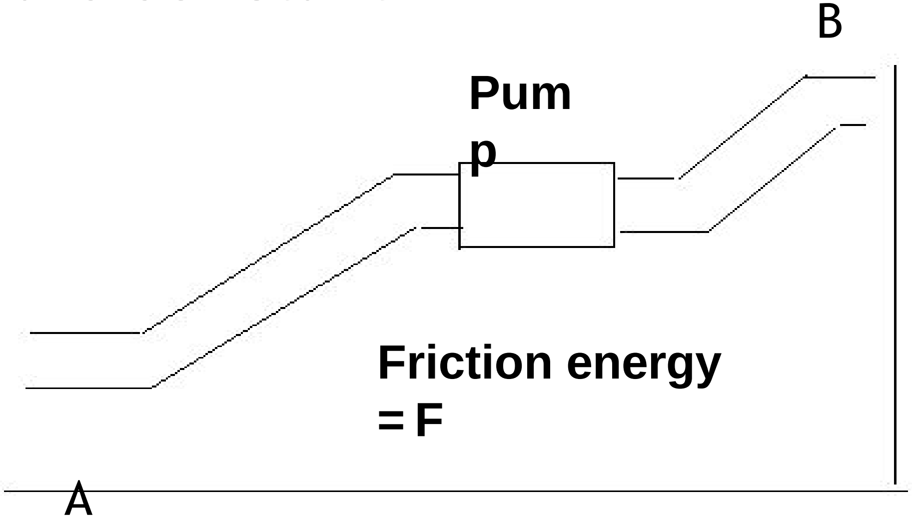
BERNOULLI'S THEOREM

- When the principles of the law of energy is applied to the flow of the fluids the resulting equation is a Bernoulli's theorem

- Consider a pump working under isothermal conditions between points A and B

- Bernoulli's theorem statement, "In a steady state the total energy per unit mass **consists of pressure, kinetic and potential energies are constant.**

Kinetic energy = $u^2 / 2g$
Pressure energy = $P_a / \rho_A g$



- At point A one kilogram of liquid is assumed to be entering at point A,

Pressure energy = $P_a / g \rho_A$

Where P_a = Pressure at point a
g = Acceleration due to gravity
ρ_A = Density of the liquid

- Potential energy of a body is defined as the energy possessed by the body by the virtue of its position

Potential energy = X_A

- Kinetic energy of a body is defined as the energy possessed by the body by virtue of its motion,

kinetic energy = $U_A^2 / 2g$

Total energy at point A = Pressure energy + Potential energy + K. E

Total energy at point A = $P_aV + X_A + U_A^2 / 2g$

- According to the Bernoulli's theorem the total energy at point A is constant

$$\text{Total energy at point A} = P_A V + X_A + (U_A^2/2g) = \text{Constant}$$

- After the system reaches the steady state, whenever one kilogram of liquid enters at point A, another one kilogram of liquid leaves at point B

$$\text{Total energy at point B} = P_B V + X_B + U_B^2/2g$$

$$P_A V + X_A + (U_A^2/2g) + \text{Energy added by the pump}$$
$$= P_B V + X_B + (U_B^2/2g)$$

- V is specific volume and it is reciprocal of density.

Theoretically all kinds of the energies involved in fluid flow should be accounted, pump has added certain amount of energy.

- During the transport, some energy is converted to heat due to frictional Forces

Energy loss due to friction in the line = F Energy added by pump = W

$$P_A / \rho_A + X_A + U_A 2 / 2g - F + W = P_B / \rho_B + X_B + U_B 2 / 2g$$

$P_A / \rho_A + X_A + U_A 2 / 2g - F + W = P_B / \rho_B + X_B + U_B 2 / 2g$

This equation is called as Bernoulli's equation

ENERGY LOSS

- According to the law of conversation of energy, energy balance have to be properly calculated
- Fluids experiences energy losses in several ways while flowing through pipes, theyare
  - ✓Frictional losses
  - ✓Losses in thefitting
  - ✓Enlargement losses
  - ✓Contraction losses

Application of BERNOULLI'S THEOREM

- Used in the measurement of rate of fluid flow using flowmeters

- It applied in the working of the centrifugal pump, in this kinetic energy is converted in to pressure.

