DEPARTMENT OF MECHANICAL ENGINEERING

SUBJECT: - FLUID MECHANICS

(TH.2)

PREPARED BY : ER. RANJIT GIRI

SEMESTER – 4TH

NILASAILA INSTITUTE OF SCIENCE AND TECHNOLOGY

SERGARH (BALASORE)

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Unit-01 PROPERTIES OF FLUID

1. Introduction

Fluid mechanics is a branch of engineering science which deals with the behavior of fluids (liquid or gases) at rest as well as in motion.

2. Properties of Fluids

2.1 Density or Mass Density

-Density or mass density of fluid is defined as the ratio of the mass of the fluid to its volume.

Mass per unit volume of a fluid is called density.

-It is denoted by the symbol „ρ‟ (rho).

-The unit of mass density is kg per cubic meter i.e. kg/m3.

-Mathematically,

$$\rho = \frac{Mass\ of\ fluid}{Volume\ of\ fluid}$$

-The value of density of water is 1000 kg/m3, density of Mercury is 13600 kg/m3.

2.2 Specific Weight or Weight Density

-Specific weight or weight density of a fluid is defined as the ratio of weight of a fluid to its volume.

-Thus weight per unit volume of a fluid is called weight density.

-It is denoted by the symbol „w‟.

-Mathematically,

$$w = \frac{Weight\ of\ fluid}{Volume\ of\ fluid} = \frac{\text{Mass of fluid X Acceleration due to gravity}}{\text{Volume of fluid}} = \frac{\text{m X g}}{V}$$

$w = \rho g$

-The value of specific weight of water is 9.81 X 1000 = 9810 N/m3 in SI unit.

2.3 Specific Volume

-Specific volume of a fluid is defined as the volume of a fluid occupied by a unit mass of fluid.

-Thus specific volume is volume per unit mass of fluid.

-It is expressed as m3/kg.

-Thus specific volume is the reciprocal of mass density.

- Mathematically,

$$v = \frac{Volume\ of\ fluid}{Mass\ of\ fluid}$$

2.4 Specific Gravity or Relative Density

-Specific gravity is define as the ratio of the density (or weight density) of a fluid to the density

(or weight density) of a standard fluid.

-For liquids, standard fluid is taken water and for gases, standard fluid is taken air.

-Specific gravity is also called relative density.

-It is dimensionless quantity and is denoted by symbol S.

- Mathematically,

$$S = \frac{\text{Density of fluid}}{\text{Density of standard fluid}}$$

-Specific gravity of Mercury is 13.6 and water is 1.

2.5 Dynamic Viscosity

-Viscosity is defined as the property of fluid which offers resistance to the movement of one layer of fluid over another adjacent layer of fluid.

-When two layers of a fluid distance „dy‟ apart, move one over the another at different velocities, say u and u + du as shown in fig., the viscosity together with relative velocity causes a shear stress acting between the fluid layers.

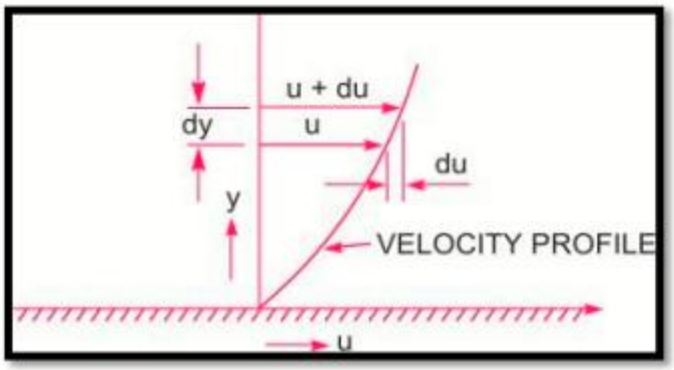


Fig. Velocity variation near a solid boundary

Velocity variation near a solid boundary

-The top layer causes a shear stress on the adjacent lower layer while the lower layer causes shear stress on the adjacent top layer. This shear stress is proportional to the rate of change of velocity with respect to y.

-It is denoted by symbol (Tau).

$$\tau \; \alpha \frac{du}{dy}$$

$$\tau = \mu \frac{du}{dy}$$

-Where µ (called mu) is the constant of proportionality and is known as the co- efficient of Dynamic viscosity or only viscosity. (du/dy) represents the rate of shear strain or rate of shear deformation or velocity gradient.

$$\mu = \frac{\tau}{du/dy}$$

-Viscosity is also defined as the shear stress required producing unit rate of shear strain.

Unit- SI Unit- Ns/ m2or Pa.s, CGS Unit- dyne.s/cm2

or posie.

1 Poise = 0.1 Ns/ m2

Newton’s Law of Viscosity-

-Its states that the shear stress ( ) on a fluid element layer is directly proportional to the rate of

shear strain. The constant of proportionality is called the co-efficient of viscosity.

-Mathematically,

$$\tau \,\alpha\, \frac{du}{dy} \longrightarrow \tau = \mu \frac{du}{dy}$$

Variation of Viscosity with Temperature-

-The viscosity of fluid is due to two contributing factors, namely

1. Cohesion between the fluid molecules

2. Transfer of momentum between the molecules

-In the case of gases the inter space between the molecules is larger and so the intermolecularcohesion is negligible. Hence temperature increases viscosity also increases.

- The intermolecular cohesive force decreases with rise of temperature and hence with theincrease in temperature the viscosity of a liquid decreases.

2.6 Kinematic viscosity

It is define as the ratio between the dynamic viscosity and density of fluid.

It is denoted by the Greek symbol υ (called „nu‟).

Thus mathematically,

Kinematic viscosity

$$\upsilon = \frac{Dynamic\ Viscosity}{Density} \qquad \upsilon = \frac{\mu}{\rho}$$

Unit – SI Unit – m^2/s, CGS Unit- cm/s or stoke.

