Chapter 11
Fluid Mechanics

Fluid is the name given to a substance which begins to flow when external force is applied on it. Liquids and gases are fluids. Fluids do not have their own shape but take the shape of the containing vessel. The branch of physics which deals with the study of fluids at rest is called hydrostatics and the branch which deals with the study of fluids in motion is called hydrodynamics.

Pressure

The normal force exerted by liquid at rest on a given surface in contact with it is called thrust of liquid on that surface.

The normal force (or thrust) exerted by liquid at rest per unit area of the surface in contact with it, is called pressure of liquid or hydrostatic pressure.

If F be the normal force acting on a surface of area A in contact with liquid, then pressure exerted by liquid on this surface is $P = F/A$

(1) Units : N/m^2 or Pascal (S.I.) and Dyne/cm (C.G.S.)

(2) Dimension : $[P] = \frac{[F]}{[A]} = \frac{[MLT^{-2}]}{[L^2]} = [ML^{-1}T^{-2}]$

(3) At a point pressure acts in all directions and a definite direction is not associated with it. So pressure is a tensor quantity.

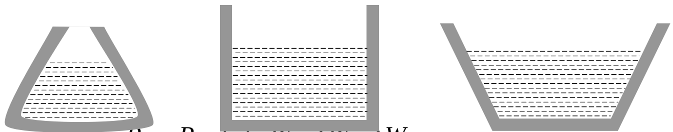
(4) Atmospheric pressure : The gaseous envelope surrounding the earth is called the earth's atmosphere and the pressure exerted by the atmosphere is called atmospheric pressure. Its value on the surface of the earth at sea level is nearly $1.013 \times 10^5 N/m^2$ or Pascal in S.I., other practical units of pressure are atmosphere, bar and torr (*mm* of *Hg*)

$$1 atm = 1.01 \times 10^5 Pa = 1.01 \text{bar} = 760 \text{ torr}$$

The atmospheric pressure is maximum at the surface of earth and goes on decreasing as we move up into the earth's atmosphere.

(5) If P_0 is the atmospheric pressure then for a point at depth h below the surface of a liquid of density ρ, hydrostatic pressure P is given by $P = P_0 + h\rho g$

(6) Hydrostatic pressure depends on the depth of the point below the surface (*h*), nature of liquid (ρ) and acceleration due to gravity (*g*) while it is independent of the amount of liquid, shape of the container or cross-sectional area considered. So if a given liquid is filled in vessels of different shapes to same height, the pressure at the base in each vessel's will be the same, though the volume or weight of the liquid in different vessels will be different.



$P_A = P_B = P_C$ but $W_A < W_B < W_C$

Fig. 11.2

(7) In a liquid at same level, the pressure will be same at all points, if not, due to pressure difference the liquid cannot be at rest. This is why the height of liquid is the same in vessels of different shapes containing different amounts of the same liquid at rest when they are in communication with each other.

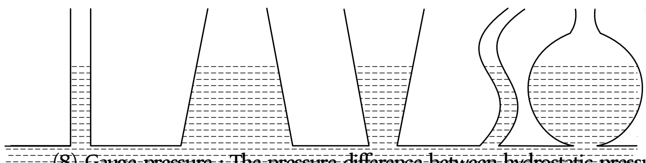


Fig. 11.3

(8) Gauge pressure : The pressure difference between hydrostatic pressure P and atmospheric pressure P_0 is called gauge pressure.

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

Density

In a fluid, at a point, density ρ is defined as:

$$\rho = \lim_{\Delta V \to 0} \frac{\Delta m}{\Delta V} = \frac{dm}{dV}$$

(1) In case of homogenous isotropic substance, it has no directional properties, so is a scalar.

(2) It has dimensions $[ML^{-3}]$ and S.I. unit *kg/m* while C.G.S. unit *g/cc* with $1g / cc = 10^3 kg / m^3$

(3) Density of substance means the ratio of mass of substance to the volume occupied by the substance while density of a body means the ratio of mass of a body to the volume of the body. So for a solid body.

Density of body = Density of substance

While for a hollow body, density of body is lesser than that of substance $[\text{As } V_{\text{body}} > V_{\text{sub.}}]$

(4) When immiscible liquids of different densities are poured in a container, the liquid of highest density will be at the bottom while that of lowest density at the top and interfaces will be plane.

(5) Sometimes instead of density we use the term relative density or specific gravity which is defined as :

$$RD = \frac{\text{Density of body}}{\text{Density of water}}$$

(6) If m_1 mass of liquid of density ρ_1 and m_2 mass of density ρ_2 are mixed, then as

$$m = m_1 + m_2 \text{ and } V = (m_1 / \rho_1) + (m_2 / \rho_2)$$

$$[\text{As } V = m / \rho]$$

$$\rho = \frac{m}{V} = \frac{m_1 + m_2}{(m_1/\rho_1) + (m_2/\rho_2)} = \frac{\Sigma m_i}{\Sigma(m_i/\rho_i)}$$

If $m_1 = m_2$ $\quad \rho = \dfrac{2\rho_1\rho_2}{\rho_1 + \rho_2}$ = Harmonic mean

(7) If V_1 volume of liquid of density ρ_1 and V_2 volume of liquid of density ρ_2 are mixed, then as:

$$m = \rho_1 V_1 + \rho_2 V_2 \text{ and } V = V_1 + V_2 \qquad [\text{As } \rho = m / V]$$

If $V_1 = V_2 = V$ $\qquad \rho = (\rho_1 + \rho_2)/2$ = Arithmetic Mean

(8) With rise in temperature due to thermal expansion of a given body, volume will increase while mass will remain unchanged, so density will decrease, *i.e.*,

$$\frac{\rho}{\rho_0} = \frac{(m/V)}{(m/V_0)} = \frac{V_0}{V} = \frac{V_0}{V_0(1 + \gamma\Delta\theta)} \qquad [\text{As } V = V_0(1 + \gamma\Delta\theta)]$$

or $\quad \rho = \dfrac{\rho_0}{(1 + \gamma\Delta\theta)} \simeq \rho_0(1 - \gamma\Delta\theta)$

(9) With increase in pressure due to decrease in volume, density will increase, *i.e.,*

$$\frac{\rho}{\rho_0} = \frac{(m/V)}{(m/V_0)} = \frac{V_0}{V} \qquad [\text{As } \rho = \frac{m}{V}]$$

But as by definition of bulk-modulus

$$B = -V_0 \frac{\Delta p}{\Delta V} \quad i.e., \; V = V_0\left[1 - \frac{\Delta p}{B}\right]$$

So $\quad \rho = \rho_0\left(1 - \dfrac{\Delta p}{B}\right)^{-1} \simeq \rho_0\left(1 + \dfrac{\Delta p}{B}\right)$

Pascal's Law

It states that if gravity effect is neglected, the pressure at every point of liquid in equilibrium of rest is same.

or

The increase in pressure at one point of the enclosed liquid in equilibrium of rest is transmitted equally to all other points of the liquid and also to the walls of the container, provided the effect of gravity is neglected.

Example : Hydraulic lift, hydraulic press and hydraulic brakes

Working of hydraulic lift : It is used to lift the heavy loads. If a small force *f* is applied on piston of *C* then the pressure exerted on the liquid

$$P = f / a \qquad [a = \text{Area of cross section of the piston in } C]$$

This pressure is transmitted equally to piston of cylinder *D*.

Hence the upward force acting on piston of cylinder *D*.

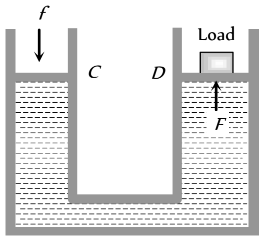


Fig. 11.4

$$F = PA = \frac{f}{a}A = f\left(\frac{A}{a}\right)$$

As $A >> a$, therefore $F >> f$. So heavy load placed on the larger piston is easily lifted upwards by applying a small force.

Archimedes Principle

Accidentally Archimedes discovered that when a body is immersed partly or wholly in a fluid, at rest, it is buoyed up with a force equal to the weight of the fluid displaced by the body. This principle is called Archimedes principle and is a necessary consequence of the laws of fluid statics.

When a body is partly or wholly dipped in a fluid, the fluid exerts force on the body due to hydrostatic pressure. At any small portion of the surface of the body, the force exerted by the fluid is perpendicular to the surface and is equal to the pressure at that point multiplied by the area. The resultant of all these constant forces is called upthrust or buoyancy.

To determine the magnitude and direction of this force consider a body immersed in a fluid of density σ as shown in figure. The forces on the vertical sides of the body will cancel each other. The top surface of the body will experience a downward force.

$$F_1 = AP_1 = A(h_1\sigma g + P_0) \qquad [\text{As } P = h\sigma g + P_0]$$

While the lower face of the body will experience an upward force.

$$F_2 = AP_2 = A(h_2\sigma g + P_0)$$

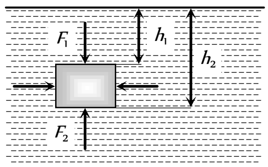


Fig. 11.5

As $h_2 > h_1, F_2$ will be greater than F_1, so the body will experience a net upward force

$$F = F_2 - F_1 = A\sigma g(h_2 - h_1)$$

If *L* is the vertical height of the body $F = A\sigma gL = V\sigma g$

$$[\text{As } V = AL = A(h_2 - h_1)]$$

i.e., *F* = Weight of fluid displaced by the body.

This force is called upthrust or buoyancy and acts vertically upwards (opposite to the weight of the body) through the centre of gravity of displaced fluid (called centre of buoyancy). Though we have derived this result for a body fully submerged in a fluid, it can be shown to hold good for partly submerged bodies or a body in more than one fluid also.

(1) Upthrust is independent of all factors of the body such as its mass, size, density etc. except the volume of the body inside the fluid.

(2) Upthrust depends upon the nature of displaced fluid. This is why upthrust on a fully submerged body is more in sea water than in fresh water because its density is more than fresh water.

(3) Apparent weight of the body of density (ρ) when immersed in a liquid of density (σ).

Apparent weight = Actual weight – Upthrust $= W - F_{up}$

$$= V\rho g - V\sigma g = V(\rho - \sigma)g = V\rho g\left(1 - \frac{\sigma}{\rho}\right)$$

$$\therefore \quad W_{APP} = W\left(1 - \frac{\sigma}{\rho}\right)$$

(4) If a body of volume V is immersed in a liquid of density σ then its weight reduces.

W_1 = Weight of the body in air, W_2 = Weight of the body in water

Then apparent (loss of weight) weight $W_1 - W_2 = V\sigma g$

$$\therefore \quad V = \frac{W_1 - W_2}{\sigma g}$$

(5) Relative density of a body

$$\text{(R.D.)} = \frac{\text{density of body}}{\text{density of water}}$$

$$= \frac{\text{Weight of body}}{\text{Weight of equal volume of water}} = \frac{\text{Weight of body}}{\text{Water thrust}}$$

$$= \frac{\text{Weight of body}}{\text{Loss of weight in water}}$$

$$= \frac{\text{Weight of body in air}}{\text{Weight in air} - \text{weight in water}} = \frac{W_1}{W_1 - W_2}$$

(6) If the loss of weight of a body in water is 'a' while in liquid is 'b'

$$\therefore \quad \frac{\sigma_L}{\sigma_W} = \frac{\text{Upthrust on body in liquid}}{\text{Upthrust on body in water}}$$

$$= \frac{\text{Loss of weight in liquid}}{\text{Loss of weight in water}} = \frac{a}{b} = \frac{W_{\text{air}} - W_{\text{liquid}}}{W_{\text{air}} - W_{\text{water}}}$$

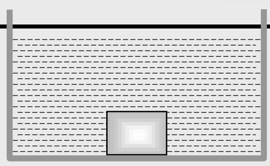
Floatation

(1) **Translatory equilibrium :** When a body of density ρ and volume V is immersed in a liquid of density σ, the forces acting on the body are

Weight of body $W = mg = V\rho g$, acting vertically downwards through centre of gravity of the body.

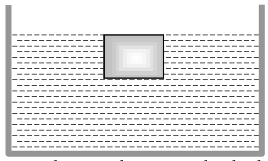
Upthrust force = $V\sigma g$ acting vertically upwards through the centre of gravity of the displaced liquid *i.e.*, centre of buoyancy.

If density of body is greater than that of liquid $\rho > \sigma$



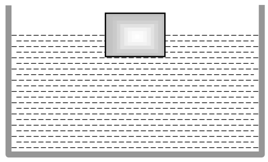
Weight will be more than upthrust so the body will sink

If density of body is equal to that of liquid $\rho = \sigma$



Weight will be equal to upthrust so the body will float fully submerged in neutral equilibrium with its top surface in it just at the top of liquid

If density of body is lesser than that of liquid $\rho < \sigma$



Weight will be less than upthrust so the body will, move upwards and in equilibrium will float and partially immersed in the liquid Such that, $W = V_{in}\sigma g \Rightarrow V\rho g = V_{in}\sigma g$

$V\rho = V_{in}\sigma$ Where V_{in} is the volume of body in the liquid

(i) A body will float in liquid only and only if $\rho \le \sigma$

(ii) In case of floating as weight of body = upthrust

So W_{App} = Actual weight – upthrust = 0

(iii) In case of floating $V\rho g = V_{in}\sigma g$

So the equilibrium of floating bodies is unaffected by variations in g though both thrust and weight depend on g.

(2) **Rotatory Equilibrium :** When a floating body is slightly tilted from equilibrium position, the centre of buoyancy B shifts. The vertical line passing through the new centre of buoyancy B' and initial vertical line meet at a point M called meta-centre. If the meta-centre M is above the centre of gravity the couple due to forces at G (weight of body W) and at B' (upthrust) tends to bring the body back to its original position. So for rotational equilibrium of floating body the meta-centre must always be higher than the centre of gravity of the body.

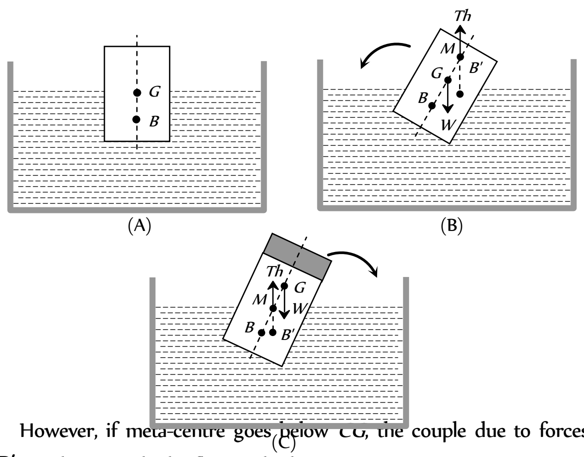


Fig. 11.6

However, if meta-centre goes below CG, the couple due to forces at G and B' tends to topple the floating body.

That is why a wooden log cannot be made to float vertical in water or a boat is likely to capsize if the sitting passengers stand on it. In these situations *CG* becomes higher than *MG* and so the body will topple if slightly tilted.

(3) **Application of floatation**

(i) When a body floats then the weight of body = Upthrust

$$V\rho g = V_{in}\sigma g \;\Rightarrow\; V_{in} = \left(\frac{\rho}{\sigma}\right)V$$

$$\therefore\; V_{\text{out}} = V - V_{in} = \left(1 - \frac{\rho}{\sigma}\right)V$$

i.e., Fraction of volume outside the liquid $f_{\text{out}} = \frac{V_{\text{out}}}{V} = \left[1 - \frac{\rho}{\sigma}\right]$

(ii) For floatation $V\rho = V_{in}\sigma \;\Rightarrow\; \rho = \frac{V_{in}}{V}\sigma = f_{in}\sigma$

If two different bodies *A* and *B* are floating in the same liquid then $\frac{\rho_A}{\rho_B} = \frac{(f_{in})_A}{(f_{in})_B}$

(iii) If the same body is made to float in different liquids of densities σ_A and σ_B respectively.

$$V\rho = (V_{in})_A\sigma_A = (V_{in})_B\sigma_B \qquad \therefore \qquad \frac{\sigma_A}{\sigma_B} = \frac{(V_{in})_B}{(V_{in})_A}$$

(iv) If a platform of mass *M* and cross-section *A* is floating in a liquid of density σ with its height *h* inside the liquid

$$Mg = hA\sigma g \qquad \text{...(i)}$$

Now if a body of mass *m* is placed on it and the platform sinks by *y* then

$$(M + m)g = (y + h)A\sigma g \qquad \text{...(ii)}$$

Subtracting equation (i) from (ii),

$$mg = A\sigma y\, g\,,\; i.e.,\; W \propto y \qquad \text{...(iii)}$$

So we can determine the weight of a body by placing it on a floating platform and noting the depression of the platform in the liquid by it.

Streamline, Laminar and Turbulent Flow

(1) **Stream line flow :** Stream line flow of a liquid is that flow in which each element of the liquid passing through a point travels along the same path and with the same velocity as the preceding element passes through that point.

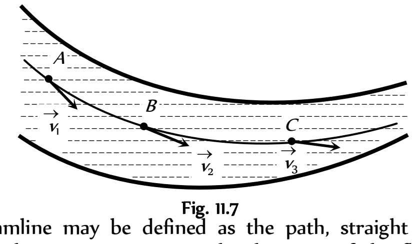


Fig. 11.7

A streamline may be defined as the path, straight or curved, the tangent to which at any point gives the direction of the flow of liquid at that point.

The two streamlines cannot cross each other and the greater is the crowding of streamlines at a place, the greater is the velocity of liquid particles at that place.

Path *ABC* is streamline as shown in the figure and v_1, v_2 and v_3 are the velocities of the liquid particles at *A*, *B* and *C* point respectively.

(2) **Laminar flow :** If a liquid is flowing over a horizontal surface with a steady flow and moves in the form of layers of different velocities which do not mix with each other, then the flow of liquid is called laminar flow.

In this flow, the velocity of liquid flow is always less than the critical velocity of the liquid. The laminar flow is generally used synonymously with streamlined flow.

(3) **Turbulent flow :** When a liquid moves with a velocity greater than its critical velocity, the motion of the particles of liquid becomes disordered or irregular. Such a flow is called a turbulent flow.

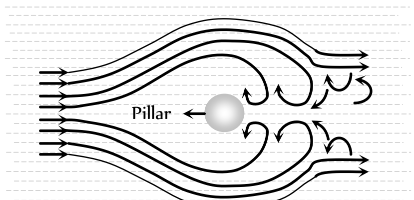


Fig. 11.8

In a turbulent flow, the path and the velocity of the particles of the liquid change continuously and haphazardly with time from point to point. In a turbulent flow, most of the external energy maintaining the flow is spent in producing eddies in the liquid and only a small fraction of energy is available for forward flow. For example, eddies are seen by the sides of the pillars of a river bridge.

Critical Velocity and Reynold's Number

The critical velocity is that velocity of liquid flow upto which its flow is streamlined and above which its flow becomes turbulent.

Reynold's number is a pure number which determines the nature of flow of liquid through a pipe.

It is defined as the ratio of the inertial force per unit area to the viscous force per unit area for a flowing fluid.

$$N_R = \frac{\text{Inertial force per unit area}}{\text{Viscous force per unit area}}$$

If a liquid of density ρ is flowing through a tube of radius *r* and cross section *A* then mass of liquid flowing through the tube per second $\frac{dm}{dt}$ = volume flowing per second × density = $Av \times \rho$

$\therefore$ Inertial force per unit area = $\frac{dp/dt}{A} = \frac{v(dm/dt)}{A} = \frac{v\,Av\,\rho}{A} = v^2\rho$

Viscous force per unit area $F/A = \frac{\eta v}{r}$

So by the definition of Reynolds number

$$N_R = \frac{\text{Inertial force per unit area}}{\text{Viscous force per unit area}} = \frac{v^2\rho}{\eta v/r} = \frac{v\rho r}{\eta}$$

If the value of Reynold's number

(i) Lies between 0 to 2000, the flow of liquid is streamline or laminar.

(ii) Lies between 2000 to 3000, the flow of liquid is unstable and changing from streamline to turbulent flow.

(iii) Above 3000, the flow of liquid is definitely turbulent.

Equation of Continuity

The equation of continuity is derived from the principle of conservation of mass.

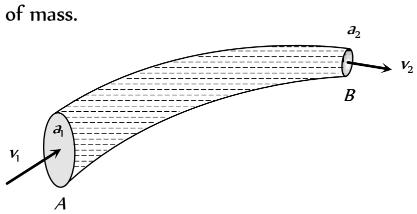


Fig. 11.9

A non-viscous liquid in streamline flow passes through a tube *AB* of varying cross section. Let the cross sectional area of the pipe at points *A* and *B* be a_1 and a_2 respectively. Let the liquid enter with normal velocity v_1 at *A* and leave with velocity v_2 at *B*. Let ρ_1 and ρ_2 be the densities of the liquid at point *A* and *B* respectively.

Mass of the liquid entering per second at *A* = Mass of the liquid leaving per second at *B*

$a_1 v_1 \rho_1 = a_2 v_2 \rho_2$ and $a_1 v_1 = a_2 v_2$

[If the liquid is incompressible $\rho_2 = \rho_1$]

or $av =$ constant or $a \propto \frac{1}{v}$

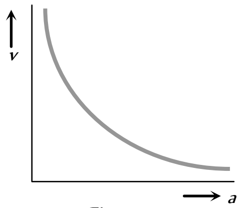


Fig. 11.10

This expression is called the equation of continuity for the steady flow of an incompressible and non-viscous liquid.