Fluid Flow and Pressure measurements

- Pressure measurement-
  - Classification of manometers,
  - simple manometer/
  - Utube manometer and modifications (Differential/inclined),
  - Bourdon gauge
- Measurement of flow-
  - Classification of flowmeters,
  - venturimeter,
  - orificemeter,
  - pitot tube,
  - rotameter
  - current flow meters

MANOMETERS

- Manometers are the devices used for measuring the pressure difference

- Different type of manometers are there they are

  1)Simple manometer

  2)Differential manometer

  3)Inclined manometer

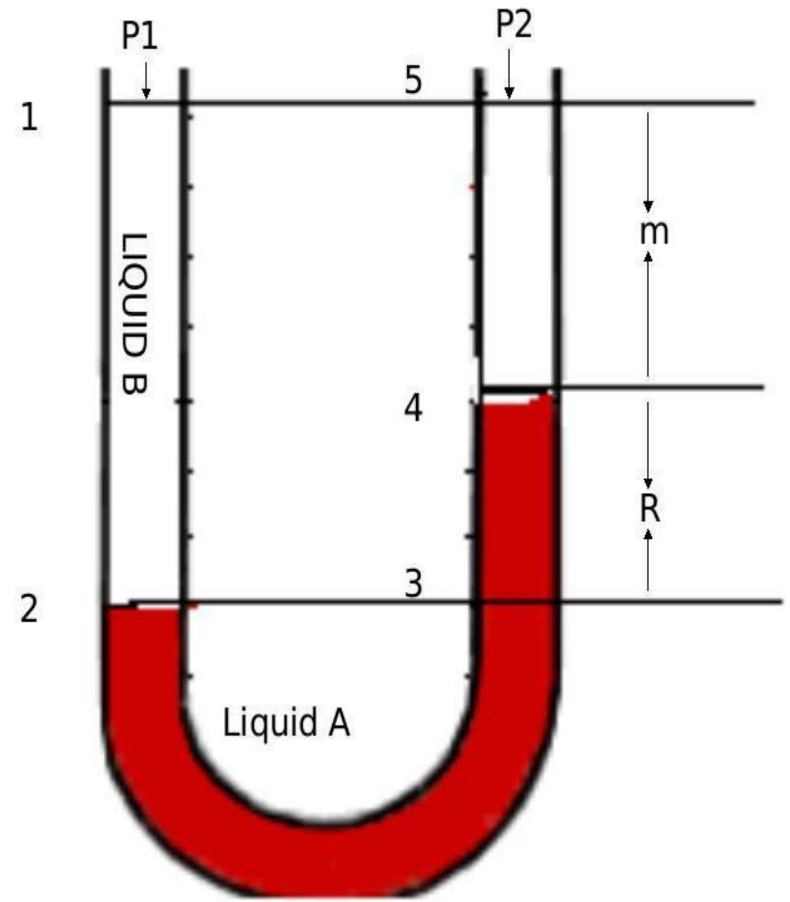
SIMPLE MANOMETER

- This manometer is the most commonly used one

- **It consists of a glass U shaped tube filled with a liquid A- of density** ρ_A kg /meter cube and above Athe arms are filled with liquid B of density ρ_B