1 stoke = 10^{-4} m^2/s

Classification of fluid

The fluid may be classified into the following five types:

1. Ideal fluid 2. Real fluid 3. Newtonian fluid 4. Non-Newtonian fluid 5. Ideal plastic fluid.

Ideal Fluid

1. - A fluid, which is incompressible and is having no viscosity, is known as ideal

fluid. Ideal fluid is only an imaginary fluid because all the fluids, which exit, have some viscosity.

2. Real Fluid-

A fluid which possesses viscosity is knownas real fluid. All the fluids in practice are real fluids.

3. Newtonian fluid-

A real fluid, in which the shear stress is directly proportional to the rate of shear strain (or velocity

gradient), is known as the Newtonian fluid.

Example: Water, Air, Thin motor oil

4. Non-Newtonian Fluid –

A real fluid, in which the shear stress is not proportional to the rate of shear strain (or velocity gradient), is known as the non Newtonian fluid.

Example: Tooth Paste

5. Ideal-Plastic Fluid- A fluid, in which shear stress is more than the yield value and shear

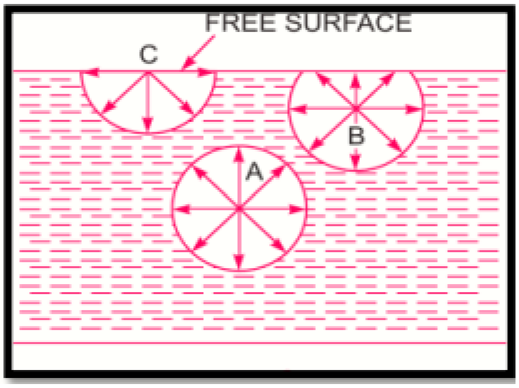
stress is proportional to the rate of shear strain(or velocity gradient), is known as ideal plastic

fluid.

2.7 Surface tension

-Surface tension is defined as the tensile force acting on the surface of a liquid in contact with a gas or on the surface between two immiscible liquid such that the contact surface behaves like a membrane under tension.

-It is denoted by Greek letter σ (sigma).-SI unit of surface tension is N/m, and MKS unit iskgf/m.



- Consider three molecules A, B, C of a liquid in a mass of liquid. The molecule A is attracted in all directions equally by the surrounding molecules of the liquid. Thus resultant force acting on molecule A is zero. But molecule B, which is situated near the free surface, is acted upon by upward and downward forces which are unbalanced. Thusa net resultant force on molecule B is acting in the downward direction. The molecule C,Situated on the free surface of liquid, does experience resultant downward force. All the molecules on the free surface of the liquid act like a very thin film under tension of the surface of the liquid act as through it is an elastic membrane under tension.

1. Surface Tension on Liquid Droplet – P =

$\frac{4\sigma}{d}$ Where, P= Pressure developed inside droplet.

σ = Surface tension and d = diameter of droplet.

2. Surface Tension on a Hollow Bubble- P =

$\frac{8\sigma}{d}$

3. Surface Tension on a Liquid Jet- P=

$P = \frac{2\sigma}{d}$

2.8 Capillarity or Meniscus Effect

-Capillarity is defined as a phenomenon of rise or fall of s liquid surface in a small tube relative to the adjacent general level of liquid when tube is held vertically in the liquid.

-The rise of the liquid surface is known as capillarity rise while the fall of liquid surface is known as capillarity depression or fall.

-It is expressed in terms of cm or mm of liquid.

-Its value depends upon the specific weight of the liquid, diameter of the tube and surface tension of the liquid.

Capillary Rise Fig.

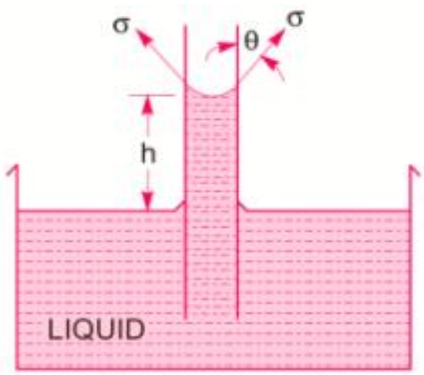


Fig. Capillary Rise

Capillary fall fig

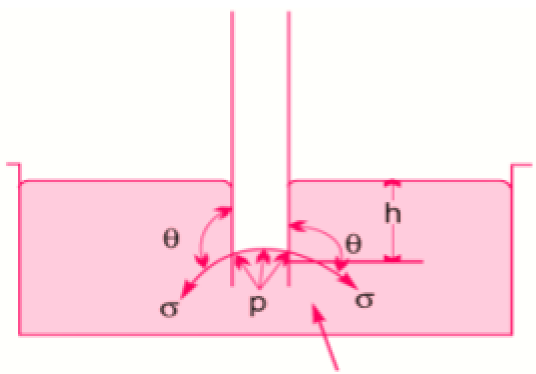


Fig. Capillary fall

- Expression for Capillarity Rise or fall,

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

-Where, h = Capillarity Rise or fall

,σ = Surface tension

Ɵ = Angle of contact between glass and tube.

Value of Ɵ for mercury and glass tube is 128 ^{0}and water and glass tube is 0 ^{0}

. ρ= Density of fluid d = Diameter of capillary tube

UNIT -02Fluid Pressure & Pressure Measurement

3.1 Fluid pressure

"It is defined as a normal force exerted by a fluid per unit area."

Pressure =

$$\frac{Force}{Area}$$

Unit: 1 Pa = 1 N/m^2 ,1 bar = 105 N/m^2

Pressure head

"Pressure exerted by a liquid column can also be expressed as the height of equivalent liquid

column called pressure head."

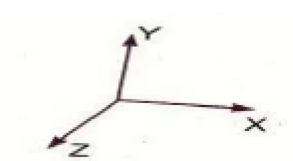
Pressure P = ρ g h

Where, P = Fluid Pressure, ρ = Density of fluid, h = Pressure head

Pressure head =

$\frac{P}{\rho g}$ Unit, meter of fluid, cm of fluid.

Pascal's Law



"Pressure or Intensity of pressure at a point in a static fluid is equal inall directions."

