HYDRAULICS

INTRODUCTION

- Matter exists in three main states viz. solid, liquid and gas.
- The intermolecular forces are strongest in solids that's why their size and shape cannot be changed easily.
- The intermolecular force in liquids are comparatively weaker than in solids. Therefore, their shape can be changed easily. Thus liquids assume the shape of the container. But their volume (or density) cannot be changed so easily. Liquids are incompressible and have free surface of their own.
- The intermolecular forces are weakest in gases,so their shape and size can be changed easily. Gases are compressible and occupy all the space of the container.
- *Fluids are the substances that can flow*. Therefore *liquids and gases both are fluids*.
- Study of a fluid at rest is called ***fluid statics*** or ***hydrostatics*** and the study of fluid in motion is called ***fluid dynamics*** or ***hydo dynamics***. Both combined are called ***fluid mechanics****.*

HYDRO STATICS

The main characteristic properties of liquid are :

(1) Density (2) Specific weight (3) Relative density
(4) Specific gravity (5) Pressure (6) Compressibility
(7) Viscosity (8) Surface tension (9) Capillarity

1. DENSITY (ρ)

Mass per unit volume is defined as density. So density at a point of a fluid is represented as

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

Dimensions : $[ML^{-3}]$ **S I Unit :** kg/m^3, **C G S Unit :** g/cm^3 or g/cc

Such that 1 g/cc = 1000 kg/m^3 = 1kg/L ($\because$ 1L = 10^3 cm^3 = 10^{-3} m^3)

The density of water at 4°C (277 K) is 1.0×10^3 kg/m^3 and density of mercury is 13.6×10^3 kg/m^3.

Golden key points

- Density is a positive scalar quantity.
- For a solid body volume and density will be same as that of its constituent substance of equal mass i.e. if $M_{body} = M_{sub}$ then $V_{body} = V_{sub}$ and $\rho_{body} = \rho_{sub}$. But for a hollow body or body with air gaps $M_{body} = M_{sub}$ and $V_{body} > V_{sub}$ then $\rho_{body} < \rho_{sub}$
- If m_1 mass of liquid of density ρ_1 and m_2 mass of liquid of density ρ_2 are mixed then

$M_{mix.} = m_1 + m_2$ and $V_{mix} = V_1 + V_2 = \dfrac{m_1}{\rho_1} + \dfrac{m_2}{\rho_2}$

$$\therefore \quad \rho_{mix.} = \frac{M_{mix}}{V_{mix}} = \frac{m_1 + m_2}{\dfrac{m_1}{\rho_1} + \dfrac{m_2}{\rho_2}}$$

If same masses are mixed i.e. $m_1 = m_2 = m$ then

$$\rho_{mix.} = \frac{2\rho_1\rho_2}{\rho_1 + \rho_2}$$ (*Harmonic mean of densities*)

- If V_1 volume of liquid of density ρ_1 and V_2 volume of liquid of density ρ_2 are mixed then

  $V_{mix.} = V_1 + V_2$ and $M_{mix.} = m_1 + m_2 = \rho_1 V_1 + \rho_2 V_2$

$$\therefore \quad \rho_{mix.} = \frac{M_{mix}}{V_{mix}} = \frac{\rho_1 V_1 + \rho_2 V_2}{V_1 + V_2}$$

If same volumes are mixed i.e. $V_1 = V_2 = V$ then

$$\rho_{mix.} = \frac{\rho_1 + \rho_2}{2}$$ (*Arithmatic mean of densities*)

QUESTIONS FOR PRACTICE

Q.1 When equal volumes of two metals are mixed together, the density of mixture is 4 kg/m^3. When equal masses of the same two metals are mixed together, the mix density is 3 kg/m^3. Calculate the densities of each metal.