- The liquid A and B are immiscible and the interference can be seen clearly

- If two different pressures are applied on the two arms the

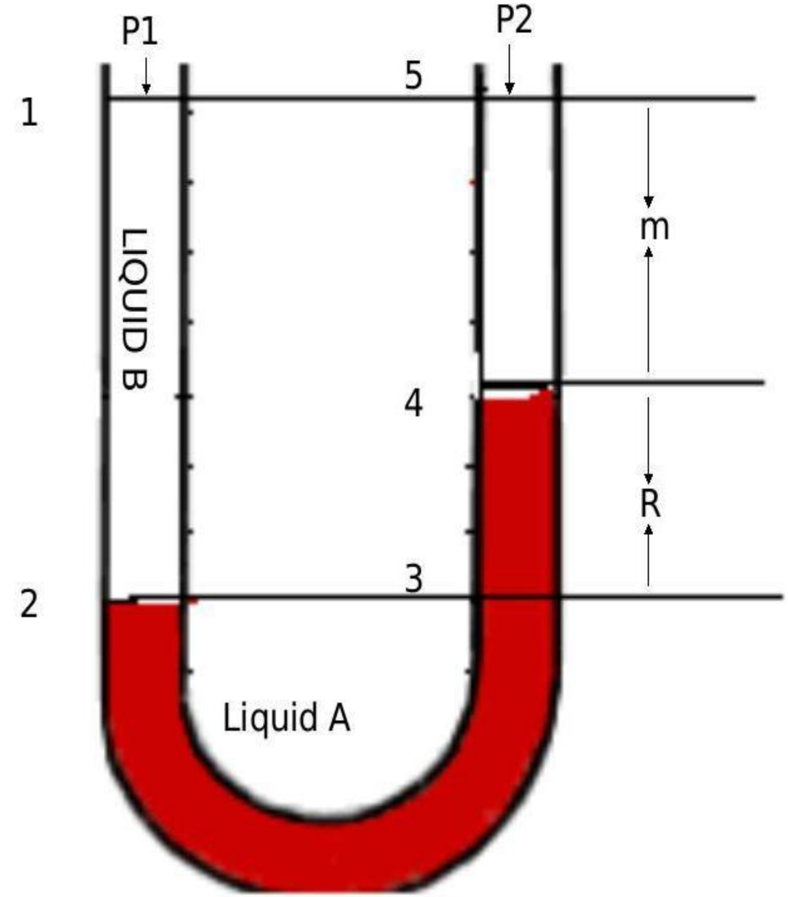


- Let pressure at point 1 will be P_1 Pascal's and point 5 will be P_2 Pascal's

- The pressure at point 2 can be written as

$=P_1 + (m + R)\rho_B g$

since $\Delta P = \Delta h \rho g$ (m + R) = distance from 3 to 5



- Since the points 2 and 3 are at same height the pressure

Pressure at **3** $= P_1 + (m + R)\rho_B g$

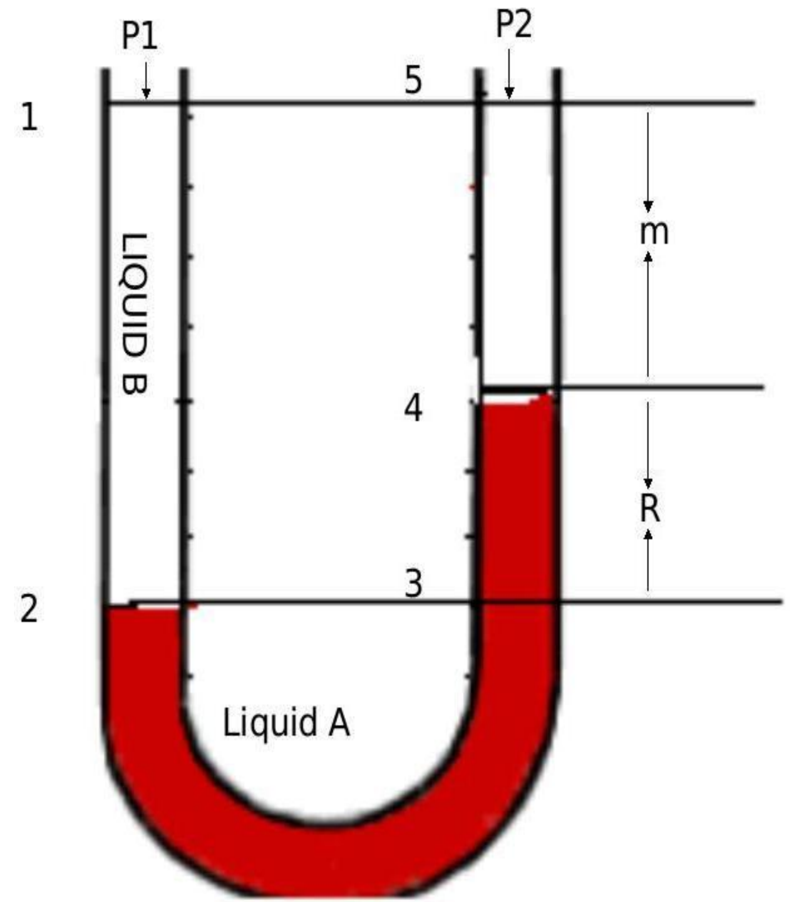
- Pressure at **4** is less than pressure at point 3 by $R \rho_A g$