Px = Py = Pz

3.2 Concept of absolute vacuum, gauge pressure, atmospheric pressure, absolutepressure

1. Atmospheric Pressure

-This pressure exerted by the atmosphere on any surface is called atmospheric pressure.

-Atmospheric pressure at a place depends on the elevation of the place and the temperature.

Atmospheric pressure is measured using an instrument called „Barometer‟ and hence atmospheric pressure is also called Barometric pressure.

-Atmospheric pressure ate Mean Sea Level is 1.01325 bar or 1.01325 X 105 N/m^2

.- Atmospheric pressure = 1.01325 bar =1.01325 X 105 N/m^2

= 10.33 m of water = 0.76 m of Hg

2. Absolute Pressure

-It is defined as the pressure which is measured with reference to absolute zero pressure.

-Absolute pressure at a point can never be negative since there can be no pressure less than absolute zero pressure.

3. Gauge Pressure

-It is defined as the pressure which is measured above the atmospheric pressure.

-It can be measured by pressure measuring instrument in which atmospheric pressure is taken as datum and it marked as zero.

4. Vacuum Pressure (Negative Gauge Pressure)

-It is defined as the pressure below the atmospheric pressure.

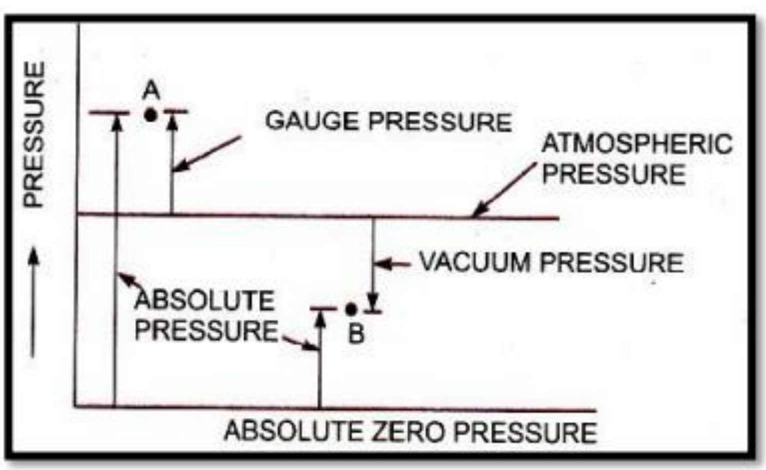


Fig. Relationship between pressures

Relationship between pressures

-Absolute Gauge Pressure = Atmospheric Pressure + Gauge Pressure

-Absolute Vacuum Pressure = Atmospheric Pressure - Vacuum Pressure

3.3 Measurement of Pressure

Various devices used to measure fluid pressure can be classified into,

1. Manometers 2. Mechanical gauges

1. Manometers- Manometers are the pressure measuring devices which are based on the principal of balancing the column of the liquids whose pressure is to be measured by the same liquid or another liquid.

Manometers are broadly classified into:

A. Simple Manometers

B. Differential Manometers

2. Mechanical Gauges - Mechanical gauges consist of an elastic element which deflects under the action of applied pressure and this movement will operate a pointer on a graduated scale.

The mechanical pressure gauges are:

A. Diaphragm pressure gauge

B. Bourdon tube pressure gauge

C. Dead weight pressure gauge

D. Below pressure gauge

3.4 Simple Manometers and Differential Manometer

1. Simple Manometers

-Simple monometers consists of glass tube having one of its end connected to a point where pressure is to be measured and other end is open to atmosphere.

-Types of Simple manometers are:

a. Piezometer

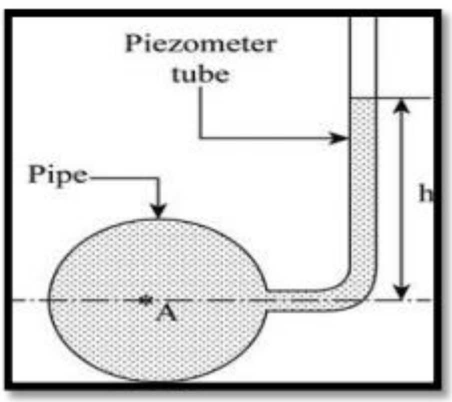
b. U-tube manometer

c. Single column manometer

d. Inclined column manometer

a. Piezometer

-It consists of a glass tube inserted in the wall of the vessel or pipe at the level of point at which the intensity of pressure is to be measured as shown in Fig. The other end of the piezometer is exposed to air. The height of the liquid in the piezometer gives the pressure head from which theintensity of pressure can be calculated.



-If at a point A, the height of liquid say water h in piezometer tube, then pressure at point A is given by ρ g h.

PA = ρ g h

-To minimize capillary rise effects the diameters of the tube is kept more than 12mm.

Merits

1. Simple in construction

2. Economical

1. Not suitable for high pressure intensity.

2. Pressure of gases cannot be measured.

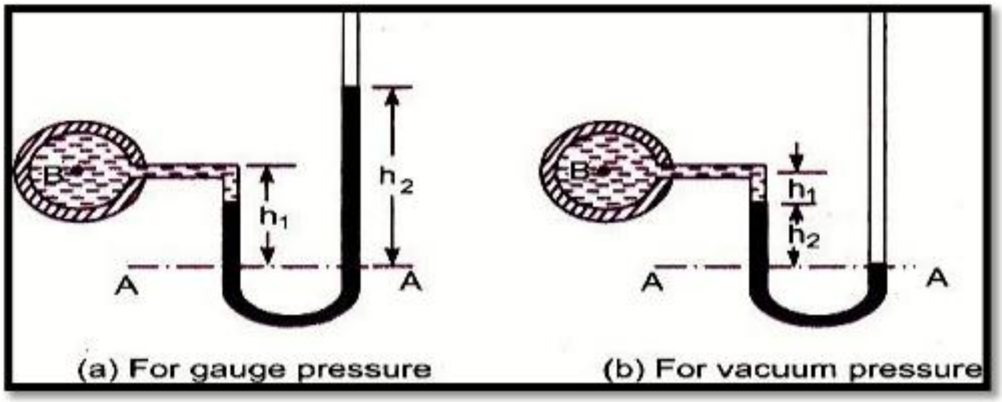
b Simple U-tube Manometer.