2. SPECIFIC WEIGHT OR WEIGHT DENSITY (ω)

It is defined as the ratio of the weight of the fluid to its volume or the weight acting per unit volume of the fluid.

$$\omega = \frac{\text{Weight (W)}}{\text{Volume (V)}} = \frac{mg}{V} = \left(\frac{m}{V}\right)g = \rho g$$

S I Unit : N/m^3 **Dimension :** $[ML^{-2}T^{-2}]$

Specific weight of pure water at 4°C is 9.81 kN/m^3

3. RELATIVE DENSITY

It is defined as the ratio of the density of the given fluid to the density of pure water at 4°C.

$$\text{Relative density (R.D.)} = \frac{\text{Density of given liquid}}{\text{Density of pure water at } 4^\circ C}$$

4. SPECIFIC GRAVITY

It is defined as the ratio of the specific weight of the given fluid to the specific weight of pure water at 4°C.

$$\text{Specific gravity} = \frac{\text{Specific weight of given liquid}}{\text{Specific weight of pure water at } 4^\circ C\ (9.81\ kN/m^3)}$$

$$= \frac{\rho_\ell \times g}{\rho_w \times g} = \frac{\rho_\ell}{\rho_w} = \text{R.D. of the liquid}$$

Thus specific gravity of a liquid is numerically equal to the relative density of that liquid and for calculation purposes they are used interchangeably.

Golden key points

- Relative density or specific gravity is a unitless and dimensionless positive scalar physical quantity.
- Being a dimensionless/unitless quantity R.D. of a substance is same in SI and CGS system.

QUESTIONS FOR PRACTICE

Q.2 In an experiment the weight of 2.5 m^3 of a certain liquid was found to be 18.75 kN. Then find the specific weight of given liquid.

Q.3 A vessel of 4 m^3 volume contains an oil which weight 30.2 kN. Determine the specific gravity of the oil.

5. PRESSURE

If a uniform force is exerted normal to an area (A), then pressure (P) is defined as the normal force (F) per unit area i.e.

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

Dimension of Pressure : $[ML^{-1}T^{-2}]$

Units of Pressure :

SI unit is pascal (Pa) such that 1 Pa = 1 N/m^2

Practical units are atmospheric (atm), bar and torr

1 atm = 1.01325×10^5 Pa = 1.01325 bar = 760 torr = 10.33 m of water

1 bar = 10^5 Pa

1 torr = Pressure exerted by 1 mm of mercury column = 133 Pa.

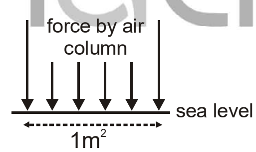
5.1 Types of Pressure : Pressure is of three types

(1) Atmospheric pressure (P_o)

(2) Gauge pressure (P_{gauge})

(3) Absolute pressure ($P_{abs.}$)

Atmospheric pressure :- Force exerted by atmospheric air column on unit Cross-section area of sea level called atmospheric pressure (P_o)

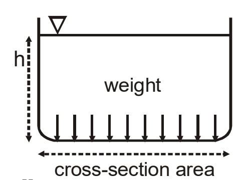


$$P_o = \frac{F}{A} = 101.3\ KN/m^2$$

$\therefore\ P_o = 1.013 \times 10^5\ N/m^2$

Note :- Barometer is used to measure atmospheric pressure.

Gauge Pressure :- Excess Pressure ($P - P_{atm}$) measured with the help of pressure measuring instrument called Gauge pressure.



$$P_{gauge} = \frac{F}{A} = \frac{Mg}{A} = \frac{(\text{volume} \times \text{density})g}{A} = \frac{(Ah)\rho g}{A}$$

$P_{gauge} = h\rho g$ or $P_{gauge} \propto h$

Note :- Gauge pressure is always measured with help of **"manometer".**

Absolute Pressure :- Sum of atmospheric and Gauge pressure is called absolute pressure.

$$P_{abs} = P_{atm} + P_{gauge}$$

$$P_{abs} = P_o + h\rho g$$

QUESTIONS FOR PRACTICE

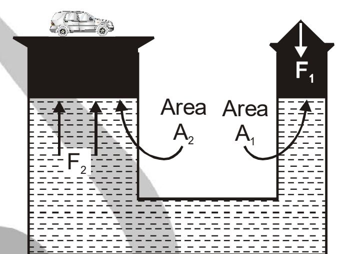
Q.4 A mercury barometer reads 75 cm in a stationary lift. What reading does it show when the lift is moving downwards, with an acceleration of 1 m/s^2 ?