- Pressure at **5** is still less than pressure at point 4 by $m\rho_B g$

- **This can be summarise as**

$$P_1 + (m + R)\rho_B g - R\rho_A g - m\rho_B g = P2$$

$$\Delta P = P_1 - P_2 = R(\rho_A - \rho_B)g$$



Application

- Pressure difference can be determined by measuring R

- Manometers are use in measuring flow of fluid.

DIFFERENTIAL MANOMETERS

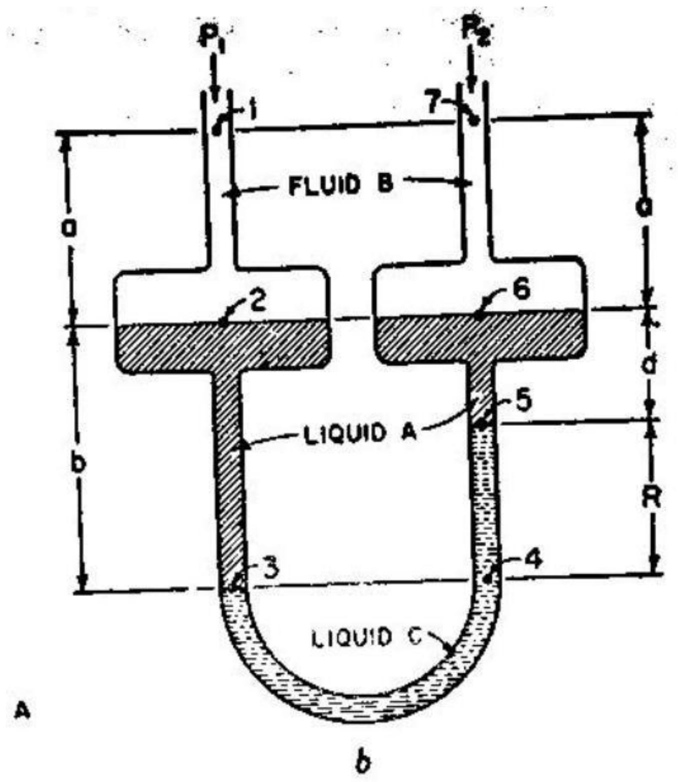
DIFFERENTIAL MANOMETERS

- These manometers are suitable for measurement of small pressure differences
- It is also known as *two – Fluid* U- *tube manometer*
- It contains two immiscible liquids A and B having nearly same densities
- The U tube contains of enlarged chambers on both limbs,
- Using the principle of simple manometer the pressure differences can be written as

