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FLUID MECHANICS

FLUID MECHANICS

CHEMICAL: GATE & PSUs

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CHEMICAL ENGINEERING

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STUDY MATERIAL

FLUID MECHANICS

CONTENTS

List of Topics in GATE 2024 paper from Fluid Mechanics

Surface tension, Fluid kinematics, laminar flow incircular pipe, Laminar flow through parallel plates, Pump, Venturimeter

1×3 , 2×3 =Total 9 Marks


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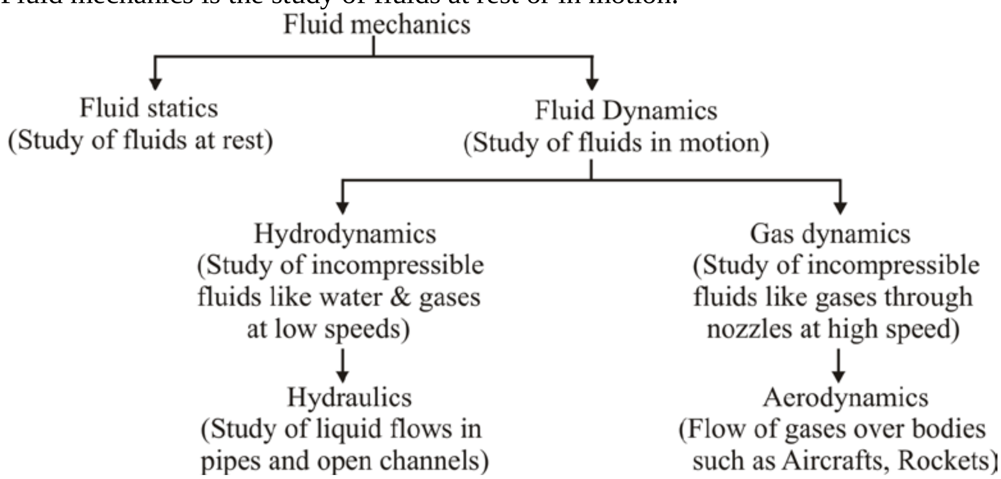
CHAPTER-1

INTRODUCTION

Introduction

Fluid mechanics is the study of fluids at rest or in motion.



Definition of fluid: A substance in the liquid or gas phase is referred to as a fluid. A fluid is a substance that deforms continuously under the utilization of a shear (tangential) stress no matter how small the shear stress may be. As shown in figure when a shear stress is applied at any location in a fluid, the element oaa' which is initially at rest, will move to obb', then to occ', odd' and so on.

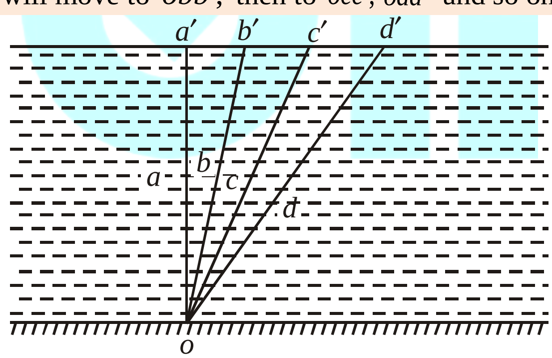


Fig.: Shear stress on a fluid only

→ The tangential stress in a fluid body relies on the velocity of deformation, and vanishes as the velocity approaches zero.

Distinction between a solid and a fluid

The molecules of a solid are more tightly packed as compared to that of the fluid.

A deformation of solid body undergoes either a definite angular deformation as shown in fig. The amount of deformation is proportional to the magnitude of utilized stress up to some limiting conditions.

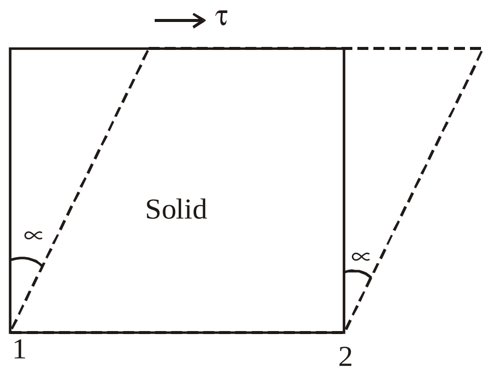


Figure: Deformation of a solid body

The angle of deformation α is called shear strain or angular displacement. Stress is defined as force per unit area. Normal component of a force acting on a surface per unit area is called normal stress, and tangential component of force acting on a surface per unit area is called shear stress. Here τ is the shear stress.

-In solids, stress is proportional to strain, but in fluids, stress is proportional to strain rate.