5.2 Pascal's Law : Pascal's law is stated in following ways –

- The pressure in a fluid at rest is same at all the points if gravity is ignored.
- A liquid exerts equal pressures in all directions.
- If the pressure in an enclosed fluid is changed at a particular point, the change is transmitted to every point of the fluid and to the walls of the container without being diminished in magnitude.

Applications of pascal's law :- hydraulic jacks, lifts, presses, brakes, etc

For the hydraulic lift :-



principle of hydraulic lift or press

Pressure applied = $\frac{F_1}{A_1}$

$\therefore$ Pressure transmitted = $\frac{F_2}{A_2}$

$\because$ Pressures $\frac{F_1}{A_1} = \frac{F_2}{A_2}$

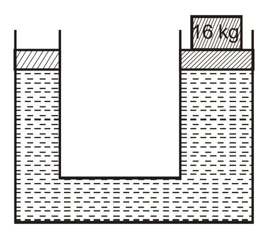
$\therefore$ Upward force F_2 on A_2 = $\frac{F_1}{A_1} \times A_2$ or $F_2 = \frac{A_2}{A_1} \times F_1$

- Pressure is a scalar quantity.
- Atmospheric pressure is measured by *barometer* which was discovered by **Torricelli**.
- Atmospheric pressure varies from place to place and at a particular place from time to time.
- The pressure which we measure in our automobile tyres is gauge pressure.

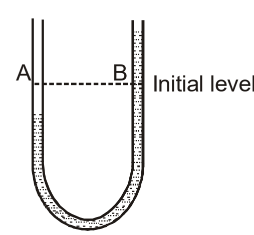
QUESTIONS FOR PRACTICE

Q.5 The diameter of the piston P_2 is 50 cm and that of the piston P_1 is 10 cm. What is the force exerted on P_2 when a force of 1 N is applied on P_1 ?

Q.6 The area of cross-section of wider tube is 800 cm^2. If a mass of 16 kg is placed on the massless piston, find the difference in the level of water in the two tubes.



Q.7 An open U-tube of uniform cross-section contains mercury. When 27.2 cm of water column is poured into one limb of the tube, how high does the mercury rise in the other limb from its initial level [ρ_w = 1 and ρ_{Hg} = 13.6]

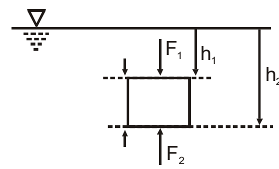


6. BUOYANCY AND ARCHIMEDE'S PRINCIPLE

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

6.2 Archimede's Principle : It states that the buoyant force on a body that is partially or totally immersed in a liquid is equal to the weight of the fluid displaced by it.

Now consider a body immersed in a liquid of density (ρ_L) as shown in fig.



Top surface of the body experiences a downward force

$F_1 = A.P_1 = A[h_1.\rho_L.g + P_0]$ ----(1)

Lower face of the body will exp. a upward force

$F_2 = AP_2 = A[h_2.\rho_L.g + P_0]$ -------(2)

