Chapter 10

Mechanical Properties of Fluids

FLUIDS

Fluid is something that can flow. All liquids and gases are fluids. *The force exerted normally at a unit area of the surface of a fluid is called* **fluid pressure**.

$$\text{i.e., } P = \frac{F}{a}$$

Its **S.I. unit** is Nm^{-2} or Pascal. Its **dimensions** are $[ML^{-1}T^{-2}]$.

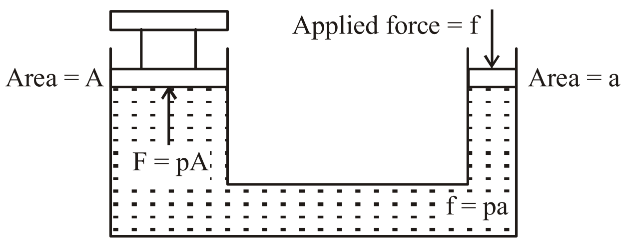
PASCAL'S LAW AND ITS APPLICATIONS

Pascal's law : *Pressure in a fluid in equilibrium is the same everywhere, if the effect of gravity is neglected.*

Another form of Pascal's law : *The excess pressure, applied anywhere in a mass of confined incompressible fluid is transmitted by the fluid in all directions without being diminished in magnitude.*

Applications of Pascal's Law

Hydraulic lift : Its working is based on Pascal's law. A piston of small cross-sectional area (a) exerts a force (f) on the liquid.



The pressure is transmitted undiminished to the larger cylinder of cross-sectional area A.

$$P = \frac{f}{a} = \frac{F}{A} \Rightarrow F = \frac{A}{a} f$$

Hydraulic brakes also work on pascal's law.

ATMOSPHERIC, HYDROSTATIC AND GUAGE PRESSURE

Atmospheric pressure : The atmosphere exerts pressure on the earth's surface. The atmospheric pressure at sea level is given by

$$P_0 = 1.01 \times 10^5\ Pa$$

Hydrostatic pressure : The hydrostatic pressure at a depth h below the surface of a fluid is given by

$$P = h\rho g$$

where ρ is the density of the fluid, g acceleration due to gravity and h is the depth of the liquid column.

Gauge pressure : The pressure at any point in a fluid is equal to the sum of the atmospheric pressure acting on its surface and the hydrostatic pressure due to the weight of the fluid above that point which is at a depth h below the surface of the fluid.

The gauge pressure is given by

$$P = P_0 + h\rho g$$

or, $$P - P_0 = h\rho g$$

BUOYANCY AND ARCHIMEDES' PRINCIPLE

Buoyancy

If a body is partially or wholly immersed in a fluid, it experiences an upward force due to the fluid surrounding it. The phenomenon of force exerted by fluid on the body called **buoyancy** and the force is called **buoyant force** or **upthrust**.

A body experiences buoyant force whether it floats or sinks, under its own weight or due to other forces applied on it.

Archimedes' Principle

When any body is immersed (totally or partially) in a liquid it appears to lose part of its weight and the apparent loss of weight is equal to the weight of liquid displaced.

Let a body of weight W is immersed in a fluid and W' is upthrust on it then

(i) if W > W', then body will sink.

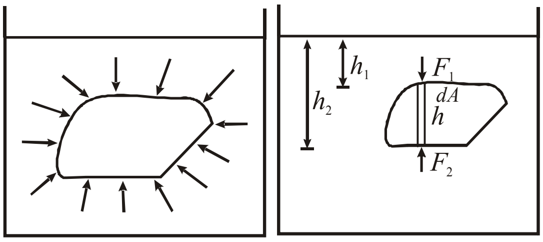
(ii) if W = W', then the body floats with whole or some part of its volume inside the fluid.

Let V be the volume of a body of density d and V' be the volume of liquid of density ρ displaced. If the body floats then $Vd = V'\rho$

$\therefore \frac{d}{\rho} = \frac{V'}{V}$ gives the fraction of the volume inside the liquid in which the body floats.

Also, body immersed in a fluid experiences an upward buoyant force equivalent to the weight of the fluid displaced by it.

The proof of this principle is very simple. Imagine a body of arbitrary shape completely immersed in a liquid of density ρ as shown in the figure (a). A body is being acted upon by the forces from all directions. Let us consider a vertical element of height h and cross-sectional area dA (as shown in the figure (b)).



(a) **(b)**

The force acting on the upper surface of the element is F_1 (downward) and that on the lower surface is F_2 (upward). Since $F_2 > F_1$, therefore, the net upward force acting on the element is $dF = F_2 - F_1$

It can be easily seen from the figure (b), that

$F_1 = (\rho g h_1)dA$ and $F_2 = (\rho g h_2)dA$ so $dF = \rho g(h)dA$

Also, $h_2 - h_1 = h$ and $d\,(dA) = dV$

$\therefore$ The net upward force is $F = \int \rho g dV = \rho V g$

Hence, for the entire body, the buoyant force is the weight of the volume of the fluid displaced.

The buoyant force acts through the centre of gravity of the displaced fluid.

Keep in Memory

1. The pressure is perpendicular to the surface of the fluid.
2. The upthrust on a body immersed in a liquid does not depend on the mass, density or shape of the body. It only depends on the volume of the body.
3. The weight of the plastic bag full of air is same as that of the empty bag because the upthrust is equal to the weight of the air enclosed.
4. The cross-section of the water stream from a top decreases as it goes down in accordance with the equation of continuity.
5. We cannot sip a drink with a straw on the moon, because there is no atmosphere on the moon.
6. The line joining the centre of gravity and centre of buoyancy is called **central line**.
7. **Metacenter** - is a point where the vertical line passing through the centre of buoyancy intersects the central line.
8. The floating body is in **stable equilibrium** when the metacenter is **above** the centre of gravity (centre of gravity is below the centre of buoyancy).
9. The floating body is in the **unstable equilibrium** when the metacenter lies **below** the centre of gravity (centre of gravity is above the centre of buoyancy).
10. The floating body is in the **neutral equilibrium** when centre of gravity coincides with the metacenter (centre of gravity coincides with the centre of buoyancy).
11. The wooden rod cannot float vertically in a pond of water because centre of gravity lies above the metacenter.
12. (i) If a body just floats in a liquid (density of the body is equal to the density of liquid) then the body sinks if it is pushed downwards.
    (ii) If two bodies have equal upthrust when just immersed in a liquid, both will have the same volume.
    (iii) If a person floats on his back on the surface of water, the apparent weight of person is zero.
13. The hydrometer can be used to measure density of the liquid or fluid.

Relative Density (or Specific Gravity)

Liquids may be treated as incompressible. Hence their density may be assumed to be constant throughout.

$$\text{Relative density} = \frac{\textit{Weight of substance in air}}{\textit{Weight of equal volume of water}}$$

$$= \frac{\textit{Weight of substance in air}}{\textit{Loss of weight in water}}$$

$$= \frac{\textit{Density of substance}}{\textit{Density of water at } 4^\circ C}$$

Density in SI system = 1000 × density in the cgs system.

(i) The density of liquid of bulk modulus B at a depth h is given by $\rho_h = \rho_0\left(1 + \frac{\rho g h}{B}\right)$ where ρ_0 is the density of liquid on its surface and ρ is the average density of liquid.

(ii) The density of liquid changes with pressure as

$$P_h = P_0\left(1 + \frac{\Delta P}{B}\right)$$

where $\Delta P =$ change in pressure and B = bulk modulus of liquid.

(iii) If two liquids of masses m_1, m_2 and densities ρ_1, ρ_2 are mixed together, then the density of the mixture is given by

$$\rho = \frac{m_1 + m_2}{\frac{m_1}{\rho_1} + \frac{m_2}{\rho_2}}$$

And if $m_1 = m_2$ but different densities are mixed together, then the density of the mixture is harmonic mean of the densities.

$$\text{i.e., } \rho = \frac{2\rho_1\rho_2}{\rho_1 + \rho_2} \text{ or } \frac{1}{\rho} = \frac{1}{2}\left[\frac{1}{\rho_1} + \frac{1}{\rho_2}\right]$$

(iv) If two drops of same volume but different densities are mixed together, then the density of the mixture is the arithmetic mean of the densities.

$$\text{i.e., } \rho = \frac{\rho_1 + \rho_2}{2} \quad \left(as\ \rho = \frac{\rho_1 V_0 + \rho_2 V_0}{V_0 + V_0}\right)$$

SURFACE TENSION

It is defined as the force per unit length acting at right angles on either side of an imaginary line drawn on the free surface of the liquid.

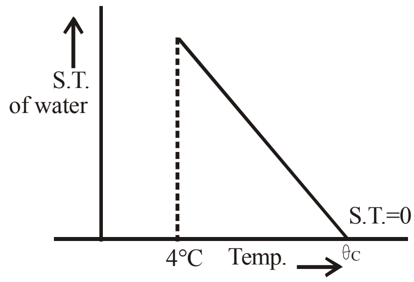
$$\text{i.e., } S = \frac{F}{\ell}$$

The surface tension is also defined as the work required to increase unit area of that liquid film.

Its **SI unit** is N/m or J/m^2 and **dimensions** are $[ML^0T^{-2}]$.

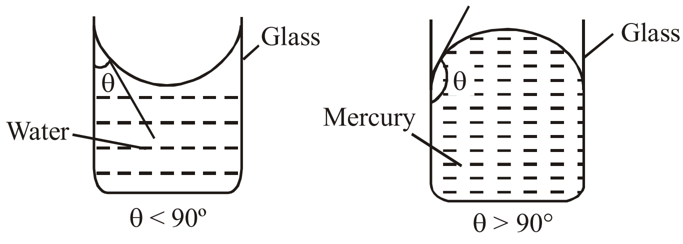
Keep in Memory

1. The liquid surface always acquires **minimum surface area** due to **surface tension (ST)**. So, the small droplet of any liquid is always spherical.
2. The ST is a molecular phenomenon as ST is due to 'cohesion' between the molecules of a liquid.
3. The force of attraction between the molecules of the same substance is called a **cohesive force** and that between molecules of different substance is called **adhesive force**.
4. The molecular range is the maximum distance (10^{-9} m) upto which the molecules attract each other.
5. In general the ST of liquids decreases with increase in temperature but the ST of molten Cadmium and Copper increases with increase in temperature.
6. If the impurity is completely soluble then on mixing it in the liquid, its surface tension increases. For example on dissolving ionic salts in small quantities in a liquid, its surface tension increases. On dissolving salt in water, its surface tension increases.
7. If the impurity is partially soluble in a liquid, then its surface tension decreases. For example on mixing detergent or phenol in water its surface tension decreases.
8. On increasing temperature surface tension decreases. At critical temperature and boiling point it becomes zero. Surface tension of water is maximum at 4°C.



ANGLE OF CONTACT

The angle between the tangent to the liquid surface and the tangent to the solid surface at the point of contact (inside the liquid) is known as angle of contact.