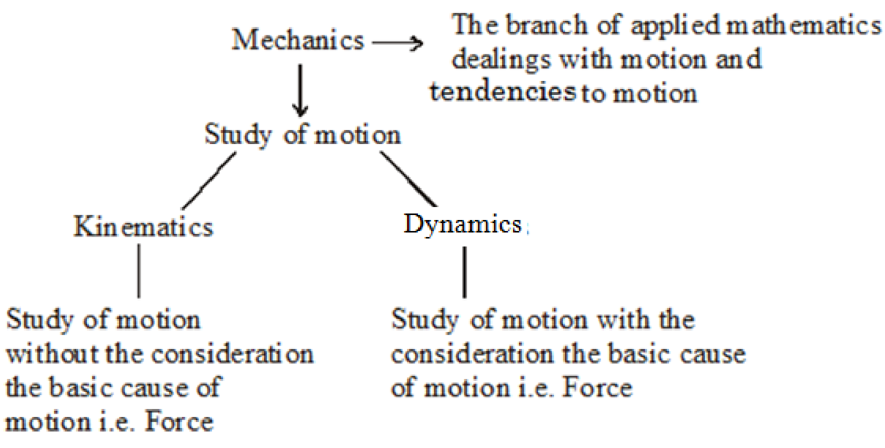
-When this was an element of fluid, there would have been no fixed and even angular deformation an infinitesimally small shear stress was utilized.

-It can be simply said that while solids can resists tangential stress under static conditions, fluids can do it only under Dynamics situation.

Gas and Vapour:

-Gas and vapour are used as synonymous words.

-The vapour phase of a substance is customarily called a gas when it is above critical temperature.



- S – distance in m $\quad \vec{V} = \dfrac{d\vec{s}}{dt}\ (\text{m/s}) \quad \vec{a} = \dfrac{d\vec{v}}{dt}\ (\text{m/s}^2)$
- $\boxed{\textbf{CGS system}}$
- $\vec{a}(\text{acceleration in m/s}^2) = \dfrac{d\vec{v}}{dt}$

Fluid is continuum: In macro system of fluid particles, the inter molecular distances can be treated as negligible as compare to the characteristics dimension of systems, so therefore we can assume adjacent to

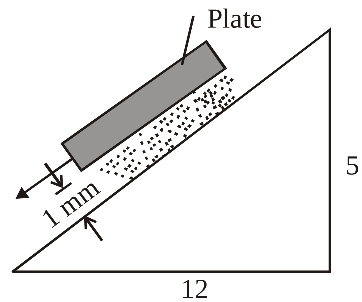
SOLVED PROBLEM

Example 1: A square plate of size 1m × 1m and weighting 350 N slides down an inclined plane with a uniform velocity of 1.5 m/sec. The inclined plane is laid on a slope of 5 vertical to 12 horizontal. Oil film thickness = 1mm

$\mu = ?$

Solution:

$$F = W\sin\theta = 350 \times \frac{5}{13} = 134.615$$

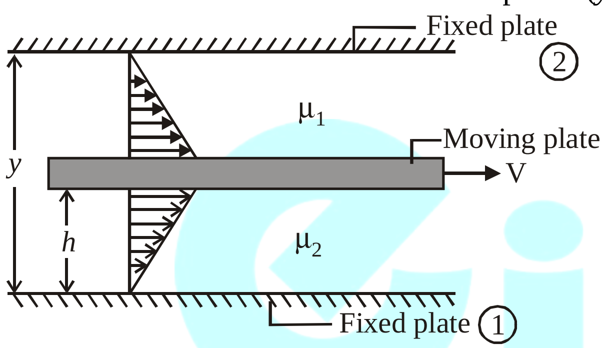


$$S = \mu\left(\frac{du}{dy}\right) \qquad du = u - 0 = 1.5 \text{ m/sec}$$

$$\frac{F}{A} = \mu\frac{du}{dy} \qquad \mu = \left(\frac{134.615}{1}\right) \times \frac{1\times10^{-3}}{1.5}$$

$$\boxed{\mu = 0.897 \text{ Poise}}$$

Example 2: What will be the distance between two plates (y)



where $\mu_1, \mu_2 \rightarrow$ viscosity

(a) $\left(\frac{\mu_1}{\mu_1+\mu_2}\right)h$ (b) $\left(\frac{\mu_2}{\mu_1+\mu_2}\right)h$ (c) $\left(\frac{\mu_1+\mu_2}{\mu_1}\right)h$ (d) $\left(\frac{\mu_1+\mu_2}{\mu_2}\right)h$

Solution: Equating stress intensity on both side of moving plate.

$$\mu_1\frac{V-0}{y-h} = \mu_2\frac{V-0}{h}$$

$$\boxed{y = \frac{\mu_2 h}{\mu_1+\mu_2}}$$

Example 3: A vertical gap 2.2 cm wide of infinite extent contains a fluid of viscosity 2.0N.s/m^2 and specific gravity 0.9. A metallic plate 1.2m × 1.2 m × 0.2 cm. is to be lifted up with a constant velocity of 0.15 m/sec through the gap if the plate is in the middle of the gap find the force required the weight of the plate is 40N.

