

# physics

## 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  $Dyne/cm^2$  (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  $Hg$ )

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

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  $\rho$ , 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 ( $\rho$ ) 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.

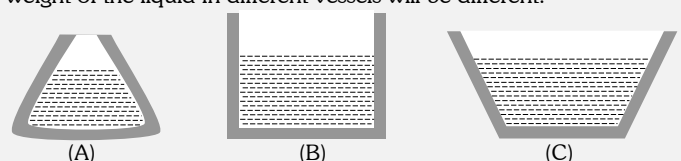


Fig. 11.2

$$P_A = P_B = P_C \text{ but } W_A < W_B < W_C$$

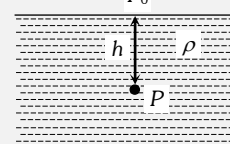
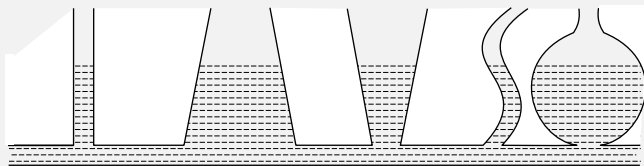


Fig. 11.1



(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  $\rho$  is defined as:

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

(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  $kg/m^3$  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 [As  $V_{body} > V_{sub.}$ ]

(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  $\rho_1$  and  $m_2$  mass of density  $\rho_2$  are mixed, then as

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

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

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

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

(7) If  $V_1$  volume of liquid of density  $\rho_1$  and  $V_2$  volume of liquid of density  $\rho_2$  are mixed, then as:

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

$$\text{If } V_1 = V_2 = V \quad \rho = (\rho_1 + \rho_2) / 2 = \text{Arithmetic Mean}$$

(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.,

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

$$\text{or } \rho = \frac{\rho_0}{(1 + \gamma\Delta\theta)} \approx \rho_0(1 - \gamma\Delta\theta)$$

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

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

But as by definition of bulk-modulus

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

$$\text{So } \rho = \rho_0 \left( 1 - \frac{\Delta p}{B} \right)^{-1} \approx \rho_0 \left( 1 + \frac{\Delta p}{B} \right)$$

### 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.

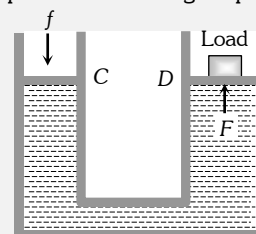
**Example :** Hydraulic lift, hydraulic press and hydraulic brakes

**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

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

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  $A \gg a$ , therefore  $F \gg f$ . 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  $\sigma$  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.

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

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

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

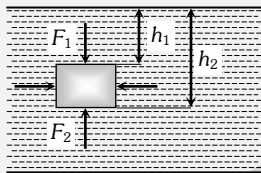


Fig. 11.5

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  $F = A\sigma gL = V\sigma g$   
[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 ( $\rho$ ) when immersed in a liquid of density ( $\sigma$ ).

$$\begin{aligned} \text{Apparent weight} &= \text{Actual weight} - \text{Upthrust} = W - F_{up} \\ &= V\rho g - V\sigma g = V(\rho - \sigma)g = V\rho g \left(1 - \frac{\sigma}{\rho}\right) \end{aligned}$$

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

(4) If a body of volume  $V$  is immersed in a liquid of density  $\sigma$  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  $W_1 - W_2 = V\sigma g$

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

(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'

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

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

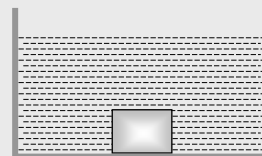
## Floatation

(1) **Translatory equilibrium** : When a body of density  $\rho$  and volume  $V$  is immersed in a liquid of density  $\sigma$ , 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.

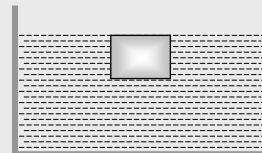
Upthrust force =  $V\sigma g$  acting vertically upwards through the centre of gravity of the displaced liquid i.e., centre of buoyancy.

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



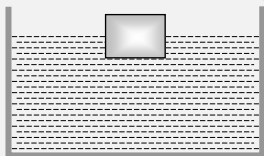
Weight will be more than upthrust so the body will sink

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  $\rho \leq \sigma$

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

So  $W_{App} = \text{Actual weight} - \text{upthrust} = 0$

(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.

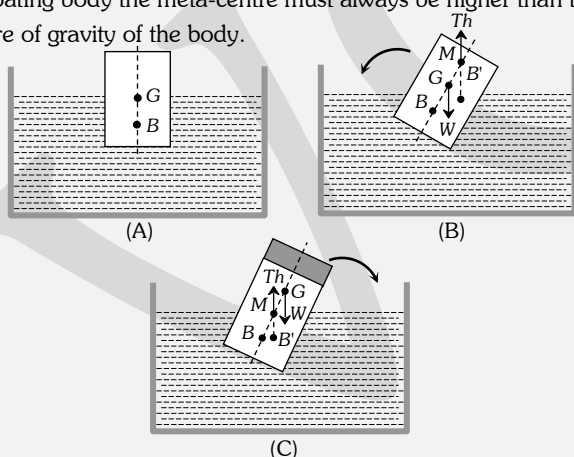


Fig. 11.6

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

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

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

i.e., Fraction of volume outside the liquid

$$f_{out} = \frac{V_{out}}{V} = \left[1 - \frac{\rho}{\sigma}\right]$$

(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  $\sigma_A$  and  $\sigma_B$  respectively.

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

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

$$Mg = hA\sigma g \quad \dots(i)$$

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

$$(M + m)g = (y + h)A\sigma g \quad \dots(ii)$$

Subtracting equation (i) from (ii),

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

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.