Some values of angle of contact of solid and liquid :

Pair of surface	Angle of contact
Pure water and glass	0°
Silver and glass	90°
Alcohol and glass	138°
Normal water & glass	8°
Mercury & glass	135°

Adhesion > cohesion	Adhesion = cohesion	Adhesion < cohesion
1. Liquid will wet the solid	Critical	Liquid will not wet the solid
2. Meniscus is concave	Meniscus is plane	Meniscus is convex
3. Angle of contact is acute (θ < 90°)	Angle of contact is 90º	Angle of contact is obtuse (θ > 90°)
4. Pressure below the menisucs is lesser than above it by (2T/r), i.e. $p = p_0 - \frac{2T}{r}$	Pressure below the meniscus is same as above it, i.e. $p = p_0$	Pressure below the meniscus is more then above it by (2T/r), i.e., $p = p_0 + \frac{2T}{r}$
5. In capillary tube liquid will ascend.	No capillary rise	In capillary tube liquid will descend.

Keep in Memory

1. The value of angle of contact lies between 0º and 180º. For pure water and glass it is 0º, for tap water and glass it is 8º and for mercury and glass it is 135º.
2. For all those liquids which wet the solid surface and which rise up in a capillary tube, the angle of contact is an acute angle (θ < 90°), e.g. water and glass.
3. For all those liquids which do not wet a solid surface and which depress in a capillary tube, the angle of contact is an obtuse angle (θ > 90°), e.g. glass and mercury.
4. For all those liquids which neither rise nor get depressed in a capillary tube, the angle of contact is right angle (θ = 90°), e.g. silver and water.
5. Angle of contact depends on impurities, water proofing agent, surface in contact and temperature. Angle of contact $\theta_C \propto T$ where T is the temperature.

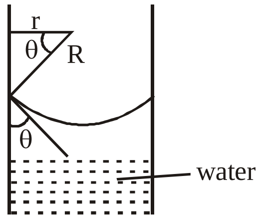
Capillarity :

The phenomenon of rise or fall of liquids in capillary tube is known as capillarity.

The rise or fall of a liquid in a capillary tube is given by

$$h = \frac{2T\cos\theta}{r\rho g} = \frac{2T}{R\rho g}$$

$$\Rightarrow h\rho g = \frac{2T}{R}$$



where T = surface tension, θ = angle of contact, ρ = density of liquid, r = radius of capillary tube, R = radius of meniscus.

(i) If capillary tube is of insufficient length ℓ (i.e. ℓ < h), then the liquid rises to a full height h with radius R' such that $hR = \ell R'$

(ii) When the capillary tube is tilted from vertical by an angle α, then the vertical height h of liquid column remains the same. The length of liquid in capillary increases such that

$$\cos\alpha = \frac{h}{h'} \text{ or } h' = \frac{h}{\cos\alpha}.$$

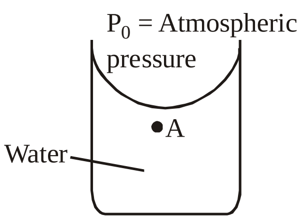
According to **Zurin's law** capillary rise $h \propto \frac{1}{r}$ where r is the radius of the capillary tube.

Keep in Memory

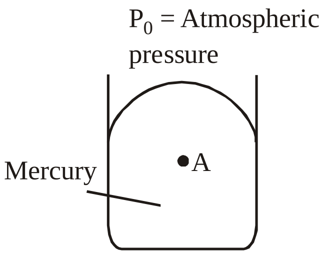
1. Work done in forming a liquid drop of radius R, surface tension T is, $W = 4\pi R^2 T$.
2. Work done in forming a soap bubble of radius R, surface tension T is, $W = 2\times 4\pi R^2 T = 8\pi R^2 T$.
3. When n no. of smaller drops of liquid, each of radius r, surface tension T are combined to form a bigger drop of radius R then $R = n^{1/3} r$.
4. The surface area of bigger drop = $4\pi R^2 = 4\pi n^{2/3} r^2$. It is less than the area of n smaller drops.

SHAPE OF LIQUID MENISCUS :

The pressure on the concave side is always greater than the pressure on the convex side.



θ < 90º
Concave meniscus
$P_A = P_0 - 2T/r$



θ > 90º
Convex meniscus
$P_A = P_0 + 2T/r$
(r is radius of meniscus)

Excess pressure of liquid drop and soap bubble :

(i) Excess of pressure for spherical soap bubble is $p = 4T/r$ and excess of pressure for liquid drop and air bubble in a liquid is $p = 2T/r$.

(ii) (a) Excess of pressure within a cylindrical liquid drop $p = T/R$

(b) Excess of pressure within a cylindrical soap bubble $p = 2T/R$

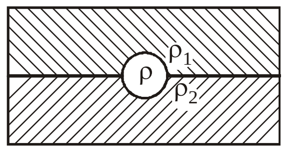
where T = surface tension, R = radius of the cylindrical drop.

Keep in Memory

1. Work done in breaking a liquid drop of radius R into n equal small drops = $4\pi R^2 (n^{1/3} - 1)T$; where T = surface tension.
2. Work done in breaking a soap bubble of radius R into n equal small drops = $8\pi R^2 (n^{1/3} - 1)T$; where T = surface tension.

Example 1.

A solid uniform ball having volume V and density ρ floats at the interface of two unmixable liquids as shown in fig. The densities of the upper and the lower liquids are ρ_1 and ρ_2 respectively, such that $\rho_1 < \rho < \rho_2$. What fraction of the volume of the ball will be in the lower liquid ?



Solution :

Let V_1 and V_2 be the volumes of the ball in the upper and lower liquids respectively. So $V_1 + V_2 = V$.

As ball is floating in the two liquids ; weight of the ball = upthrust on ball due to two liquids

i.e., $V\rho g = V_1\rho_1 g + V_2\rho_2 g$;

or $V\rho = V_1\rho_1 + (V - V_1)\rho_2$;

or $V_1 = \left(\frac{\rho - \rho_2}{\rho_1 - \rho_2}\right)V$

$\therefore$ Fraction in the upper liquid = $\frac{V_1}{V} = \frac{\rho - \rho_2}{\rho_1 - \rho_2}$

Fraction in the lower liquid $= 1 - \frac{V_1}{V}$

$$= 1 - \frac{\rho - \rho_2}{\rho_1 - \rho_2} = \frac{\rho_1 - \rho}{\rho_1 - \rho_2}$$

Example 2.

A piece of cork is embedded inside of block of ice which floats on water. What will happen to the level of water when all the ice melts?

Solution :

Let , M = mass of the block of ice, m = mass of piece of cork and V = Volume of water displaced.

Now $(M + m) = V \times 1 = V$ ...(1)

When the ice melts, let it be converted into V' c.c. of water.

Also $M = V' \times 1 = V'$

The piece of cork floats on the surface of water when all ice melts. Let the cork displaces a volume V'' c.c. of water.

Then $m = V'' \times 1 = V''$

If V_1 be the volume of water displaced by melted ice and cork, then

$(M + m) = V' + V'' = V_1$ ...(2)

From eqns. (1) and (2), $V = V_1$

Hence, no change in the level of water.

Example 3.

Two substances of densities ρ_1 and ρ_2 are mixed in equal volume and the relative density of mixture is 4. When they are mixed in equal masses, the relative density of the mixture is 3. Determine the values of ρ_1 and ρ_2.

Solution :

When the substances are mixed in equal volumes, then

$$V\rho_1 + V\rho_2 = 2V \times 4 \quad \text{... (1)}$$

When the two substances are mixed in equal masses, then

$$\frac{m}{\rho_1} + \frac{m}{\rho_2} = \frac{2m}{3} \quad \text{...(2)}$$

From eq. (1), $\rho_1 + \rho_2 = 8$ ... (3)

From eqn. (2) $\frac{1}{\rho_1} + \frac{1}{\rho_2} = \frac{2}{3}$ or $\frac{\rho_1 + \rho_2}{\rho_1 \rho_2} = \frac{2}{3}$

or $\frac{8}{\rho_1 \rho_2} = \frac{2}{3}$ or $\rho_1 \rho_2 = 12$ . ...(4)

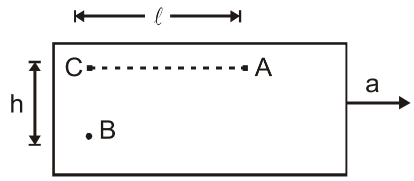
Now $\rho_1 - \rho_2 = [(\rho_1 + \rho_2)^2 - 4\rho_1\rho_2]^{1/2}$

$= [64 - 48]^{1/2} = 4$ ...(5)

Solving eqns. (3) and (5), we get $\rho_1 = 6$ and $\rho_2 = 2$]

Example 4.

A sealed tank containing a liquid of density ρ moves with a horizontal acceleration a, as shown in fig. Find the difference in pressure between the points A and B.



Solution :

Since points A and C are in the same horizontal line but separated by distance ℓ and liquid tank is moving horizontally with acceleration a, hence

$P_C - P_A = \ell\rho a$ or $P_C = P_A + \ell\rho a$

Points B and C are vertically separated by h

$\therefore \quad P_B - P_C = h\rho g$

or $\quad P_B - (P_A + \ell\rho a) = h\rho g$

or $\quad P_B - P_A = h\rho g + \ell\rho a$

Example 5.

Calculate the excess pressure within a bubble of air of radius 0.1 mm in water. If the bubble had been formed 10 cm below the water surface when the atmospheric pressure was 1.013×10^5 Pa, then what would have been the total pressure inside the bubble?

Solution :

Excess pressure within air bubble

$$= \frac{2T}{r} = \frac{2 \times 73 \times 10^{-3}}{0.1 \times 10^{-3}} = 1460 \text{ Pa}$$

The pressure at a depth d, in liquid P = hdg. Therefore, the total pressure inside the air bubble is

$$P_{in} = P_{atm} + hdg + \frac{2T}{r}$$

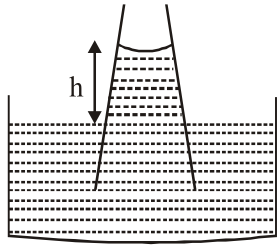
or $P_{in} = 1.013 \times 10^5 + 10 \times 10^{-2} \times 10^3 \times 9.8 + 1460$

$= 101300 + 980 + 1460$

$= 103740 = 1.037 \times 10^5$ Pa.

Example 6.

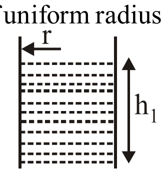
A capillary of the shape as shown is dipped in a liquid. Contact angle between the liquid and the capillary is 0° and effect of liquid inside the meniscus is to be neglected. T is the surface tension of the liquid, r is radius of the meniscus, g is acceleration due to gravity and ρ is density of the liquid then determine the height h in equilibrium.



Solution :

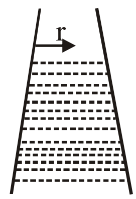
As weight of liquid in capillary is balanced by surface tension, then $T \times 2\pi r = \pi r^2 h_1 \rho g$ (for a tube of uniform radius r)

$$h_1 = \frac{2T}{r\rho g}$$



But weight of liquid in tapered tube is more than uniform tube of radius r, then in order to balance $h < h_1$.

$$h < \frac{2T}{r\rho g}$$



Example 7.

A hydraulic automobile lift is designed to lift car with a maximum mass of 3000 kg. The area of cross-section of the piston carrying the load is 425 cm^2. What maximum pressure would the smaller piston have to bear ?

Solution :

Here mass of car = 3000 kg.

Area of cross section of larger piston

$= 425 \text{ cm}^2 = 425 \times 10^{-4} \text{ m}^2$.