Solution:

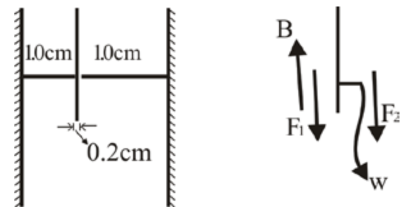
Given,

μ= 2.0 N.s/m^2, G=0.9, width of gap, T=2.2 cm, thickness of plate, t=0.2 cm, V=0.15m/sec. weight of plate w=40 N, density of fluid, $\rho = G.\rho_1 = 0.9\times1000 = 900$ Kg/m^3 .

Distance of the plate from vertical surface, $H = \dfrac{2.2 - 0.2}{2} = 1cm = 0.01m$

Volume of plate, $V = 1.2 \times 1.2 \times \dfrac{0.2}{100} = 0.00288 m^3$

Shear force on the plate on the both side will be equal in this case.



$\therefore$ Shear force on plate $F_1 = F_2$ = shear stress × area

$$= \left(\mu \times \frac{du}{dy}\right) \times A$$

$$= 2 \times \frac{0.15}{0.01} \times 1.2 \times 1.2 = 43.2\, N(\downarrow) \text{ Acting in downward direction}$$

Upward thrust or buoyancy force acting on plate , B = (volume of fluid displaced) × $\rho \times g$

$\therefore$ B = 0.00288 × 900 × 9.81

= 25.43 N($\uparrow$) acting in upward direction

$\therefore$ Total force required to lift plate in upward direction.

= net force acting in downward direction = $F_1 + F_2 + \omega - B$

= 43.2 + 43.2 + 40 – 25.43 N = 100.97 N **Ans.**

Example 4: Find the surface tension in a soap bubble of 30mm. diameter when the inside pressure is 3.0 N/m^2 above atmosphere pressure

Solution:

Given

$$r = \frac{d}{2} = \frac{30}{2} = 15mm, \quad p = 3.0\, N/m^2$$

From formula

$$p = \frac{4s}{r} \therefore 3 = \frac{4 \times s}{15 \times 10^{-3}} \quad \therefore \quad S$$

$$\therefore \quad S = \frac{3 \times 15}{1000 \times 4} = 0.01125\, N/m$$

Example-5: Three litres of the petrol weight 23.7 N. calculate the mass density specific weight , specific volume and specific gravity of petrol

Sol. (1) Mass density of petrol

$$\rho_p = mass/volume = \frac{(23.7/9.81)}{3.0}$$

$$= 0.805 kg/litre$$

$$= 805\ kg/m^3$$

$$\rho_w = 998 kg/m^3$$

Specific gravity of petrol $= \frac{\rho_p}{\rho_w} = \frac{805}{998}$ =0.807

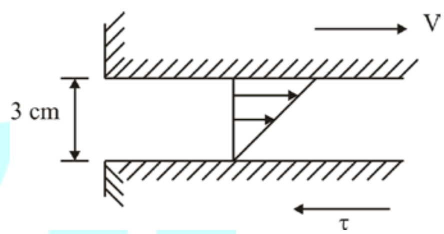
(2.) Specific weight of petrol =weight per unit volume

$$= \frac{23.7}{3.0} = 7.9\ N/litre$$

(3.) Specific volume= $\frac{1}{\rho_p}$ $= 1.242 \times 10^{-3} m^3/kg$

Example-6: The space between two parallel plates kept 3mm apart is filled with an oil of dynamic viscosity 0.2 pa.s . What is t he shear stress on the lower fixed plate, if the upper one is moved with a velocity of 1.5 m/s (as shown in figure)

Sol.



$$\frac{du}{dy} = \frac{v}{h} = \frac{1.50}{3 \times 10^{-3}} = 500(s^{-1})$$

τ=shear stress on lattom plate

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

$$\tau = 100 N/m^2$$

Example-7: The velocity distribution near the solid wall at a section in a linear flow is given

$u = 5.0 \sin(5\pi x)$ for $x \le 0.10m$ determine the τ at a section at x=0

Sol.

$$\mu = \frac{5}{10} pas.\sec$$

$$\mu = 5\sin(5\pi x)$$

$$\frac{du}{dy} = 5.0 \times 5\pi \cos(5\pi x)$$

$$\tau = \mu \frac{du}{dy} = \frac{5}{10} \times 25 \times \pi \cos(5\pi x)$$

$$\tau = 12.5\ \cos(5\pi x)$$

$$at = x = 0$$

$$\tau = 12.5\pi \cos 0$$

$$\tau = 39.27\ N/m^2$$

Example-8: A hydraulic lift used for lifting automobile has a 25 cm diameter ram which slides in a 25.018 cm diameter cylinder the annular space being filled with oil having a kinematic viscosity of 3.7 cm^2/s and relative density of 0.85. If the rate of travel of the ram is 15 cm/s, determine the frictional resistance when 3.3m of ram is engaged in the cylinder?