(1) The velocity of flow is independent of the liquid (assuming the liquid to be non-viscous)

(2) The velocity of flow will increase if cross-section decreases and vice-versa. That is why :

(a) In hilly region, where the river is narrow and shallow (*i.e.,* small cross-section) the water current will be faster, while in plains where the river is wide and deep (*i.e.,* large cross-section) the current will be slower, and so deep water will appear to be still.

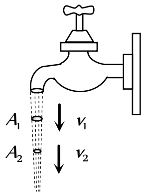


Fig. 11.11

(b) When water falls from a tap, the velocity of falling water under the action of gravity will increase with distance from the tap (*i.e,* $v_2 > v_1$). So in accordance with continuity equation the cross section of the water stream will decrease (*i.e.,* $A_2 < A_1$), *i.e.,* the falling stream of water becomes narrower.

Energy of a Flowing Fluid

A flowing fluid in motion possesses the following three types of energy

Pressure Energy	Potential energy	Kinetic energy
It is the energy possessed by a liquid by virtue of its pressure. It is the measure of work done in pushing the liquid against pressure without imparting any velocity to it.	It is the energy possessed by liquid by virtue of its height or position above the surface of earth or any reference level taken as zero level.	It is the energy possessed by a liquid by virtue of its motion or velocity.
Pressure energy of the liquid *PV*	Potential energy of the liquid *mgh*	Kinetic energy of the liquid $\frac{1}{2}mv^2$
Pressure energy per unit mass of the liquid $\frac{P}{\rho}$	Potential energy per unit mass of the liquid *gh*	Kinetic energy per unit mass of the liquid $\frac{1}{2}v^2$
Pressure energy per unit volume of the liquid *P*	Potential energy per unit volume of the liquid ρgh	Kinetic energy per unit volume of the liquid $\frac{1}{2}\rho v^2$

Bernoulli's Theorem

According to this theorem the total energy (pressure energy, potential energy and kinetic energy) per unit volume or mass of an incompressible and non-viscous fluid in steady flow through a pipe remains constant throughout the flow, provided there is no source or sink of the fluid along the length of the pipe.

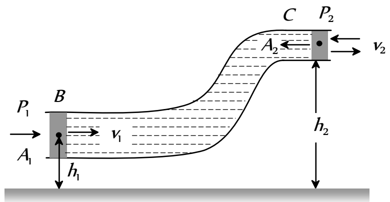


Fig. 11.12

Mathematically for unit volume of liquid flowing through a pipe.

$$P + \rho gh + \frac{1}{2}\rho v^2 = \text{constant}$$

To prove it, consider a liquid flowing steadily through a tube of non-uniform area of cross-section as shown in fig. If P_1 and P_2 are the pressures at the two ends of the tube respectively, work done in pushing the volume *V* of incompressible fluid from point B to C through the tube will be

$$W = P_1 V - P_2 V = (P_1 - P_2)V \qquad ...(i)$$

This work is used by the fluid in two ways.

(a) In changing the potential energy of mass *m* (in the volume *V*) from mgh_1 to mgh_2

i.e., $\Delta U = mg(h_2 - h_1)$ ...(ii)

(b) In changing the kinetic energy from $\frac{1}{2}mv_1^2$ to $\frac{1}{2}mv_2^2$,

i.e., $\Delta K = \frac{1}{2}m(v_2^2 - v_1^2)$ ...(iii)

Now as the fluid is non-viscous, by conservation of mechanical energy

$$W = \Delta U + \Delta K$$

i.e., $(P_1 - P_2)V = mg(h_2 - h_1) + \frac{1}{2}m(v_2^2 - v_1^2)$

or $P_1 - P_2 = \rho g(h_2 - h_1) + \frac{1}{2}\rho(v_2^2 - v_1^2)$ [As $\rho = m/V$]

or $P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$

or $P + \rho g h + \frac{1}{2}\rho v^2 = \text{constant}$

This equation is the so called Bernoulli's equation and represents conservation of mechanical energy in case of moving fluids.

(i) Bernoulli's theorem for unit mass of liquid flowing through a pipe can also be written as:

$$\frac{P}{\rho} + gh + \frac{1}{2}v^2 = \text{constant}$$

(ii) Dividing above equation by g we get $\frac{P}{\rho g} + h + \frac{v^2}{2g}$ = constant

Here $\frac{P}{\rho g}$ is called pressure head, h is called gravitational head and $\frac{v^2}{2g}$ is called velocity head. From this equation Bernoulli's theorem can be stated as.

"In stream line flow of an ideal liquid, the sum of pressure head, gravitational head and velocity head of every cross section of the liquid is constant."

Applications of Bernoulli's Theorem

(i) **Attraction between two closely parallel moving boats (or buses)**

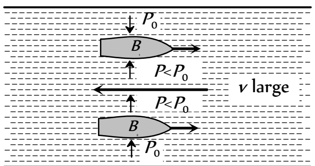


Fig. 11.13

When two boats or buses move side by side in the same direction, the water (or air) in the region between them moves faster than that on the remote sides. Consequently in accordance with *Bernoulli's principle* the pressure between them is reduced and hence due to pressure difference they are pulled towards each other creating the so called attraction.

(ii) **Working of an aeroplane**

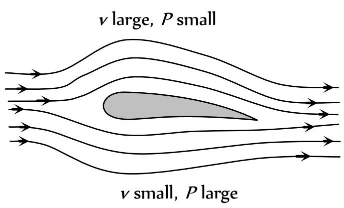


Fig. 11.14

This is also based on Bernoulli's principle. The wings of the aeroplane are of the shape as shown in fig. 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.

(iii) **Action of atomiser**

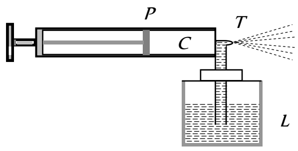


Fig. 11.15

The action of carburetor, paint-gun, scent-spray or insect-sprayer is based on Bernoulli's principle. In all these, by means of motion of a piston P in a cylinder C, high speed air is passed over a tube T dipped in liquid L to be sprayed. High speed air creates low pressure over the tube due to which liquid (paint, scent, insecticide or petrol) rises in it and is then blown off in very small droplets with expelled air.

(iv) **Blowing off roofs by wind storms**

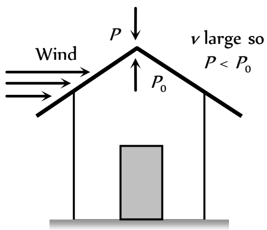


Fig. 11.16

During a tornado or hurricane, when a high speed wind blows over a straw or tin roof, it creates a low pressure (P) in accordance with Bernoulli's principle.

However, the pressure below the roof (*i.e.,* inside the room) is still atmospheric ($= P_0$). So due to this difference of pressure, the roof is lifted up and is then blown off by the wind.

(v) **Magnus effect :** When a spinning ball is thrown, it deviates from its usual path in flight. This effect is called Magnus effect and plays as important role in tennis, cricket and soccer, etc. as by applying appropriate spin the moving ball can be made to curve in any desired direction.

If a ball is moving from left to right and also spinning about a horizontal axis perpendicular to the direction of motion as shown in fig. then relative to the ball, air will be moving from right to left.

The resultant velocity of air above the ball will be $(v + r\omega)$ while below it $(v - r\omega)$. So in accordance with Bernoulli's principle pressure above the ball will be less than below it. Due to this difference of pressure an upward force will act on the ball and hence the ball will deviate from its usual path OA_0 and will hit the ground at A_1 following the path OA_1 *i.e.,* if a ball is thrown with back-spin, the pitch will curve less sharply prolonging the flight.

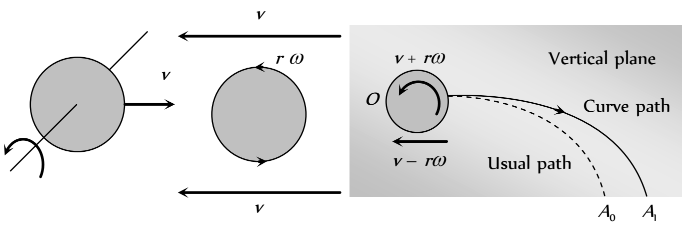


Fig. 11.17

Similarly if the spin is clockwise *i.e.,* the ball is thrown with top-spin, the force due to pressure difference will act in the direction of gravity and so the pitch will curve more sharply shortening the flight.

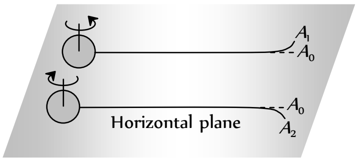


Fig. 11.18

Furthermore, if the ball is spinning about a vertical axis, the curving will be sideways as shown in producing the so called out swing or in swing.

(vi) **Venturimeter :** It is a device based on Bernoulli's theorem used for measuring the rate of flow of liquid through pipes.

It consists of two identical coaxial tubes *A* and *C* connected by a narrow co-axial tube *B*. Two vertical tubes *D* and *E* are mounted on the tubes *A* and *B* to measure the pressure of the flowing liquid.

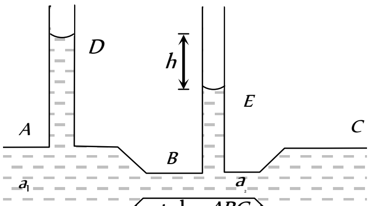


Fig. 11.19

When the ... the tube *ABC*, ... f flow in part *B* will be larger than in the tube *A* or *C*. So the pressure in part *B* will be less than that in tube *A* or *C*. By measuring the pressure difference between *A* and *B*, the rate of flow of the liquid in the tube can be calculated.

Let a_1 and a_2 are area of cross section of tube A and B respectively

v_1, v_2 = Velocity of flow of liquid through A and B respectively

P_1, P_2 = Liquid pressure at A and B respectively

$\therefore\ P_1 - P_2 = h\rho g$ ...(i)

[ρ = density of flowing liquid]

From Bernoulli's theorem for horizontal flow of liquid

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

$$P_1 - P_2 = \frac{1}{2}\rho(v_2^2 - v_1^2) \quad \text{...(ii)}$$

From (i) and (ii) $h\rho g = \frac{1}{2}\rho(v_2^2 - v_1^2) = \frac{1}{2}\rho\left[\frac{V^2}{a_2^2} - \frac{V^2}{a_1^2}\right]$

[As $V = a_1 v_1 = a_2 v_2$]

$$\therefore\quad V^2 = \frac{2a_1^2 a_2^2 hg}{a_1^2 - a_2^2} \text{ or } V = a_1 a_2\sqrt{\frac{2hg}{a_1^2 - a_2^2}}$$

Velocity of Efflux

If a liquid is filled in a vessel up to height *H* and a hole is made at a depth *h* below the free surface of the liquid as shown in fig. then taking the level of hole as reference level (*i.e.,* zero point of potential energy) and applying Bernoulli's principle to the liquid just inside and outside the hole (assuming the liquid to be at rest inside) we get

$$\therefore\quad (P_0 + h\rho g) + 0 = P_0 + \frac{1}{2}\rho v^2 \text{ or } v = \sqrt{2gh}$$

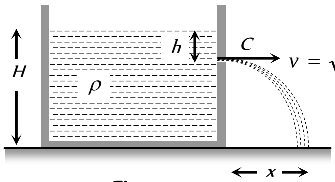


Fig. 11.20

Which is same as the speed that an object would acquire in falling from rest through a distance *h* and is called velocity of efflux or velocity of flow.

This result was first given by Torricelli, so this is known as Torricelli's theorem.

(i) The velocity of efflux is independent of the nature of liquid, quantity of liquid in the vessel and the area of orifice.

(ii) Greater is the distance of the hole from the free surface of liquid, greater will be the velocity of efflux [*i.e.,* $v \propto \sqrt{h}$]

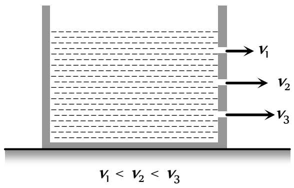


Fig. 11.21

(iii) As the vertical velocity of liquid at the orifice is zero and it is at a height $(H - h)$ from the base, the time taken by the liquid to reach the base-level $t = \sqrt{\frac{2(H-h)}{g}}$

(iv) Now during time *t* liquid is moving horizontally with constant velocity *v*, so it will hit the base level at a horizontal distance *x* (called range) as shown in figure.

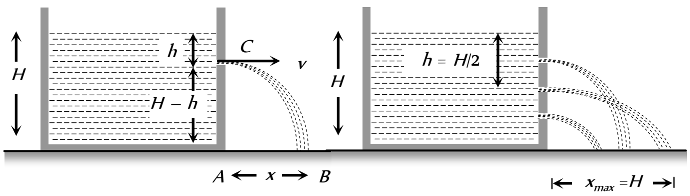


Fig. 11.22

Such that $x = vt = \sqrt{2gh} \times \sqrt{[2(H-h)/g]} = 2\sqrt{h(H-h)}$

For maximum range $\frac{dx}{dh} = 0$

$\therefore\ h = \frac{H}{2}$

i.e., range *x* will be maximum when

$h = \frac{H}{2}$.

$\therefore$ Maximum range $x_{max} = 2\sqrt{\frac{H}{2}\left[H - \frac{H}{2}\right]} = H$

(v)

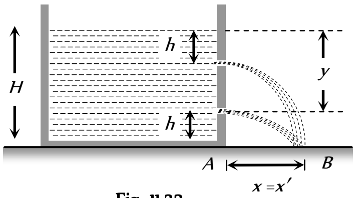


Fig. 11.23

If the level of free surface in a container is at height *H* from the base and there are two holes at depth *h* and *y* below the free surface, then

$x = 2\sqrt{h(H-h)}$ and $x' = 2\sqrt{y(H-y)}$

Now if $x = x'$, *i.e.,* $h(H-h) = y(H-y)$

i.e., $y^2 - Hy + h(H-h) = 0$

or $y = \frac{1}{2}[H \pm (H-2h)]$,

i.e., $y = h$ or $(H-h)$

i.e., the range will be same if the orifice is at a depth h or $(H-h)$ below the free surface. Now as the distance $(H-h)$ from top means $H-(H-h) = h$ from the bottom, so the range is same for liquid coming out of holes at same distance below the top and above the bottom.

(vi)

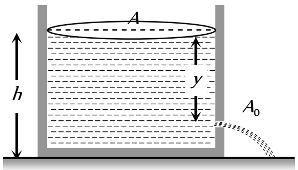


Fig. 11.24

If A_0 is the area of orifice at a depth *y* below the free surface and *A* is that of container, the volume of liquid coming out of the orifice per second will be $(dV/dt) = vA_0 = A_0\sqrt{2gy}$ [As $v = \sqrt{2gy}$]

Due to this, the level of liquid in the container will decrease and so if the level of liquid in the container above the hole changes from *y* to $y - dy$ in time *t* to $t + dt$ then $-dV = A\,dy$

So substituting this value of dV in the above equation

$$-A\frac{dy}{dt} = A_0\sqrt{2gy}$$

i.e., $\int dt = -\frac{A}{A_0}\frac{1}{\sqrt{2g}}\int y^{-1/2}dy$

So the time taken for the level to fall from *H to* H'

$$t = -\frac{A}{A_0}\frac{1}{\sqrt{2g}}\int_H^{H'} y^{-1/2}dy = \frac{A}{A_0}\sqrt{\frac{2}{g}}[\sqrt{H} - \sqrt{H'}]$$

If the hole is at the bottom of the tank, time *t* to make the tank empty :

$t = \frac{A}{A_0}\sqrt{\frac{2H}{g}}$ [As here $H' = 0$]

Viscosity and Newton's law of Viscous Force

In case of steady flow of a fluid when a layer of fluid slips or tends to slip on adjacent layers in contact, the two layer exert tangential force on each other which tries to destroy the relative motion between them. The property of a fluid due to which it opposes the relative motion between its different layers is called viscosity (or fluid friction or internal friction) and the force between the layers opposing the relative motion is called viscous force.

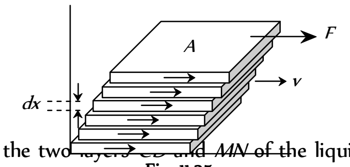


Fig. 11.25

Consider the two layers *CD* and *MN* of the liquid at distances *x* and *x* + *dx* from the fixed surface *AB*, having the velocities *v* and *v* + *dv* respectively. Then $\frac{dv}{dx}$ denotes the rate of change of velocity with distance and is known as velocity gradient.

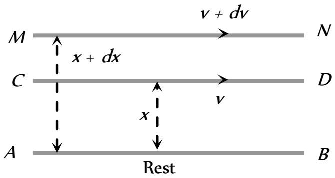


Fig. 11.26

According to Newton's hypothesis, the tangential force *F* acting on a plane parallel layer is proportional to the area of the plane A and the velocity gradient $\frac{dv}{dx}$ in a direction normal to the layer, *i.e.,*

$F \propto A$ and $F \propto \frac{dv}{dx}$

$\therefore$ $F \propto A\frac{dv}{dx}$

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

Where η is a constant called the coefficient of viscosity. Negative sign is employed because viscous force acts in a direction opposite to the flow of liquid.

If $A = 1, \frac{dv}{dx} = 1$ then $\eta = F$.

Hence the coefficient of viscosity is defined as the viscous force acting per unit area between two layers moving with unit velocity gradient.

(1) Units : dyne-*s*-cm^{-2} or Poise (C.G.S. system); Newton-*s*-m^{-2} or Poiseuille or decapoise (S.I. system)

1 Poiseuille = 1 decapoise = 10 Poise

(2) Dimension : $[ML^{-1}T^{-1}]$

(3) Viscosity of liquid is much greater (about 100 times more) than that of gases i.e. $\eta_L > \eta_G$

Example : Viscosity of water = 0.01 Poise.

While of air = 200 μ Poise

(4) With increase in pressure, the viscosity of liquids (except water) increases while that of gases is practically independent of pressure. The viscosity of water decreases with increase in pressure.

(5) Difference between viscosity and solid friction : Viscosity differs from the solid friction in the respect that the viscous force acting between two layers of the liquid depends upon the area of the layers, the relative velocity of two layers and distance between two layers, but the friction between two solid surfaces is independent of the area of surfaces in contact and the relative velocity between them.

(6) From kinetic theory point of view viscosity represents transport of momentum, while diffusion and conduction represents transport of mass and energy respectively.

(7) The viscosity of thick liquids like honey, glycerin, coaltar *etc.* is more than that of thin liquids like water.

(8) The cause of viscosity in liquids is cohesive forces among molecules where as in gases, it is due to diffusion.

(9) The viscosity of gases increases with increase of temperature, because on increasing temperature the rate of diffusion increases.

(10) The viscosity of liquid decreases with increase of temperature, because the cohesive force between the liquid molecules decreases with increase of temperature

Relation between coefficient of viscosity and temperature; Andrade formula $\eta = \frac{A e^{C\rho/T}}{\rho^{-1/3}}$

Where T= Absolute temperature of liquid, ρ = density of liquid, *A* and C are constants.

Stoke's Law and Terminal Velocity

When a body moves through a fluid, the fluid in contact with the body is dragged with it. This establishes relative motion in fluid layers near the body, due to which viscous force starts operating. The fluid exerts viscous force on the body to oppose its motion. The magnitude of the viscous force depends on the shape and size of the body, its speed and the viscosity of the fluid. Stokes established that if a sphere of radius *r* moves with velocity *v* through a fluid of viscosity η, the viscous force opposing the motion of the sphere is

$F = 6\pi\eta r v$

This law is called Stokes law.

If a spherical body of radius *r* is dropped in a viscous fluid, it is first accelerated and then it's acceleration becomes zero and it attains a constant velocity called terminal velocity.

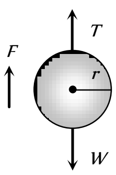


Fig. 11.27

Force on the body

(i) Weight of the body (W) = mg

= (*volume* × *density*) × $g = \frac{4}{3}\pi r^3 \rho g$

(ii) Upward thrust (T) = weight of the fluid displaced

= (*volume* × *density*) of the fluid × $g = \frac{4}{3}\pi r^3 \sigma g$

(iii) Viscous force (F) = $6\pi\eta r v$

When the body attains terminal velocity the net force acting on the body is zero. $\therefore W - T - F = 0$ or $F = W - T$

$$\Rightarrow 6\pi\eta r v = \frac{4}{3}\pi r^3 \rho g - \frac{4}{3}\pi r^3 \sigma g = \frac{4}{3}\pi r^3 (\rho - \sigma) g$$

$$\therefore \text{ Terminal velocity } v = \frac{2}{9}\frac{r^2(\rho - \sigma) g}{\eta}$$

(i) Terminal velocity depend on the radius of the sphere so if radius is made *n* - fold, terminal velocity will become *n* times.

(ii) Greater the density of solid greater will be the terminal velocity

(iii) Greater the density and viscosity of the fluid lesser will be the terminal velocity.

(iv) If $\rho > \sigma$ then terminal velocity will be positive and hence the spherical body will attain constant velocity in downward direction.

(v) If $\rho < \sigma$ then terminal velocity will be negative and hence the spherical body will attain constant velocity in upward direction. Example : Air bubble in a liquid and clouds in sky.