$\therefore$ The maximum pressure that the smaller piston would have to bear

$$= \frac{\text{Weight of car}}{\text{Area of cross-section}} = \frac{3000 \times 9.8}{425 \times 10^{-4}}$$

$$= 6.92 \times 10^5 \text{ Nm}^{-2}$$

FLOW OF LIQUIDS

The motion of fluids are of following four types :

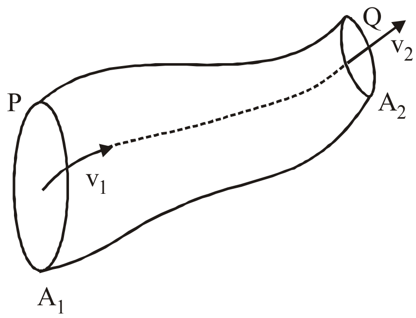
(i) Streamline motion : *When fluid in motion, if fluid particles preceeding or succeeding a fluid particle follow the same path, then the path is called streamline and the motion of the fluid is called streamline motion*. This type of motion takes place in non-viscous fluids having very small speed.

Principle of continuity : *When incompressible, non-viscous liquid flows in non-uniform tube then in streamline flow product of area and velocity at any section remains same*.

The mass of liquid flowing in equals the mass flowing out.

i.e., $m_1 = m_2$

or, $v_1 A_1 \rho_1 \, \Delta t = v_2 \, A_2 \rho_2 \Delta t$ ..... (1)



As we have considered the fluid incompressible thus,

$v_1 A_1 = v_2 A_2$ or $Av = constant$ ....(2)

(Since $\rho_1 = \rho_2$)

Equations (1) and (2) are said to be as **equation of continuity**.

(ii) Steady state motion : *In a liquid in motion, when liquid particles, crossing a point, cross it with same velocity, then the motion of the liquid is called steady state motion*. This type of motion takes place in non-viscous liquids having very small speed.

(iii) Laminar motion : *Viscous liquids flow in bounded region or in a pipe, in layers and when viscous liquid is in motion, different layers have different velocities. The layers in contact with the fixed surface has least velocity and the velocity of other parallel layers increases uniformly and continuously with the distance from the fixed surface to the free surface of the liquid. This is called laminar motion of the liquid.*

(iv) Turbulent motion : *When the velocity of a liquid is irregular, haphazard and large, i.e. Beyond a limiting value called critical velocity the flow of liquid loses steadiness then the motion of the liquid is called turbulent motion*.

Critical velocity $V_c = \dfrac{K\eta}{\rho r}$

Here η is called coefficient of viscosity.

VISCOSITY

The internal friction of the fluid, which tends to oppose relative motion between different layers of the fluid is called viscosity.

The viscous force between two layers of a fluid of area A having a velocity gradient $\dfrac{dv}{dx}$ is given by

$$F = -\eta A \frac{dv}{dx}$$

where η is called the **coefficient of viscosity**.

Its **S.I. unit** is poiseuille or decapoise. The **C.G.S. unit** is called poise.

1 decapoise = 10 poise.

Effects on Viscosity :

(1) Effect of temperature : On increasing temperature viscosity of a liquid decreases.

(2) Effect of pressure : On increasing pressure viscosity of a liquid increases but viscosity of water decreases.

Keep in Memory

1. The viscosity of gases increases with increase of temperature, the rate of diffusion increases.
2. The viscosity of liquids decrease with increase of temperature, because the cohesive force between the liquid molecules decreases with increase of temperature.

Critical Velocity :

It is the maximum velocity of a fluid above which a stream line flow changes to a turbulent flow, i.e. it is the maximum velocity of a liquid below which its flow remains streamline.

(i) Reynold's formula for critical velocity is

$$V_c = \frac{N\eta}{\rho r} \quad \text{or} \quad N = \frac{V_c \rho r}{\eta}$$

where N = Reynold's no., η = coefficient of viscosity, ρ = density of liquid; r = radius of tube, N = 1000 for narrow tube.

(ii) (a) If $0 < N < 2000$ then the flow is laminar
(b) If $2000 < N < 3000$ then flow of liquid is unstable and may change from laminar to turbulent
(c) If $N > 3000$, then the flow is turbulent.

(iii) When velocity of fluid is less than its critical velocity then the flow of liquid is determined by its viscosity, its density has no effect on its flow.

(iv) When the velocity of liquid is more than its critical velocity then its flow is determined by its density, where viscosity has little effect on its flow. For example lava from volcano is highly thick, despite that it comes out with high speed.

(v) When $V \le V_c$ the flow of liquid is streamline and when $V > V_c$ then the flow of liquid is turbulent.

$\dfrac{V_{c_1}}{V_{c_2}} = \dfrac{r_2}{r_1}$ for same liquid, which is flowing in two tubes of radii r_1 and r_2 respectively.

(vi) The critical velocity of a liquid with high viscosity and smaller radius is higher than that of a liquid with low viscosity and greater radius.

Reynold's Number (N) :

It is pure number which determines the nature of flow of liquid through a pipe.

$$N = \frac{V_c dr}{\eta} = \frac{V_c^2}{\left(\frac{\eta V_c}{r}\right)} = \frac{Inertial\ \ force/area}{Viscous\ \ force/area}$$

N is a dimensionless quantity and carries no unit.

BERNOULLI'S THEOREM

For non-viscous, incompressible, streamline flow of fluids the sum of pressure per unit volume, potential energy per unit volume and Kinetic energy per unit volume remain constant.

i.e., $\frac{p}{\rho} + gh + \frac{1}{2}v^2 = constant$

where ρ = density of fluid.

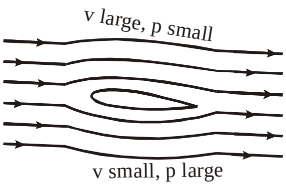
When h = 0 then $\frac{p}{\rho} + \frac{1}{2}v^2$ = constant

Bernoulli's theorem is strictly applicable for an ideal fluid. An ideal fluid is one which is (a) incompressible (b) streamline (c) irrotational and (d) non-viscous.

Applications of Bernoulli's Principle

Dynamic lift :

(i) ***Wings of aeroplane :*** The wings of the aeroplane are having tapering. Due to this specific shape of wings when the aeroplane runs, air passes at higher speed over it as compared to its lower surface. This difference of air speeds above and below the wings, in accordance with Bernoulli's principle, creates a pressure difference, due to which an upward force called 'dynamic lift' (= pressure difference area of wing) acts on the plane. If this force becomes greater than the weight of the plane, the plane will rise up.



(ii) ***Ball moving without spin:*** The velocity of fluid (air) above and below the ball at corresponding points is the same resulting in zero pressure difference. The air therefore, exerts no upward or downward force on the ball.

(iii) ***Ball moving with spin:*** A ball which is spinning drags air along with it. If the surface is rough more air will be dragged. The streamlines of air for a ball which is moving and spinning at the same time. The ball is moving forward and relative to it the air is moving backwards. Therefore, the velocity of air above the ball relative to it is larger and below it is smaller. The stream lines thus get crowded above and rarified below.

This difference in the velocities of air results in the pressure difference between the lower and upper faces and their is a net upward force on the ball. This dynamic lift due to spinning is called **Magnus effect**.

Some other applications of Bernoulli's principle :

(i) The action of carburator, sprayer or atomizer based on Bernoulli's principle.
(ii) The action of bunsen burner, exhaust pump etc.
(iii) Air foil or lift on aircraft wing works on Bernoulli's principle.
(iv) Motion of a spinning ball i.e., magnus effect.
(v) Blowing of roofs by wind storms etc. based on Bernoullis principle.

STOKE'S LAW

When a solid moves through a viscous medium, its motion is opposed by a viscous force depending on the velocity and shape and size of the body. The energy of the body continuously decreases in overcoming the viscous resistance of the medium. This is why cars, aeroplanes etc. are shaped streamline to minimize the viscous resistance on them.

The viscous drag on a spherical body of radius r, moving with velocity v, in a viscous medium of viscosity η is given by

$F_{viscous} = 6\pi\eta rv$

This relation is called Stokes' law. .

Importance of Stoke's law :

(i) It is used in the determination of electronic charge with the help of milikan's experiment.
(ii) It accounts the formation of clouds.
(iii) It accounts why the speed of rain drops is less than that of a body falling freely with a constant velocity from the height of clouds.
(iv) It helps a man coming down with the help of a parachute.

Terminal Velocity :

When a spherical body is allowed to fall through viscous medium, its velocity increases till the viscous drag plus upthrust is equal to the weight of the body. After that body moves with constant velocity, called terminal velocity.

The terminal velocity is given by $v = \frac{2R^2}{9\eta}(d - \sigma)g$

where d = density of body,
σ = density of medium,
η = coefficient of viscosity of medium,
R = radius of the spherical body.

From terminal velocity, $V \alpha \frac{1}{\eta}$, i.e. greater the viscosity, smaller is the terminal speed.

Flow of liquid through tube /pipe :

(i) Poiseuille's equation is $Q = \frac{\pi pr^4}{8\eta\ell}$, where p is the pressure difference between the two ends of the tubes, r is the radius, ℓ is the length of the tube and η is the coefficient of viscosity, Q = rate of flow of liquid.

Equivalent liquid resistance = $\frac{8\eta\ell_1}{\pi r_1^4} + \frac{8\eta\ell_2{}^2}{\pi r_2^4}$, *when tube are joined* **in series**.

It means that liquid flow through capillary tube is similar to flow of electric current through a conductor i.e., Q (rate of liquid flow) corresponds to I (rate of flow of charge), pressure difference similar to potential difference.

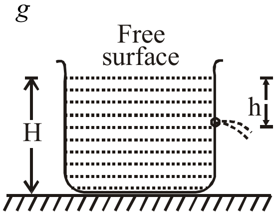
(ii) When two tubes are joined in series then the volume of fluid flowing through the two tubes is the same but the pressure difference across the two tubes is different. The total pressure difference, $P = P_1 + P_2$.

(iii) If two tubes are joined in **parallel** then the pressure difference across the two tubes is the same but the volume of fluid flowing through the two tubes is different. The total volume of the fluid flowing through the tube in one second is $Q = Q_1 + Q_2$.

VELOCITY OF EFFLUX AND TORRICELLI'S THEOREM

(i) **Torricelli's theorem :** For liquid filled in a tank upto a height H having a hole O at a depth h from free level of liquid through which the liquid is coming out, *velocity of efflux of liquid* $v = \sqrt{2gh}$.

(ii) *Time taken by the liquid in falling from hole to ground level* $t = \sqrt{\dfrac{2(H-h)}{g}}$



(iii) *The horizontal range covered by the liquid*
x = horizontal velocity (v) ×time (t)

$$= \sqrt{2gh} \times \sqrt{\frac{2(H-h)}{g}} = 2\sqrt{h(H-h)}.$$

For maximum horizontal range, differentiating both side w.r.t. h and we get h = H/2, the range is maximum.

Keep in Memory

1. The cross-section of the water stream from a top decreases as it goes down in accordance with the equation of continuity.
2. When a hale blows over a roof, the force on the roof is upwards.
3. Sudden fall in atmospheric pressure predicts possibility of a storm.
4. **Venturimeter** is a device used for the measurement of the rate of flow of incompressible fluid through a tube. Its working is based on Bernoulli's principle.