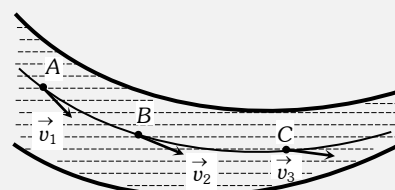


Fig. 11.7

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.

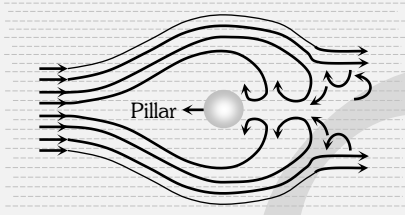


Fig. 11.8

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

$$\therefore \text{Inertial force per unit area} = \frac{dp/dt}{A} = \frac{v(dm/dt)}{A} =$$

$$\frac{vAv\rho}{A} = v^2\rho$$

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

So by the definition of Reynold's 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.

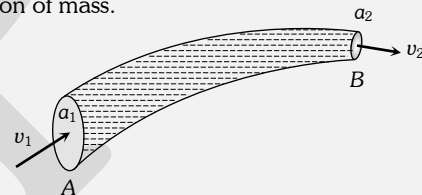


Fig. 11.9

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  $\rho_1$  and  $\rho_2$  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

$$a_1 v_1 \rho_1 = a_2 v_2 \rho_2 \text{ and } a_1 v_1 = a_2 v_2$$

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

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

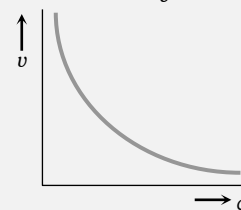


Fig. 11.10

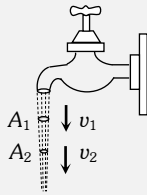
This expression is called the equation of continuity for the steady flow of an incompressible and non-viscous liquid.

(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.

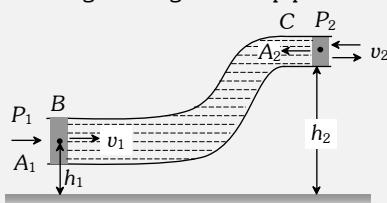
### Energy of a Flowing Fluid

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 $\rho gh$	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

$$W = P_1 V - P_2 V = (P_1 - P_2) V \quad \dots(i)$$

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  $mgh_2$ ,

$$\text{i.e., } \Delta U = mg(h_2 - h_1) \quad \dots(ii)$$

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

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

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

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

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

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

$$\text{or } P_1 + \rho gh_1 + \frac{1}{2} \rho v_1^2 = P_2 + \rho gh_2 + \frac{1}{2} \rho v_2^2$$

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

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)

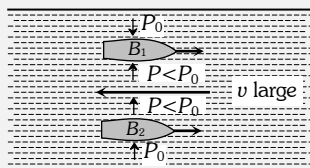


Fig. 11.13

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

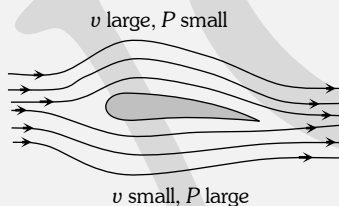


Fig. 11.14

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  $\times$  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

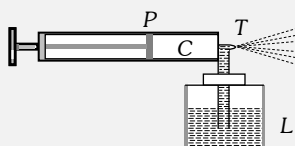


Fig. 11.15

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

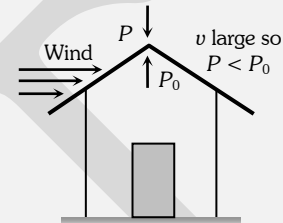


Fig. 11.16

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 an 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.

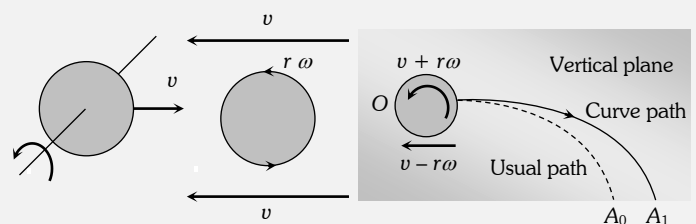


Fig. 11.17

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.

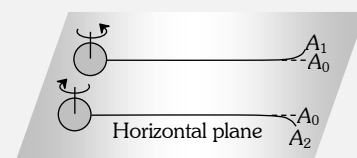
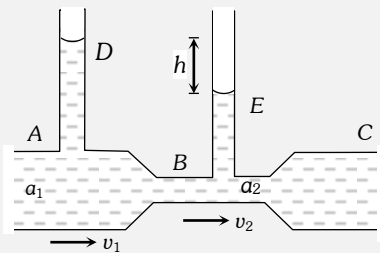


Fig. 11.18

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 liquid flows in the tube ABC, the velocity of 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

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

[ $\rho$  = density of flowing liquid]

From Bernoulli's theorem for horizontal flow of liquid

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

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

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

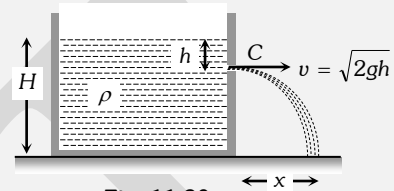
[As  $V = a_1 v_1 = a_2 v_2$ ]

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

## 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

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



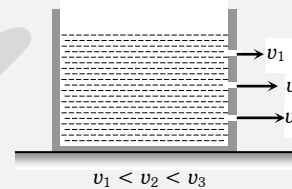
**Fig. 11.20**

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.,  $v \propto \sqrt{h}$ ]