-A U-tube manometer consists of a glass tube bent in U-Shape, one end of which is connected to the point at which pressure is to be measured and the other end is exposed to atmosphere. U-tube consists of a liquid of specific of gravity is greater than the specific gravity of the liquid whose pressure intensity is to be measured.

(A) For Gauge Pressure

Let B is the point at which pressure is to be measured, whose value is p. The datum line is A-A

as shown in Fig.



Let, h1 = Height of the light liquid above the datum line

h2 = Height of the heavy liquid above the datum line

ρ1 is density of light liquid (pipe fluid) and ρ2 is density of heavy liquid (Monomeric Fluid)

-As the pressure is the same for the horizontal surface. Hence pressure above the horizontal datum line A- A in the left column and in the right column of U-tube manometer should be same.

Hence, Pressure above datum line above A- A in the left column = Pressure above datum line above A-A in the right column

PB + ρ1 g h1 = ρ2 g h2

PB = ρ2 g h2 - ρ1 g h1

(B) For Vacuum Pressure

-For measuring vacuum pressure, the level of the heavy liquid in the manometer will be as

Shown in Fig.

Hence, Pressure above datum line above A- A in the left column = Pressure above datum line

Above A-A in the right column

PB + ρ1 g h1 + ρ2 g h2 = 0

$P_B = -(\rho_2 g h_2 + \rho_1 g h_1)$

c. Single Column Manometer

-A single column manometer is a modified form of U-tube manometer in which reservoir having large cross sectional area (100 times) as compared to cross sectional area of U – tube connected to it as shown in Fig. 2.7.

-For any change in pressure, change in the level of manometeric liquid in the reservoir is small and change in level of manometric liquid in the U- tube is large. The other limb may be vertical or inclined. Thus there are two type of single column manometer as:

1. Vertical single column manometer
2. Inclined single column manometer

1. Vertical single column manometer

Fig. shows the vertical single column manometer. Let X-X be the datum line the reservoir and in the right limb of the manometer, when it is not connected to the pipe. When the manometer is connected to the pipe, due to high pressure at A, the heavy liquid in the reservoir will be pushed downwards and will rise in the right limb.

Where, dh= Fall of the heavy liquid in reservoir

h_2 = Rise of heavy liquid in right limb

h_1 = Height of centre of pipe above X -X

P_A = Pressure at A

ρ_1 is density of liquid in pipe and ρ_2 liquid in reservoir.

As the area A is very large compared to a, hence dh is neglected.

$P_A = \rho_2 g h_2 - \rho_1 g h_1$

2. Inclined Single Column Manometer

Fig. shows the inclined single column manometer. This manometer is more sensitive. Due to inclination the distance moved by the heavy liquid in the right limb will be more.

Let L = length of heavy liquid moved in right limb form X – X

= Inclination of right limb with horizontal

h_2 = Vertical rise of heavy liquid in right limb from = L Sin

The pressure at A is, $P_A = \rho_2 g h_2 - \rho_1 g h_1$

$P_A = \rho_2 g L \sin - \rho_1 g h_1$

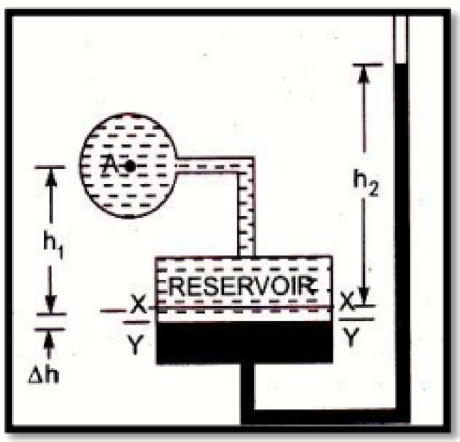


Fig. Vertical single column manometer

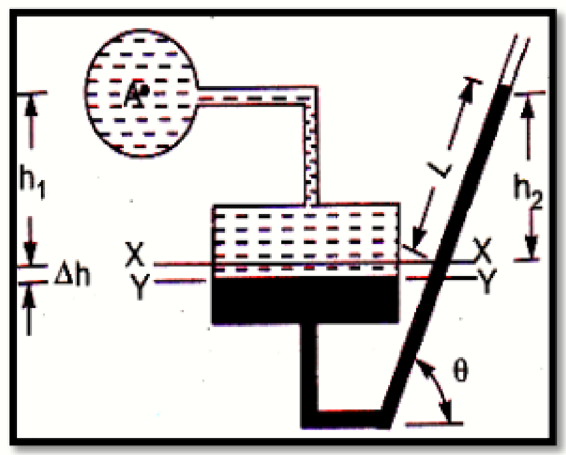


Fig. Inclined single column manometer

2. Differential Manometer

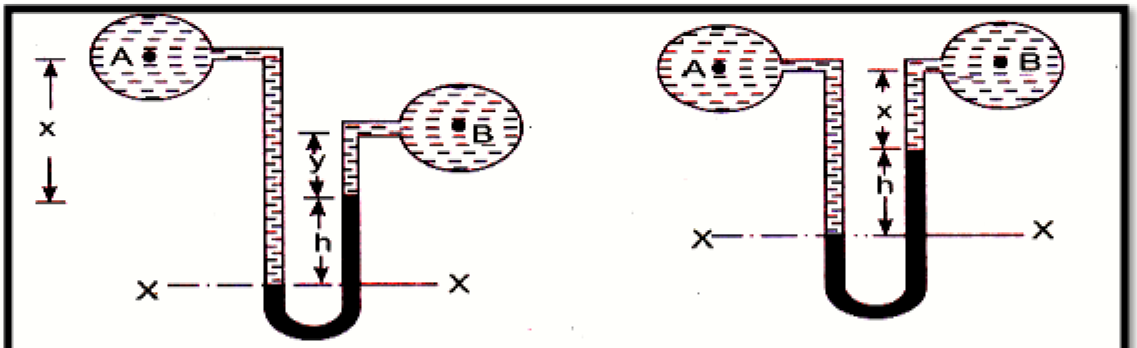
-Differential manometers are used to measure the pressure difference between two points. It is consists of a U-tube, containing heavy liquid, whose two ends are connected to the two points, whose difference of pressure is to be measured.