As $h_2 > h_1$ so F_2 is greater than F_1

so net upward force (F) is-

$F = F_2 - F_1 = A\rho_L g[h_2 - h_1]$

$\therefore$ $F = A.\rho_L.g.L. = V_{in}\ \rho_L.g$ = wt. of liquid displaced

$\because$ $V_{in} = AL$

Golden key points

- Buoyant force act vertically upward through the *centre of gravity* (*C.G.*) of the displaced fluid. This point is called *centre of buoyancy* (*C.B.*). Thus centre of buoyancy is the point through which the force of buoyancy is supposed to act.
- Buoyant force or upthrust does not depend upon the characteristics of the body such as its mass, size, density, etc. But it depends upon the volume of the body inside the liquid. $Th \propto V_{in}$
- It depends upon the nature of the fluid as it is proportional to the density of the fluid. $Th \propto \rho_L$ This is the *reason* that upthrust on a fully submerged body is more in sea water than in pure water ($\because\ \rho_{sea} > \rho_{pure}$)
- It depends upon the effective accelaration.
  If a lift is accelerated downwards with accelaration a (a< g) then $Th = V_{in}\ \rho_L\ (g - a)$
  If a lift is accelerated downwards with a = g then $Th = V_{in}\ \rho_L\ (g - a) = 0$
  If a lift is accelerated upward with accelaration *a* then $Th = V_{in}\ \rho_L\ (g + a)$
- Due to upthrust the weight of the body decreases
  $W_{App} = W - Th$ (W is the true weight of the body)
  Decrease in weight $= W - W_{App} = Th$ = Weight of the fluid displaced
- Using Archimede's principle we can determine relative density (R D) of a body as

$$\text{R.D.} = \frac{\text{density of body}}{\text{density of pure water at } 4^\circ\text{C}} = \frac{\text{wt. of body}}{\text{wt. of equal volume of water}}$$

$$= \frac{\text{wt. of body}}{\text{thrust due to water}} = \frac{\text{wt. of body}}{\text{loss of wt. in water}} = \frac{\text{wt. of body in air}}{\text{wt. in air - wt. in water}} = \frac{W_A}{W_A - W_W}$$

- If a body is weighed in air (W_A), in water (W_w) and in a liquid (W_L), then

$$\text{specific gravity of liquid} = \frac{\rho_L}{\rho_w} = \frac{\rho_L}{\rho_w}\times\frac{Vg}{Vg} = \frac{(Th)_\ell}{(Th)_w} = \frac{\text{Loss of weight in Liquid}}{\text{Loss of weight in water}} = \frac{W_A - W_L}{W_A - W_W}$$

SOLVED EXAMPLES

Ex. 1 A body weighs 160 g in air, 130 g in water and 136 g in oil. What is the specific gravity of oil?

Sol. Specific gravity of oil $= \dfrac{\text{Loss of weight in oil}}{\text{Loss of weight in water}} = \dfrac{160\text{-}136}{160\text{-}130} = \dfrac{24}{30} = \dfrac{8}{10} = 0.8$

QUESTIONS FOR PRACTICE

Q.8 A certain block weighs 15N in air, it weighs 12N when immersed in water. When immersed in another liquid, it weighs 13N, calculate the relative density of (i) the block (ii) the other liquid.

6.3 Floatation : When a body of density (ρ_B) and volume (V) is completely immersed in a liquid of density (ρ_L), the forces acting on the body are :

(i) Weight of the body $W = Mg = V\rho_B g$ directed vertically downwards through C.G. of the body.

(ii) Buoyant force or Upthrust $Th = V\rho_L g$ directed vertically upwards through C.B.

The apparent weight W_{App} is equal to $W - Th$. The following three cases are possible :

Case I If density of the body is greater than that of liquid ($\rho_B > \rho_L$)

In this case if $\rho_B > \rho_L$ then $W > Th$

So the body will sink to the bottom of the liquid.

$$W_{App} = W - Th = V\rho_B g - V\rho_L g = V\rho_B g\,(1 - \rho_L/\rho_B) = W\,(1 - \rho_L/\rho_B).$$

Case II if density of the body is equal to the density of liquid ($\rho_B = \rho_L$)

In this case

if $\rho_B = \rho_L$ then $W = Th$

So the body will float fully submerged in the liquid. It will be in neutral equilibrium.

$$W_{App} = W - Th = 0$$

Case III if density of the body is lesser than that of liquid ($\rho_B < \rho_L$)

In this case

if $\rho_B < \rho_L$ then $W < Th$

So the body will float partially submerged in the liquid. In this case the body will move up and the volume of liquid displaced by the body (V_{in}) will be less than the volume of body (V). So as to make Th equal to W

$$\therefore \quad W_{App} = W - Th = 0$$

The above three cases are called the ***law of floatation*** which states that a body will float in a liquid if weight of the liquid displaced by the immersed part of the body (i.e. upthrust) is greater than or equal to the weight of the body.

Golden key points

- A body will float only if its density is less than or equal to the density of the liquid i.e.