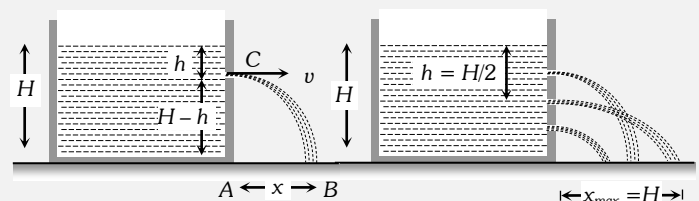


**Fig. 11.21**

(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**

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

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

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



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

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

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

(v)

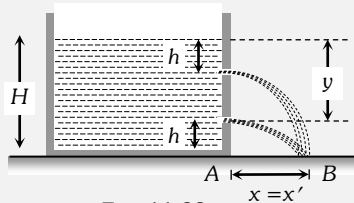


Fig. 11.23

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

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

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

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

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

$$\text{i.e., } y = h \text{ or } (H-h)$$

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)

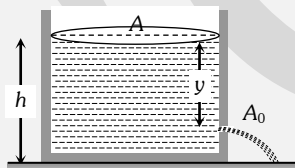


Fig. 11.24

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  $(dV/dt) = vA_0 = A_0\sqrt{2gy}$

$$[\text{As } v = \sqrt{2gy}]$$

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

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

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

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 :

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

## 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 layers 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.

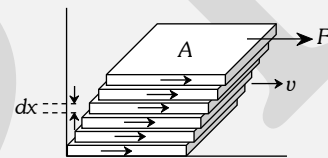


Fig. 11.25

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.

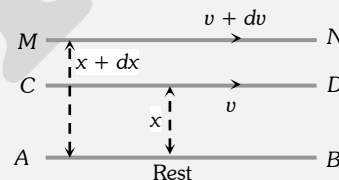


Fig. 11.26

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.,

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

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

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

Where  $\eta$  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.

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

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



## 10 Fluid Mechanics

- (1) Units : dyne-s-cm<sup>-2</sup> or Poise (C.G.S. system);  
Newton-s-m<sup>-2</sup> or Poiseuille or decapoise (S.I. system)

1 Poiseuille = 1 decapoise = 10 Poise

- (2) Dimension : [ML<sup>-1</sup> T<sup>-1</sup>]

(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  $\mu$  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;

$$\text{Andrade formula } \eta = \frac{Ae^{C\rho/T}}{\rho^{-1/3}}$$

Where T = Absolute temperature of liquid,  $\rho$  = 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  $\eta$ , the viscous force opposing the motion of the sphere is

$$F = 6\pi\eta rv$$

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 its acceleration becomes zero and it attains a constant velocity called terminal velocity.

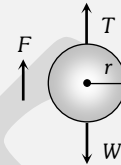


Fig. 11.27

Force on the body

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

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

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

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

- (iii) Viscous force ( $F$ ) =  $6\pi\eta rv$

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

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

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

(i) Terminal velocity depend on the radius of the sphere so if radius is made  $n$  - fold, terminal velocity will become  $n^2$  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 :

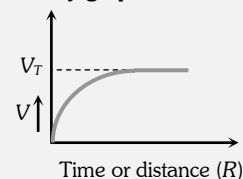


Fig. 11.28

### 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

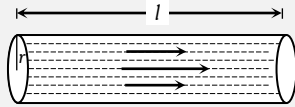


Fig. 11.29

- (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 ( $\eta$ ) of the liquid.
- (iv) Inversely proportional to the length ( $l$ ) of the capillary tube.

$$\text{i.e. } V \propto \frac{Pr^4}{\eta l} \text{ or } V = \frac{KPr^4}{\eta l}$$

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

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

This is known as Poiseuille's equation.

This equation also can be written as,

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

$R$  is called as liquid resistance.

#### (1) Series combination of tubes

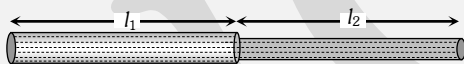


Fig. 11.30

- (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.

$$\text{Therefore } V = V_1 = V_2$$

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

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

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

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

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

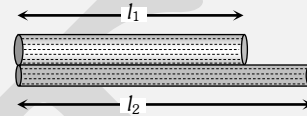


Fig. 11.31

$$(i) P = P_1 = P_2$$

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

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

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

(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



## 12 Fluid Mechanics

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 =  $\frac{\text{density of the substance}}{\text{density of water (at } 4^\circ\text{C)}}$

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

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

(li)  $x \times 10^3 \text{ kg m}^{-3}$  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  $\rho_1, \rho_2$  are mixed together, then the density of the mixture is given by

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

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

✍ The density of the liquid changes with pressure as follows :

$\rho = \rho_0 \left[ 1 + \frac{\Delta p}{B} \right]$  where  $\Delta p$  = change in pressure and  $B$  is the bulk modulus.

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

Where  $\rho$  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 buoyancy 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 ( $\rho$ ) is less than the density of water ( $\sigma$ ). 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.



# T 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  $9 \text{ g/cm}^3$ . If the mass of the other is 48 g, its density in  $\text{g/cm}^3$  is

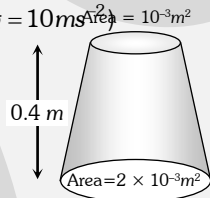
- (a)  $\frac{4}{3}$  (b)  $\frac{3}{2}$   
(c) 3 (d) 5

3. An inverted bell lying at the bottom of a lake 47.6 m deep has  $50 \text{ cm}^3$  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 =  $13.6 \text{ g/cm}^3$ )

- (a)  $350 \text{ cm}^3$  (b)  $300 \text{ cm}^3$   
(c)  $250 \text{ cm}^3$  (d)  $22 \text{ cm}^3$

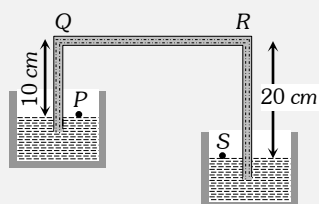
4. A uniformly tapering vessel is filled with a liquid of density  $900 \text{ kg/m}^3$ . The force that acts on the base of the vessel due to the liquid is ( $g = 10 \text{ ms}^{-2}$ ,  $A_{\text{top}} = 10^{-3} \text{ m}^2$ )