Sol.

$$\tau = \mu\frac{du}{dy} = V\rho\frac{du}{dy} = 3.7\times10^{-4}\times0.85\times998\times\frac{0.15}{(25.018-25)/(2\times10^{2})} = 523.1N/m^{2}$$

Frictional resistance

$$F_s = A\tau \Rightarrow F_s = (\pi dl)\times\tau \quad \Rightarrow F_s\times\frac{5}{100}\times33\times523.1 \;\Rightarrow\; \boxed{F_s = 1356N}$$

Example-9: The velocity distribution in a viscous flow over plate is $u = 4x - x^2 \quad for \;\; x \le 2m$ where u velocity in m/s at a point distant *x* from the plate. When the coefficient of dynamic viscosity is 1.5 pa.s find the shear stress at *x*=0 at *x*=2.0m

Sol.

$$u = 4x - x^2 \qquad \Rightarrow \frac{du}{dx} = 4 - 2x$$

$$\because \qquad \tau = \mu\frac{du}{dx}$$

$$\tau \; at \;\; x = 0 = 1.5\times(4 - 2\times0)\; pa.s$$

$$\& \;\; \tau \; at \;\; x = 2 = 1.5\times(4 - 2\times2) = 0\, pa.s$$

CHAPTER-2
FLUID STATICS AND ITS APPLICATION

Fluid Pressure at a point:

'Intensity of pressure' or 'pressure' may be defined as the force exerted on a unit area.

– When F represents the total force uniformly distributed over an area A, the pressure at any point is:

$$\boxed{P = \frac{F}{A}}$$

– Pressure is scalar quantity C.

– The counterpart of pressure in solids is normal stress which is the force acting perpendicular to the solid surface per unit area.

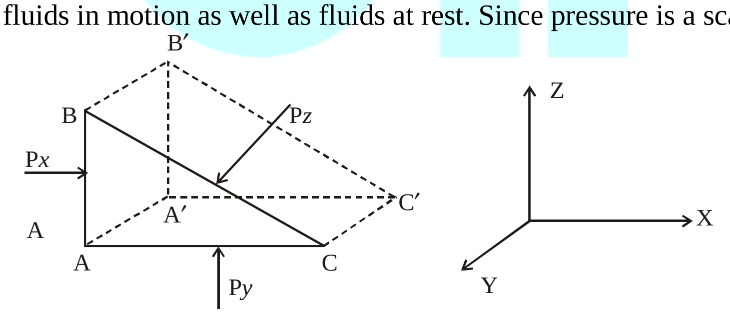
– Unit of pressure: SI system – $N/m^2 \rightarrow Pa$
FPS (English) – $lbf/in^2 \rightarrow psi$
other – kgf/cm^2

– A fluid is a substance which is capable of flowing. As such when a certain mass of fluid is held in static equilibrium by confining solid boundaries, it exerts forces against boundary surfaces.

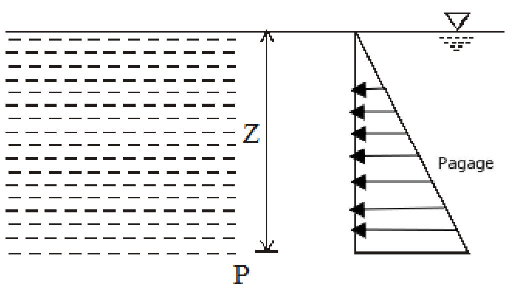
– The forces so exerted always act in the directional normal to the surface is contact. This is so because of a fluid at rest cannot sustain shear stress and hence the forces cannot have tangential components.

– The normal force exerted by a fluid per unit area of the surface is said to be the fluid pressure.

Pascal's law: The pressure at any point in a static mass of liquid rely on the vertical depth of the point below the free surface and the specific weight of the liquid, and it independent upon the shape and size of the bounding container. "It states that pressure at a point in a static fluid is equal in all direction". This result is applicable to fluids in motion as well as fluids at rest. Since pressure is a scalar, not a vector.



– Pressure changes with depth in a static fluid and pressure at a depth 'z' from free surface of a static fluid is $P = \rho g z$



Hydrostatic Equillibrium in centrifugal field:

In industrial centrifuge rotational speed is so high and the centrifugal force so much greater than force of gravity that the liquid surface is virtually cylindrical and coaxial with axis of rotation.