(vi) Terminal velocity graph :

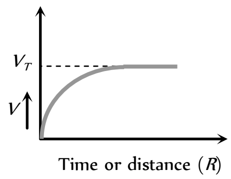


Fig. 11.28

Poiseuille's Formula

Poiseuille studied the stream-line flow of liquid in capillary tubes. He found that if a pressure difference (*P*) is maintained across the two ends of a capillary tube of length '*l*' and radius *r*, then the volume of liquid coming out of the tube per second is

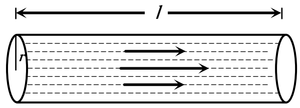


Fig. 11.29

(i) Directly proportional to the pressure difference (P).

(ii) Directly proportional to the fourth power of radius (r) of the capillary tube

(iii) Inversely proportional to the coefficient of viscosity (η) of the liquid.

(iv) Inversely proportional to the length (l) of the capillary tube.

i.e. $V \propto \frac{P r^4}{\eta l}$ or $V = \frac{K P r^4}{\eta l}$

$$\therefore V = \frac{\pi P r^4}{8\eta l}$$

[Where $K = \frac{\pi}{8}$ is the constant of proportionality]

This is known as Poiseuille's equation.

This equation also can be written as,

$V = \frac{P}{R}$ where $R = \frac{8\eta l}{\pi r^4}$

R is called as liquid resistance.

(1) **Series combination of tubes**

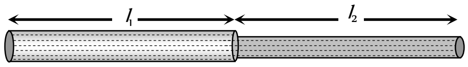


Fig. 11.30

(i) When two tubes of length l_1, l_2 and radii r_1, r_2 are connected in series across a pressure difference P,

Then $P = P_1 + P_2$ ...(i)

Where P_1 and P_2 are the pressure difference across the first and second tube respectively

(ii) The volume of liquid flowing through both the tubes *i.e.* rate of flow of liquid is same.

Therefore $V = V_1 = V_2$

i.e., $V = \dfrac{\pi P_1 r_1^4}{8\eta l_1} = \dfrac{\pi P_2 r_2^4}{8\eta l_2}$ ...(ii)

Substituting the value of P_1 and P_2 from equation (ii) to equation (i) we get

$$P = P_1 + P_2 = V\left[\frac{8\eta l_1}{\pi r_1^4} + \frac{8\eta l_2}{\pi r_2^4}\right]$$

$$\therefore\ V = \frac{P}{\left[\dfrac{8\eta l_1}{\pi r_1^4} + \dfrac{8\eta l_2}{\pi r_2^4}\right]} = \frac{P}{R_1 + R_2} = \frac{P}{R_{eff}}$$

Where R_1 and R_2 are the liquid resistance in tubes

(iii) Effective liquid resistance in series combination $R_{eff} = R_1 + R_2$

(2) **Parallel combination of tubes**

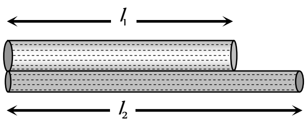


Fig. 11.31

(i) $P = P_1 = P_2$

(ii) $V = V_1 + V_2 = \dfrac{P\pi r_1^4}{8\eta l_1} + \dfrac{P\pi r_2^4}{8\eta l_2}$

$$= P\left[\frac{\pi r_1^4}{8\eta l_1} + \frac{\pi r_2^4}{8\eta l_2}\right]$$

$$\therefore\ V = P\left[\frac{1}{R_1} + \frac{1}{R_2}\right] = \frac{P}{R_{eff}}$$

(iii) Effective liquid resistance in parallel combination

$$\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_2} \text{ or } R_{eff} = \frac{R_1 R_2}{R_1 + R_2}$$

Tips & Tricks

✍ When a liquid is in equilibrium, the force acting on its surface is perpendicular everywhere.

✍ In a liquid, the pressure is same at the same horizontal level.

✍ Pressure at any point is same in all directions.

✍ The pressure is perpendicular to the surface of the fluid.

✍ The pressure at any point in the liquid depends on depth (h) below the surface, density of liquid and acceleration due to gravity.

It is independent of the shape of the containing vessel, or total mass of the liquid.

✍ Force is a vector quantity but pressure is a tensor quantity

✍ Pressure and density play the same role in case of fluids as force and mass play in case of solids.

✍ Bar and millibar are commonly used units for pressure in meteorology.

✍ Sudden fall in atmospheric pressure predicts possibility of a storm.

✍ Water barometer was constructed in 17th century by Von Guericke and fixed on the outside wall of his house. With the help of this barometer Von Guericke made the first recorded scientific weather forecast. He correctly predicted the severe storm after noting a sudden fall in the height of the water column.

✍ The specific gravity is also known as relative density. Thus, S.G. of a substance $= \dfrac{\text{density of the substance}}{\text{density of water (at } 4°C)}$

✍ If the specific gravity of the material of a body is x, then its density is

(I) $x\ g\ cm^{-3}$ in C.G.S.

(Ii) $x \times 10^3\ kg\ m^{-3}$ in SI.

✍ The number of moles in a sample of any substance containing N molecules is given by

$$\mu = \frac{N}{N_A}$$

✍ The force between atoms and molecules is electrical in nature. However, it does not obey inverse square law.

✍ 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

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

✍ If two liquids of same mass but different densities are mixed together, then the density of the mixture is harmonic mean of the densities. That is

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

✍ It two drops of same volume but different densities are mixed together, then the density of the mixture is arithmetic mean of the densities. That is $\rho = \dfrac{\rho_1 + \rho_2}{2}$

✍ The density of the liquid changes with pressure as follows : $\rho = \rho_0\left[1 + \dfrac{\Delta p}{B}\right]$ where $\Delta p =$ change in pressure and B is the bulk modulus.

✍ The density of a liquid of bulk modules B at depth h is given $\rho_d = \rho_0\left[1 + \dfrac{h\rho g}{B}\right]$

Where ρ is the average density of the liquid.

✍ The hydrometer can be used to measure density of the liquid or fluid.

✍ If a vessel contains liquid upto a height H and it has a hole in the side at a height h, then the velocity of efflux is $v = \sqrt{2g(H-h)}$. The time taken by the liquid to reach the ground level is $t = \sqrt{2h/g}$. Horizontal range of the liquid $R = 2[h(H-h)]^{1/2}$. The range is same for the hole at a height h above the bottom or at the depth h below the surface of the liquid.

The range is maximum for $h = H/2$. It is given by :

$$R_{\max} = 2\left[\left(\frac{H}{2}\right)\left(H - \frac{H}{2}\right)\right]^{1/2} = H$$

✍ The cross-section of the water stream from a tap decreases as it goes down in accordance with the equation of continuity.

✍ The upthrust on 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.

✍ 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.

✍ Upthrust depends on the density of the fluid, not the density of the body.

✍ If two bodies have equal upthrust in a liquid, both have the same volume.

✍ When air blows over a roof, the force on the roof is upwards.

✍ If one floats one's back on the surface of water, the apparent weight is zero.

✍ If a body just floats in liquid (density of the body is equal to the density of liquid) then the body sinks if it is pushed downwards.

✍ The line joining the centre of gravity and centre of buoyancy is called central line.

✍ The point where the vertical line through centre of huoyancy intersects the central line is called metacentre.

✍ The floating body is in stable equilibrium where the metacentre is above the centre of gravity. (Centre of gravity is below the centre of buoyancy)

✍ The floating body is in unstable equilibrium when the metancetre lies below the centre of gravity. (Centre of gravity is above the centre of buoyancy).

✍ The floating body is in the neutral equilibrium when centre of gravity coincides with the metacentre. (Centre of gravity coincides with the centre of buoyancy).

✍ The wooden rod cannot float vertically in a pond of water because centre of gravity lies above the metacentre.

✍ Air bubble in water always goes up. It is because density of air (ρ) is less than the density of water (σ). So the terminal velocity for air bubble is negative, which implies that the air bubble will go up. Positive terminal velocity means the body will fall down.

✍ The faster the air, the lower the pressure.

✍ Wings of an aeroplane are shaped to make air travel further and faster over their top surfaces.

✍ The lift force on a wing or aerofoil is proportional to the square of the speed of flow.

✍ Viscous force between the layers of a liquid is analogous to friction between two solid surfaces.

✍ With increase in temperature, the coefficient of viscosity of liquids decreases but that of gases increases. The reason is that as temperature rises, the atoms of the liquid become more mobile, whereas in case of a gas, the collision frequency of atoms increases as their motion becomes more random.

✍ We cannot sip a drink with a straw on the moon because there is no atmosphere on the moon.

Ordinary Thinking

Objective Questions

Pressure and Density

1. If pressure at half the depth of a lake is equal to 2/3 pressure at the bottom of the lake then what is the depth of the lake

[RPET 2000]

(a) 10 *m* (b) 20 *m*

(c) 60 *m* (d) 30 *m*

2. Two bodies are in equilibrium when suspended in water from the arms of a balance. The mass of one body is 36 *g* and its density is 9 *g / cm*^{3}. If the mass of the other is 48 *g*, its density in *g / cm*^{3} is

[CBSE PMT 1994]

(a) $\frac{4}{3}$ (b) $\frac{3}{2}$

(c) 3 (d) 5

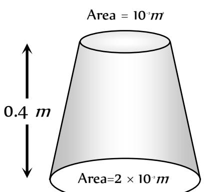
3. An inverted bell lying at the bottom of a lake 47.6 *m* deep has 50 *cm*^{3} of air trapped in it. The bell is brought to the surface of the lake. The volume of the trapped air will be (atmospheric pressure = 70 *cm* of *Hg* and density of *Hg* = 13.6 *g/cm*^{3})

[CPMT 1989]

(a) 350 *cm*^{3} (b) 300 *cm*^{3}

(c) 250 *cm*^{3} (d) 22 *cm*^{3}

4. A uniformly tapering vessel is filled with a liquid of density 900 *kg/m*^{3}. The force that acts on the base of the vessel due to the liquid is $(g = 10\,ms^{-2})$



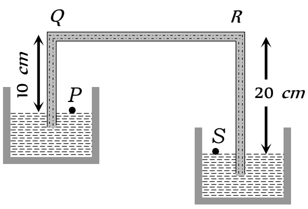
(a) 3.6 *N*

(b) 7.2 *N*

(c) 9.0 *N*

(d) 14.4 *N*

5. A siphon in use is demonstrated in the following figure. The density of the liquid flowing in siphon is 1.5 *gm/cc*. The pressure difference between the point *P* and *S* will be



(a) 10^5 *N/m*^{2}

(b) 2×10^5 *N/m*^{2}

(c) Zero

(d) Infinity

6. The height of a mercury barometer is 75 *cm* at sea level and 50 *cm* at the top of a hill. Ratio of density of mercury to that of air is 10^4. The height of the hill is

(a) 250 *m* (b) 2.5 *km*

(c) 1.25 *km* (d) 750 *m*

7. Density of ice is ρ and that of water is σ. What will be the decrease in volume when a mass *M* of ice melts

(a) $\frac{M}{\sigma - \rho}$ (b) $\frac{\sigma - \rho}{M}$

(c) $M\left[\frac{1}{\rho} - \frac{1}{\sigma}\right]$ (d) $\frac{1}{M}\left[\frac{1}{\rho} - \frac{1}{\sigma}\right]$

8. Equal masses of water and a liquid of density 2 are mixed together, then the mixture has a density of

(a) 2/3 (b) 4/3

(c) 3/2 (d) 3

9. A body of density d_1 is counterpoised by Mg of weights of density d_2 in air of density *d*. Then the true mass of the body is

(a) *M* (b) $M\left(1 - \frac{d}{d_2}\right)$

(c) $M\left(1 - \frac{d}{d_1}\right)$ (d) $\frac{M(1 - d/d_2)}{(1 - d/d_1)}$

10. The pressure at the bottom of a tank containing a liquid does not depend on

[Kerala (Engg.) 2002]

(a) Acceleration due to gravity

(b) Height of the liquid column

(c) Area of the bottom surface

(d) Nature of the liquid

11. When a large bubble rises from the bottom of a lake to the surface. Its radius doubles. If atmospheric pressure is equal to that of column of water height *H*, then the depth of lake is

[AIIMS 1995; AFMC 1997]

(a) *H* (b) 2*H*

(c) 7*H* (d) 8*H*

12. The volume of an air bubble becomes three times as it rises from the bottom of a lake to its surface. Assuming atmospheric pressure to be 75 *cm* of *Hg* and the density of water to be 1/10 of the density of mercury, the depth of the lake is

(a) 5 *m* (b) 10 *m*

(c) 15 *m* (d) 20 *m*

13. The value of *g* at a place decreases by 2%. The barometric height of mercury

(a) Increases by 2%

(b) Decreases by 2%

(c) Remains unchanged

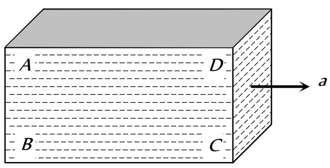
(d) Sometimes increases and sometimes decreases

14. A barometer kept in a stationary elevator reads 76 *cm*. If the elevator starts accelerating up the reading will be

(a) Zero (b) Equal to 76 *cm*

(c) More than 76 *cm* (d) Less than 76 *cm*

15. A closed rectangular tank is completely filled with water and is accelerated horizontally with an acceleration *a* towards right. Pressure is (i) maximum at, and (ii) minimum at



(a) (i) B (ii) D

(b) (i) C (ii) D

(c) (i) B (ii) C

(d) (i) *B* (ii) *A*

16. A beaker containing a liquid is kept inside a big closed jar. If the air inside the jar is continuously pumped out, the pressure in the liquid near the bottom of the liquid will

(a) Increases

(b) Decreases

(c) Remain constant

(d) First decrease and then increase

17. A barometer tube reads 76 *cm* of mercury. If the tube is gradually inclined at an angle of 60° with vertical, keeping the open end immersed in the mercury reservoir, the length of the mercury column will be

(a) 152 *cm* (b) 76 *cm*

(c) 38 *cm* (d) $38\sqrt{3}cm$

18. The height to which a cylindrical vessel be filled with a homogeneous liquid, to make the average force with which the liquid presses the side of the vessel equal to the force exerted by the liquid on the bottom of the vessel, is equal to

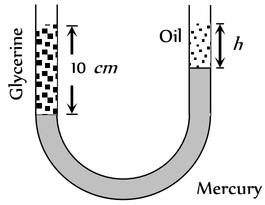
(a) Half of the radius of the vessel

(b) Radius of the vessel

(c) One-fourth of the radius of the vessel

(d) Three-fourth of the radius of the vessel

19. A vertical U-tube of uniform inner cross section contains mercury in both sides of its arms. A glycerin (density = 1.3 *g/cm*) column of length 10 *cm* is introduced into one of its arms. Oil of density 0.8 *gm/cm* is poured into the other arm until the upper surfaces of the oil and glycerin are in the same horizontal level. Find the length of the oil column, Density of mercury = 13.6 *g/cm*



(a) 10.4 cm

(b) 8.2 cm

(c) 7.2 cm

(d) 9.6 cm

20. A triangular lamina of area A and height h is immersed in a liquid of density ρ in a vertical plane with its base on the surface of the liquid. The thrust on the lamina is

(a) $\frac{1}{2}A\rho gh$ (b) $\frac{1}{3}A\rho gh$

(c) $\frac{1}{6}A\rho gh$ (d) $\frac{2}{3}A\rho gh$

21. If two liquids of same masses but densities ρ_1 and ρ_2 respectively are mixed, then density of mixture is given by

(a) $\rho = \frac{\rho_1 + \rho_2}{2}$ (b) $\rho = \frac{\rho_1 + \rho_2}{2\rho_1\rho_2}$

(c) $\rho = \frac{2\rho_1\rho_2}{\rho_1 + \rho_2}$ (d) $\rho = \frac{\rho_1\rho_2}{\rho_1 + \rho_2}$

22. If two liquids of same volume but different densities ρ_1 and ρ_2 are mixed, then density of mixture is given by

(a) $\rho = \frac{\rho_1 + \rho_2}{2}$ (b) $\rho = \frac{\rho_1 + \rho_2}{2\rho_1\rho_2}$

(c) $\rho = \frac{2\rho_1\rho_2}{\rho_1 + \rho_2}$ (d) $\rho = \frac{\rho_1\rho_2}{\rho_1 + \rho_2}$

23. The density ρ of water of bulk modulus B at a depth y in the ocean is related to the density at surface ρ_0 by the relation

(a) $\rho = \rho_0\left[1 - \frac{\rho_0 gy}{B}\right]$ (b) $\rho = \rho_0\left[1 + \frac{\rho_0 gy}{B}\right]$

(c) $\rho = \rho_0\left[1 + \frac{B}{\rho_0 hgy}\right]$ (d) $\rho = \rho_0\left[1 - \frac{B}{\rho_0 gy}\right]$

24. With rise in temperature, density of a given body changes according to one of the following relations

(a) $\rho = \rho_0[1 + \gamma\, d\theta]$ (b) $\rho = \rho_0[1 - \gamma\, d\theta]$

(c) $\rho = \rho_0 \gamma d\theta$ (d) $\rho = \rho_0 / \gamma d\theta$

25. Three liquids of densities $d, 2d$ and $3d$ are mixed in equal volumes. Then the density of the mixture is

(a) d (b) $2d$

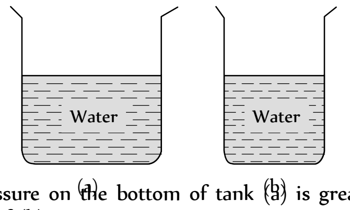
(c) $3d$ (d) $5d$

26. Three liquids of densities $d, 2d$ and $3d$ are mixed in equal proportions of weights. The relative density of the mixture is

(a) $\frac{11d}{7}$ (b) $\frac{18d}{11}$

(c) $\frac{13d}{9}$ (d) $\frac{23d}{18}$

27. From the adjacent figure, the correct observation is **[KCET 2005]**



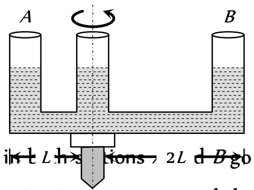
(a) The pressure on the bottom of tank (a) is greater than at the bottom of (b).