Example 8.

The vessel of area of cross-section A has liquid to a height H. There is a hole at the bottom of vessel having area of cross-section a. Find the time taken to decrease the level from H_1 to H_2.

Solution :

The average velocity of efflux, $v = \dfrac{\sqrt{2gH_1} + \sqrt{2gH_2}}{2}$

Let t be the time taken to empty the tank from level H_1 to H_2.

Then, $\dfrac{\sqrt{2gH_1} + \sqrt{2gH_2}}{2} \times a \times t = A\,[H_1 - H_2]$

$$\text{or } t = \frac{A}{a} \times \sqrt{\left(\frac{2}{g}\right)} \times \left[\frac{(H_1 - H_2) \times \left(\sqrt{H_1} - \sqrt{H_2}\right)}{\left(\sqrt{H_1} + \sqrt{H_2}\right)\left(\sqrt{H_1} - \sqrt{H_2}\right)}\right]$$

$$= \frac{A}{a} \times \sqrt{\left(\frac{2}{g}\right)} \times \left(\sqrt{H_1} - \sqrt{H_2}\right)$$

$$= \frac{A}{a} \times \sqrt{\left(\frac{2}{g}\right)} \times \left(\sqrt{H_1} - \sqrt{H_2}\right)$$

Example 9.

In a test experiment on a model aeroplane in a wind tunnel, the flow speeds on the upper and lower surfaces of the wing are 70 m/s and 63 m/s respectively. What is the lift on the wing if its area is 2.5 m^2 ? Take the density of air to be 1.3 kg m^{-3}.

Solution :

Let v_1 be the speed and P_1 be the pressure on the upper surface of the wing, and corresponding values on the lower surface be v_2 and P_2 respectively.

$\therefore$ $v_1 = 70$ m/s, $v_2 = 63$ m/s, $A = 2.5$ m^2,

$P = 1.3$ kg m^{-3}.

According to Bernoulli's theorem

$$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$$

$$P_2 - P_1 = \frac{1}{2}\rho(v_1^2 - v_2^2) = P_2 - P_1 = \frac{1}{2} \times 3 \times (70^2 - 63^2)$$

Force (lift) on the wing $= A\,(P_2 - P_1)$

$$= 2.5 \times \frac{1}{2} \times 1.3 \times (70^2 - 63^2)$$

$$= 2.5 \times \frac{1}{2} \times 1.3 \times 133 \times 7$$

$$= 1.5 \times 10^3\,\text{N}$$

Example 10.

In Millikan's oil drop experiment, what is the terminal speed of an uncharged drop of radius 2.0 × 10^{-5} m and density 1.2 × 10^3 kg m^{-3}. Take the viscosity of air at the temperature of the experiment to be 1.8 × 10^{-5} Pa s. How much is the viscous force on the drop at that speed ? Neglect buoyancy of the drop due to air.

Solution :

Here, $r = 2.0 \times 10^{-5}$ m, $\rho = 1.2 \times 10^3$ kg m^{-3},

$\eta = 1.8 \times 10^{-5}$ Pa s.

From formula, terminal velocity

$$V = \frac{2}{9}\frac{r^2(\rho - \sigma)\,g}{\eta}$$

$$\Rightarrow V = \frac{2 \times (2 \times 10^{-5})^2(1.2 \times 10^3 - 0) \times 9.8}{9 \times 1.8 \times 10^{-5}}$$

$$= 5.8 \times 10^{-2}\,\text{ms}^{-1}$$

Now viscous force on the drop

$F = 6\pi\eta r v$

$$\Rightarrow F = 6 \times \frac{22}{7} \times (1.8 \times 10^{-5}) \times (2 \times 10^{-5}) \times 5.8 \times 10^{-2}$$

$$= 3.93 \times 10^{-19}\,\text{N}$$

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CONCEPT MAP

MECHANICAL PROPERTIES OF FLUIDS
Fluids – Liquids and Gases that can flow

Pressure $P = \frac{\text{thrust (F)}}{\text{area (A)}} = \lim_{\Delta A \to 0} \frac{\Delta F}{\Delta A}$
Pressure exerted by a liquid column of height h, density ρ, $P = h\rho g$

Atmospheric pressure (P)
Pressure (atm) exerted by the atmosphere. At sea-level, 1 atm = pressure exerted by 0.76 m of Hg = hρg $= 0.76 \times 13.6 \times 10^3 \times 9.8 = 1.013 \times 10^5$ Nm^{-2} = 101.3 kPa

Absolute pressure (P)
The total or actual pressure (P) at a point absolute pressure = atmospheric pressure + gauge pressure

Gauge pressure (P_g)
Difference between the absolute pressure (P) at a point and the atmospheric pressure (Pa) Gauge pressure (P_g) = absolute pressure (P) – atmospheric pressure (Pa)

Pascal's law: The pressure exerted at any point on an enclosed liquid is transmitted equally in all directions. Hydraulic lift and hydraulic brakes are based on Pascal's law

Density $(\rho) = \frac{\text{mass(M)}}{\text{volume(V)}}$
Density of water at 4°C i.e., maximum density of water $= 1.0 \times 10^3$ kg/m^3

Relative density or specific gravity
$= \frac{\text{density of substance}}{\text{density of water at 4°C}}$

Flow of fluids
Streamline: When the liquid flow velocity is less than critical velocity, each particle of the liquid passing through a point travels along the same path sand same velocity as the preceding particles passing.
Tarbulent: When velocity of liquid flow greater than critical velocity particles follow zig-zag path.

Equation of continuity, $m = a_1 v_1 \rho_1 = a_2 v_2 \rho_2$
For an incompressible liquid, $\rho_1 = \rho_2$ then
$a_1 v_1 = a_2 v_2$ or av = constant

Bernoulli's Principle
For an incompressible, non-viscous streamline, irrotational flow of fluid,
$$P + \frac{1}{2}\rho v^2 + \rho g h = \text{constant}$$

Applications of Bernoulli's principle

- Lift of an aircraft wing.
- Sprayer or atomizer
- Blowing off the roofs during windstorm.

Torricelli's law
Velocity of efflux of liquid through an orifice,
$V = \sqrt{2gh}$

Venturimeter A device used to measure rate of flow of liquid. Volume of liquid flowing per second
$$Q = a_1 a_2 \sqrt{\frac{2h\rho_m g}{\rho(a_1^2 - a_2^2)}}$$

Viscosity
Opposing force between different layers of fluid in relative motion

Viscous drag $F = -\eta A \frac{dV}{dx}$

η = coefficient of viscosity

Stoke's law $F = 6\pi\eta v r$

Surface tension, $S = \frac{f}{\ell}$

Surface energy $= \frac{\text{Work done in increasing surface area}}{\text{increase in surface area}}$

Capillary rise or fall, $h = \frac{2S\cos\theta}{r\rho g}$

Excess pressure inside a drop (liquid)
$P_{excess} = \frac{2S}{R}$

Excess pressure inside a bubble (soap)
$P_{excess} = \frac{4S}{R}$

EXERCISE - 1
Conceptual Questions

1. The constant velocity attained by a body while falling through a viscous medium is termed as
(a) critical velocity (b) terminal velocity
(c) threshold velocity (d) None of these

2. The difference between viscosity and solid friction is/are
(a) viscosity depends on area while solid friction does not
(b) viscosity depends on nature of material but solid friction does not
(c) both (a) and (b)
(d) neither (a) nor (b)

3. Water is not used in thermometer because
(a) it sticks to glass
(b) its shows anamalous expansion
(c) both (a) and (b)
(d) neither (a) nor (b)

4. Toricelli's theorem is used to find
(a) the velocity of efflux through an orifice.
(b) the velocity of flow of liquid through a pipe.
(c) terminal velocity
(d) critical velocity

5. Gases do not posses
(a) density (b) surface tension
(c) volume (d) viscosity

6. Paint-gun is based on
(a) Bernoulli's theorem (b) Archimedes' principle
(c) Boyle's law (d) Pascal's law

7. Water is flowing through a horizontal pipe having a restriction, then
(a) pressure will be greater at the restriction.
(b) pressure will be greater in the wider portion.
(c) pressure will be same throughout the length of the pipe.
(d) None of these

8. Fevicol is added to paint to be painted on the walls, because
(a) it increases adhesive force between paint and wall.
(b) it decreases adhesive force between paint and wall molecules.
(c) it decreases cohesive force between paint molecules.
(d) None of these

9. A beaker containing a liquid of density ρ moves up with an acceleration a. The pressure due to the liquid at a depth h below the free surface of the liquid is
(a) $h\rho g$ (b) $h\rho(g-a)$
(c) $h\rho(g+a)$ (d) $2h\rho g\left(\frac{g+a}{g-a}\right)$

10. The density of ice is x gram/litre and that of water is y gram/litre. What is the change in volume when m gram of ice melts?
(a) $mxy(x-y)$ (b) $m/(y-x)$
(c) $m\left(\frac{1}{y}-\frac{1}{x}\right)$ (d) $(y-x)/x$

11. Consider a 1 c.c. sample of air at absolute temperature T_0 at sea level and another 1 c.c. sample of air at a height where the pressure is one-third atmosphere. The absolute temperature T of the sample at the height is
(a) equal to $T_0/3$
(b) equal to $3/T_0$
(c) equal to T_0
(d) cannot be determined in terms of T_0 from the above data

12. A small ball (menu) falling under graivty in a viscous medium experiences a drag force proportional to the instantaneous speed u such that $F_{drag} = Ku$. Then the terminal speed of the ball within the viscous medium is
(a) $\frac{K}{mg}$ (b) $\frac{mg}{K}$
(c) $\sqrt{\frac{mg}{K}}$ (d) $\left(\frac{mg}{K}\right)^2$

13. A cylinder is filled with non-viscous liquid of density d to a height h_0 and a hole is made at a height h_1 from the bottom of the cylinder. The velocity of the liquid issuing out of the hole is
(a) $\sqrt{2gh_0}$ (b) $\sqrt{2g(h_0-h_1)}$
(c) $\sqrt{dgh_1}$ (d) $\sqrt{dgh_0}$

14. The terminal velocity depends upon
(a) $\frac{1}{r}$ (b) $\frac{1}{r^2}$ (c) $\frac{1}{r^3}$ (d) r^2

15. The velocity of efflux of a liquid through an orifice in the bottom of the tank does not depend upon
(a) size of orifice
(b) height of liquid
(c) acceleration due to gravity
(d) density of liquid

16. At the boiling point of a liquid, surface tension
(a) is zero
(b) is infinite
(c) is same as that at any other temperature
(d) cannot be determined

17. The surface energy of a liquid drop of radius r is proportional to
(a) r^3 (b) r^2 (c) r (d) $\frac{1}{r}$

18. A liquid is contained in a vessel. The liquid-solid adhesive force is very weak as compared to the cohesive force in the liquid. The shape of the liquid surface will be
(a) horizontal (b) vertical
(c) concave (d) convex

19. Two liquids drops coalesce to form a large drop. Now,
(a) energy is liberated
(b) energy is neither liberated nor absorbed
(c) some mass gets converted into energy
(d) energy is absorbed

20. A man is sitting in a boat which is floating in pond. If the man drinks some water from the pond, the level of water in the pond will
(a) rise a little (b) fall a little
(c) remain stationary (d) none of these

21. A liquid is allowed to flow into a tube of truncated cone shape. Identify the correct statement from the following.
(a) The speed is high at the wider end and high at the narrow end.
(b) The speed is low at the wider end and high at the narrow end.
(c) The speed is same at both ends in a stream line flow.
(d) The liquid flows with uniform velocity in the tube.