Figure

$r_1 \rightarrow$ **radial distance of free surface from axis**

$r_2 \rightarrow$ **radius of centrifuge.**

The pressure drop over any ring of rotating liquid is calculated, as follows.

$$dF = \omega^2 r\, dm$$

dF = centrifugal force

dm = mass of liquid element

$\omega =$ **angular velocity rad/sec.**

$$dm = 2\pi\rho r b\, dr$$

$$dP = \frac{dF}{2\pi r b} = \omega^2 \rho r\, dr$$

$$P_2 - P_1 = \int_{r_1}^{r_2} \omega^2 \rho r\, dr$$

$$\boxed{P_2 - P_1 = \frac{\omega^2 \rho (r_2^2 - r_1^2)}{2}}$$

Pressure drop over enirering is $P_2 - P_1$ application of hydrostatic equilibrium in centrifuge is in centrifugal decanter for separation of two liquids of different densities.

Summary:

1. Pressure inside a closed vessel or closed equipment given by pressure and read by measuring device.
2. Absolute pressure = atmospheric pressure gauge pressure may be positive or negative.
3. For inclined manometer g is replaced by g sin θ.
4. For measuring small difference in pressure, the inclined manometer is used.

QUESTION SET

Q.1. The problems of fluid statics are influenced by:

(a.) Frictional and surface tension forces (b.) Gravity and surface tension forces

(c.) Gravity and pressure forces (d.) Frictional & pressure forces.

Solution: c

Q.2. The differential equation for pressure variations in x, y and z – directions (vertically up ward) at any point in an un-accelerated fluid may be written as:

(a.) $\frac{\partial P}{\partial x}=0,\ \frac{\partial P}{\partial y}=-r,\ \frac{\partial P}{\partial z}=0$ (b.) $\frac{\partial P}{\partial x}=0,\ \frac{\partial P}{\partial y}=0,\ \frac{\partial P}{\partial z}=-r$

(c.) $\frac{\partial P}{\partial x}=-r,\ \frac{\partial P}{\partial y}=0,\ \frac{\partial P}{\partial z}=0$ (d.) $\frac{\partial P}{\partial x}=-r,\ \frac{\partial P}{\partial y}=r,\ \frac{\partial P}{\partial z}=0$

Where $\gamma = \rho g/g_c$

Solution: a

Q.3. How deep can a diver descend in ocean ($\gamma = 64 lbf/ft^3$) without damaging his watch which will withstand an absolute pressure of $80 lbf/in^2$:

(a.) 136.9ft (b.) 180ft (c.) 1.25ft (d.) 1.02ft

Solution: b

$$\gamma = \rho g$$

$$\gamma h = P$$

$$64\frac{lbf}{ft^3}\times h = 80\frac{lbf}{in^2} \qquad [1\,ft = 12 inch]$$

$$64\frac{lbf}{ft^3}\times h = 80\frac{lbf}{\frac{1}{12}\times\frac{1}{12}\,ft^2}$$

$$h=\frac{80}{64}\times 12\times 12\,ft = 180\,ft$$

Q.4. The pressure 20in. Hg abs with barometer reading 29.50 in Hg may be expressed as:

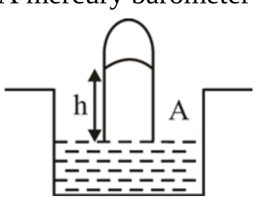
(a.) 20 in Hg vacuum (b.) 9.50 in Hg vacuum

(c.) 29.50in Hg vacuum (d.) 9.92 in Hg vacuum

Solution: b

Vacuum pressure = atmospheric pressure – absolute pressure = (29.50 – 20) in. Hg = 9.50 in. Hg

Q.5. A mercury barometer is shown in figure:



If the vapour pressure of mercury is h_v cm Hg and h is measured in metres, the pressure, in cm Hg, at A is

(a.) 100h (b.) h_v + 100h (c.) h_v + h (d.) h_v

Solution: pressure at A = Atm. Pressure + pressure due to mercury column of height h m

Pressure at A = h_V (cm Hg) + h (m Hg)

Pressure at A = (h_v + 100h) cm Hg

Q.6. For the standard atmosphere upto the stratosphere, temperature of air decreases uniformly at the rate of:

(a.) 0.65ºC/m (b.) 0.065ºC/m (c.) 0.0065ºC/m (d.) 0.00065ºC/m

Solution: c

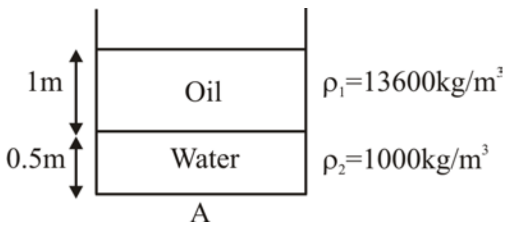
Q.7. In a mercury differential manometer used for measuring pressure differences across a venturimeter, if an error of 1mm has been made in observing a differential head of 20mm, the percentage error in pressure difference is:

(a.) 4.76 (b.) 1 (c.) 0.05 (d.) 5

Solution: d

$$\frac{Error}{Actual\ value} \times 100 = \frac{1}{20} \times 100 = 5\%$$

Q.8.