- (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  $1.5 \text{ gm/cc}$ . The pressure difference between the point P and S will be

- (a)  $10^5 \text{ N/m}$   
(b)  $2 \times 10^5 \text{ N/m}$   
(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  $\rho$  and that of water is  $\sigma$ . 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]

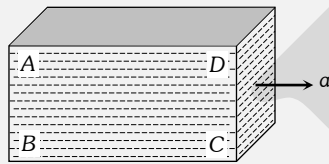
- (a)  $H$  (b)  $2H$   
(c)  $7H$  (d)  $8H$

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 [AMU 1995]

- (a) 5 m (b) 10 m  
(c) 15 m (d) 20 m

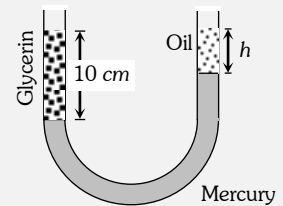
13. The value of  $g$  at a place decreases by 2%. The barometric height of mercury
- Increases by 2%
  - Decreases by 2%
  - Remains unchanged
  - Sometimes increases and sometimes decreases
14. A barometer kept in a stationary elevator reads 76 cm. If the elevator starts accelerating up the reading will be
- Zero
  - Equal to 76 cm
  - More than 76 cm
  - 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

- (i) B (ii) D
- (i) C (ii) D
- (i) B (ii) C
- (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
- Increases
  - Decreases
  - Remain constant
  - First decrease and then increase
17. A barometer tube reads 76 cm of mercury. If the tube is gradually inclined at an angle of  $60^\circ$  with vertical, keeping the open end immersed in the mercury reservoir, the length of the mercury column will be
- 152 cm
  - 76 cm
  - 38 cm
  - $38\sqrt{3}$  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
- Half of the radius of the vessel
  - Radius of the vessel
  - One-fourth of the radius of the vessel
  - 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 =  $1.3 \text{ g/cm}^3$ ) column of length 10 cm is introduced into one of its arms. Oil of density  $0.8 \text{ gm/cm}^3$  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 =  $13.6 \text{ g/cm}^3$

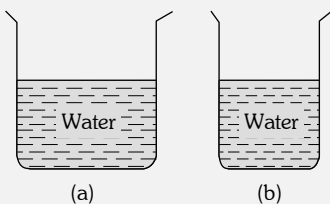


- 10.4 cm
  - 8.2 cm
  - 7.2 cm
  - 9.6 cm
20. A triangular lamina of area  $A$  and height  $h$  is immersed in a liquid of density  $\rho$  in a vertical plane with its base on the surface of the liquid. The thrust on the lamina is
- $\frac{1}{2} A \rho g h$
  - $\frac{1}{3} A \rho g h$
  - $\frac{1}{6} A \rho g h$
  - $\frac{2}{3} A \rho g h$
21. If two liquids of same masses but densities  $\rho_1$  and  $\rho_2$  respectively are mixed, then density of mixture is given by
- $\rho = \frac{\rho_1 + \rho_2}{2}$
  - $\rho = \frac{\rho_1 + \rho_2}{2\rho_1\rho_2}$
  - $\rho = \frac{2\rho_1\rho_2}{\rho_1 + \rho_2}$
  - $\rho = \frac{\rho_1\rho_2}{\rho_1 + \rho_2}$
22. If two liquids of same volume but different densities  $\rho_1$  and  $\rho_2$  are mixed, then density of mixture is given by
- $\rho = \frac{\rho_1 + \rho_2}{2}$
  - $\rho = \frac{\rho_1 + \rho_2}{2\rho_1\rho_2}$
  - $\rho = \frac{2\rho_1\rho_2}{\rho_1 + \rho_2}$
  - $\rho = \frac{\rho_1\rho_2}{\rho_1 + \rho_2}$
23. The density  $\rho$  of water of bulk modulus  $B$  at a depth  $y$  in the ocean is related to the density at surface  $\rho_0$  by the relation
- $\rho = \rho_0 \left[ 1 - \frac{\rho_0 g y}{B} \right]$
  - $\rho = \rho_0 \left[ 1 + \frac{\rho_0 g y}{B} \right]$
  - $\rho = \rho_0 \left[ 1 + \frac{B}{\rho_0 g y} \right]$
  - $\rho = \rho_0 \left[ 1 - \frac{B}{\rho_0 g y} \right]$
24. With rise in temperature, density of a given body changes according to one of the following relations
- $\rho = \rho_0 [1 + \gamma d\theta]$
  - $\rho = \rho_0 [1 - \gamma d\theta]$

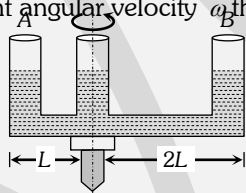


## 16 Fluid Mechanics

- (c)  $\rho = \rho_0 d\theta$  (d)  $\rho = \rho_0 / d\theta$
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  $\omega$  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
- (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 Archimides Principle

1. An ice berg of density  $900 \text{ Kg/m}^3$  is floating in water of density  $1000 \text{ Kg/m}^3$ . The percentage of volume of ice-cube outside the water is  
[CPMT 2004]
- (a) 20% (b) 35%  
(c) 10% (d) 25%
2. A log of wood of mass  $120 \text{ Kg}$  floats in water. The weight that can be put on the raft to make it just sink, should be (density of wood =  $600 \text{ Kg/m}^3$ )  
[AIIMS 2003]
- (a)  $80 \text{ Kg}$  (b)  $50 \text{ Kg}$   
(c)  $60 \text{ Kg}$  (d)  $30 \text{ Kg}$
3. A hemispherical bowl just floats without sinking in a liquid of density  $1.2 \times 10^3 \text{ kg/m}^3$ . If outer diameter and the density of the bowl are  $1 \text{ m}$  and  $2 \times 10^4 \text{ kg/m}^3$  respectively, then the inner diameter of the bowl will be  
[SCRA 1998]
- (a)  $0.94 \text{ m}$  (b)  $0.97 \text{ m}$   
(c)  $0.98 \text{ m}$  (d)  $0.99 \text{ m}$
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]