$$\Delta P = P1 - P_2 = R(\rho_c - \rho_A)g$$

- $\Delta P = P_1 - P_2 = R(\rho_c - \rho_A)\,g$

- Hence smaller the difference between **ρ_c and ρ_A** larger will be R



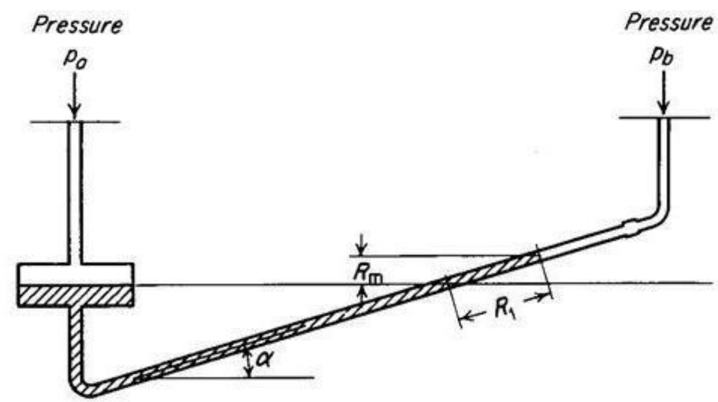
INCLINED TUBE MANOMETERS

INCLINED TUBE MANOMETERS

- Many applications require accurate measurement of low pressure such as drafts and very low differentials, primarily in air and gas installations.

- In these applications the manometer is arranged with the indicating tube inclined,

- This enables the measurement of small pressure changes with increased accuracy.



$$P_a - P_b = gR_1(\rho_a - \rho_b)\sin\alpha$$

$$P_A - P_B = g\,R\,(\rho_A - \rho_B)\sin\alpha$$

MEASUREMENT OF RATE OF FLOW OF FLUIDS

MEASUREMENT OF RATE OF FLOW OF FLUIDS

- Methods of measurement are
  - Direct **weighing** or measuring
  - **Hydrodynamic** methods
    - Orifice meter
    - Venturi meter
    - Pitot meter
    - Rotameter
  - Direct **displacement** meter
    - Disc meters
    - Current meter

DIRECT WEIGHING OR MEASURING

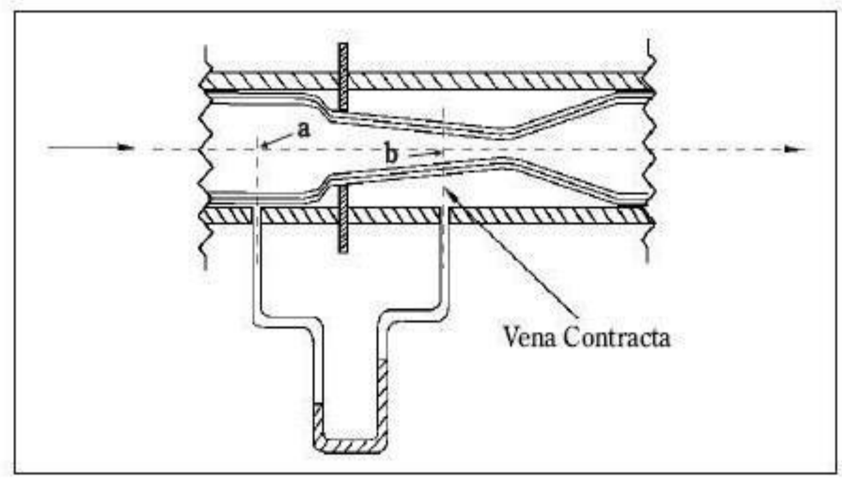
- The liquid flowing through a pipe is collected for specific period at any point and weighed or measured, and the rate of flow can be determined.

- Gases can not be determined by this method

ORIFICE METER

Variable head meter

- **Principle**
  - Orifice meter is a thin plate containing a narrow and sharp aperture.
  - When a fluid stream is allowed to pass through a narrow constriction the **velocity of the fluid increase** compared to up stream
  - This results in **decrease in pressure** head and the difference in the pressure may be read from a manometer



The orifice meter measures pressure e.g. at point a and b determines the flow rate.