Calculate the pressure at the base of container due to the presence of 2 fluids (Take g = 10m/s^2)

(a.) 1.41N/m^2 (b.) 141Pa (c.) 141Kpa (d.) 1.41KPa

Solution: c

$$P_{base} = \rho_1 g h_1 + \rho_2 g h_2$$
$$= 13600 \times 10 \times 1 + 1000 \times 10 \times 0.5$$
$$= 136000 + 5000 = 141000 Pa = 141 kPa$$

NUMERICAL BASED ON FLUID STATICS

1. An open tank contain liquid having a density of $1400\ \text{kg/m}^3$. At a certain point the gauge pressure is $35\ \text{kN/m}^2$. What height above the given point is the liquid level?

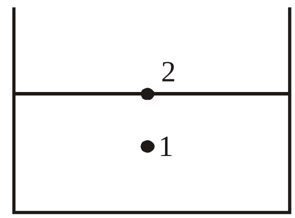
Sol. Consider following figure:

Let at point 2 pressure is atmosphere (due to open tank) *i.e.*,

$$101.325\ \text{kN/m}^2 = 101325\ \text{N/m}^2 = P_2$$

At point 1, absolute pressure = gauge pressure + atmospheric pressure

$= 35 + 101.325 = 136.325\ \text{kN/m}^2 = 136,325\ \text{N/m}^2 = P_1$



Let h be the height above point 1

$\Rightarrow$ $\Delta P = (P_1 - P_2) = h\rho g$

ρ = liquid density = $1400\ \text{kg/m}^3$

$g = 9.81\ \text{m/s}^2$

Put all value in equation,

$\Rightarrow$ $(136325 - 101325) = h \times 1400 \times 9.81$

$h = 2.55$ meter

2. In orifice meter pressure drop is measured by a U-tube manometer. The manometric fluid is mercury (Specific gravity 13.6) and fluid flowing through the pipe line and fills manometric leads. (Specific gravity 2.26).

When the pressure at taps are equal the level of mercury in the manometer is one meter below the taps. In operating conditions, the pressure at upstream top is $215.324\ \text{kN/m}^2$ absolute and that at the down stream tap is $43.864\ \text{kN/m}^3$ below the atmospheric pressure. What is the reading of manometer in centimeters?

Sol. Let P_1 = Upstream tap pressure (absolute)

$= 215.324\ \text{kN/m}^2 = 215.324\ \text{N/m}^2$

P_2 = Downstream tap pressure (absolute)

$= 101.325 - 43.864 = 57.461\ \text{kN/m}^2$

$P_2 = 57461\ \text{N/m}^2$

and we know that

$$\boxed{\Delta P = P_1 - P_2 = h(\rho_A - \rho_B)g}$$

Put all value in equation we get

$\Rightarrow$ $215324 - 57461 = h(13600 - 2260)\ 9.81$

$\Rightarrow$ $h = 1.419$ m

$\Rightarrow$ $h = 141.9$ cm

CHAPTER-3
BUOYANCY AND FLOATATION

Buoyancy: An immersed body to be lifted up in the fluid because of an upward force opposite to the action of gravity is called as buoyancy.

Buoyant force: The force tending to lift up the body under such conditions is called buoyant force.

Centre of Buoyancy: The point of application of the force of buoyancy on the body is said to be center of buoyancy.

- The magnitude of the buoyant force can be calculated by the Archimedes principles, which states that if a body is submersed in a fluid either totally or partially, it is buoyant or lifted up by a force which is identical to the weight of the fluid displaced by the body.
- As per the Archimedies principle, buoyant force equal to the weight of the fluid displaced by the body.

  i.e. $F_B = \rho g V$

  where, F_B – Buoyancy force, ρ – density of fluid

  V – volume of submerged body or volume of water displaced

- If a body is floating at the free surface of a liquid, it remains partially submerged in the fluid (shown in fig.) with the top portion of the body is in contact with air and its bottom portion submerged in the liquid.