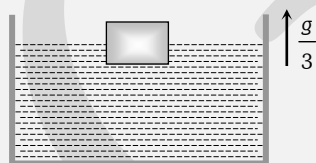
- (a) 8 (b) 4  
(c) 3 (d) Zero

6. A metallic block of density  $5 \text{ gm cm}^{-3}$  and having dimensions  $5 \text{ cm} \times 5 \text{ cm} \times 5 \text{ cm}$  is weighed in water. Its apparent weight will be

- (a)  $5 \times 5 \times 5 \times 5 \text{ gf}$  (b)  $4 \times 4 \times 4 \times 4 \text{ gf}$   
(c)  $5 \times 4 \times 4 \times 4 \text{ gf}$  (d)  $4 \times 5 \times 5 \times 5 \text{ gf}$

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)  $\frac{3}{8}$   
(c)  $\frac{2}{3}$   
(d)  $\frac{3}{4}$



8. A silver ingot weighing  $2.1 \text{ kg}$  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  $\text{kg-wt}$  is

- (a) 1.6 (b) 1.94  
(c) 3.1 (d) 5.25

9. A sample of metal weighs  $210 \text{ gm}$  in air,  $180 \text{ gm}$  in water and  $120 \text{ gm}$  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  $5 \text{ cm} \times 5 \text{ cm} \times 5 \text{ cm}$  is weighed in water. If the relative density of steel is 7, its apparent weight is

- (a)  $6 \times 5 \times 5 \times 5 \text{ gf}$  (b)  $4 \times 4 \times 4 \times 7 \text{ gf}$   
(c)  $5 \times 5 \times 5 \times 7 \text{ gf}$  (d)  $4 \times 4 \times 4 \times 6 \text{ gf}$

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]

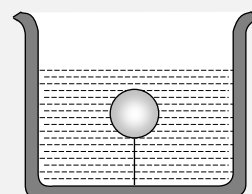
- (a) It will slowly come back to its earlier position  
(b) It will remain submerged, where it is left  
(c) It will sink  
(d) It will come out violently

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

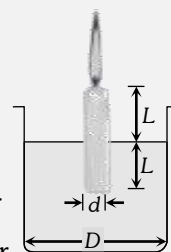




17. A hollow sphere of volume  $V$  is floating on water surface with *half* immersed in it. What should be the minimum volume of water poured inside the sphere so that the sphere now sinks into the water
- (a)  $V/2$  (b)  $V/3$   
(c)  $V/4$  (d)  $V$
18. A rectangular block is  $5\text{ cm} \times 5\text{ cm} \times 10\text{ cm}$  in size. The block is floating in water with  $5\text{ cm}$  side vertical. If it floats with  $10\text{ cm}$  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  $0.4 \times 10^3\text{ kg/m}^3$  falls into water from a height of  $9\text{ cm}$ . To what depth does the ball sink
- (a)  $9\text{ cm}$  (b)  $6\text{ cm}$   
(c)  $4.5\text{ cm}$  (d)  $2.25\text{ cm}$
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
- (a) It will remain unchanged  
(b) It will rise  
(c) It will fall  
(d) First it will 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  $D$  ( $D \gg d$ ) as shown in figure. If it is burning at the rate of  $2\text{ cm/hour}$  then the top of the candle will



- (a) Remain at the same height  
(b) Fall at the rate of  $1\text{ cm/hour}$   
(c) Fall at the rate of  $2\text{ cm/hour}$   
(d) Go up the rate of  $1\text{ cm/hour}$
25. An ice block contains a glass ball when the ice melts within the water containing vessel, the level of water [AFMC 2000]
- (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

[J&K CET 2005]

### Fluid Flow

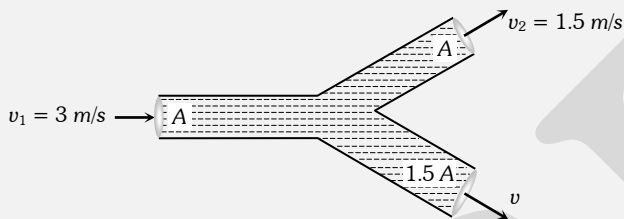
1. In which one of the following cases will the liquid flow in a pipe be most streamlined
- (a) Liquid of high viscosity and high density flowing through a pipe of small radius  
(b) Liquid of high viscosity and low density flowing through a pipe of small radius  
(c) Liquid of low viscosity and low 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

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

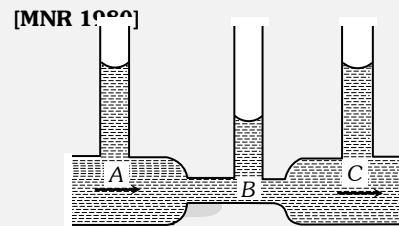
- (a)  $3.0 \text{ ms}^{-1}$  (b)  $5.7 \text{ ms}^{-1}$   
 (c)  $3.82 \text{ ms}^{-1}$  (d)  $2.86 \text{ ms}^{-1}$

6. The velocity of kerosene oil in a horizontal pipe is 5 m/s. If  $g = 10 \text{ m/s}^2$  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  $3.5 \times 10^5 \text{ N/m}^2$ . When the valve is opened, the reading of manometer falls to  $3.0 \times 10^5 \text{ N/m}^2$ , then velocity of flow of water is