(b) The pressure on the bottom of the tank (a) is smaller than at the bottom of (b)

(c) The pressure depend on the shape of the container

(d) The pressure on the bottom of (a) and (b) is the same

28. A given shaped glass tube having uniform cross section is filled with water and is mounted on a rotatable shaft as shown in figure. If the tube is rotated with a constant angular velocity ω then



(a) Water levels in both sections A and B go up

(b) Water level in Section A goes up and that in B comes down

(c) Water level in Section A comes down and that in B it goes up

(d) Water levels remains same in both sections

29. Why the dam of water reservoir is thick at the bottom **[AFMC 2005]**

(a) Quantity of water increases with depth

(b) Density of water increases with depth

(c) Pressure of water increases with depth

(d) Temperature of water increases with depth

30. Air is blown through a hole on a closed pipe containing liquid. Then the pressure will **[AFMC 2005]**

(a) Increase on sides

(b) Increase downwards

(c) Increase in all directions

(d) Never increases

31. Radius of an air bubble at the bottom of the lake is r and it becomes $2r$ when the air bubbles rises to the top surface of the lake. If P cm of water be the atmospheric pressure, then the depth of the lake is

(a) $2p$ (b) $8p$

(c) $4p$ (d) $7p$

Pascal's Law and Archmidies Principle

1. An ice berg of density 900 *Kg/m* is floating in water of density 1000 *Kg/m*. The percentage of volume of ice-cube outside the water is

(a) 20% (b) 35%

(c) 10% (d) 25%

2. A log of wood of mass 120 *Kg* floats in water. The weight that can be put on the raft to make it just sink, should be (density of wood = 600 *Kg/m*) [CPMT 2004]

(a) 80 *Kg* (b) 50 *Kg*

(c) 60 *Kg* (d) 30 *Kg*

3. A hemispherical bowl just floats without sinking in a liquid of density 1.2 × 10 *kg/m*. If outer diameter and the density of the bowl are 1 *m* and 2 × 10 *kg/m* respectively, then the inner diameter of the bowl will be [SCRA 1998]

(a) 0.94 *m* (b) 0.97 *m*

(c) 0.98 *m* (d) 0.99 *m*

4. In making an alloy, a substance of specific gravity s_1 and mass m_1 is mixed with another substance of specific gravity s_2 and mass m_2; then the specific gravity of the alloy is [CPMT 1995]

(a) $\left(\frac{m_1+m_2}{s_1+s_2}\right)$ (b) $\left(\frac{s_1 s_2}{m_1+m_2}\right)$

(c) $\frac{m_1+m_2}{\left(\frac{m_1}{s_1}+\frac{m_2}{s_2}\right)}$ (d) $\frac{\left(\frac{m_1}{s_1}+\frac{m_2}{s_2}\right)}{m_1+m_2}$

5. A concrete sphere of radius R has a cavity of radius r which is packed with sawdust. The specific gravities of concrete and sawdust are respectively 2.4 and 0.3 for this sphere to float with its entire volume submerged under water. Ratio of mass of concrete to mass of sawdust will be [AIIMS 1995]

(a) 8 (b) 4

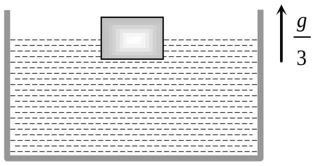
(c) 3 (d) Zero

6. A metallic block of density 5 *gm* cm and having dimensions 5 *cm* × 5 *cm* × 5 *cm* is weighed in water. Its apparent weight will be

(a) 5 × 5 × 5 × 5 *gf* (b) 4 × 4 × 4 × 4 gf

(c) 5 × 4 × 4 × 4 gf (d) 4 × 5 × 5 × 5 gf

7. A cubical block is floating in a liquid with half of its volume immersed in the liquid. When the whole system accelerates upwards with acceleration of *g/3*, the fraction of volume immersed in the liquid will be



(a) $\frac{1}{2}$

(b) $\frac{3}{8}$ [Kerla PET 2005]

(c) $\frac{2}{3}$

(d) $\frac{3}{4}$

8. A silver ingot weighing 2.1 *kg* is held by a string so as to be completely immersed in a liquid of relative density 0.8. The relative density of silver is 10.5. The tension in the string in *kg-wt* is [CPMT 2004]

(a) 1.6 (b) 1.94

(c) 3.1 (d) 5.25

9. A sample of metal weighs 210 *gm* in air, 180 *gm* in water and 120 *gm* in liquid. Then relative density (RD) of

(a) Metal is 3 (b) Metal is 7

(c) Liquid is 3 (d) Liquid is $\frac{1}{3}$

10. Two solids A and B float in water. It is observed that A floats with half its volume immersed and B floats with 2/3 of its volume immersed. Compare the densities of A and B

(a) 4 : 3 (b) 2 : 3

(c) 3 : 4 (d) 1 : 3

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

(a) $\frac{d_0}{d}$ (b) $\frac{dd_0}{d+d_0}$

(c) $\frac{d-d_0}{d}$ (d) $\frac{dd_0}{d-d_0}$

12. Pressure applied to an enclosed fluid is transmitted undiminished to every portion of the fluid and the walls of the containing vessel. This law was first formulated by

(a) Bernoulli (b) Archimedes

(c) Boyle (d) Pascal

13. A block of steel of size 5 *cm* × 5 *cm* × 5 *cm* is weighed in water. If the relative density of steel is 7, its apparent weight is

(a) 6 × 5 × 5 × 5 *gf* (b) 4 × 4 × 4 × 7 *gf*

(c) 5 × 5 × 5 × 7 *gf* (d) 4 × 4 × 4 × 6 *gf*

14. A body is just floating on the surface of a liquid. The density of the body is same as that of the liquid. The body is slightly pushed down. What will happen to the body [AIIMS 1980]

(a) It will slowly come back to its earlier position

(b) It will remain submerged, where it is left

(c) It will sink

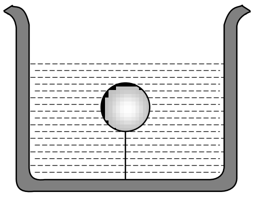
(d) It will come out violently

15. A cork is submerged in water by a spring attached to the bottom of a bowl. When the bowl is kept in an elevator moving with acceleration downwards, the length of spring

(a) Increases (b) Decreases

(c) Remains unchanged (d) None of these

16. A solid sphere of density η (> 1) times lighter than water is suspended in a water tank by a string tied to its base as shown in fig. If the mass of the sphere is m then the tension in the string is given by



(a) $\left(\frac{\eta-1}{\eta}\right)mg$

(b) ηmg

(c) $\frac{mg}{\eta-1}$

(d) $(\eta-1)mg$

17. A hollow sphere of volume V is floating on water surface with *half* immersed in it. What should be the minimum volume of water poured inside the sphere so that the sphere now sinks into the water

(a) $V/2$ (b) $V/3$

(c) $V/4$ (d) V

18. A rectangular block is 5 cm × 5 cm × 10cm in size. The block is floating in water with 5 cm side vertical. If it floats with 10 cm side vertical, what change will occur in the level of water?

(a) No change

(b) It will rise

(c) It will fall

(d) It may rise or fall depending on the density of block

19. A ball whose density is 0.4×10^{3} kg/m^{3} falls into water from a height of 9 cm. To what depth does the ball sink

(a) 9 cm (b) 6 cm

(c) 4.5 cm (d) 2.25 cm

20. Two solids A and B float in water. It is observed that A floats with $\frac{1}{2}$ of its body immersed in water and B floats with $\frac{1}{4}$ of its volume above the water level. The ratio of the density of A to that of B is

(a) 4 : 3 (b) 2 : 3

(c) 3 : 4 (d) 1 : 2

21. A boat carrying steel balls is floating on the surface of water in a tank. If the balls are thrown into the tank one by one, how will it affect the level of water **[J&K CET 2005]**

(a) It will remain unchanged

(b) It will rise

(c) It will fall

(d) First it will first rise and then fall

22. Two pieces of metal when immersed in a liquid have equal upthrust on them; then

(a) Both pieces must have equal weights

(b) Both pieces must have equal densities

(c) Both pieces must have equal volumes

(d) Both are floating to the same depth

23. A wooden cylinder floats vertically in water with half of its length immersed. The density of wood is

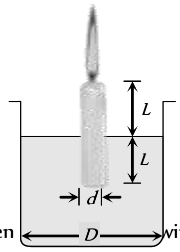
(a) Equal of that of water

(b) Half the density of water

(c) Double the density of water

(d) The question is incomplete

24. A candle of diameter d is floating on a liquid in a cylindrical container of diameter D (D>>d) as shown in figure. If it is burning at the rate of 2$cm/hour$ then the top of the candle will



(a) Remain at the same height

(b) Fall at the rate of 1 $cm/hour$

(c) Fall at the rate of 2 $cm/hour$

(d) Go up the rate of 1$cm/hour$

25. An ice block contains a glass ball when within the water containing vessel, the level of water **[AFMC 2005]**

(a) Rises (b) Falls

(c) Unchanged (d) First rises and then falls

26. A large ship can float but a steel needle sinks because of **[AFMC 2005]**

(a) Viscosity (b) Surface tension

(c) Density (d) None of these

27. Construction of submarines is based on **[Kerala PMT 2005]**

(a) Archimedes' principle (b) Bernoulli's theorem

(c) Pascal's law (d) Newton's laws

Fluid Flow

1. In which one of the following cases will the liquid flow in a pipe be most streamlined **[Pb. CET 2005]**

(a) Liquid of high viscosity and high density flowing through a pipe of small radius

(b) Liquid of high viscosity and low density flowing through a pipe of small radius

(c) Liquid of low viscosity and low density flowing through a pipe of large radius

(d) Liquid of low viscosity and high density flowing through a pipe of large radius

2. Two water pipes of diameters 2 cm and 4 cm are connected with the main supply line. The velocity of flow of water in the pipe of 2 cm diameter is **[MNR 1980]**

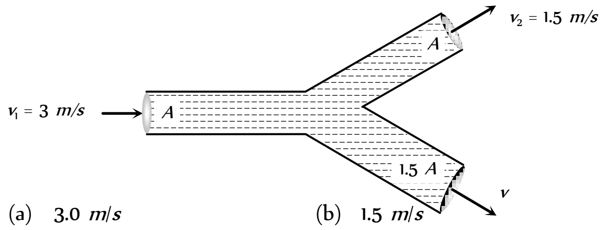
(a) 4 times that in the other pipe

(b) $\frac{1}{4}$ times that in the other pipe

(c) 2 times that in the other pipe

(d) $\frac{1}{2}$ times that in the other pipe

3. An incompressible liquid flows through a horizontal tube as shown in the following fig. Then the velocity v of the fluid is



(a) 3.0 m/s (b) 1.5 m/s
(c) 1.0 m/s (d) 2.25 m/s

4. Water enters through end A with speed v_1 and leaves through end B with speed v_2 of a cylindrical tube AB. The tube is always completely filled with water. In case I tube is horizontal and in case II it is vertical with end A upwards and in case III it is vertical with end B upwards. We have $v_1 = v_2$ for

(a) Case I (b) Case II
(c) Case III (d) Each case

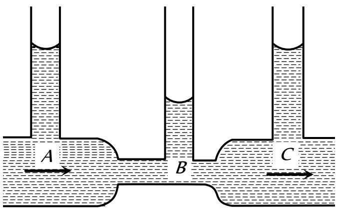
5. Water is moving with a speed of 5.18 ms^{-1} through a pipe with a cross-sectional area of 4.20 cm^2. The water gradually descends 9.66 m as the pipe increase in area to 7.60 cm^2. The speed of flow at the lower level is

(a) 3.0 ms^{-1} (b) 5.7 ms^{-1}
(c) 3.82 ms^{-1} (d) 2.86 ms^{-1}

6. The velocity of kerosene oil in a horizontal pipe is 5 m/s. If $g = 10 m / s^2$ then the velocity head of oil will be

(a) 1.25 m (b) 12.5 m
(c) 0.125 m (d) 125 m

7. In the following fig. is shown the flow of liquid through a horizontal pipe. Three tubes A, B and C are connected to the pipe. The radii of the tubes A, B and C at the junction are respectively 2 cm, 1 cm and 2 cm. It can be said that the



(a) Height of the liquid in the tube A is maximum
(b) Height of the liquid in the tubes A and B is the same
(c) Height of the liquid in all the three tubes is the same
(d) Height of the liquid in the tubes A and C is the same

8. A manometer connected to a closed tap reads 3.5×10^5 N/m^2. When the valve is opened, the reading of manometer falls to 3.0×10^5 N/m^2, then velocity of flow of water is

(a) 100 m/s (b) 10 m/s
(c) 1 m/s (d) $10\sqrt{10}$ m/s

9. Air is streaming past a horizontal air plane wing such that its speed in 120 m/s over the upper surface and 90 m/s at the lower surface. If the density of air is 1.3 kg per metre^3 and the wing is 10 m long and has an average width of 2 m, then the difference of the pressure on the two sides of the wing of

(a) 4095.0 *Pascal* (b) 409.50 *Pascal*
(c) 40.950 *Pascal* (d) 4.0950 *Pascal*

10. A large tank filled with water to a height 'h' is to be emptied through a small hole at the bottom. The ratio of time taken for the level of water to fall from h to $\frac{h}{2}$ and from $\frac{h}{2}$ to zero is

(a) $\sqrt{2}$ (b) $\frac{1}{\sqrt{2}}$
(c) $\sqrt{2} - 1$ (d) $\frac{1}{\sqrt{2} - 1}$

11. A cylinder of height 20 m is completely filled with water. The velocity of efflux of water (in m/s) through a small hole on the side wall of the cylinder near its bottom is

[AIEEE 2002]

(a) 10 (b) 20
(c) 25.5 (d) 5

12. 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 **[CPMT 2002]**

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

13. There is a hole of area A at the bottom of cylindrical vessel. Water is filled up to a height h and water flows out in t second. If water is filled to a height $4h$, it will flow out in time equal to

(a) t (b) $4t$
(c) $2\ t$ (d) $t/4$

14. A cylindrical tank has a hole of 1 cm^2 in its bottom. If the water is allowed to flow into the tank from a tube above it at the rate of 70 cm^3/sec. then the maximum height up to which water can rise in the tank is

(a) 2.5 cm (b) 5 cm
(c) 10 cm (d) 0.25 cm

15. A square plate of 0.1 m side moves parallel to a second plate with a velocity of 0.1 m/s, both plates being immersed in water. If the viscous force is 0.002 N and the coefficient of viscosity is 0.01 *poise*, distance between the plates in m is

[EAMCET (Med.) 2003]

(a) 0.1 (b) 0.05
(c) 0.005 (d) 0.0005

16. Spherical balls of radius 'r' are falling in a viscous fluid of viscosity 'η' with a velocity 'v'. The retarding viscous force acting on the spherical ball is **[AIEEE 2004]**

(a) Inversely proportional to 'r' but directly proportional to velocity 'v'
(b) Directly proportional to both radius 'r' and velocity 'v'
(c) Inversely proportional to both radius 'r' and velocity 'v'
(d) Directly proportional to 'r' but inversely proportional to 'v'

17. A small sphere of mass m is dropped from a great height. After it has fallen 100 m, it has attained its terminal velocity and continues to fall at that speed. The work done by air friction against the sphere during the first 100 m of fall is

[MP PMT 1990]

(a) Greater than the work done by air friction in the second 100 m

(b) Less than the work done by air friction in the second 100 *m*

(c) Equal to 100 *mg*

(d) Greater than 100 *mg*

18. 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 [MP PMT 1990]

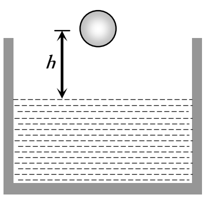
(a) 10 *cm* per *sec* (b) 2.5 *cm* per *sec*

(c) $5 \times (4)^{1/3}\, cm$ per *sec* (d) $5 \times \sqrt{2}\, cm$ per sec

19. A ball of radius *r* and density ρ falls freely under gravity through a distance *h* before entering water. Velocity of ball does not change even on entering water. If viscosity of water is η, the value of *h* is given by

(a) $\frac{2}{9} r^2 \left(\frac{1-\rho}{\eta}\right) g$

(b) $\frac{2}{81} r^2 \left(\frac{\rho-1}{\eta}\right) g$



(c) $\frac{2}{81} r^4 \left(\frac{\rho-1}{\eta}\right)^2 g$

(d) $\frac{2}{9} r^4 \left(\frac{\rho-1}{\eta}\right)^2 g$

20. The rate of steady volume flow of water through a capillary tube of length '*l*' and radius '*r*' under a pressure difference of *P* is *V*. This tube is connected with another tube of the same length but half the radius in series. Then the rate of steady volume flow through them is (The pressure difference across the combination is *P*)

(a) $\frac{V}{16}$ (b) $\frac{V}{17}$

(c) $\frac{16V}{17}$ (d) $\frac{17V}{16}$

21. A liquid is flowing in a horizontal uniform capillary tube under a constant pressure difference *P*. The value of pressure for which the rate of flow of the liquid is doubled when the radius and length both are doubled is [EAMCET 2001]

(a) *P* (b) $\frac{3P}{4}$

(c) $\frac{P}{2}$ (d) $\frac{P}{4}$

22. We have two (narrow) capillary tubes T_1 and T_2. Their lengths are l_1 and l_2 and radii of cross-section are r_1 and r_2 respectively. The rate of flow of water under a pressure difference *P* through tube T_1 is 8*cm/sec*. If $l_1 = 2l_2$ and $r_1 = r_2$, what will be the rate of flow when the two tubes are connected in series and pressure difference across the combination is same as before (= *P*)

(a) 4 *cm/sec* (b) (16/3) *cm/sec*

(c) (8/17) *cm/sec* (d) None of these

23. In a laminar flow the velocity of the liquid in contact with the walls of the tube is

(a) Zero

(b) Maximum

(c) In between zero and maximum

(d) Equal to critical velocity

24. In a turbulent flow, the velocity of the liquid molecules in contact with the walls of the tube is

(a) Zero

(b) Maximum

(c) Equal to critical velocity

(d) May have any value

25. The Reynolds number of a flow is the ratio of

(a) Gravity to viscous force

(b) Gravity force to pressure force

(c) Inertia forces to viscous force

(d) Viscous forces to pressure forces

26. Water is flowing through a tube of non-uniform cross-section ratio of the radius at entry and exit end of the pipe is 3 : 2. Then the ratio of velocities at entry and exit of liquid is [RPMT 2001]

(a) 4 : 9 (b) 9 : 4

(c) 8 : 27 (d) 1 : 1

27. Water is flowing through a horizontal pipe of non-uniform cross-section. At the extreme narrow portion of the pipe, the water will have [MP PMT 1992]

(a) Maximum speed and least pressure

(b) Maximum pressure and least speed

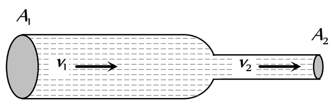
(c) Both pressure and speed maximum

(d) Both pressure and speed least

28. A liquid flows in a tube from left to right as shown in figure. [EAMCET (Engg.) 2003] A_1 and A_2 are the cross-sections of the portions of the tube as shown. Then the ratio of speeds v_1 / v_2 will be

(a) A_1 / A_2

(b) A_2 / A_1



(c) $\sqrt{A_2} / \sqrt{A_1}$

(d) $\sqrt{A_1} / \sqrt{A_2}$

29. In a streamline flow

(a) The speed of a particle always remains same

(b) The velocity of a particle always remains same

(c) The kinetic energies of all the particles arriving at a given point are the same

(d) The moments of all the particles arriving at a given point are the same

30. An application of Bernoulli's equation for fluid flow is found in

(a) Dynamic lift of an aeroplane

(b) Viscosity meter

(c) Capillary rise

(d) Hydraulic press

31. The Working of an atomizer depends upon

[MP PMT 1992; AFMC 2005]

(a) Bernoulli's theorem (b) Boyle's law

(c) Archimedes principle (d) Newton's law of motion

32. The pans of a physical balance are in equilibrium. Air is blown under the right hand pan; then the right hand pan will

(a) Move up

(b) Move down

(c) Move erratically

(d) Remain at the same level

33. According to Bernoulli's equation

$$\frac{P}{\rho g}+h+\frac{1}{2}\frac{v^2}{g}=\text{constant}$$

The terms *A*, *B* and *C* are generally called respectively:

(a) Gravitational head, pressure head and velocity head

(b) Gravity, gravitational head and velocity head

(c) Pressure head, gravitational head and velocity head

(d) Gravity, pressure and velocity head

34. At what speed the velocity head of a stream of water be equal to 40 *cm* of *Hg*

(a) 282.8 *cm/sec* (b) 432.6 *cm/sec*

(c) 632.6 *cm/sec* (d) 832.6 *cm/sec*

35. The weight of an aeroplane flying in air is balanced by

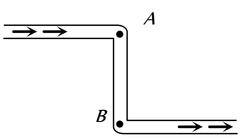
(a) Upthrust of the air which will be equal to the weight of the air having the same volume as the plane

(b) Force due to the pressure difference between the upper and lower surfaces of the wings, created by different air speeds on the surface

(c) Vertical component of the thrust created by air currents striking the lower surface of the wings

(d) Force due to the reaction of gases ejected by the revolving propeller

36. In this figure, an ideal liquid flows through the tube, which is of uniform cross-section. The liquid has velocities v_A and v_B, and pressure P_A and P_B at points *A* and *B* respectively



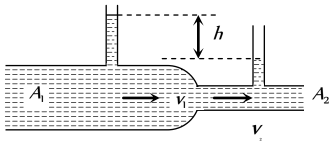
(a) $v_A = v_B$

(b) $v_B > v_A$

(c) $P_A = P_B$

(d) $P_B > P_A$

37. A liquid flows through a horizontal tube. The velocities of the liquid in the two sections, which have areas of cross-section A_1 and A_2, are v_1 and v_2 respectively. The difference in the levels of the liquid in the two vertical tubes is h



(a) The volume of the liquid flowing through the tube in unit time is A_1v_1

(b) $v_2 - v_1 = \sqrt{2gh}$

(c) $v_2^2 - v_1^2 = 2gh$

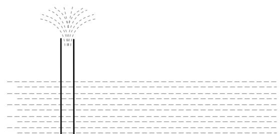
(d) The energy per unit mass of the liquid is the same in both sections of the tube

38. A sniper fires a rifle bullet into a gasoline tank making a hole 53.0 *m* below the surface of gasoline. The tank was sealed at 3.10 *atm*. The stored gasoline has a density of 660 kgm^{-3}. The velocity with which gasoline begins to shoot out of the hole is

(a) $27.8\,ms^{-1}$ (b) $41.0\,ms^{-1}$

(c) $9.6\,ms^{-1}$ (d) $19.7\,ms^{-1}$

39. An L-shaped tube with a small orifice is held in a water stream as shown in fig. The upper end of the tube is 10.6 *cm* above the surface of water. What will be the height of the jet of water coming from the orifice? Velocity of water stream is 2.45 *m/s*



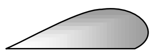
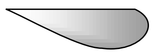
(a) Zero

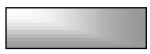
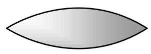
(b) 20.0 *cm*

(c) 10.6 *cm*

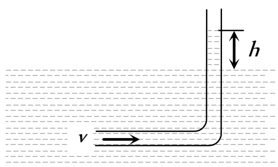
(d) 40.0 *cm*

40. Fig. represents vertical sections of four wings ... rizontally in air. In which case the force is upwards

(a)  (b) 

(c)  (d) 

41. An L-shaped glass tube is just immersed in flowing water such that its opening is pointing against flowing water. If the speed of water current is *v*, then



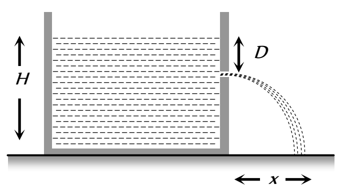
(a) The water in the tube rises to height $\frac{v^2}{2g}$

(b) The water in the tube rises to height $\frac{g}{2v^2}$

(c) The water in the tube does not rise at all

(d) None of these

42. A tank is filled with water up to a height *H*. Water is allowed to come out of a hole *P* in one of the walls at a depth *D* below the surface of water. Express the horizontal distance *x* in terms of *H* and *D* [MNR 1992; CPMT 2004]