22. The rain drops falling from the sky neither injure us nor make holes on the ground because they move with
(a) constant acceleration
(b) variable acceleration
(c) variable speed
(d) constant terminal velocity

23. The lift of an air plane is based on
(a) Torricelli's theorem
(b) Bernoulli's theorem
(c) Law of gravitation
(d) conservation of linear momentum

24. Surface tension may be defined as
(a) the work done per unit area in increasing the surface area of a liquid under isothermal condition
(b) the work done per unit area in increasing the surface area of a liquid under the adiabatic condition
(c) the work done per unit area in increasing the surface area of liquid under both isothermal and adiabatic condition
(d) free surface energy per unit volume

25. A liquid does not wet the sides of a solid, if the angle of contact is
(a) Zero (b) Obtuse (more than 90°)
(c) Acute (less than 90°) (d) 90° (right angle)

EXERCISE - 2
Applied Questions

1. The reading of spring balance when a block is suspended from it in air is 60 newton. This reading is changed to 40 newton when the block is submerged in water. The specific gravity of the block must be therefore
(a) 3 (b) 2 (c) 6 (d) 3/2

2. An ice-berg floating partly immersed in sea water of density 1.03 g/cm^3. The density of ice is 0.92 g/cm^3. The fraction of the total volume of the iceberg above the level of sea water is
(a) 8.1% (b) 11% (c) 34% (d) 0.8%

3. A boat having a length of 3 metres and breadth 2 metres is floating on a lake. The boat sinks by one cm when a man gets on it. The mass of the man is
(a) 60 kg (b) 62 kg (c) 72 kg (d) 128 kg

4. The excess of pressure inside a soap bubble is twice the excess pressure inside a second soap bubble. The volume of the first bubble is n times the volume of the second where n is
(a) 0.125 (b) 0.250 (c) 1 (d) 2

5. The level of water in a tank is 5m high. A hole of area 1 cm^2 is made in the bottom of the tank. The rate of leakage of water from the hole (g = 10 m/s^2) is
(a) 10^{-2} m^3/s (b) 10^{-3} m^3/s
(c) 10^{-4} m^3/s (d) 10^3 m^3/s

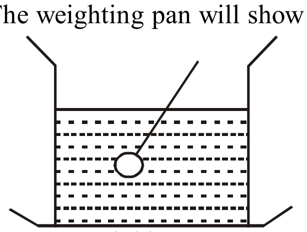
6. A spherical ball of iron of radius 2 mm is falling through a column of glycerine. If densities of glycerine and iron are respectively 1.3×10^3 kg/m^3 and 8×10^3 kg/m^3. η for glycerine = 0.83 Nm^{-2} sec, then the terminal velocity is
(a) 0.7 m/s (b) 0.07 m/s
(c) 0.007 m/s (d) 0.0007 m/s

7. A cylinder of height 20m is completely filled with water. The velocity of efflux of water (in ms^{-1}) through a small hole on the side wall or the cylinder near its bottom is
(a) 10 m/s (b) 20 m/s (c) 25.5 m/s (d) 5 m/s

8. 8 mercury drops coalesce to form one mercury drop, the energy changes by a factor of
(a) 1 (b) 2 (c) 4 (d) 6

9. Water rises to a height of 10 cm in capillary tube and mercury falls to a depth of 3.1 cm in the same capillary tube. If the density of mercury is 13.6 and the angle of contact for mercury is 135°, the approximate ratio of surface tensions of water and mercury is
(a) 1 : 0.15 (b) 1 : 3 (c) 1 : 6 (d) 1.5 : 1

10. A vessel with water is placed on a weighing pan and it reads 600 g. Now a ball of mass 40 g and density 0.80 g cm^{-3} is sunk into the water with a pin of negligible volume, as shown in figure keeping it sunk. The weighting pan will show a reading
(a) 600 g
(b) 550 g
(c) 650 g
(d) 632 g


Weighing pan

11. Water flows in a stream line manner through a capillary tube of radius a, the pressure difference being P and the rate flow Q. If the radius is reduced to $\frac{a}{2}$ and the pressure is increased to 2P, the rate of flow becomes

(a) 4Q (b) Q (c) $\frac{Q}{2}$ (d) $\frac{Q}{8}$

12. A rain drop of radius 0.3 mm has a terminal velocity in air = 1 m/s. The viscosity of air is 8×10^{-5} poise. The viscous force on it is

(a) 45.2×10^{-4} dyne (b) 101.73×10^{-5} dyne
(c) 16.95×10^{-4} dyne (d) 16.95×10^{-5} dyne

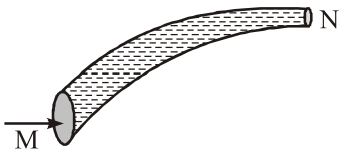
13. A big drop of radius R is formed by 1000 small droplets of water. The radius of small drop is

(a) $\frac{R}{10}$ (b) $\frac{R}{100}$ (c) $\frac{R}{500}$ (d) $\frac{R}{1000}$

14. 1 m^3 water is brought inside the lake upto 200 metres depth from the surface of the lake. What will be change in the volume when the bulk modulus of elastically of water is 22000 atmosphere?
(density of water is 1×10^3 kg/m^3 atmosphere pressure = 10^5 N/m^2 and g = 10 m/s^2)

(a) $8.9 \times 10^{-3}\, m^3$ (b) $7.8 \times 10^{-3}\, m^3$
(c) $9.1 \times 10^{-4}\, m^3$ (d) $8.7 \times 10^{-4}\, m^3$

15. Horizontal tube of non-uniform cross-section has radii of 0.1 m and 0.05 m respectively at M and N for a streamline flow of liquid the rate of liquid flow is

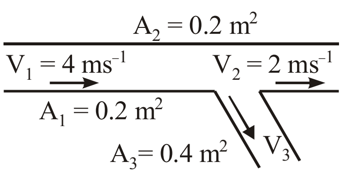


(a) continuously changes with time
(b) greater at M than at N
(c) greater at N than at M
(d) same at M and N

16. There is a hole in the bottom of tank having water. If total pressure at bottom is 3 atm (1 atm = 10^5 N/m^2) then the velocity of water flowing from hole is

(a) $\sqrt{400}$ m/s (b) $\sqrt{600}$ m/s
(c) $\sqrt{60}$ m/s (d) None of these

17. In the figure, the velocity V_3 will be

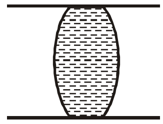
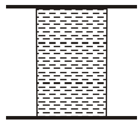


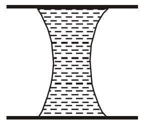
(a) Zero (b) 4 ms^{-1} (c) 1 ms^{-1} (d) 3 ms^{-1}

18. 1 centipoise is equal to

(a) 1 kg m^{-1} s^{-1} (b) 1000 kg m^{-1} s^{-1}
(c) 0.1 kg m^{-1} s^{-1} (d) 0.001 kg m^{-1} s^{-1}

19. If a water drop is kept between two glass plates, then its shape is

(a)  (b) 

(c)  (d) None of these

20. The fraction of a floating object of volume V_0 and density d_0 above the surface of liquid of density d will be

(a) $\frac{d_0}{d - d_0}$ (b) $\frac{d - d_0}{d}$
(c) $\frac{d_0}{d}$ (d) $\frac{d_0 d}{d + d_0}$

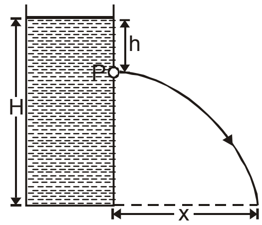
21. An open vessel containing water is given a constant acceleration a in the horizontal direction. Then the free surface of water gets sloped with the horizontal at an angle θ, given by

(a) $\theta = \cos^{-1}\frac{g}{a}$ (b) $\theta = \tan^{-1}\frac{a}{g}$
(c) $\theta = \sin^{-1}\frac{a}{g}$ (d) $\theta = \tan^{-1}\frac{g}{a}$

22. Two drops of the same radius are falling through air with a steady velocity of 5 cm per sec. If the two drops coalesce, the terminal velocity would be

(a) 10 cm per sec (b) 2.5 cm per sec
(c) $5 \times (4)^{1/3}$ cm per sec (d) $5 \times \sqrt{3}$ cm per sec

23. A tank is filled with water upto a height H. Water is allowed to come out of a hole P in one of the walls at a depth h below the surface of water (see fig.) Express the horizontal distance X in terms H and h.



(a) $X = \sqrt{h(H-h)}$ (b) $X = \sqrt{\frac{h}{2}(H-h)}$
(c) $X = 2\sqrt{h(H-h)}$ (d) $X = 4\sqrt{h(H-h)}$

24. A body of density ρ' is dropped from rest at a height h into a lake of density ρ where ρ > ρ' neglecting all dissipative forces, calculate the maximum depth to which the body sinks before returning to float on the surface :

(a) $\frac{h}{\rho - \rho'}$ (b) $\frac{h\rho'}{\rho}$ (c) $\frac{h\rho'}{\rho - \rho'}$ (d) $\frac{h\rho}{\rho - \rho'}$

25. Two capillary of length L and 2L and of radius R and 2R are connected in series. The net rate of flow of fluid through them will be (given rate to the flow through single capillary, $X = \frac{\pi P R^4}{8\eta L}$)

(a) $\frac{8}{9}X$ (b) $\frac{9}{8}X$ (c) $\frac{5}{7}X$ (d) $\frac{7}{5}X$

26. One drop of soap bubble of diameter D breaks into 27 drops having surface tension σ. The change in surface energy is

(a) $2\pi\sigma D^2$ (b) $4\pi\sigma D^2$
(c) $\pi\sigma D^2$ (d) $8\pi\sigma D^2$

27. In case A, when an 80 kg skydiver falls with arms and legs fully extended to maximize his surface area, his terminal velocity is 60 m/s. In Case B, when the same skydiver falls with arms and legs pulled in and body angled downward to minimize his surface area, his terminal velocity increases to 80 m/s. In going from Case A to Case B, which of the following statements most accurately describes what the skydiver experiences?

(a) $F_{\text{air resistance}}$ increases and pressure P increases
(b) $F_{\text{air resistance}}$ increases and pressure P decreases
(c) $F_{\text{air resistance}}$ decreases and pressure P increases
(d) $F_{\text{air resistance}}$ remains the same and pressure P increases

28. A ring is cut from a platinum tube 8.5 cm internal and 8.7 cm external diameter. It is supported horizontally from the pan of a balance, so that it comes in contact with the water in a glass vessel. If an extra 3.97. If is required to pull it away from water, the surface tension of water is

(a) 72 dyne cm^{-1} (b) 70.80 dyne cm^{-1}
(c) 63.35 dyne cm^{-1} (d) 60 dyne cm^{-1}

29. A capillary tube of radius r is immersed in a liquid. The liquid rises to a height h. The corresponding mass is m. What mass of water shall rise in the capillary if the radius of the tube is doubled?