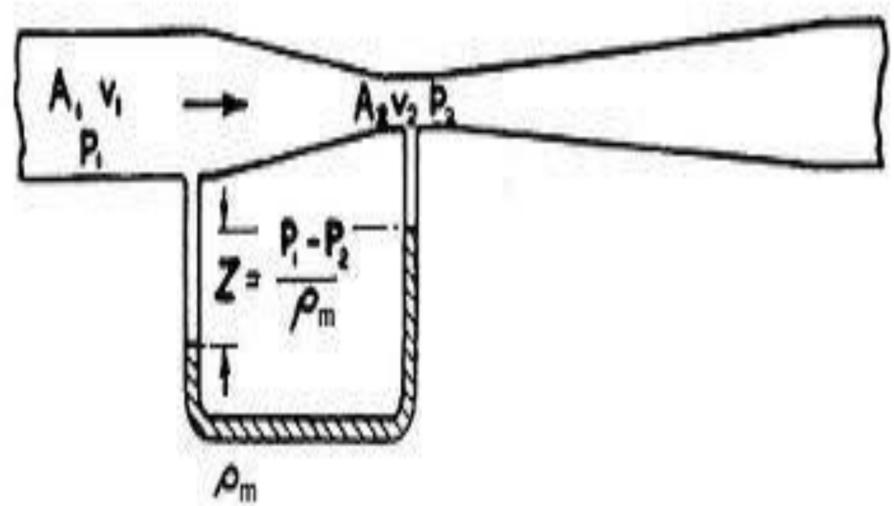
Applications

- Velocity at either of the point A and B can be measured.
- Volume of liquid flowing per hour can be determined by knowing area of cross section.

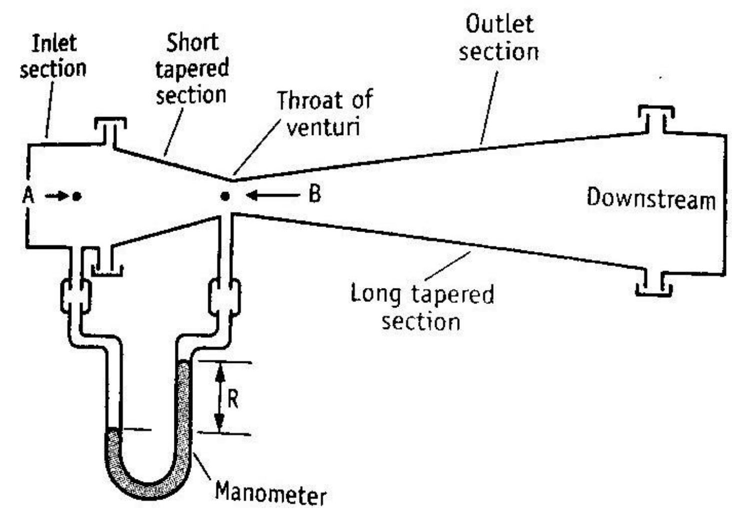
VENTURI METER
Variable head meter

- Principle
  - When fluid is allowed to pass through narrow venturi throat then velocity of fluid increases and pressure decreases
  - Difference in upstream and downstream pressure head can be measured by using Manometer

$$U_v = C_v \sqrt{2g \cdot \Delta H}$$



Velocity head increased
Pressure head decreased



Why Venturi meter if Orifice meter is available?

- Main disadvantage of orifice meter is power loss due to **sudden contraction** with consequent **eddies** on other side of orifice plate.

- We can minimize power loss by gradual contraction of pipe

- Ventury meter consist of two tapperd (conical section) inserted in pipeline

- Friction losses and eddies can be minimized by this arrangement.