Types of differential manometers are:

a. U-tube Differential manometers

b. Inverted U-tube differential manometers

a. U-tube Differential manometers



(a)Two pipes at different levels (b) A and B are at the same level

(a), the two points A and B are at different level and also contained liquids of differentspecific gravity. These points are connected to the U-tube manometer. Let the pressure at A and B are PA and PB .

Let, h = Difference of mercury level,

y = Distance of the centre of B, from the mercury level in the right limb

x = Distance of the centre of A, from the mercury level in the right limb

$\rho 1$ Density of liquid at A, $\rho 2$ Density of liquid at B and ρg Density of manometric liquid.

Taking at datum line at X-X,

Pressure above X-X in the left limb = Pressure above X-X in the right limb

$PA + \rho 1\, g\, (x + h) = PB + \rho 2\, g\, y + \rho g\, g\, h$

$PA - PB = \rho 2\, g\, y + \rho g\, g\, h - \rho 1\, g\, (x + h)$

In Fig. (b), the two points A and B are at same level and contained liquids of different density.

Taking at datum line at X-X,

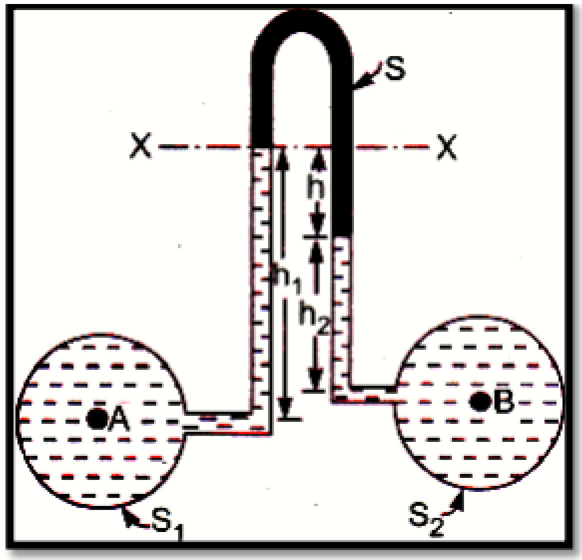
Pressure above X-X in the left limb = Pressure above X-X in the right limb

$PA + \rho 1\, g\, (x + h) = PB + \rho 2\, g\, x + \rho g\, g\, h$

$PA - PB = \rho 2\, g\, x + \rho g\, g\, h - \rho 1\, g\, (x + h)$

b. Inverted U-Tube Differential Manometers

-It consists of an inverted U-tube having two ends are connected to the pipes at points A and Bwhose difference of pressure is to be measured as shown in Fig. It is used for measuring the difference of low pressures. Let the pressure at A is more than the pressure at B.



Let, h1= Height of liquid in left limb below the datum line X- X

h2 = Height of liquid in right limb

h = Difference of manometric fluid (Generally Light Liquid used)

ρ1 = Density of liquid at A

ρ2 = Density of liquid at B

ρs = Density of light liquid

PA = Pressure at A

PB = Pressure at B

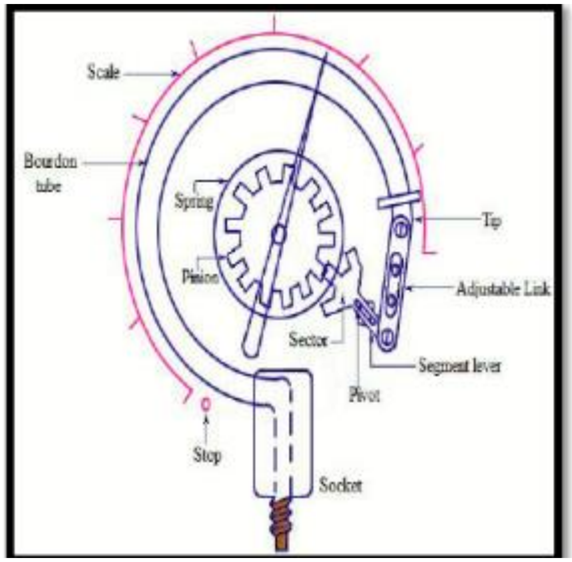
Pressure below datum line X-X in the left limb = Pressure below datum line X-X in the right limb

$P_A - \rho_1 g h_1 = P_B - \rho_2 g h_2 - \rho_S g h$

$P_A - P_B = \rho_1 g h_1 - (\rho_2 g h_2 + \rho_S g h)$

3.5 Bourdon tube pressure gauge

-This gauge is consist of elastic bent in circular arc, fixed at one end and free at other end as shown in Fig. The fixed end is attached at the side of application of pressure and free endattached with the sector through adjustable link. The sector is in mesh with the pinion which is fixed with the pointer on the calibrated scale.



-When the pressure inside the tube is increase tube will uncoil. So that the pointer gives are ading on the scale due to movement of the pinion through sector and free end of tube. Tube material: Brass, copper, stainless steel etc.

Advantages: Simple construction,

Low cost, high pressure range (up to 700 kPa)

, Accuracy is a good.

Disadvantage: Susceptibility to shock andvibration, spring constant effect is majorconsideration.

Why mercury is used as Manometric fluid / Desirable property of manometricfluid1. It has very high density so Hg column require les height.

2. It does not mix up with the liquids in the pipes.

3. It does not stick to the surface of tube.

4. At room temperature, the vapour pressure is negligible.

5. It does not chemically react with other liquids.

Advantages of Mechanical gauges over manometer

1. It provides correct measurement.

2. Small in size, occupies less space.

3. It can use for large variation in pressure.

4. Pressure can directly read on the scale and does not require any conversion.

Liquid use for manometer

1. Mercury 2. Water 3. Alcohol 4. Kerosene 5. Oil

UNIT-3 HYDROSTATIES

DEFINITION OF HYDROSTATIC PRESSURE

Hydrostatic pressure is the pressure exerted by a fluid at rest due to the force of gravity. It's the pressure you feel when you dive to the bottom of a swimming pool. Hydrostatic pressure applies to all fluids, meaning all liquids and gases (a fluid is any substance that can flow and change its shape).