(a) $x = \sqrt{D(H-D)}$

(b) $x = \sqrt{\frac{D(H-D)}{2}}$

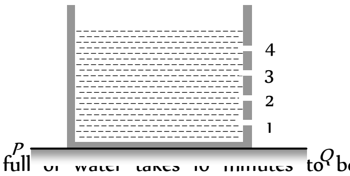
(c) $x = 2\sqrt{D(H-D)}$

(d) $x = 4\sqrt{D(H-D)}$

43. A cylindrical vessel of 90 *cm* height is kept filled upto the brim. It has four holes 1, 2, 3, 4 which are respectively at heights of 20 *cm*, 30 *cm*, 45 *cm* and 50 *cm* from the horizontal floor *PQ*. The water falling at the maximum horizontal distance from the vessel comes from

[CPMT 1989]

(a) Hole number 4
(b) Hole number 3
(c) Hole number 2
(d) Hole number 1



44. A rectangular vessel when full of water takes 10 minutes to be emptied through an orifice in its bottom. How much time will it take to be emptied when half filled with water

(a) 9 *minute* (b) 7 *minute*
(c) 5 *minute* (d) 3 *minute*

45. A streamlined body falls through air from a height h on the surface of a liquid. If d and $D(D > d)$ represents the densities of the material of the body and liquid respectively, then the time after which the body will be instantaneously at rest, is

(a) $\sqrt{\frac{2h}{g}}$ (b) $\sqrt{\frac{2h}{g}\cdot\frac{D}{d}}$

(c) $\sqrt{\frac{2h}{g}\cdot\frac{d}{D}}$ (d) $\sqrt{\frac{2h}{g}}\left(\frac{d}{D-d}\right)$

46. A large tank is filled with water to a height *H*. A small hole is made at the base of the tank. It takes T_1 time to decrease the height of water to $\frac{H}{\eta}(\eta > 1)$; and it takes T_2 time to take out the rest of water. If $T_1 = T_2$, then the value of η is

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

47. Velocity of water in a river is [CBSE PMT 1988]

(a) Same everywhere
(b) More in the middle and less near its banks
(c) Less in the middle and more near its banks
(d) Increase from one bank to other bank

48. As the temperature of water increases, its viscosity

(a) Remains unchanged
(b) Decreases
(c) Increases
(d) Increases or decreases depending on the external pressure

49. The coefficient of viscosity for hot air is

(a) Greater than the coefficient of viscosity for cold air
(b) Smaller than the coefficient of viscosity for cold air
(c) Same as the coefficient of viscosity for cold air
(d) Increases or decreases depending on the external pressure

50. A good lubricant should have

(a) High viscosity (b) Low viscosity
(c) Moderate viscosity (d) High density

51. We have three beakers *A*, *B* and *C* containing glycerine, water and kerosene respectively. They are stirred vigorously and placed on a table. The liquid which comes to rest at the earliest is

(a) Glycerine
(b) Water
(c) Kerosene
(d) All of them at the same time

52. A small drop of water falls from rest through a large height h in air; the final velocity is

(a) $\propto \sqrt{h}$
(b) $\propto h$
(c) $\propto (1/h)$
(d) Almost independent of h

53. The rate of flow of liquid in a tube of radius *r*, length *l*, whose ends are maintained at a pressure difference P is $V = \frac{\pi Q P r^4}{\eta l}$ where η is coefficient of the viscosity and Q is

[DCE 2002]

(a) 8 (b) $\frac{1}{8}$

(c) 16 (d) $\frac{1}{16}$

54. In Poiseuilli's method of determination of coefficient of viscosity, the physical quantity that requires greater accuracy in measurement is

(a) Pressure difference
(b) Volume of the liquid collected
(c) Length of the capillary tube
(d) Inner radius of the capillary tube

55. Two capillary tubes of the same length but different radii r_1 and r_2 are fitted in parallel to the bottom of a vessel. The pressure head is *P*. What should be the radius of a single tube that can replace the two tubes so that the rate of flow is same as before

(a) $r_1 + r_2$ (b) $r_1^2 + r_2^2$

(c) $r_1^4 + r_2^4$ (d) None of these

56. Two capillaries of same length and radii in the ratio 1 : 2 are connected in series. A liquid flows through them in streamlined condition. If the pressure across the two extreme ends of the combination is 1 *m* of water, the pressure difference across first capillary is

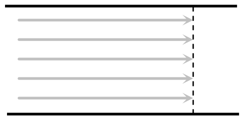
(a) 9.4 *m* (b) 4.9 *m*
(c) 0.49 *m* (d) 0.94 *m*

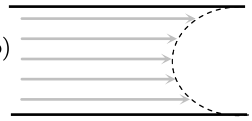
57. Water flows in a streamlined manner through a capillary tube of radius *a*, the pressure difference being *P* and the rate of flow *Q*. If the radius is reduced to *a*/2 and the pressure increased to 2*P*, the rate of flow becomes

(a) $4Q$ (b) Q

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

58. A viscous fluid is flowing through a cylindrical tube. The velocity distribution of the fluid is best represented by the diagram

(a) 

(b) 

(c) 

(d) None of these

59. Water is flowing in a pipe of diameter 4 *cm* with a velocity 3 *m/s*. The water then enters into a tube of diameter 2 *cm*. The velocity of water in the other pipe is [BCECE 2005]

(a) 3 *m/s* (b) 6 *m/s*

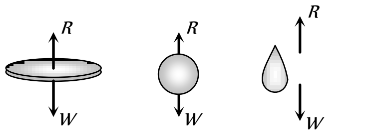
(c) 12 *m/s* (d) 8 *m/s*

60. 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 of the flow through single capillary, $X = \pi PR^4 / 8\eta L$) [DCE 2005]

(a) $\frac{8}{9}X$ (b) $\frac{9}{8}X$

(c) $\frac{5}{7}X$ (d) $\frac{7}{5}X$

61. When a body falls in air, the resistance of air depends to a great extent on the shape of the body, 3 different shapes are given. Identify the combination of air resistances which truly represents the physical situation. (The cross sectional areas are the same).



(a) 1 < 2 < 3 (b) 2 < 3 < 1

(c) 3 < 2 < 1 (d) 3 < 1 < 2

62. Water falls from a tap, down the streamline

[Orissa JEE 2005]

(a) Area decreases (b) Area increases

(c) Velocity remains same (d) Area remains same

63. A manometer connected to a closed tap reads 4.5×10^5 *pascal*. When the tap is opened the reading of the manometer falls to 4×10^5 *pascal*. Then the velocity of flow of water is

(a) 7 ms^{-1} (b) 8 ms^{-1}

(c) 9 ms^{-1} (d) 10 ms^{-1}

64. What is the velocity v of a metallic ball of radius r falling in a tank of liquid at the instant when its acceleration is one-half that of a freely falling body ? (The densities of metal and of liquid are ρ and σ respectively, and the viscosity of the liquid is η).

(a) $\frac{r^2 g}{9\eta}(\rho - 2\sigma)$ (b) $\frac{r^2 g}{9\eta}(2\rho - \sigma)$

(c) $\frac{r^2 g}{9\eta}(\rho - \sigma)$ (d) $\frac{2r^2 g}{9\eta}(\rho - \sigma)$

65. Consider the following equation of Bernouilli's theorem.

$P + \frac{1}{2}\rho V^2 + \rho g h = K$ (constant)

The dimensions of *K/P* are same as that of which of the following [AFMC 2005]

(a) Thrust (b) Pressure

(c) Angle (d) Viscosity

66. An incompressible fluid flows steadily through a cylindrical pipe which has radius $2r$ at point A and radius r at B further along the flow direction. If the velocity at point A is v, its velocity at point B is [Kerala PMT 2005]

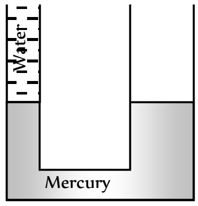
(a) $2v$ (b) v

(c) $v/2$ (d) $4v$

Critical Thinking

Objective Questions

1. A U-tube in which the cross-sectional area of the limb on the left is one quarter, the limb on the right contains mercury (density 13.6 *g/cm*). The level of mercury in the narrow limb is at a distance of 36 *cm* from the upper end of the tube. What will be the rise in the level of mercury in the right limb if the left limb is filled to the top with water



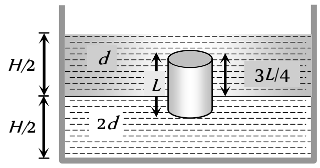
(a) 1.2 *cm*

(b) 2.35 *cm*

(c) 0.56 *cm* [KCET 2005]

(d) 0.8 *cm*

2. A homogeneous solid cylinder of length $L(L < H/2)$. Cross-sectional area $A/5$ is immersed such that it floats with its axis vertical at the liquid-liquid interface with length $L/4$ in the denser liquid as shown in the fig. The lower density liquid is open to atmosphere having pressure P_0. Then density D of solid is given by



(a) $\frac{5}{4}d$

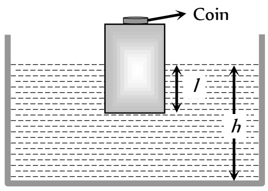
(b) $\frac{4}{5}d$

(c) d

(d) $\frac{d}{5}$

3. A wooden block, with a coin placed on its top, floats in water as shown in fig. the distance l and h are shown there. After some time the coin falls into the water. Then [Kerala PET 2005]

[IIT-JEE (Screening) 2002]



(a) l decreases and h increases

(b) l increases and h decreases

(c) Both l and h increase [Kerala PET 2005]

(d) Both l and h decrease

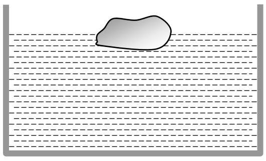
4. A vessel contains oil (density = 0.8 *gm/cm*) over mercury (density = 13.6 *gm/cm*). A homogeneous sphere floats with half of its volume immersed in mercury and the other half in oil. The density of the material of the sphere in *gm/cm* is

(a) 3.3 (b) 6.4

(c) 7.2 (d) 12.8

5. A body floats in a liquid contained in a beaker. The whole system as shown falls freely under gravity. The upthrust on the body due to the liquid is

[IIT-JEE 1982]



(a) Zero

(b) Equal to the weight of the liquid displaced

(c) Equal to the weight of the body in air

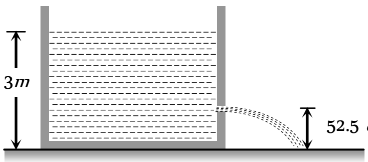
(d) Equal to the weight of the immersed position of the body

6. A liquid is kept in a cylindrical vessel which is being rotated about a vertical axis through the centre of the circular base. If the radius of the vessel is r and angular velocity of rotation is ω, then the difference in the heights of the liquid at the centre of the vessel and the edge is

(a) $\frac{r\omega}{2g}$ (b) $\frac{r^2\omega^2}{2g}$

(c) $\sqrt{2gr\omega}$ (d) $\frac{\omega^2}{2gr^2}$

7. Water is filled in a cylindrical container to a height of 3*m*. The ratio of the cross-sectional area of the orifice and the beaker is 0.1. The square of the speed of the liquid coming out from the orifice is (g = 10 *m/s*) [IIT JEE 2004]



(a) 50 *m/s*

(b) 50.5 *m/s*

(c) 51 *m/s*

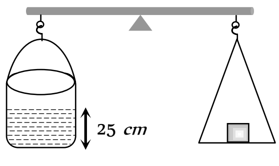
(d) 52 *m/s*

8. A large open tank has two holes in the wall. One is a square hole of side L at a depth y from the top and the other is a circular hole of radius R at a depth $4y$ from the top. When the tank is completely filled with water the quantities of water flowing out per second from both the holes are the same. Then R is equal to

(a) $2\pi L$ (b) $\frac{L}{\sqrt{2\pi}}$

(c) L (d) $\frac{L}{2\pi}$

9. A cylinder containing water up to a height of 25 *cm* has a hole of cross-section $\frac{1}{4}cm^2$ in its bottom. It is counterpoised in a balance. What is the initial change in the balancing weight when water begins to flow out



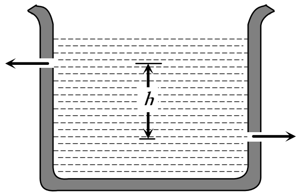
(a) Increase of 12.5 *gm-wt*

(b) Increase of 6.25 *gm-wt*

(c) Decrease of 12.5 *gm-wt*

(d) Decrease of 6.25 *gm-wt*

10. There are two identical small holes of area of cross-section a on the opposite sides of a tank containing a liquid of density ρ. The difference in height between the holes is h. Tank is resting on a smooth horizontal surface. Horizontal force which will has to be applied on the tank to keep it in equilibrium is



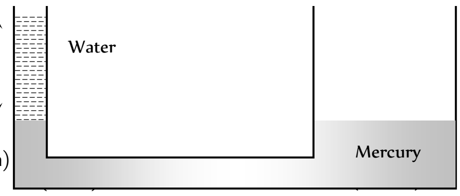
(a) $gh\rho a$

(b) $\frac{2gh}{\rho a}$

(c) $2\rho agh$

(d) $\frac{\rho gh}{a}$

11. Two communicating vessels contain mercury. The diameter of one vessel is n times larger than the diameter of the other. A column of water of height h is poured into the left vessel. The mercury level will rise in the right-hand vessel (s = relative density of mercury and ρ = density of water) by



(a)

(c) $\frac{h}{(n+1)^2 s}$ (d) $\frac{h}{n^2 s}$

12. A uniform rod of density ρ is placed in a wide tank containing a liquid of density $\rho_0 (\rho_0 > \rho)$. The depth of liquid in the tank is half the length of the rod. The rod is in equilibrium, with its lower end resting on the bottom of the tank. In this position the rod makes an angle θ with the horizontal

(a) $\sin\theta = \frac{1}{2}\sqrt{\rho_0 / \rho}$ (b) $\sin\theta = \frac{1}{2}\cdot\frac{\rho_0}{\rho}$

(c) $\sin\theta = \sqrt{\rho / \rho_0}$ (d) $\sin\theta = \rho_0 / \rho$

13. A block of ice floats on a liquid of density 1.2in a beaker then level of liquid when ice completely melt [IIT-JEE (Screening) 2000]

[IIT-JEE 1994]

(a) Remains same (b) Rises

(c) Lowers (d) (a), (b) or (c)

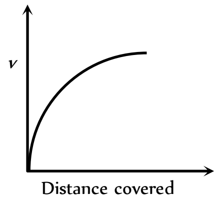
14. A vessel of area of cross-section A has liquid to a height H. There is a hole at the bottom of vessel having area of cross-section a. The time taken to decrease the level from H_1 to H_2 will be

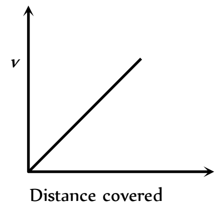
(a) $\frac{A}{a}\sqrt{\frac{2}{g}}[\sqrt{H_1} - \sqrt{H_2}]$ (b) $\sqrt{2gh}$

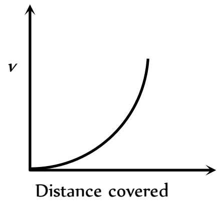
(c) $\sqrt{2gh(H_1 - H_2)}$ (d) $\frac{A}{a}\sqrt{\frac{g}{2}}[\sqrt{H_1} - \sqrt{H_2}]$

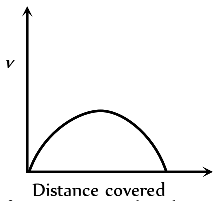
GQ Graphical Questions

1. A lead shot of 1mm diameter falls through a long column of glycerine. The variation of its velocity v. with distance covered is represented by [AIIMS 2003]

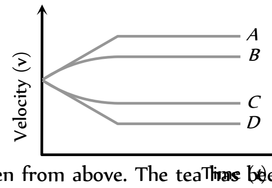
(a) 

(b) 

(c) 

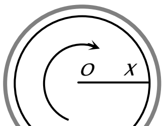
(d) 

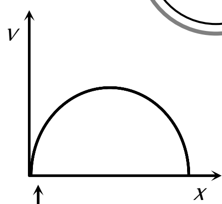
2. A small spherical solid ball is dropped from a great height in a viscous liquid. Its journey in the liquid is best described in the diagram given below by the [CPMT 1988]

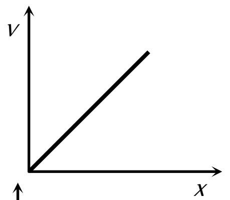


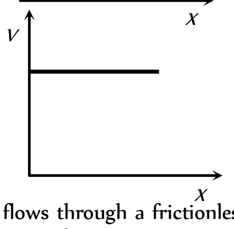
(a) Curve A
(b) Curve B
(c) Curve C
(d) Curve D

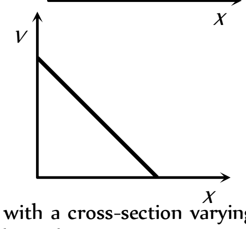
3. The diagram shows a cup of tea seen from above. The tea has been stirred and is now rotating without turbulence. A graph showing the speed v with which the liquid is crossing points at a distance X from O along a radius XO would look like



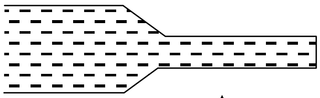
(a) 

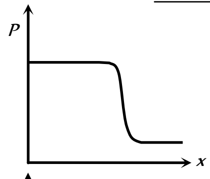
(b) 

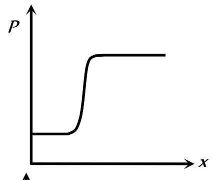
(c) 

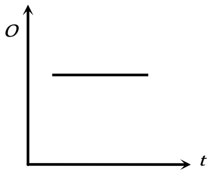
(d) 

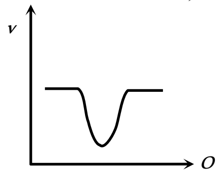
4. Water flows through a frictionless duct with a cross-section varying as shown in fig. Pressure p at points along the axis is represented by



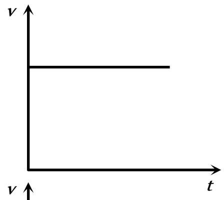
(a) 

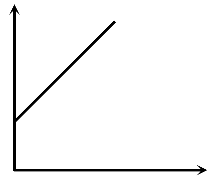
(b) 

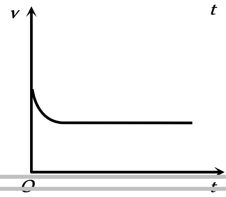
(c) 

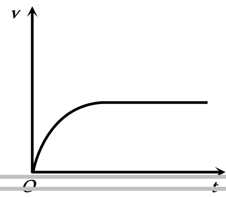
(d) 

5. From amongst the following curves, which one shows the variation of the velocity v with time t for a small sized spherical body falling vertically in a long column of a viscous liquid

(a) 

(b) 

(c) 

(d) 

Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) *If both assertion and reason are true and the reason is the correct explanation of the assertion.*
(b) *If both assertion and reason are true but reason is not the correct explanation of the assertion.*
(c) *If assertion is true but reason is false.*
(d) *If the assertion and reason both are false.*
(e) *If assertion is false but reason is true.*

1. Assertion : Pascal law is the working principle of a hydraulic lift.
   Reason : Pressure is equal to thrust per area.
2. Assertion : The blood pressure in humans is greater at the feet than at the brain.
   Reason : Pressure of liquid at any point is proportional to height, density of liquid and acceleration due to gravity.
3. Assertion : Hydrostatic pressure is a vector quantity.
   Reason : Pressure is force divided by area, and force is a vector quantity.
4. Assertion : To float, a body must displace liquid whose weight is greater than the actual weight of the body.
   Reason : The body will experiences no net downward force, in the case of floating.
5. Assertion : A man sitting in a boat which is floating on a pond. If the man drinks some water from the pond, the level of the water in the pond decreases.
   Reason : According to Archimede's principle the weight displaced by body is equal to the weight of the body.
6. Assertion : A piece of ice floats in water, the level of water remains unchanged when the ice melts completely.
   Reason : According to Archimede's principle, the loss in weight of the body in the liquid is equal to the weight of the liquid displaced by the immersed part of the body.
7. Assertion : The velocity increases, when water flowing in broader pipe enter a narrow pipe.

Reason : According to equation of continuity, product of area and velocity is constant.

8. Assertion : The velocity of fall of a man jumping with a parachute first increases and then becomes constant.

Reason : The constant velocity of fall of man is called terminal velocity.

9. Assertion : The velocity of flow of a liquid is smaller when pressure is larger and viceversa.

Reason : According to Bernoulli's theorem, for the stream line flow of an ideal liquid, the total energy per unit mass remains constant.

10. Assertion : The shape of an automobile is so designed that its front resembles the stream line pattern of the fluid through which it moves.

Reason : The resistance offered by the fluid is maximum.

11. Assertion : The size of the needle of a syringe controls flow rate better than the thumb pressure exerted by a doctor while administering an injection.

Reason : Flow rate is independent of pressure exerted by the thumb of the doctor.

12. Assertion : A fluid flowing out of a small hole in a vessel apply a backward thrust on the vessel.

Reason : According to equation of continuity, the product of area and velocity remain constant.

13. Assertion : For a floating body to be in stable equilibrium, its centre of buoyancy must be located above the centre of gravity.