Differences Between Orifice Meter and Venturi Meter

Orifice meter	*Venturi meter*
(1) Cheap	Expensive
(2) Easy to install	Fabrication is highly technical
(3) Construction can be made at home	It should be purchased from the instrument dealer
(4) Head losses are more	Head losses are insignificant
(5) Power losses are more particularly coefficient of discharge is high	Power losses are less, hence on fluid that is carried for long periods of time
(6) Normally used for testing purposes, for example, steam lines etc.,	Used in on-line installation
(7) Greater flexibility	Not flexible, permanent
(8) Reading of the orifice meter is larger under identical conditions	The reading of venturi meter is comparatively smaller under identical conditions

Pitot tube

Pitot tube

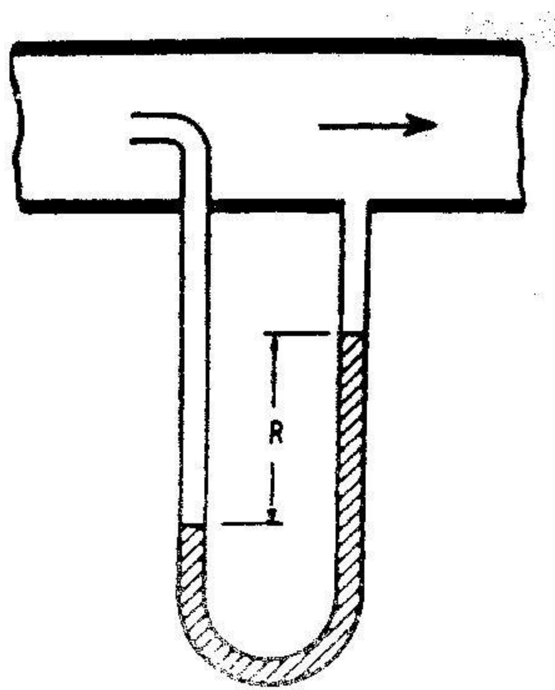
Insertion meter

- Principle
- According to Bernoulli's therom

Total energy at any point =Pressure energy + Potential energy + K. E

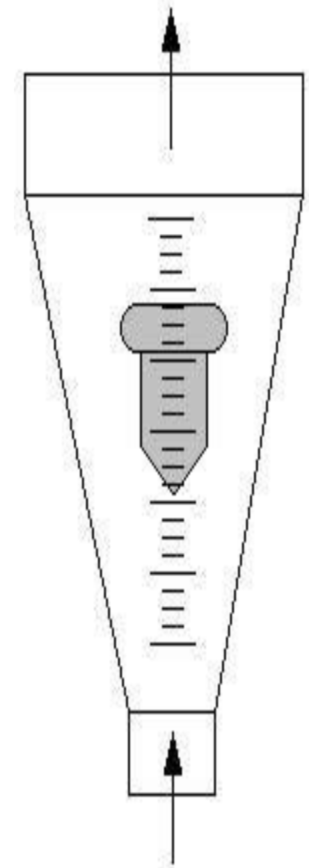
$U_0 = C_0 \sqrt{2g \Delta H}$ ....ΔH= Difference in pressure head

$\Delta H = U_2 / 2g$ ....U= Velocity at point of incertion



ROTAMETER
Variable area meter

- **Principle**
  - In this device a stream of water enters Transparent tapered tube and strikes the moving plummet
  - During fluid flow plummet rise or fall
  - As a result, **annular space (area) between plummet and tapperd tube may increase or decrease**, depending on variation of flow rate.
  - Head across annulus is equal to weight of plummet.
- **Use**
  - To measure flow rate of gas as well as liquid
  - Easy to use and allow direct visual inspection



CURRENT FLOW METER

CURRENT FLOW METER

- **Construction**
- It has a **propeller** which is rotated when water hits it and is connected to magnets which actuates **recorders** when the propeller rotates.

- The velocity of water increases the propeller rotation.
- The number of rotations are measured and correlated to velocity of fluid using the formula:

$$V = a + bN$$

-where **N** is the rotation of the propeller (revs per sec)
-a and **b** are coefficients determined by calibration in an experimental setup

Thank you !!!