Total Pressure and Centre of Pressure

Total pressure is defined as the force exerted by a static fluid on a surface either plane or curved when the fluid comes in contact with the surface and this force always normal to the surface.

Centre of pressure is defined as the point of application of the total pressure on the surface.

The submerged surfaces may be:

1. Plane surface submerged in static fluid

a. Vertical plane surface

b. Horizontal plane surface

c. Inclined plane surface

Sr. No.	Type of Submerged Surface	Diagram	Total Pressure (F)	Centre of pressure (h)
1	Vertical plane surface		F= ρ g A x	$h = \frac{IG\ Sin^2\theta}{A\ x} + x$ Where $\theta = 90^0$ $Sin90^0 = 1$ Hence, $\mathbf{h = \frac{IG}{A\ x} + x}$
2	Horizontal plane surface		F= ρ g A x	$h = \frac{IG\ Sin^2\theta}{A\ x} + x$ Where $\theta = 0^0$ $Sin0^0 = 0$ Hence, $\mathbf{h = x}$
3	Inclined plane surface		F= ρ g A x	Where $\theta =$ Between 0^0 to 90^0 $\mathbf{h = \frac{IG\ Sin^2\theta}{A\ x} + x}$

Where, F = Total Pressure, N

h = Centre of pressure, m

ρ = Density of fluid, kg/m3

A = Area of given surface, m

2

IG = MI about centroidal axis X-X, m

4

= Inclination angle of surface

x = Distance of CG of given surface from free surface, m

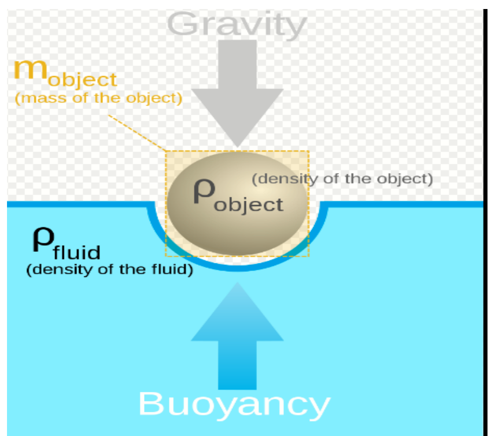
h = Distance of Centre of pressure from free surface, m

Archimedes Principle

When a body is immersed fully or partially in a fluid, it experiences a buoyant force in upward direction which is equal to the weight of the fluid displaced by the body. Archimedes' principle is a law of physics fundamental to fluid mechanics.It was given by archimedes of syracuse.The principle applies to both floating and submerged bodies and to all fluids, i.e., liquids and gases. It explains not only the buoyancy of ships and other vessels in water but also the rise of a balloon in the air and the apparent loss of weight of objects underwater. It will help to determine whether a body placed in a liquid will float or it will sink.

Definition of Buoyancy

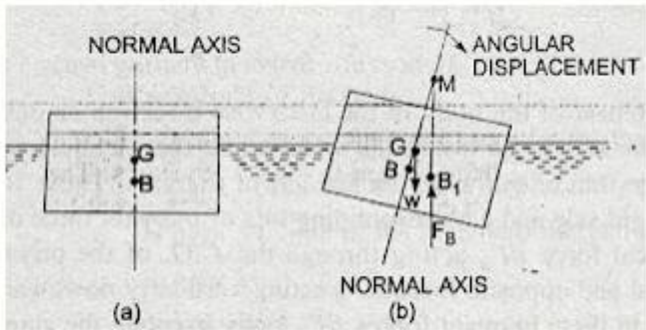
Buoyancy, or up thrust, is an upward force exerted by a fluid that opposes the weight of a partially or fully immersed object In a column of fluid, pressure increases with depth as a result of the weight of the overlying fluid. Thus the pressure at the bottom of a column of fluid is greater than at the top of the column. Similarly, the pressure at the bottom of an object submerged in a fluid is greater than at the top of the object. The pressure difference results in a net upward force on the object. The magnitude of the force is proportional to the pressure difference, and (as explained by Archimedes' principle) isequivalent to the weight of the fluid that would otherwise occupy the submerged volume of the object, i.e. the displaced fluid.



META-CENTRE

Meta-centre is basically defined as the point about which a body in stable equilibrium will start to oscillate when body will be displaced by an angular displacement.

We can also define the meta-centre as the point of intersection of the axis of body passing through the centre of gravity and original centre of buoyancy and a vertical line passing through the centre of buoyancy of the body in tilted position.



Let us consider a body which is floating in the liquid. Let us assume that body is in equilibrium condition. Let us think that G is the centre of gravity of the body and B is the centre of buoyancy of the body when body is in equilibrium condition.

In equilibrium situation, centre of gravity G and centre of buoyancy B will lie on same axis which is displayed here in above figure with a vertical line.

Let us assume that we have given an angular displacement to the body in clockwise direction as displayed here in above figure.

Centre of buoyancy will be shifted now towards right side from neutral axis and let us assume that it is now B1.

Line of action of buoyancy force passing through this new position will intersect the normal axis passing through the centre of gravity and centre of buoyancy in original position of the body at a point M as displayed here in above figure. Where, M is the meta-centre.

Meta-centric height

Meta-centric height is basically defined as the distance between the meta-centre of the floating body and the centre of gravity of the body.

FLOATATION

The principle of floatation states that when an object floats on a liquid the buoyant force that acts on the object is equal to the weight of the object.

UNIT-4 KINEMATICS OF FLOW

Fluid Kinematics - Kinematics is the branch of classical mechanics that describes the motion of bodies and systems without consideration of the forces the cause the motion.