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

9. Air is streaming past a horizontal air plane wing such that its speed is 120 m/s over the upper surface and 90 m/s at the lower surface. If the density of air is  $1.3 \text{ kg per metre}^3$  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 [EAMCET (Engg.) 2003]

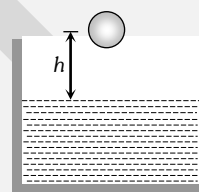
- (a)  $\sqrt{2}$  (b)  $\frac{1}{\sqrt{2}}$   
 (c)  $\sqrt{2} - 1$  (d)  $\frac{1}{\sqrt{2} - 1}$

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  $3 \text{ atm}$  ( $1 \text{ atm} = 10^5 \text{ N/m}^2$ ) then the velocity of water flowing from hole is [CPMT 2002]
- (a)  $\sqrt{400} \text{ m/s}$  (b)  $\sqrt{600} \text{ m/s}$   
 (c)  $\sqrt{60} \text{ m/s}$  (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 [MP PMT 1997]
- (a)  $t$  (b)  $4t$   
 (c)  $2t$  (d)  $t/4$
- 14.** A cylindrical tank has a hole of  $1 \text{ cm}^2$  in its bottom. If the water is allowed to flow into the tank from a tube above it at the rate of  $70 \text{ cm}^3/\text{sec}$ . then the maximum height up to which water can rise in the tank is
- (a)  $2.5 \text{ cm}$  (b)  $5 \text{ cm}$   
 (c)  $10 \text{ cm}$  (d)  $0.25 \text{ cm}$
- 15.** A square plate of  $0.1 \text{ m}$  side moves parallel to a second plate with a velocity of  $0.1 \text{ m/s}$ , both plates being immersed in water. If the viscous force is  $0.002 \text{ N}$  and the coefficient of viscosity is  $0.01 \text{ poise}$ , 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 ' $\eta$ ' with a velocity ' $v$ '. The retarding viscous force acting on the spherical ball is
- (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  $100 \text{ m}$ , 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  $100 \text{ m}$  of fall is [MP PMT 1990]
- (a) Greater than the work done by air friction in the second  $100 \text{ m}$   
 (b) Less than the work done by air friction in the second  $100 \text{ m}$   
 (c) Equal to  $100 \text{ mg}$  (d) Greater than  $100 \text{ mg}$
- 18.** Two drops of the same radius are falling through air with a steady velocity of  $5 \text{ cm per sec}$ . If the two drops coalesce, the terminal velocity would be
- (a)  $10 \text{ cm per sec}$  (b)  $2.5 \text{ cm per sec}$   
 (c)  $5 \times (4)^{1/3} \text{ cm per sec}$  (d)  $5 \times \sqrt{2} \text{ cm per sec}$
- 19.** A ball of radius  $r$  and density  $\rho$  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  $\eta$ , 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  $P$ ) [EAMCET (Engg.) 2003]
- (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  $8 \text{ cm}^3/\text{sec}$ . 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)  $4 \text{ cm}^3/\text{sec}$  (b)  $(16/3) \text{ cm}^3/\text{sec}$   
(c)  $(8/17) \text{ cm}^3/\text{sec}$  (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
- (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.  $A_1$  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

[MP PMT 1992]

- 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

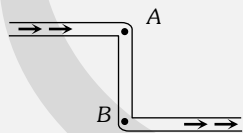
- (a) 282.8 cm/sec                      (b) 432.6 cm/sec  
(c) 632.6 cm/sec                      (d) 832.6 cm/sec

**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

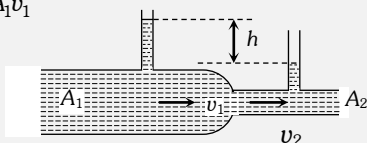
**36.** In this figure, an ideal liquid flows through the tube, which is of uniform cross-section. The liquid has velocities  $v_A$  and  $v_B$ , and pressure  $P_A$  and  $P_B$  at points A and B respectively

- (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  $A_1 v_1$   
(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

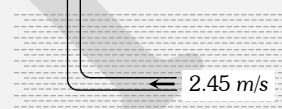


**38.** A sniper fires a rifle bullet into a gasoline tank making a hole 53.0 m below the surface of gasoline. The tank was sealed at 3.10 atm. The stored gasoline has a density of  $660 \text{ kgm}^{-3}$ . The velocity with which gasoline begins to shoot out of the hole is





- (a)  $27.8 \text{ ms}^{-1}$                       (b)  $41.0 \text{ ms}^{-1}$   
(c)  $9.6 \text{ ms}^{-1}$                       (d)  $19.7 \text{ ms}^{-1}$

**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

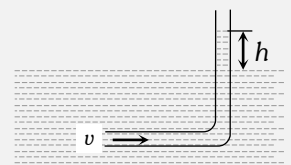


**40.** Fig. represents vertical sections of four wings moving horizontally in air. In which case the force is upwards

- (a)                       (b)   
(c)                       (d) 

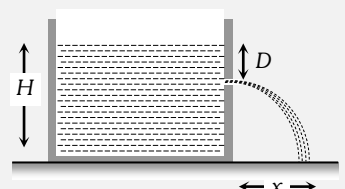
**41.** An L-shaped glass tube is just immersed in flowing water such that its opening is pointing against flowing water. If the speed of water current is  $v$ , then

- (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  $D$

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



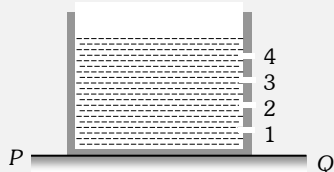


(d)  $x = 4\sqrt{D(H-D)}$

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  $\eta$  is

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

47. Velocity of water in a river is

- (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  $\eta$  is coefficient of the viscosity and  $Q$  is