(a) m (b) 2m (c) 3m (d) 4m

30. In a satellite moving round any planet, the gravitational force is effectively balanced. If an ice cube exists there, and it melts with passage of time, its shape will

(a) remain unchanged
(b) change to spherical
(c) become oval-shaped with long-axis along the orbit plane
(d) become oval-shaped with long axis perpendicular to orbit plane

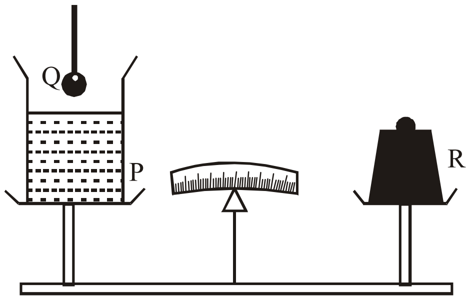
31. An egg when placed in ordinary water sinks but floats when placed in brine. This is because

(a) density of brine is less than that of ordinary water
(b) density of brine is equal to that of ordinary water
(c) density of brine is greater than that of ordinary water
(d) None of these

32. Two pieces of metals are suspended from the arms of a balance and are found to be in equilibrium when kept immersed in water. The mass of one piece is 32 g and its density 8 g cm^{-3}. The density of the other is 5 g per cm^3. Then the mass of the other is

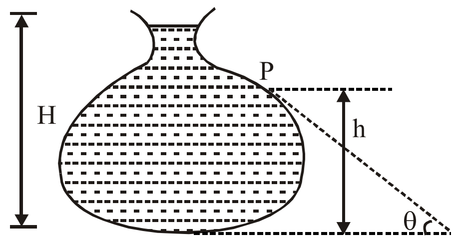
(a) 28 g (b) 35 g (c) 21 g (d) 33.6 g

33. Figure shows a weigh-bridge, with a beaker P with water on one pan and a balancing weight R on the other. A solid ball Q is hanging with a thread outside water. It has volume 40 cm^3 and weighs 80 g. If this solid is lowered to sink fully in water, but not touching the beaker anywhere, the balancing weight R' will be



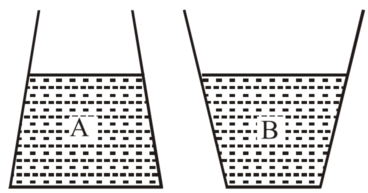
(a) same as R (b) 40 g less than R
(c) 40 g more than R (d) 80 g more than R

34. Figure here shows the vertical cross section of a vessel filled with a liquid of density ρ. The normal thrust per unit area on the walls of the vessel at the point P, as shown, will be



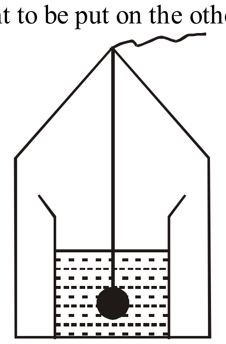
(a) $h\rho g$ (b) $H\rho g$
(c) $(H - h)\rho g$ (d) $(H - h)\rho g \cos\theta$

35. Two vessels A and B of cross-sections as shown in figure contain a liquid up to the same height. As the temperature rises, the liquid pressure at the bottom (neglecting expansion of the vessels) will



(a) increase in A, decrease in B
(b) increase in B, decrease in A
(c) increase in both A and B
(d) decrease in both A and B

36. A beaker with a liquid of density 1.4 g cm^{-3} is in balance over one pan of a weighing machine. If a solid of mass 10 g and density 8 g cm^{-3} is now hung from the top of that pan with a thread and sinking fully in the liquid without touching the bottom, the extra weight to be put on the other pan for balance will be



(a) 10.0 g

(b) 8.25 g

(c) 11.75 g

(d) –1.75 g

37. The pressure energy per unit volume of a liquid is

(a) $\frac{P}{\rho}$ (b) P (c) $P \times \rho$ (d) $\frac{\rho}{P}$

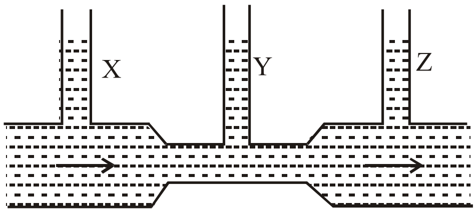
38. A water tank of height 10m, completely filled with water is placed on a level ground. It has two holes one at 3 m and the other at 7 m from its base. The water ejecting from

(a) both the holes will fall at the same spot
(b) upper hole will fall farther than that from the lower hole
(c) upper hole will fall closer than that from the lower hole
(d) more information is required

39. A fast train goes past way side station platform at high speed. A person standing at the edge of the platform is

(a) attracted to train
(b) repelled from train
(c) unaffected by outgoing train
(d) affected only if the train's speed is more than the speed of sound

40. Three tubes X, Y and Z are connected to a horizontal pipe in which ideal liquid is flowing. The radii of the tubes X, Y and Z at the junction are respectively 3 cm, 1 cm and 3 cm. It can be said

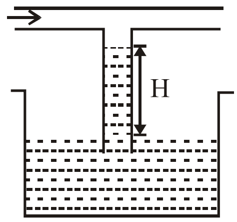


(a) the height of the liquid in the tube A is maximum.
(b) the height of liquid in the tubes Aand B is same.
(c) the height liquid in the tubes A,B and C is same.
(d) the height of the liquid in the tubes A and C is the same.

41. A sphere of brass released in a long liquid column attains a terminial speed v_0. If the terminal speed attained by sphere of marble of the same radius and released in the same liquid is nv_0, then the value of n will be (Given : The specific gravities of brass, marbles and the liquid are 8.5, 2.5 and 0.8 respectively.)

(a) $\frac{5}{17}$ (b) $\frac{17}{77}$ (c) $\frac{11}{31}$ (d) $\frac{17}{5}$

42. Figure shows a capillary rise H. If the air is blown through the horizontal tube in the direction as shown then rise in capillary tube will be



(a) = H (b) > H (c) < H (d) zero

43. Two soap bubbles (surface tension T) coalesce to form a big bubble under isothermal condition. If in this process the change in volume be V and the surface area be S, then the correct relation is (P is atmospheric pressure)

(a) $PV + TS = 0$ (b) $3PV + 4TS = 0$
(c) $3PV + TS = 0$ (d) $4PV + 3TS = 0$

44. Two liquids of densities d_1 and d_2 are flowing in identical capillary tubes uder the same pressure difference. If t_1 and t_2 are time taken for the flow of equal quantities (mass) of liquids, then the ratio of coefficient of viscosity of liquids must be

(a) $\frac{d_1t_1}{d_2t_2}$ (b) $\frac{t_1}{t_2}$ (c) $\frac{d_2}{d_1}\frac{t_2}{t_1}$ (d) $\sqrt{\frac{d_1t_1}{d_2t_2}}$

45. A tank has a small hole at its botom of area of cross-section a. Liquid is being poured in the tank at the rate Vm^3/s, the maximum level of liquid in the container will be (Area of tank A)

(a) $\frac{V}{gaA}$ (b) $\frac{V^2}{2gAa}$ (c) $\frac{V^2}{gAa}$ (d) $\frac{V}{2gaA}$

Directions for Qs. (46 to 50) : Each question contains STATEMENT-1 and STATEMENT-2. Choose the correct answer (ONLY ONE option is correct) from the following-

(a) Statement -1 is false, Statement-2 is true
(b) Statement -1 is true, Statement-2 is true; Statement -2 is a correct explanation for Statement-1
(c) Statement -1 is true, Statement-2 is true; Statement -2 is not a correct explanation for Statement-1
(d) Statement -1 is true, Statement-2 is false

46. **Statement 1 :** Smaller the droplets of water, spherical they are.
Statement 2 : Force of surface tension is equal, and opposite to force of gravity.

47. **Statement 1 :** If a body is floating in a liquid, the density of liquid is always greater than the density of solid.
Statement 2 : Surface tension is the property of liquid surface.

48. **Statement 1 :** The velocity of flow of a liquid is smaller when pressure is larger and vice-versa.
Statement 2 : According to Bernoulli's theorem, for the stream line flow of an ideal liquid, the total energy per unit mass remains constant.

49. **Statement 1 :** Falling raindrops acquire a terminal velocity.

Statement 2 : A constant force in the direction of motion and a velocity dependent force opposite to the direction of motion, always result in the acquisition of terminal velocity.

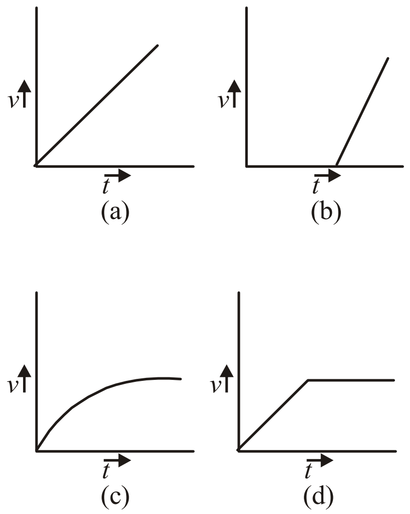
50. **Statement 1 :** The buoyant force on a submerged rigid object can be considered to be acting at the centre of mass of the object.

Statement 2 : For a rigid body a force field distributed uniformly through its volume can be considered to be acting at the centre of mass of the body.

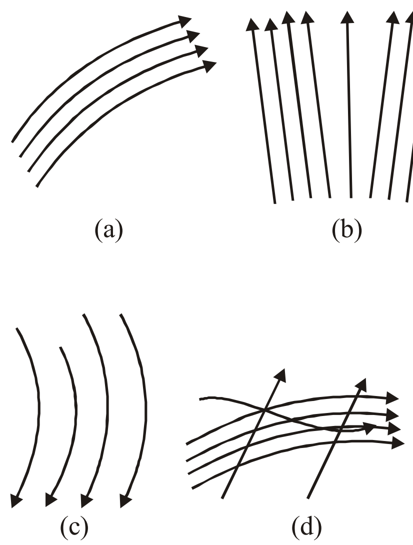
EXERCISE - 3
Exemplar & Past Years NEET/AIPMT Questions

Exemplar Questions

1. A tall cylinder is filled with viscous oil. A round pebble is dropped from the top with zero initial velocity. From the plot shown in figure, indicate the one that represents the velocity (v) of the pebble as a function of time (t).