Reason : The torque produced by the weight of the body and the upthrust will restore body back to its normal position, after the body is disturbed.

14. Assertion : Water flows faster than honey.

Reason : The coefficient of viscosity of water is less than honey.

15. Assertion : The viscosity of liquid increases rapidly with rise of temperature.

Reason : Viscosity of a liquid is the property of the liquid by virtue of which it opposes the relative motion amongst its different layers.

16. Assertion : Aeroplanes are made to run on the runway before take off, so that they acquire the necessary lift.

Reason : According to Bernoulli's theorem, as velocity increases pressure decreases and viceversa.

17. Assertion : Sudden fall of pressure at a place indicates strom.

Reason : Air flows from higher pressure to lower pressure.

18. Assertion : Machine parts are jammed in winter.

Reason : The viscosity of lubricant used in machine parts increase at low temperature.

19. Assertion : A block of wood is floating in a tank containing water. The apparent weight of the floating block is equal to zero.

Reason : Because the entire weight of the block is supported by the buoyant force (the upward thrust) due to water.

20. Assertion : A rain drop after falling through some height attains a constant velocity.

Reason : At constant velocity, the viscous drag is just equal to its weight.

21. Assertion : paper pins are made to have pointed end.

Reason : Because pointed pins have very smalll area due to which even for small applied force it exert large pressure on the surface.

22. Assertion : Railways tracks are laid on small sized wooden sleepers.

Reason : Small sized wooden sleepers are used so that rails exert more pressure on the railway track. Due to which rail does not leave the track

23. Assertion : It is difficult to stop bleeding from a cut in the body at high altitudes.

Reason : The atmospheric pressure at high altitude is lesser than the blood pressure.

24. Assertion : To empty an oil tank, two holes are made.

Reason : Oil will come out two holes so it will emptied faster.

25. Assertion : Terminal velocity is same as the critical velocity.

Reason : The constant velocity of fall of a body through a viscous fluid is called terminal velocity.

26. Assertion : When two boats sails parallel in the same direction and close to each other, they are pulled towards each other.

Reason : The viscous drag on a spherical body moving with speed v is proportional to v.

27. Assertion : Cars and aeroplanes are streamlined.

Reason : This is done to reduce the backward drag due to atmosphere.

28. Assertion : Bernoulli's theorem holds for incompressible, non-viscous fluids.

Reason : The factor $\frac{v^2}{2g}$ is called velocity head.

Answers

Pressure and Density

1	b	2	c	3	b	4	b	5	c
6	b	7	c	8	b	9	d	10	c
11	c	12	c	13	a	14	d	15	a
16	b	17	a	18	b	19	d	20	b
21	c	22	a	23	b	24	b	25	b
26	b	27	d	28	a	29	c	30	c
31	d								

Pascal's Law and Archmidies Principle

1	c	2	a	3	c	4	c	5	b
6	d	7	a	8	b	9	bc	10	c
11	c	12	d	13	a	14	b	15	b
16	d	17	a	18	a	19	b	20	b
21	c	22	c	23	b	24	b	25	b
26	d	27	a						

Fluid Flow

1	b	2	a	3	c	4	d	5	d
6	a	7	d	8	b	9	a	10	c
11	b	12	a	13	c	14	a	15	d
16	b	17	b	18	c	19	c	20	b
21	d	22	b	23	a	24	d	25	c
26	a	27	a	28	b	29	a	30	a
31	a	32	b	33	c	34	a	35	b
36	ad	37	acd	38	b	39	b	40	a
41	a	42	c	43	b	44	b	45	d
46	c	47	b	48	b	49	a	50	a
51	a	52	d	53	b	54	d	55	d
56	d	57	d	58	c	59	c	60	a
61	c	62	a	63	d	64	c	65	c
66	d								

Critical Thinking Questions

1	c	2	a	3	d	4	c	5	a
6	b	7	a	8	b	9	c	10	c
11	b	12	a	13	b	14	a		

Graphical Questions

1	a	2	b	3	d	4	a	5	d

Assertion and Reason

1	b	2	a	3	e	4	c	5	e
6	a	7	a	8	b	9	a	10	c
11	c	12	a	13	a	14	a	15	e
16	a	17	a	18	a	19	a	20	a
21	a	22	d	23	a	24	c	25	e
26	b	27	a	28	b				

Answers and Solutions

Pressure and Density

1. (b) Pressure at bottom of the lake = $P_0 + h\rho g$

Pressure at half the depth of a lake $= P_0 + \frac{h}{2}\rho g$

According to given condition

$P_0 + \frac{1}{2}h\rho g = \frac{2}{3}(P_0 + h\rho g) \Rightarrow \frac{1}{3}P_0 = \frac{1}{6}h\rho g$

$\Rightarrow h = \frac{2P_0}{\rho g} = \frac{2\times 10^5}{10^3 \times 10} = 20m$.

2. (c) Apparent weight $= V(\rho - \sigma)g = \frac{m}{\rho}(\rho - \sigma)g$

where $m =$ mass of the body,

$\rho =$ density of the body

$\sigma =$ density of water

If two bodies are in equilibrium then their apparent weight must be equal.

$\therefore \frac{m_1}{\rho_1}(\rho_1 - \sigma) = \frac{m_2}{\rho_2}(\rho_2 - \sigma)$

$\Rightarrow \frac{36}{9}(9-1) = \frac{48}{\rho_2}(\rho_2 - 1)$

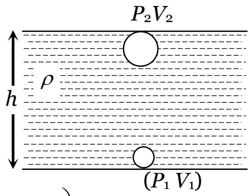
By solving we get $\rho_2 = 3$.

3. (b) According to Boyle's law, pressure and volume are inversely proportional to each other *i.e.* $P \propto \frac{1}{V}$

$\Rightarrow P_1V_1 = P_2V_2$

$\Rightarrow (P_0 + h\rho_w g)V_1 = P_0V_2$

$\Rightarrow V_2 = \left(1 + \frac{h\rho_w g}{P_0}\right)V_1$



$\Rightarrow V_2 = \left(1 + \frac{47.6\times 10^2 \times 1\times 1000}{70\times 13.6\times 1000}\right)V_1$

$\Rightarrow V_2 = (1+5)50\,cm^3 = 300\,cm^3$.

[As $P_2 = P_0 = 70\,cm$ of $Hg = 70\times 13.6\times 1000$]

4. (b) Force acting on the base

$F = P\times A = hdgA = 0.4\times 900\times 10\times 2\times 10^{-3} = 7.2N$

5. (c) As the both points are at the surface of liquid and these points are in the open atmosphere. So both point possess similar pressure and equal to 1 *atm.* Hence the pressure difference will be zero.

6. (b) Difference of pressure between sea level and the top of hill

$\Delta P = (h_1 - h_2)\times \rho_{Hg}\times g = (75-50)\times 10^{-2}\times \rho_{Hg}\times g$ ...(i)

and pressure difference due to h meter of air

$\Delta P = h\times \rho_{air}\times g$ ...(ii)

By equating (i) and (ii) we get

$h\times \rho_{air}\times g = (75-50)\times 10^{-2}\times \rho_{Hg}\times g$

$\therefore h = 25\times 10^{-2}\left(\frac{\rho_{Hg}}{\rho_{air}}\right) = 25\times 10^{-2}\times 10^4 = 2500\,m$

$\therefore$ Height of the hill = 2.5 *km.*

7. (c) Volume of ice $= \frac{M}{\rho}$, volume of water $= \frac{M}{\sigma}$.

$\therefore$ Change in volume $= \frac{M}{\rho} - \frac{M}{\sigma} = M\left(\frac{1}{\rho} - \frac{1}{\sigma}\right)$

8. (b) If two liquid of equal masses and different densities are mixed together then density of mixture

$\rho = \frac{2\rho_1\rho_2}{\rho_1 + \rho_2} = \frac{2\times 1\times 2}{1+2} = \frac{4}{3}$

9. (d) Let M_0 = mass of body in vacuum.

Apparent weight of the body in air = Apparent weight of standard weights in air

$\Rightarrow$ Actual weight – upthrust due to displaced air

= Actual weight – upthrust due to displaced air

$\Rightarrow M_0 g - \left(\frac{M_0}{d_1}\right)dg = Mg - \left(\frac{M}{d_2}\right)dg \Rightarrow M_0 = \frac{M\left[1 - \frac{d}{d_2}\right]}{\left[1 - \frac{d}{d_1}\right]}$

10. (c) $P = h\rho g$ *i.e.* pressure does not depend upon the area of bottom surface.

11. (c) $P_1V_1 = P_2V_2 \Rightarrow (P_0 + h\rho g)\times \frac{4}{3}\pi r^3 = P_0 \times \frac{4}{3}\pi(2r)^3$

Where, h = depth of lake

$\Rightarrow h\rho g = 7P_0 \Rightarrow h = 7\times \frac{H\rho g}{\rho g} = 7H.$

12. (c) $P_1V_1 = P_2V_2 \Rightarrow (P_0 + h\rho g)V = P_0\times 3V$

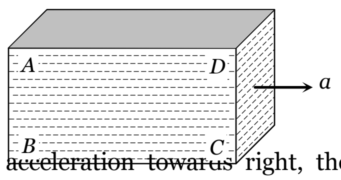
$\Rightarrow h\rho g = 2P_0 \Rightarrow h = \frac{2\times 75\times 13.6\times g}{\frac{13.6}{10}\times g} = 15\,m$

13. (a) $h = \frac{P}{\rho g}$ $\therefore h \propto \frac{1}{g}$ (P and ρ are constant)

If value of g decreased by 2% then h will increase by 2%.

14. (d) $h = \frac{P}{\rho g}$ $\therefore h \propto \frac{1}{g}$. If lift moves upward with some acceleration then effective g increases. So the value of h decreases *i.e.* reading will be less than 76 *cm.*

15. (a)



Due to acceleration towards right, there will be a pseudo force in a left direction. So the pressure will be more on rear side (Points A and B) in comparison with front side (Point D and C).

Also due to height of liquid column pressure will be more at the bottom (points B and C) in comparison with top (point A and D).

So overall maximum pressure will be at point B and minimum pressure will be at point D.

16. (b) Total pressure at (near) bottom of the liquid

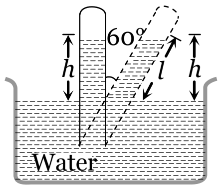
$P = P_0 + h\rho g$

As air is continuously pumped out from jar (container), P_0 decreases and hence P decreases.

17. (a) $\cos 60° = \frac{h}{l}$

$\Rightarrow l = \frac{h}{\cos 60°} = \frac{76}{1/2}$

$\therefore\ l = 152\ cm$



18. (b) Pressure at the bottom = $h\rho g$

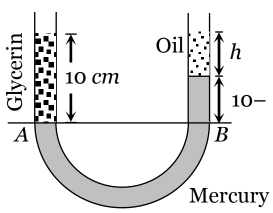
and pressure on the vertical surface = $\frac{1}{2}h\rho g$

Now, according to problem

Force at the bottom = Force on the vertical surface

$\Rightarrow\ h\rho g \times \pi r^2 = \frac{1}{2}h\rho g \times 2\pi r h \Rightarrow h = r$

19. (d)



At the condition of equilibrium

Pressure at point A = Pressure at point B

$P_A = P_B \Rightarrow\ 10 \times 1.3 \times g = h \times 0.8 \times g + (10 - h) \times 13.6 \times g$

By solving we get $h = 9.7\ cm$

20. (b) Thrust on lamina = pressure at centroid × Area

$= \frac{h\rho g}{3} \times A = \frac{1}{3}A\rho g h.$

21. (c) $\rho = \frac{\text{Total mass}}{\text{Total volume}} = \frac{2m}{V_1 + V_2} = \frac{2m}{m\left(\frac{1}{\rho_1} + \frac{1}{\rho_2}\right)}$

$\therefore\ \rho = \frac{2\rho_1\rho_2}{\rho_1 + \rho_2}$

22. (a) $\rho = \frac{\text{Total mass}}{\text{Total volume}} = \frac{m_1 + m_2}{2V} = \frac{V(\rho_1 + \rho_2)}{2V} = \frac{\rho_1 + \rho_2}{2}$

23. (b) Bulk modulus, $B = -V_0\frac{\Delta p}{\Delta V} \Rightarrow \Delta V = -V_0\frac{\Delta p}{B}$

$\Rightarrow\ V = V_0\left[1 - \frac{\Delta p}{B}\right]$

$\therefore$ Density, $\rho = \rho_0\left[1 - \frac{\Delta p}{B}\right]^{-1} = \rho_0\left[1 + \frac{\Delta p}{B}\right]$

where, $\Delta p = p - p_0 = h\rho_0 g$

= pressure difference between depth and surface of ocean

$\therefore\ \rho = \rho_0\left[1 + \frac{\rho_0 g y}{B}\right]$ (As $h = y$)

24. (b) Since, with increase in temperature, volume of given body increases, while mass remains constant so that density will decrease.

i.e. $\frac{\rho}{\rho_0} = \frac{m/V}{m/V_0} = \frac{V_0}{V} = \frac{V_0}{V_0(1 + r\Delta\theta)} = (1 - \gamma\Delta\theta)$

$\therefore\ \rho = \rho_0(1 - \gamma\Delta\theta)$

25. (b) $\rho_{mix} = \frac{m_1 + m_2 + m_3}{3V} = \frac{V(d + 2d + 3d)}{3V} = 2d.$

26. (b) $\rho_{mix} = \frac{3m}{V_1 + V_2 + V_3} = \frac{3m}{\frac{m}{d} + \frac{m}{2d} + \frac{m}{3d}} = \frac{3 \times 6}{11}d = \frac{18}{11}d$

27. (d) Pressure = $h\rho g$ *i.e.* pressure at the bottom is independent of the area of the bottom of the tank. It depends on the height of water upto which the tank is filled with water. As in both the tanks, the levels of water are the same, pressure at the bottom is also the same.

28. (a)

29. (c) A torque is acting on the wall of the dam trying to make it topple. The bottom is made very broad so that the dam will be stable.

30. (c)

31. (d)

Pascal's Law and Archmidies Principle

1. (c) Let the total volume of ice-berg is V and its density is ρ. If this ice-berg floats in water with volume V_{in} inside it then $V_{in}\sigma g = V\rho g \Rightarrow V_{in} = \left(\frac{\rho}{\sigma}\right)V$

or $V_{out} = V - V_{in} = \left(\frac{\sigma - \rho}{\sigma}\right)V$

$\Rightarrow \frac{V_{out}}{V} = \left(\frac{\sigma - \rho}{\sigma}\right) = \frac{1000 - 900}{1000} = \frac{1}{10}$

$\therefore\ V_{out} = 10\%$ of V

2. (a) Volume of log of wood $V = \frac{\text{mass}}{\text{density}} = \frac{120}{600} = 0.2\ m^3$

Let x weight that can be put on the log of wood.

So weight of the body = $(120 + x) \times 10\ N$

Weight of displaced liquid = $V\sigma g = 0.2 \times 10^3 \times 10\ N$

The body will just sink in liquid if the weight of the body will be equal to the weight of displaced liquid.

$\therefore\ (120+x)\times 10 = 0.2\times 10^3 \times 10$

$\Rightarrow 120 + x = 200\ \therefore\ x = 80\ kg$

3. (c) Weight of the bowl = mg

$= V\rho g = \frac{4}{3}\pi\left[\left(\frac{D}{2}\right)^3 - \left(\frac{d}{2}\right)^3\right]\rho g$

where D = Outer diameter ,

d = Inner diameter

ρ = Density of bowl

Weight of the liquid displaced by the bowl

$= V\sigma g = \frac{4}{3}\pi\left(\frac{D}{2}\right)^3 \sigma g$

where σ is the density of the liquid.

For the flotation $\frac{4}{3}\pi\left(\frac{D}{2}\right)^3 \sigma g = \frac{4}{3}\pi\left[\left(\frac{D}{2}\right)^3 - \left(\frac{d}{2}\right)^3\right]\rho g$

$\Rightarrow \left(\frac{1}{2}\right)^3 \times 1.2\times 10^3 = \left[\left(\frac{1}{2}\right)^3 - \left(\frac{d}{2}\right)^3\right] 2\times 10^4$

By solving we get d = 0.98 m.

4. (c) Specific gravity of alloy $= \frac{\text{Density of alloy}}{\text{Density of water}}$

$= \frac{\text{Mass of alloy}}{\text{Volume of alloy} \times \text{density of water}}$

$= \frac{m_1 + m_2}{\left(\frac{m_1}{\rho_1} + \frac{m_2}{\rho_2}\right)\times \rho_w} = \frac{m_1 + m_2}{\frac{m_1}{\rho_1/\rho_w} + \frac{m_2}{\rho_2/\rho_w}} = \frac{m_1 + m_2}{\frac{m_1}{s_1} + \frac{m_2}{s_2}}$

$\left[\text{As specific gravity of substance} = \frac{\text{density of substance}}{\text{density of water}}\right]$

5. (b) Let specific gravities of concrete and saw dust are ρ_1 and ρ_2 respectively.

According to principle of floatation weight of whole sphere = upthrust on the sphere

$\frac{4}{3}\pi(R^3 - r^3)\rho_1 g + \frac{4}{3}\pi r^3 \rho_2 g = \frac{4}{3}\pi R^3 \times 1 \times g$

$\Rightarrow R^3\rho_1 - r^3\rho_1 + r^3\rho_2 = R^3$

$\Rightarrow R^3(\rho_1 - 1) = r^3(\rho_1 - \rho_2) \Rightarrow \frac{R^3}{r^3} = \frac{\rho_1 - \rho_2}{\rho_1 - 1}$

$\Rightarrow \frac{R^3 - r^3}{r^3} = \frac{\rho_1 - \rho_2 - \rho_1 + 1}{\rho_1 - 1}$

$\Rightarrow \frac{(R^3 - r^3)\rho_1}{r^3\rho_2} = \left(\frac{1 - \rho_2}{\rho_1 - 1}\right)\frac{\rho_1}{\rho_2}$

$\Rightarrow \frac{\text{Mass of concrete}}{\text{Mass of saw dust}} = \left(\frac{1 - 0.3}{2.4 - 1}\right)\times\frac{2.4}{0.3} = 4$

6. (d) Apparent weight

$= V(\rho - \sigma)g = l\times b\times h\times(5-1)\times g$

$= 5\times 5\times 5\times 4\times g\ Dyne = 4\times 5\times 5\times 5\ gf.$

7. (a) Fraction of volume immersed in the liquid $V_{in} = \left(\frac{\rho}{\sigma}\right)V$

i.e. it depends upon the densities of the block and liquid.

So there will be no change in it if system moves upward or downward with constant velocity or some acceleration.

8. (b) Apparent weight $= V(\rho - \sigma)g = \frac{M}{\rho}(\rho - \sigma)g$

$= M\left(1 - \frac{\sigma}{\rho}\right)g = 2.1\left(1 - \frac{0.8}{10.5}\right)g = 1.94\ g\ N$

= 1.94 Kg-wt

9. (b, c) Density of metal = ρ , Density of liquid = σ

If V is the volume of sample then according to problem

$210 = V\rho g$ ...(i)

$180 = V(\rho - 1)g$ ...(ii)

$120 = V(\rho - \sigma)g$ ...(iii)

By solving (i), (ii) and (iii) we get $\rho = 7$ and $\sigma = 3$.

10. (c) If two different bodies A and B are floating in the same liquid then $\frac{\rho_A}{\rho_B} = \frac{(f_{in})_A}{(f_{in})_B} = \frac{1/2}{2/3} = \frac{3}{4}$

11. (c) For the floatation $V_0 d_0 g = V_{in}\ d\ g \Rightarrow V_{in} = V_0\frac{d_0}{d}$

$\therefore\ V_{out} = V_0 - V_{in} = V_0 - V_0\frac{d_0}{d} = V_0\left[\frac{d - d_0}{d}\right]$

$\Rightarrow \frac{V_{out}}{V_0} = \frac{d - d_0}{d}$.

12. (d)

13. (a) Apparent weight = $V(\rho - \sigma)g$

$= 5\times 5\times 5(7-1)g = 6\times 5\times 5\times 5\ gf$

14. (b)

15. (b) Effective weight $W' = m(g - a)$ which is less than actual weight mg, so the length of spring decreases.

16. (d) Tension in spring T = upthrust – weight of sphere

$= V\sigma g - V\rho g = V\eta\rho g - V\rho g \quad (\text{As } \sigma = \eta\rho)$

$= (\eta - 1)V\rho g = (\eta - 1)mg.$

17. (a) When body (sphere) is half immersed, then upthrust = weight of sphere

$\Rightarrow \frac{V}{2}\times\rho_{liq}\times g = V\times\rho\times g\ \therefore\ \rho = \frac{\rho_{liq}}{2}$

When body (sphere) is fully immersed then,

Upthrust = wt. of sphere + wt. of water poured in sphere

$\Rightarrow V\times\rho_{liq}\times g = V\times\rho\times g + V'\times\rho_{liq}\times g$

$\Rightarrow V\times\rho_{liq} = \frac{V\times\rho_{liq}}{2} + V'\times\rho_{liq} \Rightarrow V' = \frac{V}{2}$

18. (a) Since no change in volume of displaced water takes place, hence level of water remains same.