Types of Fluid Flow:

There are Six different types of fluid flow:

Steady and Unsteady

Uniform and Non-Uniform

Laminar and Turbulent

Compressible and In-compressible

Rotational and Ir-rotational and

One, Two, and Three -dimensional Fluid Flow

1. Steady and Unsteady flows:

The steady flow is defined as that type of flow in which the fluid characteristics like velocity, density, pressure, etc at a point do not change with the time.

$$\frac{\partial V}{\partial t} = 0, \frac{\partial p}{\partial t} = 0, \frac{\partial J}{\partial t} = 0$$

Steady Flow

Steady Flow

The Unsteady flow is defined as that type of flow in which the fluid characteristics like velocity, density, pressure, etc at a point change respected to time.

unsteady flow

$$\frac{\partial V}{\partial t} \neq 0, \frac{\partial p}{\partial t} \neq 0, \frac{\partial J}{\partial t} \neq 0$$

Unsteady flow

2. Uniform and Non-uniform fluid flow:

This uniform fluid flow is defined as the type of flow in which the velocity at any given time does not change with respect to space (i.e length of direction of the flow).

$$(\frac{\partial V}{\partial t})t \text{ } is \text{ } a \text{ } constant = 0$$

Uniform flow

Whereas the Non-uniform flow is defined as,

This non-uniform fluid flow is defined as the type of flow in which the velocity at any given time changes with respect to space (i.e length of the direction of the flow).

$$(\frac{\partial V}{\partial t})t \text{ } is \text{ } a \text{ } constant \neq 0$$

non uniform flow

3. Laminar, and Turbulent fluid flow:

This laminar fluid flow is defined as the type of flow in which the fluid particles move along well-defined paths or streamline and all the streamlines are straight and parallel.

Thus the particles move in laminas or layers gliding smoothly over the adjacent layer. This type of fluid is also called as streamline flow or viscous flow.

This Turbulent fluid flow is defined as the type of flow in which the fluid particles move in a zig-zag way, the eddies formation takes place which is responsible for high energy loss

For pipe flow, The type of flow is determined by a non-dimensional number [(VD) / (v) nuo] called the Reynolds number.

Where,

D = Diameter of pipe

V = Mean velocity flow in a pipe

ν = Kinematic viscosity of the fluid.

If the Reynold Number is less than 2000, the flow is called Laminar flow.

Reynold Number is more than 4000, the flow is called Turbulent flow.

If the Reynold Number is lies between 2000-4000, the flow may be laminar or turbulent.

4. Compressible and Incompressible fluid flow:

Compressible fluid flow is defined as the flow in which the density is not constant which means the density of the fluid changes from point to point.

The density notation is ρ but here i have used J.

$$J \neq \text{constant}$$

Whereas

,Incompressible fluid flow is defined as the flow in which the density is constant which means the density of the fluid does not change from point to point.

J = constant

Gases are compressible fluid flow but whereas the liquid is incompressible fluid flow.

5. Rotational and irrotational Fluid flow:

The rotational fluid flow is defined as the type of fluid flow in which the fluid particles while flowing along streamline and also rotate about there own axis.

Whereas, The Ir-rotational fluid flow is defined as the type of fluid flow in which the fluid particles while flowing along streamline and do not rotate about there own axis.

6. One, Two and Three-dimensional fluid Flow:

One dimensional flow is that type of flow in which the flow parameter such as velocity is a function of time and one space co-ordinate only, say x.

u=f(x), v=0 and w=0

Where u,v and w are velocity component in x,y and z directions respectively.

Two-dimensional fluid flow is the type of flow in which velocity is a function of time and two rectangular space co-ordinate say x,y.

u= f1(x,y,), v= f2(x,y,) and w= 0.

Three-dimensional fluid flow is the type of flow in which velocity is a function of time and three mutually perpendicular directions. The function of 3 space coordinates (x,y,z).

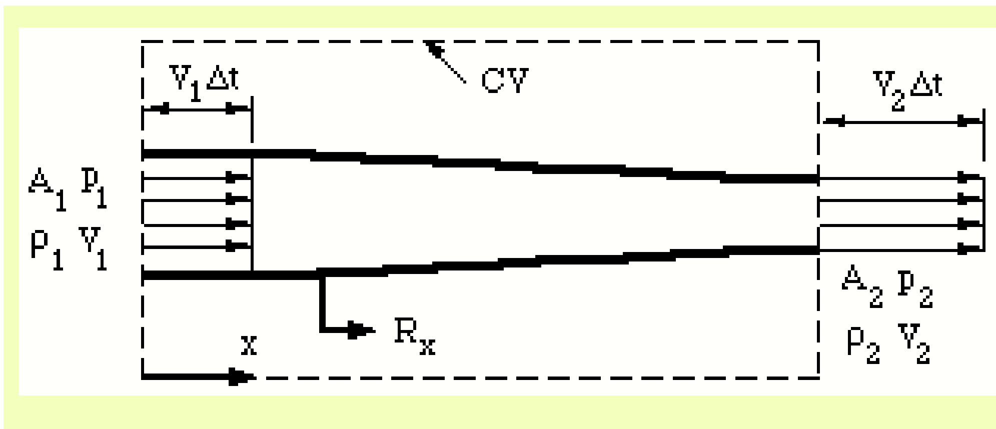
u= f1(x,y,z), v= f2(x,y,z) and w= f3(x,y,z)

CONTINUITY EQUATION

The continuity equation is defined as the product of cross-sectional area of the pipe and the velocity of the fluid at any given point along the pipe is constant.

Continuity Equation PROOF

When a fluid is in motion, it must move in such a way that mass is conserved. To see how mass conservation places restrictions on the velocity field, consider the steady flow of fluid through a duct (that is, the inlet and outlet flows do not vary with time). The inflow and outflow are one-dimensional, so that the velocity V and density \rho are constant over the area A (figure)



One-dimensional duct showing control volume.