2. Which of the following diagrams does not represent a streamline flow?



3. Along a streamline,
(a) the velocity of a fluid particle remains constant
(b) the velocity of all fluid particles crossing a given position is constant
(c) the velocity of all fluid particles at a given instant is constant
(d) the speed of a fluid particle remains constant

4. An ideal fluid flows through a pipe of circular cross-section made of two sections with diameters 2.5 cm and 3.75 cm. The ratio of the velocities in the two pipes is

(a) $9:4$ (b) $3:2$ (c) $\sqrt{3}:\sqrt{2}$ (d) $\sqrt{2}:\sqrt{3}$

5. The angle of contact at the interface of water-glass is 0°, ethyl alcohol-glass is 0°, mercury-glass is 140° and methyliodide-glass is 30°. A glass capillary is put in a trough containing one of these four liquids. It is observed that the meniscus is convex. The liquid in the trough is
(a) water (b) ethylalcohol
(c) mercury (d) methyliodide

NEET/AIPMT (2013-2017) Questions

6. The wetability of a surface by a liquid depends primarily on
(a) surface tension ***[2013]***
(b) density
(c) angle of contact between the surface and the liquid
(d) viscosity

7. A fluid is in streamline flow across a horizontal pipe of variable area of cross section. For this which of the following statements is correct? ***[NEET Kar. 2013]***
(a) The velocity is minimum at the narrowest part of the pipe and the pressure is minimum at the widest part of the pipe
(b) The velocity is maximum at the narrowest part of the pipe and pressure is maximum at the widest part of the pipe
(c) Velocity and pressure both are maximum at the narrowest part of the pipe
(d) Velocity and pressure both are maximum at the widest part of the pipe

8. A certain number of spherical drops of a liquid of radius 'r' coalesce to form a single drop of radius 'R' and volume 'V'. If 'T' is the surface tension of the liquid, then : ***[2014]***

(a) energy $= 4VT\left(\frac{1}{r}-\frac{1}{R}\right)$ is released

(b) energy $= 3VT\left(\frac{1}{r}+\frac{1}{R}\right)$ is absorbed

(c) energy $= 3VT\left(\frac{1}{r}-\frac{1}{R}\right)$ is released

(d) energy is neither released nor absorbed

9. A wind with speed 40 m/s blows parallel to the roof of a house. The area of the roof is 250 m^2. Assuming that the pressure inside the house is atmospheric pressure, the force exerted by the wind on the roof and the direction of the force will be ($\rho_{air} = 1.2\ kg/m^3$) ***[2015]***

(a) 4.8×10^5 N, upwards

(b) 2.4×10^5 N, upwards

(c) 2.4×10^5 N, downwards

(d) 4.8×10^5 N, downwards

10. The cylindrical tube of a spray pump has radius, R, one end of which has n fine holes, each of radius r. If the speed of the liquid in the tube is V, the speed of the ejection of the liquid through the holes is : ***[2015 RS]***

(a) $\frac{VR^2}{nr^2}$ (b) $\frac{VR^2}{n^3r^2}$ (c) $\frac{V^2R}{nr}$ (d) $\frac{VR^2}{n^2r^2}$

11. Water rises to a height 'h' in a capillary tube. If the length of capaillary tube above the surface of water is made less than 'h' then : ***[2015 RS]***

(a) water rises upto the top of capillary tube and stays there without overflowing

(b) water rises upto a point a little below the top and stays there

(c) water does not rise at all.

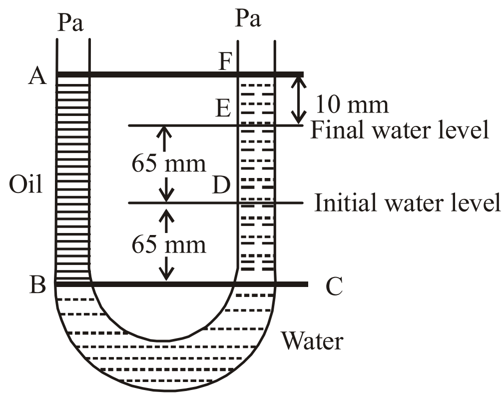
(d) Water rises upto the tip of capillary tube and then starts overflowing like fountain.

12. Two non-mixing liquids of densities ρ and $n\rho (n > 1)$ are put in a container. The height of each liquid is h. A solid cylinder of length L and density d is put in this container. The cylinder floats with its axis vertical and length $pL (p < 1)$ in the denser liquid. The density d is equal to : ***[2016]***

(a) $\{1 + (n + 1)p\}\rho$ (b) $\{2 + (n + 1)p\}\rho$

(c) $\{2 + (n - 1)p\}\rho$ (d) $\{1 + (n - 1)p\}\rho$

13. A U tube with both ends open to the atmosphere, is partially filled with water. Oil, which is immiscible with water, is poured into one side until it stands at a distance of 10 mm above the water level on the other side. Meanwhile the water rises by 65 mm from its original level (see diagram). The density of the oil is ***[2017]***



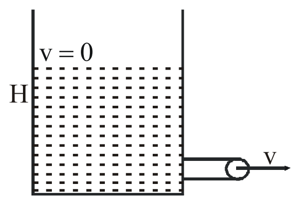
(a) 425 kg m^{-3} (b) 800 kg m^{-3}

(c) 928 kg m^{-3} (d) 650 kg m^{-3}

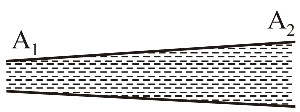
Hints & Solutions

EXERCISE - 1

1. (b) 2. (a) 3. (c) 4. (a) 5. (b)
6. (a) 7. (b) 8. (a)
9. (c) When a beaker containing a liquid of density ρ moves up with an acceleration a, it will work as a lift moving upward with acceleration a. The effective acceleration due to gravity in lift = (a + g)
$\therefore$ Pressure of liquid of height h = h ρ (a + g)
10. (c) Volume of m g of ice = m/x and
volume of m g of water = m/y. So change in volume
$$= \frac{m}{y} - \frac{m}{x} = m\left(\frac{1}{y} - \frac{1}{x}\right)$$
11. (a) $P \propto T$
12. (b)
13. (b) Velocity of liquid flowing out of hole = $\sqrt{2gh}$.
Here $h = (h_0 - h_1)$
14. (d) Terminal velocity, $v_T = \frac{2r^2g}{9\eta}(\rho - \sigma)$, $v_T \propto r^2$
15. (a) v = velocity of efflux through an orifice $= \sqrt{2gH}$



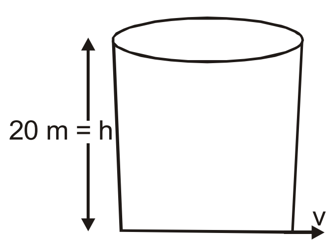
It is independent of the size of orifice.
16. (a)
17. (b) Surface energy $\propto$ surface area $= \pi r^2$
18. (d)
19. (a) When liquid drops coalesce, there is a decrease of surface area and therefore decrease of surface energy. Hence, energy is liberated.
20. (c)
21. (b) The theorem of continuity is valid.
$\therefore A_1v_1\rho = A_2v_2\rho$ as the density of the liquid can be taken as uniform.



$\therefore A_1v_1 = A_2v_2$
$\Rightarrow$ Smaller the area, greater the velocity.
22. (b)
23. (b) Apply Bernoulli's theorem.
24. (a) In Isothermal conditons $T = \frac{W}{\Delta A}$
where, T = surface tension, W = work done,
ΔA = change in area.
25. (b)

EXERCISE - 2

1. (a) Specific gravity of block $= \frac{\text{weight of block in air}}{\text{loss of weight in water}}$
$$= \frac{60}{60-40} = 3$$
2. (b) Let v be the volume of the ice-berg outside the sea water and V be the total volume of ice-berg. Then as per question
0.92 V = 1.03 (V – v) or v/V = 1 – 0.92/1.03
= 11/103
$\therefore$ (v/V) × 100 = 11 × 100 / 103 ≅ 11%
3. (a) Weight of a man = wt. of water displaced
$$= \text{volume} \times \text{density} = 3 \times 2 \times \frac{1}{100} \times 10^3 = 60 \text{ kg}$$
4. (a) Given, $\frac{4T}{r_1} = 2 \times \frac{4T}{r_2}$ or $r_2 = 2r_1$
$$\frac{4}{3}\pi r_1^3 = n \times \frac{4}{3}\pi r_2^3 = n \times \frac{4}{3}\pi(2r_1)^3 \text{ or } n = \frac{1}{8} = 0.125$$
5. (b) Velocity of efflux, $v = \sqrt{2gh}$;
volume of liquid flowing out per sec
$$= v \times A = \sqrt{2gh} \times A = \sqrt{2 \times 10 \times 5} \times 10^{-4} = 10^{-3} \text{ m}^3/\text{s}$$
6. (b) Terminal velocity, $v_0 = \frac{2r^2(\rho - \rho_0)g}{9\eta}$
$$= \frac{2 \times (2 \times 10^{-3})^2 \times (8 - 1.3) \times 10^3 \times 9.8}{9 \times 0.83} = 0.07 \text{ ms}^{-1}$$
7. (b) P.E. = K.E.



$$mgh = \frac{1}{2}mv^2$$
$$v = \sqrt{2gh} = \sqrt{2 \times 10 \times 20} \text{ (Here } g = 10 \text{ m/s}^2) = 20 \text{ m/s}$$

8. (c) Surface energy $=$ suface tension $\times$ area of surface

For 1 drop, volume $= \frac{4}{3}\pi R^3$ if $R =$ radius of drop.

Total volume of 8 drops $= 8.\frac{4}{3}\pi R^3 = \frac{4}{3}\pi(2R)^3$

$R' = 2R$, new radius of big drop

New area $= 4\pi 4R^2 = 4 \times$ old area

Energy $\propto$ area

$E_1 = 4\pi R^2$ .....(1)

$E_2 = 4.4\pi R^2$ .....(2)

From equation (1) and (2) we get, $E_2 = 4E_1$

9. (c) $h = \frac{2\sigma\cos\theta}{r\rho g} \Rightarrow \sigma \propto \frac{h\rho}{\cos\theta}$

$$\Rightarrow \frac{\sigma_w}{\sigma_m} = \frac{h_w\rho_w}{\cos\theta_w} \times \frac{\cos\theta_m}{h_m\rho_m} = \frac{10\times 1}{\cos 0°} \times \frac{\cos 135°}{-3.1\times 13.6}$$

$$= \frac{10\times(-0.707)}{-3.1\times 13.6} \approx \frac{1}{6}$$

10. (c) Volume of ball $= \frac{40}{0.8} = 50\ cm^3$

Downthrust on water $= 50$ g.

Therefore reading is 650 g.

11. (d) $Q' = \frac{\pi(2P)\left(\frac{a}{2}\right)^4}{8\eta\ell} = \frac{Q}{8}$ $\left[\because Q = \frac{\pi Pa^4}{8\eta\ell}\right]$

12. (a) $F = 6\pi\eta r v$

$= 6 \times 3.14 \times (8 \times 10^{-5}) \times 0.03 \times 100 = 4.52 \times 10^{-3}$ dyne

13. (a)

14. (c) $K = \frac{P}{\Delta V/V}$ $\therefore \Delta V = \frac{PV}{K}$

$P = h\rho g = 200 \times 10^3 \times 10\ N/m^2$

$K = 22000\ atm = 22000 \times 10^5\ N/m^2$

$V = 1m^3$

$$\Delta V = \frac{200\times 10^3 \times 10\times 1}{22000\times 10^5} = 9.1\times 10^{-4} m^3$$

15. (d) According to principle of continuity, for a streamline flow of fluid through a tube of non-uniform cross-section the rate of flow of fluid (Q) is same at every point in the tube.

i.e., $Av =$ constant $\Rightarrow A_1v_1 = A_2v_2$

Therefore, the rate of flow of fluid is same at M and N.