  $\rho_B \le \rho_L$
- When a body floats its weight is equal to the upthrust i.e.

  $W = Th$ or $V\rho_B g = V_{in}\,\rho_L g$ or $V\rho_B = V_{in}\rho_L$. ....(18)
- In case of floating as W = Th, the apparent weight of the floating body will be zero.
- In case of W = Th, the equilibrium of floating body does not depend upon variations in *g* though both thrust and weight depends upon *g*.
- The weight of the plastic bag full of atmospheric air is same as that of empty bag because the additional upthrust is equal to the weight of the air enclosed.

SOLVED EXAMPLES

Ex.2 An iceberg is floating partially immersed in sea-water. The density of sea-water is 1.03 gm/cm^3 and that of ice is 0.92 gm/cm^3. What is the fraction of the total volume of the iceberg above the level of sea-water?

Sol. In case of floation weight = upthrust i.e.

$$mg = V_{in}\rho_L g \quad \text{or} \quad V\rho_B g = V_{in}\rho_L g \quad [\text{as } \rho_B = m/V \text{ so } m = \rho_B V]$$

$$\text{or} \quad V_{in} = \frac{\rho_B}{\rho_L}V \quad \text{so} \quad V_{out} = V - V_{in} = V\left(1 - \frac{\rho_B}{\rho_L}\right)$$

$$\text{or} \quad f_{out} = \frac{V_{out}}{V} = \left(1 - \frac{\rho}{\sigma}\right) = \left(1 - \frac{0.92}{1.03}\right) = \frac{0.11}{1.03} = 0.106$$

$$\text{or} \quad f_{out} = 10.6\ \%$$

Ex.3 A piece of ice floats in water. What will happen to the level of water when the ice melts completely?

Ans. The level of water remains unchanged.

Hint. Consider a liquid of density ρ_L with level A in a beaker a shown in fig (a). Let a piece of ice of mass m floats in the liquid as shown in fig (b). The increase in level of the liquid is AB. Suppose V_D fcbe the volume of liquid displaced.

Then weight of the ice = weight of liquid displaced

$$mg = V_D\,\rho_L g \quad \text{or} \quad V_D = \frac{m}{\rho_L}$$

When ice is completely melted. let the level of (liquid + water) be at C as shown in fig (C). The difference of levels A and C is due to the ice converted into water. If thus volume be V_0 then.

$$V_0 = \frac{m}{\rho_w}$$

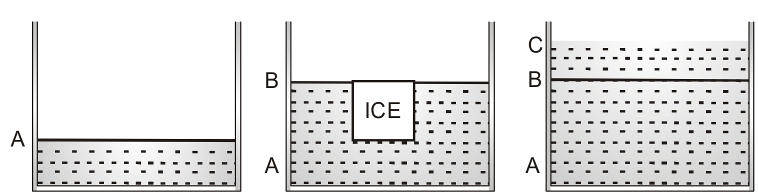
Where ρ_w = density of water are we consider the following three cases -

(i) If $\rho_L > \rho_w$ then $V_0 > V_D$

i.e., the level of (liquid + water) will rise

(ii) If $\rho_L < \rho_w$ then $V_0 < V_D$ the level of (liquid + water) will decrease.

(iii) If $\rho_L = \rho_w$ then $V_0 = V_D$ then level will remain unchanged.



(b) (b) (c)

Q. A boat carrying a number of large stones is floating in a water. What will happen to the water level if the stones are unloaded into the water.

Sol.

Let M = mass of boat, m = mass of stones

for floating condition

weight = up thrust

$(M + m)\, g = V_D\, \rho_w\, g$

$$V_D = \frac{M}{\rho_w} + \frac{m}{\rho_w} \text{ .... (1)}$$

When stones are unloaded into the water

$$V_{D_1} = \frac{M}{\rho_w} \qquad (V_{D_1} = \text{displaced volume by boat})$$

$$V_{D_2} = \frac{m}{\rho_s} \qquad (V_{D_2} = \text{displaced volume by stones})$$

$\therefore$ total displaced volume $V_D' = V_{D_1} + V_{D_2} = \frac{M}{\rho_w} + \frac{m}{\rho_s}$ ....(2)

$\therefore \quad \frac{m}{\rho_w} > \frac{m}{\rho_s} \quad \Rightarrow \quad V_D > V_D'$

So level will fall.