19. (b) The velocity of ball before entering the water surface

$v = \sqrt{2gh} = \sqrt{2g \times 9}$

When ball enters into water, due to upthrust of water the velocity of ball decreases (or retarded)

The retardation, $a = \frac{\text{apparent weight}}{\text{mass of ball}}$

$= \frac{V(\rho - \sigma)g}{V\rho} = \left(\frac{\rho - \sigma}{\rho}\right)g = \left(\frac{0.4 - 1}{0.4}\right) \times g = -\frac{3}{2}g$

If h be the depth upto which ball sink, then,

$0 - v^2 = 2 \times \left(-\frac{3}{2}g\right) \times h \Rightarrow 2g \times 9 = 3gh \therefore h = 6\ cm.$

20. (b) Upthrust = weight of body

For A, $\frac{V_A}{2} \times \rho_W \times g = V_A \times \rho_A \times g \Rightarrow \rho_A = \frac{\rho_W}{2}$

For B, $\frac{3}{4} V_B \times \rho_W \times g = V_B \times \rho_B \times g \Rightarrow \rho_B = \frac{3}{4}\rho_W$

(Since 1/4 of volume of B is above the water surface)

$\therefore \frac{\rho_A}{\rho_B} = \frac{\rho_W / 2}{3/4\ \rho_W} = \frac{2}{3}$

21. (c)

22. (c) Since, up thrust (F) = $V\sigma g$ *i.e.* $F \propto V$

23. (b) $V\rho g = \frac{V}{2}\sigma g \therefore \rho = \frac{\sigma}{2}$ (σ = density of water)

24. (b)

25. (b)

26. (d)

27. (a)

Fluid Flow

1. (b) For streamline flow, Reynold's number $N_R \propto \frac{r\rho}{\eta}$ should be less. For less value of N_R, radius and density should be small and viscosity should be high.

2. (a) $d_A = 2cm$ and $d_B = 4\ cm \therefore r_A = 1\ cm$ and $r_B = 2\ cm$

From equation of continuity, av = constant

$\therefore \frac{v_A}{v_B} = \frac{a_B}{a_A} = \frac{\pi(r_B)^2}{\pi(r_A)^2} = \left(\frac{2}{1}\right)^2 \Rightarrow v_A = 4v_B$

3. (c) If the liquid is incompressible then mass of liquid entering through left end, should be equal to mass of liquid coming out from the right end.

$\therefore M = m_1 + m_2 \Rightarrow Av_1 = Av_2 + 1.5A.v$

$\Rightarrow A \times 3 = A \times 1.5 + 1.5A.v \Rightarrow v = 1\ m/s$

4. (d) This happens in accordance with equation of continuity and this equation was derived on the principle of conservation of mass and it is true in every case, either tube remain horizontal or vertical.

5. (d) $a_1 v_1 = a_2 v_2$

$\Rightarrow 4.20 \times 5.18 = 7.60 \times v_2 \Rightarrow v_2 = 2.86\ m/s$

6. (a) Velocity head $h = \frac{v^2}{2g} = \frac{(5)^2}{2 \times 10} = 1.25\,m$

7. (d) As cross-section areas of both the tubes A and C are same and tube is horizontal. Hence according to equation of continuity $v_A = v_C$ and therefore according to Bernoulli's theorem $P_A = P_C$ *i.e.* height of liquid is same in both the tubes A and C.

8. (b) Bernoulli's theorem for unit mass of liquid

$\frac{P}{\rho} + \frac{1}{2}v^2 =$ constant

As the liquid starts flowing, it pressure energy decreases

$\frac{1}{2}v^2 = \frac{P_1 - P_2}{\rho} \Rightarrow \frac{1}{2}v^2 = \frac{3.5 \times 10^5 - 3 \times 10^5}{10^3} \Rightarrow v^2$

$= \frac{2 \times 0.5 \times 10^5}{10^3} \Rightarrow v^2 = 100 \Rightarrow v = 10\ m/s$

9. (a) From the Bernoulli's theorem

$P_1 - P_2 = \frac{1}{2}\rho(v_2^2 - v_1^2) = \frac{1}{2} \times 1.3 \times [(120)^2 - (90)^2]$

$= 4095\ N/m^2$ or *Pascal*

10. (c) Time taken for the level to fall from H to H'

$t = \frac{A}{A_0}\sqrt{\frac{2}{g}}\left[\sqrt{H} - \sqrt{H'}\right]$

According to problem- the time taken for the level to fall from h to $\frac{h}{2}$ $\quad t_1 = \frac{A}{A_0}\sqrt{\frac{2}{g}}\left[\sqrt{h} - \sqrt{\frac{h}{2}}\right]$

and similarly time taken for the level to fall from $\frac{h}{2}$ to zero $\quad t_2 = \frac{A}{A_0}\sqrt{\frac{2}{g}}\left[\sqrt{\frac{h}{2}} - 0\right]$

$\therefore \frac{t_1}{t_2} = \frac{1 - \frac{1}{\sqrt{2}}}{\frac{1}{\sqrt{2}} - 0} = \sqrt{2} - 1.$

11. (b) $v = \sqrt{2gh} = \sqrt{2 \times 10 \times 20} = 20\,m/s$

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

Pressure due to liquid column

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

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

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

13. (c) Time required to emptied the tank $t = \frac{A}{A_0}\sqrt{\frac{2H}{g}}$

$\therefore \frac{t_2}{t_1} = \sqrt{\frac{H_2}{H_1}} = \sqrt{\frac{4h}{h}} = 2 \therefore t_2 = 2t$

14. (a) The height of water in the tank becomes maximum when the volume of water flowing into the tank per second becomes equal to the volume flowing out per second.

Volume of water flowing out per second

$= Av = A\sqrt{2gh}$ ...(i)

Volume of water flowing in per second

$= 70\, cm^3/sec$ ...(ii)

From (i) and (ii) we get

$A\sqrt{2gh} = 70 \Rightarrow 1 \times \sqrt{2gh} = 70$

$\Rightarrow 1 \times \sqrt{2 \times 980 \times h} = 70$

$\therefore\ h = \frac{4900}{1960} = 2.5\, cm.$

15. (d) $A = (0.1)^2 = 0.01 m^2$,

$\eta = 0.01\ Poise = 0.001\ decapoise$ (M.K.S. unit),

$dv = 0.1\, m/s$ and $F = 0.002\, N$

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

$\therefore\ dx = \frac{\eta A dv}{F} = \frac{0.001 \times 0.01 \times 0.1}{0.002} = 0.0005 m$.

16. (b) $F = 6\pi\eta rv$

17. (b) In the first 100 m body starts from rest and its velocity goes on increasing and after 100 m it acquire maximum velocity (terminal velocity). Further, air friction *i.e.* viscous force which is proportional to velocity is low in the beginning and maximum at $v = v_T$.

Hence work done against air friction in the first 100 m is less than the work done in next 100 m.

18. (c) If two drops of same radius r coalesce then radius of new drop is given by R

$\frac{4}{3}\pi R^3 = \frac{4}{3}\pi r^3 + \frac{4}{3}\pi r^3 \Rightarrow R^3 = 2r^3 \Rightarrow R = 2^{1/3} r$

If drop of radius r is falling in viscous medium then it acquire a critical velocity v and $v \propto r^2$

$\frac{v_2}{v_1} = \left(\frac{R}{r}\right)^2 = \left(\frac{2^{1/3} r}{r}\right)^2$

$\Rightarrow v_2 = 2^{2/3} \times v_1 = 2^{2/3} \times (5) = 5 \times (4)^{1/3} m/s$

19. (c) Velocity of ball when it strikes the water surface $v = \sqrt{2gh}$ ...(i)

Terminal velocity of ball inside the water $v = \frac{2}{9} r^2 g \frac{(\rho - 1)}{\eta}$ ...(ii)

Equating (i) and (ii) we get $\sqrt{2gh} = \frac{2}{9}\frac{r^2 g}{\eta}(\rho - 1)$

$\Rightarrow h = \frac{2}{81} r^4 \left(\frac{\rho - 1}{\eta}\right)^2 g$

20. (b) Rate of flow of liquid $V = \frac{P}{R}$

where liquid resistance $R = \frac{8\eta l}{\pi r^4}$

For another tube liquid resistance

$R' = \frac{8\eta l}{\pi\left(\frac{r}{2}\right)^4} = \frac{8\eta l}{\pi r^4}.16 = 16R$

For the series combination

$V_{New} = \frac{P}{R + R'} = \frac{P}{R + 16R} = \frac{P}{17R} = \frac{V}{17}$.

21. (d) From $V = \frac{P\pi r^4}{8\eta l} \Rightarrow P = \frac{V 8\eta l}{\pi r^4}$

$\Rightarrow \frac{P_2}{P_1} = \frac{V_2}{V_1} \times \frac{l_2}{l_1} \times \left(\frac{r_1}{r_2}\right)^4 = 2 \times 2 \times \left(\frac{1}{2}\right)^4 = \frac{1}{4}$

$\Rightarrow P_2 = \frac{P_1}{4} = \frac{P}{4}$.

22. (b) $V = \frac{\pi P r^4}{8\eta l} = \frac{8cm^3}{\sec}$

For composite tube

$V_1 = \frac{P\pi r^4}{8\eta\left(l + \frac{l}{2}\right)} = \frac{2}{3}\frac{\pi P r^4}{8\eta l} = \frac{2}{3} \times 8 = \frac{16}{3}\frac{cm^3}{\sec}$

$\left[\because\ l_1 = l = 2l_2 \text{ or } l_2 = \frac{l}{2}\right]$

23. (a)

24. (d)

25. (c)

26. (a) If velocities of water at entry and exit points are v_1 and v_2, then according to equation of continuity,

$A_1 v_1 = A_2 v_2 \Rightarrow \frac{v_1}{v_2} = \frac{A_2}{A_1} = \left(\frac{r_2}{r_1}\right)^2 = \left(\frac{2}{3}\right)^2 = \frac{4}{9}$

27. (a)

28. (b)

29. (a)

30. (a)

31. (a)

32. (b) According to Bernoulli's theorem.

33. (c)

34. (a) $\frac{v^2}{2g} = h \Rightarrow v = \sqrt{2gh}$

$= \sqrt{2 \times 10^3 \times 40} = 2\sqrt{2} \times 10^2 = 282.8\ cm/s$

35. (b)

36. (a,d)

37. (a,c,d) According to equation of continuity the volume of liquid flowing through the tube in unit time remains constant *i.e.* $A_1 v_1 = A_2 v_2$, hence option (a) is correct

According to Bernoulli's theorem,

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

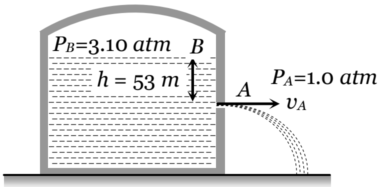
$$\Rightarrow P_1 - P_2 = \frac{1}{2}\rho\left(v_2^2 - v_1^2\right) \Rightarrow h\rho g = \frac{1}{2}\rho\left(v_2^2 - v_1^2\right)$$

$$\therefore v_2^2 - v_1^2 = 2gh$$

Hence option (c) is correct.

Also, according to Bernoulli's theorem option (d) is correct

38. (b)



According to Bernoulli's theorem,

$$P_B + h\rho g = P_A + \frac{1}{2}\rho v_A^2 \qquad (\text{As } v_A >> v_B)$$

$$3.10P + 53 \times 660 \times 10 = P + \frac{1}{2} \times 660 v_A^2$$

$$\Rightarrow 2.1 \times 1.01 \times 10^5 + 3.498 \times 10^5 = \frac{1}{2} \times 660 \times v_A^2$$

$$\Rightarrow 5.619 \times 10^5 = \frac{1}{2} \times 660 \times v_A^2$$

$$\therefore v_A = \sqrt{\frac{2 \times 5.619 \times 10^5}{660}} = 41\ m/s$$

39. (b) According to Bernoulli's theorem, $h = \frac{v^2}{2g}$

$$\Rightarrow h = \frac{(2.45)^2}{2 \times 10} = 0.314 = 31.4\ cm$$

$\therefore$ Height of jet coming from orifice

$= 31.4 - 10.6 = 20.8\ cm$

40. (a)

41. (a)

42. (c) Time taken by water to reach the bottom

$$= t = \sqrt{\frac{2(H-D)}{g}}$$

and velocity of water coming out of hole, $v = \sqrt{2gD}$

$\therefore$ Horizontal distance covered $x = v \times t$

$$= \sqrt{2gD} \times \sqrt{\frac{2(H-D)}{g}} = 2\sqrt{D(H-D)}$$

43. (b) Horizontal range will be maximum when $h = \frac{H}{2} = \frac{90}{2}$

$= 45\ cm$ *i.e.* hole 3.

44. (b) Time taken to be emptied for h height, $t = \sqrt{\frac{2h}{g}}$

and for $\frac{h}{2}$ height, $t' = \sqrt{\frac{2h/2}{g}} = \sqrt{\frac{h}{g}}$

$$\therefore \frac{t'}{t} = \frac{1}{\sqrt{2}} \Rightarrow t' = \frac{t}{\sqrt{2}} = \frac{10}{\sqrt{2}} = 7\ minute$$

45. (d) Upthrust – weight of body = apparent weight

$$VDg - Vdg = Vda,$$

Where a = retardation of body $\therefore a = \left(\frac{D-d}{d}\right)g$

The velocity gained after fall from h height in air, $v = \sqrt{2gh}$

Hence, time to come in rest,

$$t = \frac{v}{a} = \frac{\sqrt{2gh} \times d}{(D-d)g} = \sqrt{\frac{2h}{g}} \times \frac{d}{(D-d)}$$

46. (c) $t = \frac{A}{a}\sqrt{\frac{2}{g}}\left[\sqrt{H_1} - \sqrt{H_2}\right]$

Now, $T_1 = \frac{A}{a}\sqrt{\frac{2}{g}}\left[\sqrt{H} - \sqrt{\frac{H}{\eta}}\right]$

and $T_2 = \frac{A}{a}\sqrt{\frac{2}{g}}\left[\sqrt{\frac{H}{\eta}} - \sqrt{0}\right]$

According to problem $T_1 = T_2$

$$\therefore \sqrt{H} - \sqrt{\frac{H}{\eta}} = \sqrt{\frac{H}{\eta}} - 0 \Rightarrow \sqrt{H} = 2\sqrt{\frac{H}{\eta}} \Rightarrow \eta = 4$$

47. (b)

48. (b)

49. (a)

50. (a)

51. (a)

52. (d)

53. (b)

54. (d)

55. (d) $V = V_1 + V_2$

$$\Rightarrow \frac{\pi P r^4}{8\eta l} = \frac{\pi P r_1^4}{8\eta l} + \frac{\pi P r_2^4}{8\eta l} \Rightarrow r^4 = r_1^4 + r_2^4$$

$$\therefore r = (r_1^4 + r_2^4)^{1/4}$$

56. (d) Given, $l_1 = l_2 = 1$, and $\frac{r_1}{r_2} = \frac{1}{2}$

$$V = \frac{\pi P_1 r_1^4}{8\eta l} = \frac{\pi P_2 r_2^4}{8\eta l} \Rightarrow \frac{P_1}{P_2} = \left(\frac{r_2}{r_1}\right)^4 = 16$$

$$\Rightarrow P_1 = 16P_2$$

Since both tubes are connected in series, hence pressure difference across combination,

$$P = P_1 + P_2 \Rightarrow 1 = P_1 + \frac{P_1}{16} \Rightarrow P_1 = \frac{16}{17} = 0.94m$$

57. (d) $V = \frac{\pi p r^4}{8\eta l}$ $\therefore V \propto P r^4$ (η and l are constants)

$$\therefore \frac{V_2}{V_1} = \left(\frac{P_2}{P_1}\right)\left(\frac{r_2}{r_1}\right)^4 = 2 \times \left(\frac{1}{2}\right)^4 = \frac{1}{8} \therefore V_2 = \frac{Q}{8}$$

58. (c)

59. (c) $a_1v_1 = a_2v_2 \Rightarrow \frac{v_2}{v_1} = \frac{a_1}{a_2} = \left(\frac{r_1}{r_2}\right)^2$

$\Rightarrow v_2 = 3 \times (2)^2 = 12\ m/s$

60. (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

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

Equivalent resistance becomes $\frac{9}{8}$ times so rate of flow will be $\frac{8}{9}X$

61. (c) A stream lined body has less resistance due to air.

62. (a)

63. (d) $\frac{P_1 - P_2}{\rho g} = \frac{v^2}{2g} \Rightarrow \frac{4.5 \times 10^5 - 4 \times 10^5}{10^3 \times g} = \frac{v^2}{2g} \therefore v = 10 m/s$

64. (c)

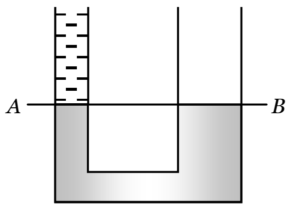
65. (c)

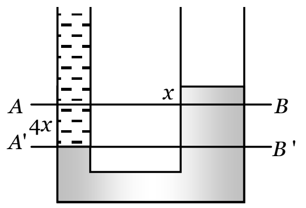
66. (d)

Critical Thinking Questions

1. (c) If the rise of level in the right limb be x *cm*. the fall of level of mercury in left limb be $4x$ *cm* because the area of cross section of right limb is 4 times as that of left limb.

$\therefore$ Level of water in left limb is $(36 + 4x)$ *cm*.





Now equating pressure at interface of Hg and water (at $A'B'$)

$(36 + 4x) \times 1 \times g = 5x \times 13.6 \times g$

By solving we get $x = 0.56$ *cm*.

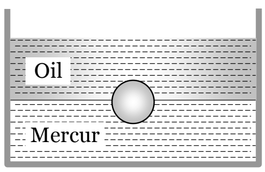
2. (a) Weight of cylinder = upthrust due to both liquids

$$V \times D \times g = \left(\frac{A}{5} \times \frac{3}{4}L\right) \times d \times g + \left(\frac{A}{5} \times \frac{L}{4}\right) \times 2d \times g$$

$$\Rightarrow \left(\frac{A}{5} \times L\right) \times D \times g = \frac{A \times L \times d \times g}{4} \Rightarrow \frac{D}{5} = \frac{d}{4} \quad \therefore D = \frac{5}{4}d$$

3. (d) As the block moves up with the fall of coin, l decreases, similarly h will also decrease because when the coin is in water, it displaces water equal to its own volume only.

4. (c)



As the sphere floats in the liquid. Therefore its weight will be equal to the upthrust force on it

Weight of sphere

$= \frac{4}{3}\pi R^3 \rho g$ ...(i)

Upthrust due to oil and mercury

$= \frac{2}{3}\pi R^3 \times \sigma_{oil} g + \frac{2}{3}\pi R^3 \sigma_{Hg} g$ ...(ii)

Equating (i) and (ii)

$$\frac{4}{3}\pi R^3 \rho g = \frac{2}{3}\pi R^3 0.8g + \frac{2}{3}\pi R^3 \times 13.6g$$

$$\Rightarrow 2\rho = 0.8 + 13.6 = 14.4 \Rightarrow \rho = 7.2$$

5. (a) Upthrust $= V\rho_{\text{liquid}}(g - a)$

where, a = downward acceleration,

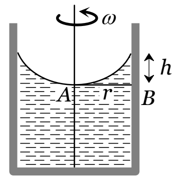
V = volume of liquid displaced

But for free fall $a = g$ $\therefore$ Upthrust = 0

6. (b) From Bernoulli's theorem,

$$P_A + \frac{1}{2}dv_A^2 + dgh_A = P_B + \frac{1}{2}dv_B^2 + dgh_B$$

Here, $h_A = h_B$



$$\therefore P_A + \frac{1}{2}dv_A^2 = P_B + \frac{1}{2}dv_B^2$$

$$\Rightarrow P_A - P_B = \frac{1}{2}d[v_B^2 - v_A^2]$$

Now, $v_A = 0, v_B = r\omega$ and $P_A - P_B = hdg$

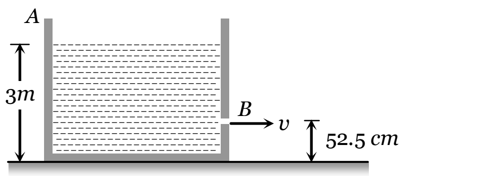
$$\therefore hdg = \frac{1}{2}dr^2\omega^2 \text{ or } h = \frac{r^2\omega^2}{2g}$$

7. (a) Let A = cross-section of tank

a = cross-section hole

V = velocity with which level decreases

v = velocity of efflux



From equation of continuity $av = AV \Rightarrow V = \frac{av}{A}$

By using Bernoulli's theorem for energy per unit volume

Energy per unit volume at point A

= Energy per unit volume at point B

$$P + \rho gh + \frac{1}{2}\rho V^2 = P + 0 + \frac{1}{2}\rho v^2$$

$$\Rightarrow v^2 = \frac{2gh}{1 - \left(\frac{a}{A}\right)^2} = \frac{2 \times 10 \times (3 - 0.525)}{1 - (0.1)^2} = 50(m/\text{sec})^2$$

8. (b) Velocity of efflux when the hole is at depth h, $v = \sqrt{2gh}$

Rate of flow of water from square hole

$Q_1 = a_1 v_1 = L^2\sqrt{2gy}$

Rate of flow of water from circular hole

$Q_2 = a_2 v_2 = \pi R^2\sqrt{2g(4y)}$

According to problem $Q_1 = Q_2$

$\Rightarrow L^2\sqrt{2gy} = \pi R^2\sqrt{2g(4y)} \Rightarrow R = \frac{L}{\sqrt{2\pi}}$

9. (c) Let A = The area of cross section of the hole

v = Initial velocity of efflux

d = Density of water,

Initial volume of water flowing out per second = Av

Initial mass of water flowing out per second = Avd

Rate of change of momentum = Adv^2

Initial downward force on the flowing out water = Adv^2

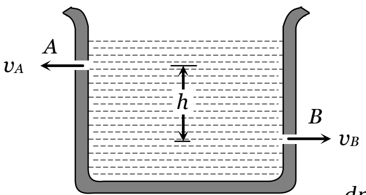
So equal amount of reaction acts upwards on the cylinder.