16. (a) Pressure at the bottom of tank $P = h\rho g = 3\times 10^5 \frac{N}{m^2}$

Pressure due to liquid column

$P_1 = 3\times 10^5 - 1\times 10^5 = 2\times 10^5$

and velocity of water $v = \sqrt{2gh}$

$$\therefore v = \sqrt{\frac{2P_1}{\rho}} = \sqrt{\frac{2\times 2\times 10^5}{10^3}} = \sqrt{400}\ m/s$$

17. (c) According to equation of continuity

$A_1V_1 = A_2V_2 + A_3V_3$

$\Rightarrow 4 \times 0.2 = 2 \times 0.2 + 0.4 \times V_3 \Rightarrow V_3 = 1$ m/s.

18. (d) 1 centipoise $= 10^{-2}\ gcm^{-1}\ s^{-1} = 0.001\ kg\ m^{-1}s^{-1}$

19. (c) Angle of contact is acute.

20. (b) Let x be the fraction of volume of object floating above the surface of the liquid.

As weight of liquid displaced = weight of object

$\therefore (V_0 - x V_0)d\,g = V_0\,d_0\,g$

$(1-x)d = d_0$ or $x = 1 - \frac{d_0}{d} = \frac{d-d_0}{d}$

21. (d) $\tan\theta = \frac{mg}{ma} = \frac{g}{a}$ or $\theta = \tan^{-1} g/a$

22. (c) If R is radius of bigger drop formed, then

$\frac{4}{3}\pi R^3 = 2\times\frac{4}{3}\pi r^3$ or $R = 2^{1/3} r$

As $v_0 \propto r^2$

$$\therefore \frac{v_{01}}{v_0} = \frac{R^2}{r^2} = \frac{(2^{1/3}r)^2}{r^2} = 2^{2/3}$$

or $v_{01} = v_0 \times 2^{2/3} = 5\times(4)^{1/3}$

23. (c) Vertical distance covered by water before striking ground $= (H-h)$. Time taken is, $t = \sqrt{2(H-h)/g}$:

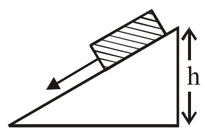
Horizontal velocity of water coming out of hole at P,

$u = \sqrt{2gh}$

$\therefore$ Horizontal range $= ut = \sqrt{2gh}\times\sqrt{2(H-h)/g}$

$= 2\sqrt{h(H-h)}$

24. (c) The effective acceleration of the body $g' = \left(1 - \frac{\rho}{\rho'}\right)g$



Now, the depth to which the body sinks

$$h' = \left(\frac{u^2}{2g'}\right) = \frac{2gh}{2g'} = \frac{gh}{g'} = \frac{h\times\rho'}{\rho-\rho'}$$

25. (a) Fluid resistance is given by $R = \frac{8\eta L}{\pi r^4}$

When two capillary tubes of same size are joined in parallel, then equivalent fluid resistance is

$$R_S = R_1 + R_2 = \frac{8\eta L}{\pi R^4} + \frac{8\eta\times 2L}{\pi(2R)^4} = \left(\frac{8\eta L}{\pi R^4}\right)\times\frac{9}{8}$$

Rate of flow $= \frac{P}{R_S} = \frac{\pi PR^4}{8\eta L} \times \frac{8}{9} = \frac{8}{9} X \quad \left[\text{as } X = \frac{\pi PR^4}{8\eta L}\right]$

26. (d) Volume of bigger bubble = volume of 27 smaller bubbles

$$\Rightarrow \frac{4}{3}\pi D^3 = 27 \times \frac{4}{3}\pi d^3 \Rightarrow d = \frac{D}{3}$$

Initial surface energy $S_i = 4\pi D^2 \sigma$

Final surface energy $S_f = 27 \times 4\pi d^2 \sigma$

$\Delta S = S_f - S_i$ and using $d = \frac{D}{3}$

$$\Delta S = \sigma \times 4\pi\left[27 \times \frac{D^2}{9} - D^2\right]$$

$$= 2D^2 \times 4\pi \times \sigma = 8\pi\sigma D^2$$

27. (d) For the first part of the question, remember that terminal velocity means the acceleration experienced becomes zero.

Since a = 0 m/s^2, then, $\Sigma F_y = F_{\text{air resistance}} - F_w = 0$

$F_{\text{air resistance}} = F_w mg$

For the second part of the question, while the velocity is higher, the acceleration is still zero. Therefore, the $F_{\text{air resistance}}$ is still equal to the skydiver's weight.

$F_{\text{air resistance Case A}} = F_{\text{air resistance Case B}}$

What has changed is the surface area of the skydiver. Since pressure is P = F/A, as A decreases, the pressure experienced increases.

$P_A A_A = P_B A_B = mg$

Since $A_A > A_B$, then $P_A < P_B$

28. (a) $(2\pi r_1 + 2\pi r_2)\sigma = mg$

$$\left[2\pi \times \frac{8.7}{2} + 2\pi \times \frac{8.5}{2}\right]\sigma = 3.97 \times 980$$

$$\Rightarrow \sigma = 72 \text{ dyne cm}^{-1}$$

29. (b) Mass of liquid which rises in the capillary,

$$m = (\pi r^2)h\rho = \pi r^2 \times \frac{2\sigma\cos\theta}{r\rho g} \times \rho$$

$\Rightarrow m \propto r$

30. (b) Because of surface tension.

31. (c) Brine due to its high density exerts an upthrust which can balance the weight of the egg.

32. (b) Volume of first piece of metal $= \frac{32}{8} = 4\,\text{cm}^3$

Upthrust = 4 gf

Effective weight = (32 – 4) gf = 28 gf

If m be the mass of second body, volume of second body is $\frac{m}{5}$

Now, $28 = m - \frac{m}{5} \Rightarrow m = 35$ g

33. (c) Upthrust = weight of 40 cm^3 of water = 40 g = down thrust on water

34. (c) Pressure is proportional to depth from the free surface and is same in all directions.

35. (a) As temperature rises, the density decreases, height increases. In A, the top cross-section is smaller. Therefore $h_A > h_B$.

36. (a) 10g is the force on water = extra wt. on other pan.

37. (b) Bernoulli's theorem.

38. (a) Velocity of water from hole

A = $v_1 = \sqrt{2gh}$

Velocity of water from hole B

$= v_2 = \sqrt{2g(H_0 - h)}$

Time of reaching the ground from hole B

$= t_1 = \sqrt{2(H_0 - h)/g}$

Time of reaching the ground from hole A

$= t_2 = \sqrt{2h/g}$

39. (a) Apply Bernoulli's theorem.

40. (d) Use the equation of continuity and Bernoulli's theorem.

41. (b) For the same radius, terminal velocity is directly proportional to density difference.

42. (b) Due to increase in velocity, pressure will be low above the surface of water.

43. (b) 44. (a) 45. (b) 46. (c) 47. (d)

48. (a) 49. (a) 50. (d)

EXERCISE - 3

Exemplar Questions

1. (c) When the pebble is dropped from the top of cylinder filled with viscous oil and pebble falls under gravity with constant acceleration, but as it is dropped it enter in oil. So dragging or viscous force is

$F = 6\pi\eta rv$

where *r* is radius of the pebble, *v* is instantaneous speed, η is coefficient of viscosity.

As the force is variable, hence acceleration is also variable so *v-t* graph will not be straight line due to viscosity of oil. First velocity increases and then becomes constant known as terminal velocity.

2. (d) In a streamline flow the velocity of fluid particles remaines constant across any cross-sectional area, then a point on the area cannot have different velocities at the same time, hence two streamlines flow layers do not cross each other.

3. (b) In streamline flow, the speed of liquid of each particle at a point in a particular cross-section is constant, between two cross-section of a tube of flow because AV = constant (law of continuity).

4. (a) As given that,
Diameter at 1st section $(d_1) = 2.5$.
Diameter at 2nd section $(d_2) = 3.75$.
According to equation of continuity,
for cross-sections A_1 and A_2.
$A_1v_1 = A_2v_2$

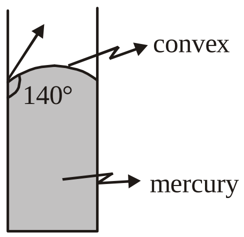
$$\frac{v_1}{v_2} = \frac{A_2}{A_1} = \frac{\pi(r_2^2)}{\pi(r_1^2)} = \left(\frac{r_2}{r_1}\right)^2$$

$$= \frac{\left(\frac{d_2}{2}\right)^2}{\left(\frac{d_1}{2}\right)^2} = \left(\frac{d_2}{d_1}\right)^2 \quad \left[\because r_2 = \frac{d_2}{2}, r_1 = \frac{d_1}{2}\right]$$

$$= \left(\frac{3.75}{2.5}\right)^2 = \frac{9}{4}$$

$\therefore v_1 : v_2 = 9 : 4$

5. (c) We observed that meniscus of liquid is convex shape as shown in figure which is possible if only, the angle of contact is obtuse. Hence, the combination will be of case of mercury-glass (140°). Hence verifies the option (c).



NEET/AIPMT (2013-2017) Questions

6. (c) Wetability of a surface by a liquid primarily depends on angle of contact between the surface and liquid.
If angle of contact is acute liquids wet the solid and vice-versa.

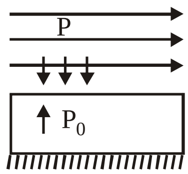
7. (b) According to Bernoulli's theorem,
$P + \frac{1}{2}\rho v^2$ = constant and Av = constant
If A is minimum, v is maximum, P is minimum.

8. (c) As surface area decreases so energy is released.
Energy released $= 4\pi R^2 T[n^{1/3} - 1]$
where $R = n^{1/3}r$

$$= 4\pi R^3 T\left[\frac{1}{r} - \frac{1}{R}\right] = 3VT\left[\frac{1}{r} - \frac{1}{R}\right]$$

9. (b) According to Bernoulli's theorem,
$P + \frac{1}{2}\rho v^2 = P_0 + 0$

So, $\Delta P = \frac{1}{2}\rho v^2$



$F = \Delta PA = \frac{1}{2}\rho v^2 A$

$= \frac{1}{2} \times 1.2 \times 40 \times 40 \times 250$

$= 2.4 \times 10^5$ N (upwards)

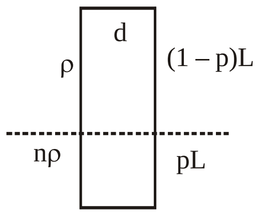
10. (a) Inflow rate of volume of the liquid = Outflow rate of volume of the liquid

$$\pi R^2 V = n\pi r^2 (v) \Rightarrow v = \frac{\pi R^2 V}{n\pi r^2} = \frac{VR^2}{nr^2}$$

11. (a) Water rises upto the top of capillary tube and stays there without overflowing.

12. (d) As we know,

Pressure P = Vdg



Here, $L A d g = (pL) A (n\rho)g + (1 - p)L A \rho g$
$\Rightarrow d = (1 - p)\rho + pn\rho = [1 + (n - 1)p]\rho$

13. (c) Here, $h_{oil} \times \rho_{oil} \times g = h_{water} \times \rho_{water} \times g$
$\rho_0 g \times 140 \times 10^{-3} = \rho_w g \times 130 \times 10^{-3}$

$$\rho_{oil} = \frac{130}{140} \times 10^3 \approx 928 \text{kg/m}^3 \quad [\because \rho_w = 1 \text{ kgm}^{-3}]$$