QUESTIONS FOR PRACTICE

Q.9 A block of wood floats in water with two-third of its volume submerged. In oil the block floats with 0.90 of its volume submerged. Find the density of (i) wood and (ii) oil. Density of water is 10^3 kg/m^3.

Q.10 A 700 g solid cube having an edge of length 10 cm floats in water. What volume of the cube is outside water ?

Q.11 If a block of iron of density 5 g cm^{-3} and size 5 cm × 5 cm × 5 cm was weighed whilst completely submerged in water, what would be the apparent weight in g – f (gram-force) ?

FLUID DYNAMICS

*When a fluid moves in such a way that there are relative motions among the fluid particles, the fluid is said to be flowing and study of flowing fluid is called **fluid dynamics** or **hydro dynamics**.*

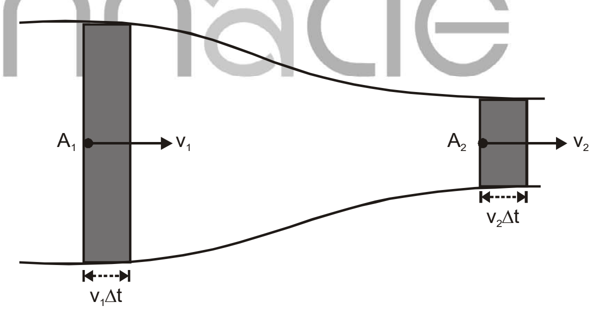
1. TYPES OF FLUID FLOW

Fluid flow can be classified in the following ways :

1. **Steady and Unsteady Flow :** *Steady flow* is defined as that type of flow in which the fluid characteristics like velocity, pressure and density at a point do not change with time.
   In an *unsteady flow*, the velocity, pressure and density at a point in the flow varies with time.
2. **Streamline Flow :** In steady flow all the particles passing through a given point follow the same path and hence a unique line of flow. This line or path is called a *streamline*. Streamlines do not intersect each other because if they intersect each other the particle can move in any one direction at the point of intersection and flow cannot be steady.
3. **Laminar and Turbulent Flow :** *Laminar flow* is the flow in which the fluid particles move along well-defined streamlines which are straight and parallel. In laminar flow the velocities at different points in the fluid may have different magnitudes, but there directions are parallel. Thus the particles move in laminar or layers sliding smoothly over the adjacent layer.
   Turbulent flow is an irregular flow in which the particles can move in zig-zag way due to which high energy losses take place.
4. **Compressible and Incompressible Flow :** In *compressible flow* the density of fluid varies from point to point i.e. the density is not constant for the fluid whereas in *incompressible flow* the density of the fluid remains constant throughout. Liquids are generally incompressible while gases are compressible.
5. **Rotational and Irrotational Flow :** *Rotational flow* is the flow in which the fluid particles while flowing along path-lines also rotate about their own axis. In *irrotational flow* particles do not rotate about their axis.

2. EQUATION OF CONTINUITY

- The continuity equation is the mathematical expression of the *law of conservation of mass in fluid dynamics*.
- In the steady flow the mass of fluid entering into a tube of flow in a particular time interval is equal to the mass of fluid leaving out the tube.



$$\frac{m_1}{\Delta t} = \frac{m_2}{\Delta t}$$

or $\rho_1 A_1 v_1 = \rho_2 A_2 v_2$

or $A_1 v_1 = A_2 v_2$ $\quad (\because \rho_1 = \rho_2)$ [Here ρ = density of fluid v = velocity of fluid

or Av = constant A = Area of cross-section of tube]

Rate of flow = volume of liquid flowing per second = Av

3. BERNOULLI'S THEOREM

- Bernoulli's equation is mathematical expression of the *law of mechanical energy conservation in fluid dynamics*.