$\therefore$ Initial upward reaction = Adv^2 [As $v = \sqrt{2gh}$]

$\therefore$ Initial decrease in weight $= Ad(2gh)$

$= 2Adgh = 2\times\left(\frac{1}{4}\right)\times 1\times 980\times 25 = 12.5$ *gm-wt.*

10. (c)



Net force (reaction) = $F = F_B - F_A = \frac{dp_B}{dt} - \frac{dp_A}{dt}$

$= av_B\rho\times v_B - av_A\rho\times v_A$

$\therefore \quad F = a\rho\left(v_B^2 - v_A^2\right)$ ...(i)

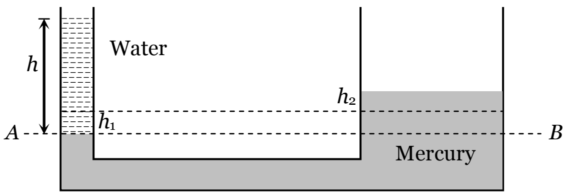
According to Bernoulli's theorem

$p_A + \frac{1}{2}\rho v_A^2 + \rho gh = p_B + \frac{1}{2}\rho v_B^2 + 0$

$\Rightarrow \frac{1}{2}\rho\left(v_B^2 - v_A^2\right) = \rho gh \Rightarrow v_B^2 - v_A^2 = 2gh$

From equation (i), $F = 2a\rho gh$.

11. (b)



If the level in narrow tube goes down by h_1 then in wider tube goes up to h_2,

Now, $\pi r^2 h_1 = \pi(nr)^2 h_2 \Rightarrow h_1 = n^2 h_2$

Now, pressure at point A = pressure at point B

$h\rho g = (h_1 + h_2)\rho' g$

$\Rightarrow h = (n^2 h_2 + h_2)sg \left(\text{As } s = \frac{\rho'}{\rho}\right) \Rightarrow h_2 = \frac{h}{(n^2+1)s}$

12. (a) Let $L = PQ$ = length of rod

$\therefore SP = SQ = \frac{L}{2}$

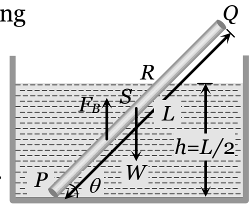
Weight of rod, $W = Al\rho g$, acting

At point S

And force of buoyancy,

$F_B = Al\rho_0 g$, $[l = PR]$

which acts at mid-point of PR.



For rotational equilibrium,

$Al\rho_0 g\times\frac{l}{2}\cos\theta = AL\rho g\times\frac{L}{2}\cos\theta$

$\Rightarrow \frac{l^2}{L^2} = \frac{\rho}{\rho_0} \Rightarrow \frac{l}{L} = \sqrt{\frac{\rho}{\rho_0}}$

From figure, $\sin\theta = \frac{h}{l} = \frac{L}{2l} = \frac{1}{2}\sqrt{\frac{\rho_0}{\rho}}$

13. (b) The volume of liquid displaced by floating ice $V_D = \frac{M}{\sigma_L}$

Volume of water formed by melting ice, $V_F = \frac{M}{\sigma_W}$

If $\sigma_1 > \sigma_W$, then, $\frac{M}{\sigma_L} < \frac{M}{\sigma_W}$ *i.e.* $V_D < V_F$

i.e. volume of liquid displaced by floating ice will be lesser than water formed and so the level if liquid will rise.

14. (a)

Graphical Questions

1. (a)

2. (b)

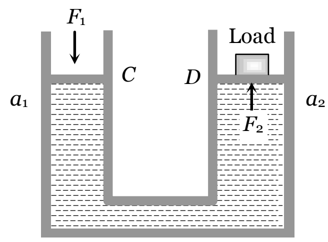
3. (d) When we move from centre to circumference, the velocity of liquid goes on decreasing and finally becomes zero.

4. (a) When cross-section of duct is decreased, the velocity of water increased and in accordance with Bernoulli's theorem, the pressure P decreased at that place.

5. (d)

Assertion and Reason

1 (b) According to Pascal's law, if gravity effect is neglected, the pressure at every point of liquid in equilibrium of rest is same.



$P_1 = P_2$ *i.e.* $\frac{F_1}{a_1} = \frac{F_2}{a_2}$ or $F_2 = \frac{a_2}{a_1} F_1$

As $a_2 >> a_1 \therefore F_2 >> F_1$

This shows that small force (F_1) applied on the smaller piston (of area a_1) will be appearing as a very large force on the larger piston.

2 (a) Height of the blood column in the human body is more at feet than at the brain. As $P = h\rho g$, therefore the blood exerts more pressure at the feet than at the brain.

3 (e) Since due to applied force on liquid, the pressure is transmitted equally in all directions inside the liquid. That is why there is no fixed direction for the pressure due to liquid. Hence hydrostatic pressure is a scalar quantity.

4 (c) Net force = actual weight – upthrust force

= Actual weight – Weight of liquid displaced.

The body will rise above the surface of liquid to such an extent that the weight of the liquid displaced by the immersed part of the body (*i.e.* upward thrust) becomes equal to the weight of the body. Thus the body will float when upward thrust is more than its actual weight. In this special case the density of solid body is less than the density of liquid.

5 (e) The level of water does not change. The reason is that on drinking the water (say *m gm*), the weight of man increases by *m gm* and hence water displaced by man increases by *m gm*, tending to raise the level. However, this much amount of water has already been consumed by the man. Therefore the level of pond remain same.

6 (a)

7 (a) In a stream line flow of a liquid, according to equation of continuity $av =$ constant.

Where a is the area of cross section and v is the velocity of liquid flow. When water flowing in a broader pipe enters a narrow pipe, the area of cross-section of water decreases therefore the velocity of water increases.

8 (b) As a man jumps-out from a height in air with a parachute, its velocity increases first, because the gravity pull dominates the viscous drag and buoyancy of air which opposes the motion. As the velocity increases, the viscous drag of air also increases and soon a stage is reached where viscous drag and buoyancy of air balances the gravity pull. Then the man with a parachute falls with a constant velocity, called terminal velocity.

9 (a) According to Bernoulli's theorem, $P + \frac{1}{2}\rho v^2 =$ a constant

i.e. when velocity is large, the pressure is less in a stream line flow of an ideal liquid through a horizontal tube.

10 (c) When a body moves through a fluid, its motion is opposed by the force of fluid friction, which increases with the speed of the body. When cars and planes move through air, their motion is opposed by the air friction, which in turn, depend upon the shape of the body. It is due to this reason that the cars or planes are given such shape (known as stream lined shaped) so that air friction is minimum. Rather the movement of air layers on the upper and lower side of stream line shape provides a lift which helps in increasing the speed of the car.

11 (c) According to Bernoulli's equation,

$\frac{P}{\rho} + hg + \frac{1}{2}v^2 =$ constant

Thus, total energy of the injectable medicine depends upon second power of the velocity and first power of the pressure. It implies that total energy of the injectable medicine has greater dependence on its velocity. Therefore, a doctor adjust the flow of the medicine with the help of the size of the needle of the syringe $a_1v_1 = a_2v_2$) rather than the thumb pressure.

12 (a) Due to small area of cross-section of the hole, fluid flows out of the vessel with a large speed and thus the fluid possesses a large linear momentum. As no external forces acts on the system, in order to conserve linear momentum, the vessel acquires a velocity in backward direction or in other words a backward thrust results on the vessel.

13 (a) The stability of a floating body depends on the relative position of centre of gravity of a body, through which its weight acts and centre of gravity of the displaced water called centre of buoyancy through which the upthrust act.

14 (a)

15 (e) The viscosity of liquid decreases rapidly with rise of temperature. The variation of viscosity of liquid with temperature is given by $\eta_t = \eta_0(1 + \alpha t + \beta t^2)$

Where η_t and η_0 are the coefficient of viscosities at $t°C$ and $0°C$ respectively and α and β are constant.

16 (a) According to Bernoulli's theorem, when wind velocity over the wings is larger than the wind velocity under the wings, pressure of wind over the wings becomes less than the pressure of wind under the wing's. This provides the necessary lift to the aeroplane.

17 (a)

18 (a) Viscosities of fluids are markedly dependent on temperature, increasing for gases and decreasing for liquids as the temperature is increased. Thus important consideration in the design of oils for engine lubrication is to reduce the temperature variation of viscosity as much as possible.

19 (a)

20 (a) When a body falls through a viscous medium, finally, it attains terminal velocity. At this velocity, viscous force on rain drop balances the weight of the body.

21 (a) Smaller the area, larger the pressure exerted by a force

22 (d) Railways tracks are laided on large sized wooden sleepers. Due to large sized sleepers the weight of rail act on the large area. Hence, the pressure exerted is reduced appreciably.

23 (a)

24 (c) When two holes are made in the tin, air keeps on entering through the other hole. Due to this the pressure inside the tin does not become less than atmospheric pressure which happen only one hole is made.

25 (e) Terminal velocity and critical velocity are not same. Critical velocity is the velocity below which the flow of liquid is streamline.

26 (b)

27 (a)

28 (b)

Fluid Mechanics — SET Self Evaluation Test -11

1. A tank 5 m high is half filled with water and then is filled to the top with oil of density 0.85 g/cm^3. The pressure at the bottom of the tank, due to these liquids is

(a) 1.85 g/cm^2 (b) 89.25 g/cm^2

(c) 462.5 g/cm^2 (d) 500 g/cm^2

2. 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. The values of ρ_1 and ρ_2 are

(a) $\rho_1 = 6$ and $\rho_2 = 2$ (b) $\rho_1 = 3$ and $\rho_2 = 5$

(c) $\rho_1 = 12$ and $\rho_2 = 4$ (d) None of these

3. A wooden block of volume 1000 cm^3 is suspended from a spring balance. It weighs 12 N in air. It is suspended in water such that half of the block is below the surface of water. The reading of the spring balance is

(a) 10 N (b) 9 N

(c) 8 N (d) 7 N

4. Two different liquids are flowing in two tubes of equal radius. The ratio of coefficients of viscosity of liquids is 52:49 and the ratio of their densities is 13:1, then the ratio of their critical velocities will be

(a) 4 : 49 (b) 49 : 4

(c) 2 : 7 (d) 7 : 2

5. Two capillary tubes of same radius r but of lengths l_1 and l_2 are fitted in parallel to the bottom of a vessel. The pressure head is P. What should be the length of a single tube that can replace the two tubes so that the rate of flow is same as before

(a) $l_1 + l_2$ (b) $\frac{1}{l_1} + \frac{1}{l_2}$

(c) $\frac{l_1 l_2}{l_1 + l_2}$ (d) $\frac{1}{l_1 + l_2}$

6. A capillary tube is attached horizontally to a constant head arrangement. If the radius of the capillary tube is increased by 10% then the rate of flow of liquid will change nearly by

(a) + 10% (b) + 46%

(c) – 10% (d) – 40%

7. Two stretched membranes of area 2 cm^2 and 3 cm^2 are placed in a liquid at the same depth. The ratio of pressures on them is

(a) 1 : 1 (b) 2 : 3

(c) 3 : 2 (d) $2^2 : 3^2$

8. Three identical vessels are filled to the same height with three different liquids A, B and $C(\rho_A > \rho_B > \rho_C)$. The pressure at the base will be

(a) Equal in all vessels (b) Maximum in vessel A

(c) Maximum in vessel B (d) Maximum in vessel C

9. Three identical vessels are filled with equal masses of three different liquids A, B and C $(\rho_A > \rho_B > \rho_C)$. The pressure at the base will be

(a) Equal in all vessels (b) Maximum in vessel A

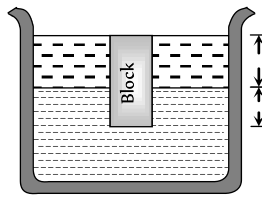
(c) Maximum in vessel B (d) Maximum in vessel C

10. A piston of cross-section area 100 cm^2 is used in a hydraulic press to exert a force of 10^7 dynes on the water. The cross-sectional area of the other piston which supports an object having a mass 2000 kg. is

(a) 100 cm^2 (b) $10^9 cm^2$

(c) $2 \times 10^4 cm^2$ (d) $2 \times 10^{10} cm^2$

11. A cubical block of wood 10 cm on a side floats at the interface between oil and water with its lower surface horizontal and 4 cm below the interface. The density of oil is $0.6 gcm^{-3}$. The mass of block is



(a) 706 g

(b) 607 g

(c) 760 g

(d) 670 g

12. A spherical ball of radius r and relative density 0.5 is floating in equilibrium in water with half of it immersed in water. The work done in pushing the ball down so that whole of it is just immersed in water is : (where ρ is the density of water)

(a) $\frac{5}{12}\pi r^4 \rho g$ (b) $0.5 \rho r g$

(c) $\frac{4}{3}\pi r^3 \rho g$ (d) $\frac{2}{3}\pi r^4 \rho g$

13. If W be the weight of a body of density ρ in vacuum then its apparent weight in air of density σ is

(a) $\frac{W\rho}{\sigma}$ (b) $W\left(\frac{\rho}{\sigma} - 1\right)$

(c) $\frac{W}{\rho}\sigma$ (d) $W\left(1 - \frac{\sigma}{\rho}\right)$

14. Which of the following is not the characteristic of turbulent flow

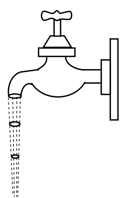
(a) Velocity more than the critical velocity

(b) Velocity less than the critical velocity

(c) Irregular flow

(d) Molecules crossing from one layer to another

15. Water coming out of the mouth of a tap and falling vertically in streamline flow forms a tapering column, *i.e.*, the area of cross-section of the liquid column decreases as it moves



down. Which of the following is the most accurate explanation for this

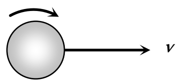
(a) As the water moves down, its speed increases and hence its pressure decreases. It is then compressed by the atmosphere

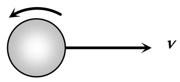
(b) Falling water tries to reach a terminal velocity and hence reduces the area of cross-section to balance upward and downward forces

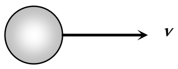
(c) The mass of water flowing past any cross-section must remain constant. Also, water is almost incompressible. Hence, the rate of volume flow must remain constant. As this is equal to velocity × area, the area decreases as velocity increases

(d) The surface tension causes the exposed surface area of the liquid to decrease continuously

16. To get the maximum flight, a ball must be thrown as

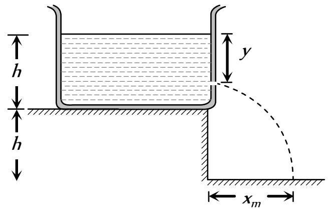
(a) 

(b) 

(c) 

(d) Any of (a), (b) and (c)

17. A tank is filled upto a height h with a liquid and is placed on a platform of height h from the ground. To get maximum range x_m a small hole is punched at a distance of y from the free surface of the liquid. Then



(a) $x_m = 2h$

(b) $x_m = 1.5h$

(c) $y = h$

(d) $y = 0.75h$

18. The relative velocity of two consecutive layers is 8 *cm/s*. If the perpendicular distance between the layers is 0.1 *cm*, then the velocity gradient will be

(a) 8*sec* (b) 80 *sec*

(c) 0.8 *sec* (d) 0.08 *sec*

19. Under a constant pressure head, the rate of flow of liquid through a capillary tube is *V*. If the length of the capillary is doubled and the diameter of the bore is halved, the rate of flow would become

(a) $V/4$ (b) 16 V

(c) $V/8$ (d) $V/32$

Answers and Solutions

(SET - 11)

1. (c) Pressure at the bottom $P = (h_1 d_1 + h_2 d_2)\dfrac{g}{cm^2}$

$= [250 \times 1 + 250 \times 0.85] = 250\ [1.85]\dfrac{g}{cm^2}$

$= 462.5\,\dfrac{g}{cm^2}$

2. (a) When substances are mixed in equal volume then density

$= \dfrac{\rho_1 + \rho_2}{2} = 4 \Rightarrow \rho_1 + \rho_2 = 8$ ....(i)

When substances are mixed in equal masses then density

$= \dfrac{2\rho_1\rho_2}{\rho_1 + \rho_2} = 3$

$\Rightarrow 2\rho_1\rho_2 = 3(\rho_1 + \rho_2)$ ....(ii)

By solving (i) and (ii) we get $\rho_1 = 6$ and $\rho_2 = 2$.

3. (d) Reading of the spring balance

= Apparent weight of the block

= Actual weight – upthrust

$= 12 - V_{in}\sigma g$

$= 12 - 500 \times 10^{-6} \times 10^3 \times 10 = 12 - 5 = 7N.$

4. (a) Critical velocity $v = N_R \dfrac{\eta}{\rho r}$

$$\Rightarrow \frac{v_1}{v_2} = \frac{\eta_1}{\eta_2} \times \frac{\rho_2}{\rho_1} = \frac{52}{49} \times \frac{1}{13} = \frac{4}{49}.$$

5. (c) For parallel combination $\dfrac{1}{R_{eff}} = \dfrac{1}{R_1} + \dfrac{1}{R_2}$

$$\Rightarrow \frac{\pi r^4}{8\eta l} = \frac{\pi r^4}{8\eta l_1} + \frac{\pi r^4}{8\eta l_2} \Rightarrow \frac{1}{l} = \frac{1}{l_1} + \frac{1}{l_2} \quad \therefore l = \frac{l_1 l_2}{l_1 + l_2}$$

6. (b) $V = \dfrac{P\pi r^4}{8\eta l} \Rightarrow \dfrac{V_2}{V_1} = \left(\dfrac{r_2}{r_1}\right)^4$

$$\Rightarrow V_2 = V_1\left(\frac{110}{100}\right)^4 = V_1(1.1)^4 = 1.4641V$$

$$\frac{\Delta V}{V} = \frac{V_2 - V_1}{V} = \frac{1.4641V - V}{V} = 0.46 \text{ or } 46\%.$$

7. (a) Pressure is independent of area of cross section

8. (b) $P \propto \rho$

9. (a) $P = \dfrac{F}{A} = \dfrac{mg}{A}$

***

10. (c) $P_1 = P_2 \Rightarrow \dfrac{F_1}{A_1} = \dfrac{F_2}{A_2} \Rightarrow \dfrac{10^7}{10^2} = \dfrac{2000 \times 10^3 \times 10^3}{A_2}$

$\therefore A_2 = 2 \times 10^4 cm^2 \qquad (g = 980 \approx 10^3 cm/s^2)$

11. (c) Weight of block

= Weight of displaced oil + Weight of displaced water

$\Rightarrow mg = V_1\rho_0 g + V_2\rho_W g$

$\Rightarrow m = (10 \times 10 \times 6) \times 0.6 + (10 \times 10 \times 4) \times 1 = 760$ *gm.*

12. (a)

13. (d) Apparent weight in air = W – upthrust = $V\rho g - V\sigma g$

$= V\rho g\left(1 - \dfrac{\sigma}{\rho}\right) = W\left(1 - \dfrac{\sigma}{\rho}\right)$

14. (b)

15. (c)

16. (b)

17. (a,c) Velocity of liquid through orifice, $v = \sqrt{2gy}$

and time taken by liquid to reach the ground

$$t = \sqrt{\frac{2(h + h - y)}{g}} = \sqrt{\frac{2(2h - y)}{g}}$$

$\therefore$ Horizontal distance covered by liquid

$$x = v.t. = \sqrt{2gy} \times \sqrt{\frac{2(2h - y)}{g}} = \sqrt{4y(2h - y)}$$

$$\Rightarrow x^2 = 4y(2h - y)$$

$$\Rightarrow \frac{d(x)^2}{dy} = 8h - 8y$$

for x to be maximum, $\dfrac{d}{dy}(x^2) = 0$

$\therefore 8h - 8y = 0$ or $h = y$

So $x_m = \sqrt{4h(2h - h)} = 2h$

18. (b) $\dfrac{dv}{dx} = \dfrac{8}{0.1} = 80s^{-1}$

19. (d) Rate of flow under a constant pressure head,

$$V = \frac{\pi p r^4}{8\eta l} \Rightarrow V \propto \frac{r^4}{l} \Rightarrow \frac{V_2}{V_1} = \left(\frac{r_2}{r_1}\right)^4 \times \frac{l_1}{l_2} = \left(\frac{1}{2}\right)^4 \times \frac{1}{2}$$

$$\Rightarrow V_2 = \frac{V_1}{32} = \frac{V}{32}$$