[DCE 2002]

[CBSE PMT 1988]

- (a) 8 (b)  $\frac{1}{8}$   
(c) 16 (d)  $\frac{1}{16}$

54. In Poiseuille'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

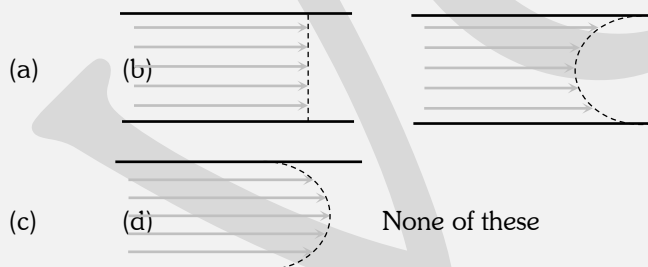
56. Two capillaries of same length and radii in the ratio 1 : 2 are connected in series. A liquid flows through them in streamlined condition. If the pressure across the two extreme ends of the combination is 1 m of water, the pressure difference across first capillary is

(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  $2P$ , 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 [BCECE 2005]



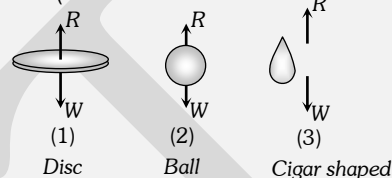
59. Water is flowing in a pipe of diameter 4 cm with a velocity 3 m/s. The water then enters into a tube of diameter 2 cm. The velocity of water in the other pipe is [BCECE 2005]

(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,  $X = \pi PR^4 / 8\eta L$ )

(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  $4.5 \times 10^5$  pascal. When the tap is opened the reading of the manometer falls to  $4 \times 10^5$  pascal. Then the velocity of flow of water is [Kerla PET 2005]

(a)  $7 \text{ ms}^{-1}$  (b)  $8 \text{ ms}^{-1}$   
(c)  $9 \text{ ms}^{-1}$  (d)  $10 \text{ ms}^{-1}$

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  $\rho$  and  $\sigma$  respectively, and the viscosity of the liquid is  $\eta$ ).

(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 Bernoulli's theorem.  $P + \frac{1}{2} \rho v^2 + \rho gh = K$  (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 [DCE 2005]

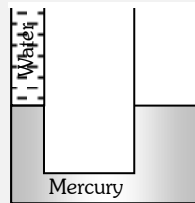
- (a)  $2v$  (b)  $v$   
(c)  $v/2$  (d)  $4v$

## Critical Thinking

### Objective Questions

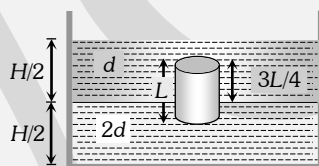
1. A U-tube in which the cross-sectional area of the limb on the left is one quarter, the limb on the right contains mercury (density  $13.6 \text{ g/cm}^3$ ). The level of mercury in the narrow limb is at a distance of  $36 \text{ cm}$  from the upper end of the tube. What will be the rise in the level of mercury in the right limb if the left limb is filled to the top with water

- (a)  $1.2 \text{ cm}$   
(b)  $2.35 \text{ cm}$   
(c)  $0.56 \text{ cm}$   
(d)  $0.8 \text{ cm}$



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

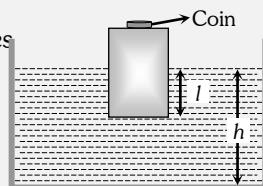
- (a)  $\frac{5}{4}d$   
(b)  $\frac{4}{5}d$   
(c)  $d$   
(d)  $\frac{d}{5}$



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

[IIT-JEE (Screening) 2002]

- (a)  $l$  decreases and  $h$  increases  
(b)  $l$  increases and  $h$  decreases  
(c) Both  $l$  and  $h$  increase  
(d) Both  $l$  and  $h$  decrease



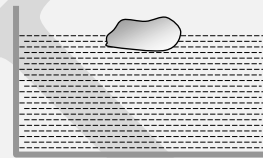
4. A vessel contains oil (density =  $0.8 \text{ gm/cm}^3$ ) over mercury (density =  $13.6 \text{ gm/cm}^3$ ). A homogeneous

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  $\text{gm/cm}^3$  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]



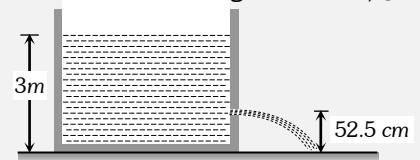
- (a) Zero  
(b) Equal to the weight of the liquid displaced  
(c) Equal to the weight of the body in air  
(d) Equal to the weight of the immersed position of the body

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  $\omega$ , 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)  $\frac{\omega^2}{2gr^2}$

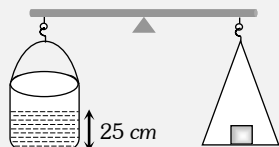
7. Water is filled in a cylindrical container to a height of  $3\text{m}$ . The ratio of the cross-sectional area of the orifice and the beaker is  $0.1$ . The square of the speed of the liquid coming out from the orifice is ( $g = 10 \text{ m/s}^2$ ) [IIT JEE 2000]

- (a)  $50 \text{ m}^2/\text{s}^2$   
(b)  $50.5 \text{ m}^2/\text{s}^2$   
(c)  $51 \text{ m}^2/\text{s}^2$   
(d)  $52 \text{ m}^2/\text{s}^2$