- Bernoullis theorem is applied to the *ideal fluids*. Characteristics of an ideal fluid are :
  (i) The fluid flow is *steady*.
  (ii) The fluid is *incompressible*.
  (iii) The fluid flow is *irrotational*.
  (iv) The fluid is *non-viscous*.
- Every point in an ideal fluid flow is associated with three kinds of energies :
  (i) Kinetic Energy : If a liquid of mass (m) and volume (V) is flowing with velocity (v) then

$$K.E. = \frac{1}{2} mv^2$$

and kinetic energy per unit volume $= \frac{K.E.}{Volume} = \frac{1}{2}\frac{m}{V}v^2 = \frac{1}{2}\rho v^2$

(ii) Potential Energy : If a liquid of mass (m) and volume (V) is at height (h) from the surface of the earth then its P.E. = mgh

and potential energy per unit volume $= \frac{P.E.}{Volume} = \frac{m}{V}gh = \rho gh$

(iii) Pressure Energy : If P is the pressure on area A of a liquid and the liquid moves through a distance (ℓ) due to this pressure then

Pressure energy = Work done
= force x displacement
= pressure x area x displacement
= $PA\ell$
= PV [$\because A\ell$ = volume V]

Pressure energy per unit volume $= \frac{\text{Pressure Energy}}{\text{Volume}} = P$

- **Bernoulli's theorem :** The sum of pressure energy, kinetic energy and potential energy per unit volume remains constant along a streamline in an ideal fluid flow i.e.,

$$P + \frac{1}{2}\rho v^2 + \rho gh = \text{constant} \quad \text{(Energy per unit volume)}$$

or $$\frac{P}{\rho g} + \frac{v^2}{2g} + h = \text{constant} \quad \text{(Energy per unit weight)}$$

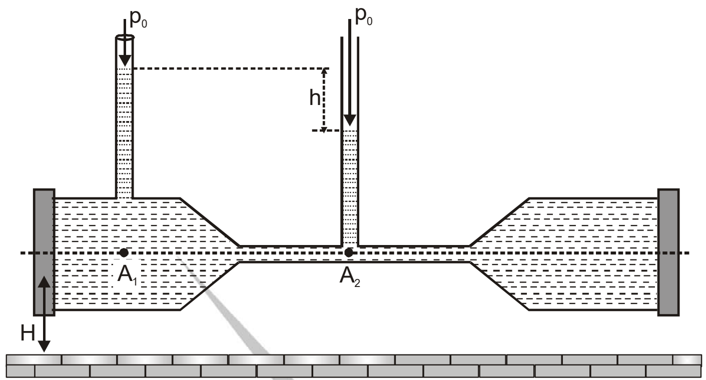
Here $\frac{P}{\rho g}$ is called ***pressure head***, $\frac{v^2}{2g}$ is called ***velocity/kinetic head*** and h is called ***gravitational/potential head***

3.1 Applications of Bernoulli's theorem :

1. Venturimeter or Venturi Tube or Flowmeter : Venturimeter is used to measure flow velocities in an incompressible fluid.

As shown in figure if P_1 and P_2 are the pressures and v_1 and v_2 are the velocities of fluid of density ρ at point 1 and 2 on the same horizontal level and A_1 and A_2 are the respective areas then from equation of continuity

$$A_1v_1 = A_2v_2 \quad \text{or} \quad v_2 = \left(\frac{A_1}{A_2}\right)v_1 \quad ......(i)$$



Venturimeter

from Bernoulli's equation

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

or $$P_1 + \frac{1}{2}\rho\, v_1^2 = P_2 + \frac{1}{2}\rho\left(\frac{A_1^2}{A_2^2}\right) v_1^2 \qquad \text{[from equation (i)]}$$

or $$P_1 - P_2 = \frac{1}{2}\rho v_1^2\left(\frac{A_1^2}{A_2^2} - 1\right)$$

But $$P_1 - P_2 = \rho gh \qquad [\because \text{ height difference in the two arms is h}]$$

$$\therefore \quad \rho gh = \frac{1}{2}\rho v_1^2\left(\frac{A_1^2}{A_2^2} - 1\right)$$

$$\therefore \quad v_1 = \sqrt{2gh}\left(\frac{A_1^2}{A_2^2} - 1\right)^{-\frac{1}{2}} = A_2\sqrt{\frac{2gh}{A_1^2 - A_2^2}}$$