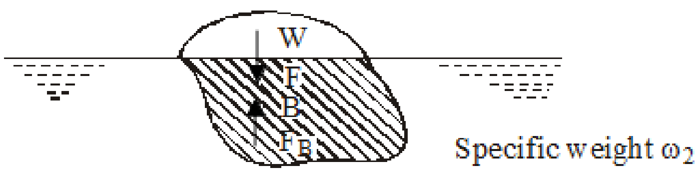


Fig. Buoyant force on a body floating at the free surface of the liquid

- In this case, the specific weight of air is negligible as compared to the specific weight of fluid, therefore weight of the air displaced by the top portion of the body is neglected.
- Thus, buoyant force exerted on a partially submerged or immersed body is equal to the weight of the liquid displaced by the body, acting at the center of buoyancy which coincides with the centroid of the value of the liquid displaced.

Buoyant force on a body floating at the surface of separation between two fluids:

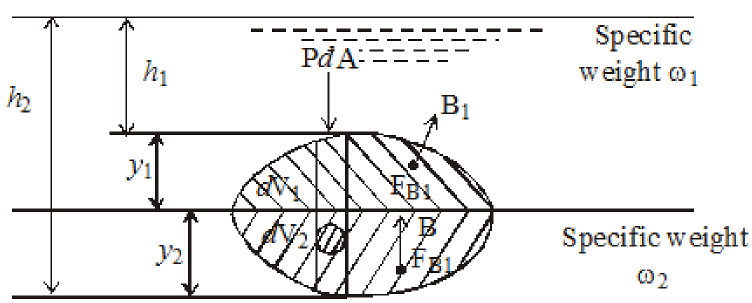


Fig.: Buoyant forces on a body floating at the surface of separation between two fluids

$$F_B = w_1 V_1 + w_2 V_2 \qquad \boxed{F_B = \rho g V_1 + \rho g V_2}$$

Important:

(1) Upthrust on a body immersed in a liquid depends on the volume of body. If two bodies have equal upthrust in same liquid, both of them may have equal volumes.

(2) A body may float in one liquid and sink in other liquid. Chances of sinking in sea water are less than the ordinary water so swimming is easier in sea water.

(3) When ice floats in a liquid of higher density than water, the level falls on melting of ice. Water level does not change when floating ice melts in the water.

(4) For floating bodies, the weight of entire body must be equal to the buoyant force, which is the weight of fluid whose volume is equal to the volume of submerged portion of floating body. That is $F_B = W$

$$\rho_f \; g \, V_{sub} = \rho_{avg\ body} \; g \, V_{total}$$

$$\boxed{\frac{V_{sub}}{V_{total}} = \frac{\rho_{avg.body}}{\rho_f}}$$

Note: When the weight of an immersed body exceeds the buoyant force, the body will tend move downward and it may finally sink, whereas a body submerged in a liquid if the buoyant force exceeds the weight of the body, the body will rise until its weight equals to the buoyant force.

Q.1. A vessel contains oil (density 0.8g/cm^3) over mercury (density 13.6g/cm^3). A sphere floats with half volume immersed in mercury and other half in oil. Density of sphere in g/cm^3 is

(a.) 3 (b.) 6.4 (c.) 7.2 (d.) 12.8

Solution: c

Let ρ be the density of material of sphere. If V is the volume of sphere, then for floating

Wt. of sphere = wt. of mercury displaced + wt. of oil displaced

$$V\rho g = \frac{V}{2}\times 13.6\times g + \frac{V}{2}\times 0.8\times g$$

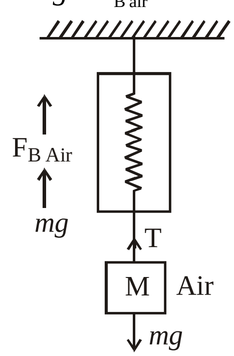
$$V\rho g = V\times 7.2\times g$$

$$\rho = 7.2 g/cm^3$$

∴ Option (c) is correct

1. Real weight of body (weight in air)

$T + F_{B\,air} = mg$ $T = mg - F_{B\,air}$



$\boxed{T = mg}$ Real weight

where, T = Reading of spring balance

EXAMPLES

1. A Jar is filled with two immiscible fluids A and B of density $2000\ kg/m^3$ and $1000\ kg/m^3$. A ball of $4\times10^{-6}\ m^3$ volume and 0.01 kg mass is held submerged successively.

(*a*) in phase A

(*b*) exactly at the interface of A and B

(*c*) in phase B.

Calculate the magnitude of force required to hold the ball in position for each of the above case.