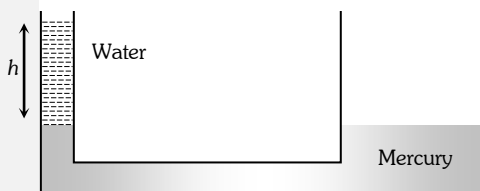


8. A large open tank has two holes in the wall. One is a square hole of side  $L$  at a depth  $y$  from the top and the other is a circular hole of radius  $R$  at a depth  $4y$  from the top. When the tank is completely filled with water the quantities of water flowing out per second from both the 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  $\frac{1}{4} \text{ cm}^2$  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  $\rho$ . The difference in height between the holes is  $h$ . Tank is resting on a smooth horizontal surface. Horizontal force which will have 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  $\rho$  = density of water) by



- (a)  $\frac{n^2 h}{(n+1)^2 s}$  (b)  $\frac{h}{(n^2 + 1) s}$   
(c)  $\frac{h}{(n+1)^2 s}$  (d)  $\frac{h}{n^2 s}$
12. A uniform rod of density  $\rho$  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

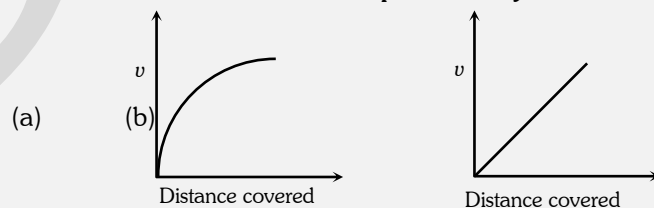
rod is in equilibrium, with its lower end resting on the bottom of the tank. In this position the rod makes an angle  $\theta$  with the horizontal

- (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 1.2 in a beaker then level of liquid when ice completely melt
- [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

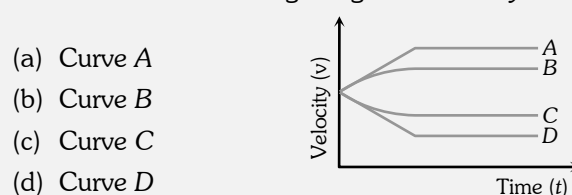
- (a)  $\frac{A}{a} \sqrt{\frac{2}{g}} [\sqrt{H_1} - \sqrt{H_2}]$  (b)  $\sqrt{2gh}$   
(c)  $\sqrt{2gh(H_1 - H_2)}$  (d)  $\frac{A}{a} \sqrt{\frac{g}{2}} [\sqrt{H_1} - \sqrt{H_2}]$

## Graphical Questions

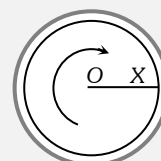
1. A lead shot of 1mm diameter falls through a long column of glycerine. The variation of its velocity  $v$  with distance covered is represented by



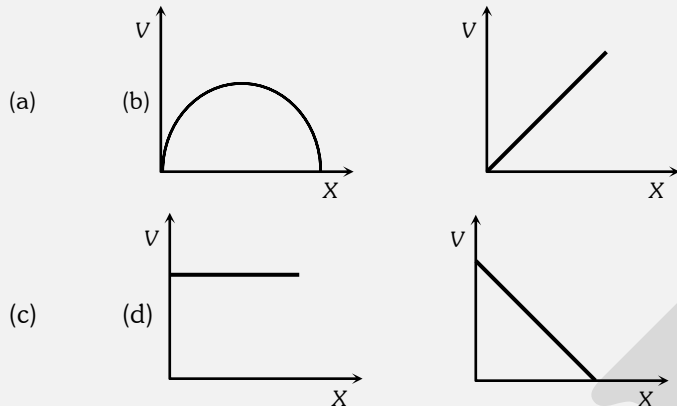
- (c) (d)
2. A small spherical solid ball is dropped from a great height in a viscous liquid. Its journey in the liquid is best described in the diagram given below by the



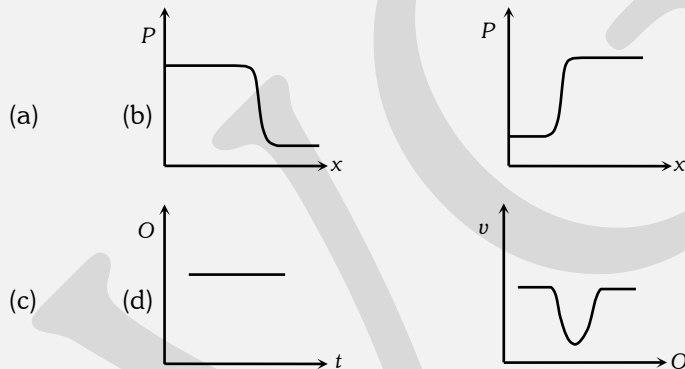
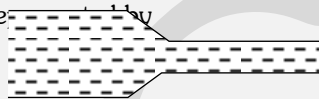
3. The diagram shows a cup of tea seen from above. The tea has been stirred and is now rotating without



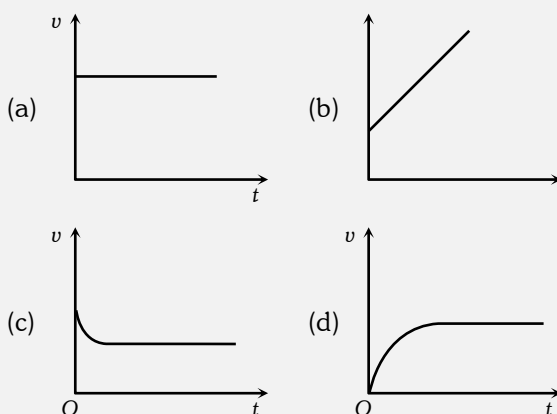
turbulence. A graph showing the speed  $v$  with which the liquid is crossing points at a distance  $X$  from  $O$  along a radius  $XO$  would look like



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



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 [CPMT 1990]



## Assertion & Reason

For AllIMS 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 experience 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 storm.  
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 small 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 Archimides 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
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### 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				