Now we apply the principle of mass conservation. Since there is no flow through the side walls of the duct, what mass comes in over A_1 goes out of A_2, (the flow is steady so that there is no mass accumulation). Over a short time interval \Delta t,

$$\text{volume flow in over } A_1 = A_1 V_1 \Delta t$$
$$\text{volume flow out over } A_2 = A_2 V_2 \Delta t$$

Therefore

$$\text{mass in over } A = \rho A_1 V_1 \Delta t$$
$$\text{mass out over } A = \rho A_2 V_2 \Delta t$$

$$\text{So:} \quad \boxed{\rho A_1 V_1 = \rho A_2 V_2}$$

This is a statement of the principle of mass conservation for a steady, one-dimensional flow, with one inlet and one outlet. This equation is called the continuity equation for steady one-dimensional flow. For a steady flow through a control volume with many inlets and outlets, the net mass flow must be zero, where inflows are negative and outflows are positive.

Streamlines and Stream tubes

Bernoulli's principle

Bernoulli's principle states that The total mechanical energy of the moving fluid comprising the gravitational potential energy of elevation, the energy associated with the fluid pressure and the kinetic energy of the fluid motion, remains constant.

Bernoulli's Principle Formula

Bernoulli's equation formula is a relation between pressure, kinetic energy, and gravitational potential energy of a fluid in a container.

The formula for Bernoulli's principle is given as:

$p + 1/2\ \rho\ v^2 + \rho gh$ =constant

Where, p is the pressure exerted by the fluid

v is the velocity of the fluid

ρ is the density of the fluid

h is the height of the container

Bernoulli's equation gives great insight into the balance between pressure, velocity and elevation.

State and prove Bernoulli's theorem.

Bernoulli's Theorem:

According to Bernoulli's theorem, the sum of the energies possessed by a flowing ideal liquid at a point is constant provided that the liquid is incompressible and non-viseous and flow in streamline.

Potential energy + Kinetic energy + Pressure energy = Constant

$P+\ 1/2\ pv^2 + pgh$ = Constant

$gh + 1/2\ v^2 + P/P = C$ ....(11.11)

Where C is a constant.

This relation is called Bernoulli's theorem.

Dividing eqn. (11.11) by g, we get

$h + p/qg + 1/\ 2pv^2\ /g = C'$ ....(11.12)

Where C is another constant.

For horizontal flow, h remains same throughout.

So,

$p/pg + v^2\ /2g = \text{Constant}$

or; $P + 1/2\ pv^2 = \text{Constant}$

P is static pressure of the liquid and $1/2\ pv^2$ is its dynamic and velocity pressure .Thus, for horizontal motion, the sum of static and dynamic pressure is constant. If p 1 v 1 and p 2 v 2 represent pressure and velocities at two points. Then

$P_1 + 1/2\ pv_1^2 = P_2 + 1/2\ pv_2^{\ 2}$

Concepts : 1. In Bernoulli's theorem $P + pgh + 1/2\ ev^2$

= constant. The term (p+pgh) is called static pressure and the term $1/\ 2\ pv^2$ is the dynamic pressure of the fluid.

2. Bernoulli theorem is fundamental principle of the energy.

3. The equation $p/\ pg + 1/2gv^2 + h = \text{constant}$ the term

$p/\ pg$ =pressure head the term

$v^2/2g$= velocity head

Derivation of Bernoulli's Theorem :

The energies possessed by a flowing liquid are mutually convertible. When one type of energy increases, the other type of energy decreases and vice-versa. Now, we will derive the Bernoulli's theorem using the work-energy theorem.

Consider the flow of liquid. Let at any time, the liquid lies between two areas of flowing liquid A_1 and A . In time interval Δt, the liquid displaces from A_1 by $\Delta x_1 = v_1 \Delta t$ and displaces from A_1 by $\Delta x_1 = v_2 \Delta t$. Here v_1 and v_2 are the velocities of the liquid at A_1 and A_2 .

The work done on the liquid is $P_1 A_1 \Delta x_1$ by the force and $P_2 A_2 \Delta x_2$ against the force respectively.Net work done,

$W=P_1 A_1 \Delta x_1 - P_2 A_2 \Delta x_2$

$\Rightarrow W=P_1 A_1 v_1 \Delta t - P_2 A_2 v_2 \Delta t$

$= (P_1 - P_2)\Delta V$ ....(11.13)

Here, ΔV→ the volume of liquid that flows through a cross-section is same (from equation of continuity).

But, the work done is equal to net change in energy (K.E. + P.E.) of the liquid, and

$\Delta K= 1/2\ p\Delta V (v_1^2 - v_2^2)$ .... (11.14)

and $\Delta U= P\delta v (h_2 - h_1)$ .... (11.15)

$\therefore (P_1 - P_2)\Delta V= 1/2\ p\Delta V (v_1^2 - v_2^2)+pg\Delta V(h_2 - h_1)$

$P_1 + 1/2\ v^2 + pgh_1 = P_2 + 1/2 v_2^2 + pgh_2$

or $P+ 1/2\ pv^2 + pgh$ =constant .... (11.16)

This is the required relation for Bernoulli's theorem.

$\therefore A_1 v_1 = A_2 v_2$

So, more the cross-sectional area, lesser is the velocity and vice-versa.

So, Bernoulli's theorem,

$P_1 + ½ p_1 v_1^2 = P_2 + 1/2 \ p_2 v_2^2$

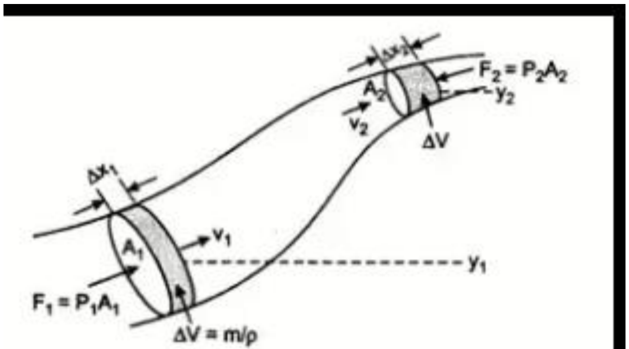


Fig. 11.11 : The flow ideal liquid in the tube of non uniform area of cross section.