Sol. We will use Archimedies principle in every case which is given by equation:

$$\boxed{F = F_g - F_b = mg - V\rho g}$$

where F = net downward force

F_g = gravity force

ρ = density of fluid

F_b = buoyancy force acting upwards

m = mass of ball

V = volume of ball

Case (*a*) When ball completely submerged in A

Then from equation:

m = 0.01 kg $\quad g = 9.812\ m/sec^2 \quad V = 4\times10^{-6}\ m^3$

F = $0.01\times9.812 - 4\times10^{-6}\times2000\times9.812 = 0.0196\ N$

Case (*b*) When ball exactly at the interface of A and B

F = $0.01\times9.812 - (0.5\times4\times10^{-6}\times2000 + 0.5\times4\times10^{-6}\times1000)\times9.812$

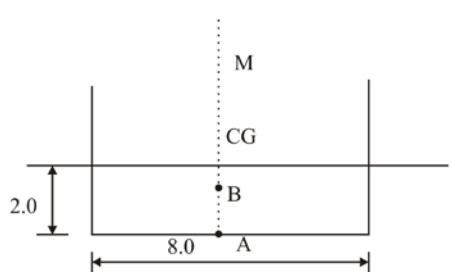
F = 0.0392 N

Case (*c*) When ball completely submerged in B

F = $0.01\times9.812 - 4\times10^{-6}\times1000\times9.812 = 0.0589\ N$

2. A large with a flat bottom and square ends has a draft of 2.0 m if fully loaded and floating in the upright position the length of the large is 15m and its width is 8.0 m. The C.G of the large when fully laden is on the axis of symmetry and is 1.5 above the H_2O surface is the large stable.

Sol.



A= a point on the bottom of the barge lying on the vertical axis of symmetry

B= centre of buoyancy

G=centre of gravity

M=Meta centre

AG=3.5 m

$$MB = \frac{I}{V} = \frac{\left[\frac{15\times 8^3}{12}\right]}{(15\times 8\times 2)} = 2.667m$$

AM =1.0+2.667

AM= 3.667 m

AM is greter than AG, that is M is above G and thus the large is stalble

3. For an inclined plane submerged in a liquid the centre of fluid pressure on one side of the plane will be

(a) Above the top edge of the area

(b) Vertically below the C.G

(c) Below the C.G

(d) In the same horizontal plane as the C.G

Ans. C

4. Buoyant force is the

(a) Lateral force acting on a submerged body

(b) Resultant force acting on a submerged body

(c) Resultant hydrostatic force on a body due to fluid surrounding it

(d) The resultant force due to water on a body

Ans. A

5. Centre of Buoyancy for a floating body to be in stable equilibrium should be located:

(a.) Above C.G (b.) Below C.G (c.) at C.G (d.) anywhere

Solution: c

When centre of buoyancy is at C.G, the torque due to (weight + upthrust) is nil.

CHAPTER-4
FLUID KINEMATICS

Kinematics is that branch of science which deals with motion of particle without considering the forces causing the motion.

Fluid motion is described by two approach:

- **Lagrangian approach:** This approach is particle concentration approach *i.e.* during study the entire concentration goes to a particular fluid particle and after completing the study of that fluid particle the concentration goes to another fluid particle and same thing is repeated.
  Since the number of fluid particles in a system are very large in number therefore, this approach is big time consuming approach, hence this approach is not prefer.
- **Eulerian Approach:** This approach is space concentration approach. Therefore the entire concentration goes to particular zone or space therefore the huge number of fluid particles crossing that space are analyzed the same moment, hence this approach is not very correct for particle motion but at an average it is giving the correct result for the bulk motion of the fluid particles.
  The major important point with Eulerian approach is that it requires very less time, hence we prefer this approach for the kinematic study of flow.
  In lagrangian approach, we are concerned with position vector $\vec{x}_A, \vec{x}_B.....$ & velocity vector $\vec{V}_A, \vec{V}_B.....$ of individual fluid particles. In Eulerian description of fluid flow, a finite volume called control volume is defined, through which fluid flows in and out. Field variables (function of space and time) are defined within the control volume.

  e.g. Velocity field.
  $\vec{V} = \vec{V}(x, y, z, t)$
  Note: Stagnation point
  A point in the flow field where the velocity is zero

Types of fluid flow:

- **Steady flow:** In which the fluid characteristics like velocity, pressure, density etc at a point do not change with time. Hence
  $$\left(\frac{\delta V}{\delta t}\right)_{x_o, y_o, z_o} = 0, \qquad \left(\frac{\delta P}{\delta t}\right)_{x_o, y_o, z_o} = 0, \qquad \left(\frac{\delta \rho}{\delta t}\right)_{x_o, y_o, z_o} = 0$$
  where (x_o, y_o, z_o) is a fixed point is fluid field.

- **Unsteady flow:** In which the velocity, pressure of density at a point changes with respect to time. Therefore, mathematically
  $$\left(\frac{\partial V}{\partial t}\right)_{x_o, y_o, z_o} \neq 0, \qquad \left(\frac{\partial P}{\partial t}\right)_{x_o, y_o, z_o} \neq 0 \qquad \text{etc.}$$