If Q be the volume of water flowing per second then

$$Q = A_1 v_1 = A_2 v_2 = A_1 A_2\sqrt{\frac{2gh}{A_1^2 - A_2^2}}$$

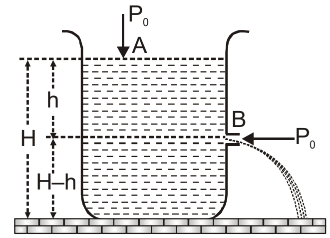
Thus *at a point where the cross-section area is smaller velocity is greater and pressure is lower and vice versa*.

2. Torricelli's Law of Efflux (Fluid Outflow): As shown in the figure since the area of cross-section at A is very large as compared to that at orifice B, speed at A i.e. $v_A \approx 0$. Also the two fluid particles at A and B are at same pressure P_0 (atmospheric pressure). Applying Bernoulli's theorem at A and B.

$$P_0 + \rho gH + \frac{1}{2}\rho v_A^2 = P_0 + \rho g(H - h) + \frac{1}{2}\rho v_B^2$$

or $$\frac{1}{2}\rho v_B^2 = \rho gh \qquad \text{or} \qquad v_B = \sqrt{2gh}$$

This equation is same as that of freely falling body after falling through *h* depth and is known as *Torricelli's law.* Writing II equation of uniformly accelerated motion in vertical direction



$$H - h = 0 + \frac{1}{2}gt^2 \qquad (\text{from } s_y = u_y t + \frac{1}{2}a_y t^2)$$

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

Horizontal range

$$R = v_x t = \sqrt{2gh} \times \sqrt{2(H-h)/g}$$

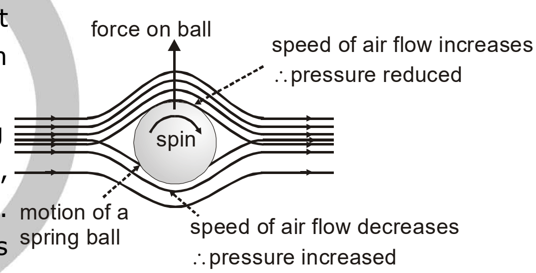
or $$R = 2\sqrt{h(H-h)}$$

Range will be maximum when

$$h = H - h \quad \text{or } h = H/2$$

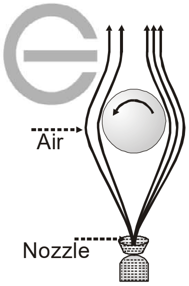
$$\therefore \quad R_{max.} = 2\sqrt{\frac{H}{2}\left(H - \frac{H}{2}\right)} = H$$

3. Magnus Effect (Spinning Ball) : Tennis and cricket players usually experience that when a ball is thrown spinning it moves along a curved path. This is called *swing* of the ball. This is due to the air which is being dragged round by the spinning ball. When the ball spins, the layer of the air around it also moves with the ball. So, as shown in figure the resultant velocity of air increases on the upper side and reduces on the lower side.

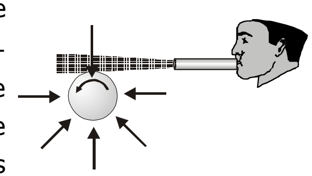


Hence according to Bernoulli's theorem the pressure on the upper side becomes lower than that on the lower side. This pressure difference exerts an upward force on the ball due to which it moves along a curved path. This effect is known as *Magnus-effect*.

4. Motion of the Ping-Pong Ball: When a ping-pong ball is placed on a vertical stream of water-fountain, it rises upto a certain height above the nozzle of the fountain and spins about its axis. The reason for this is that the streams of water rise up from the fountain with very large velocity so that the air-pressure in them decreases. Therefore, whenever the ball goes out from the streams, the outer air which is at atmospheric pressure pushes it back into the streams (in the region of low pressure). Thus the ball remains in *stable equilibrium* on the fountain.



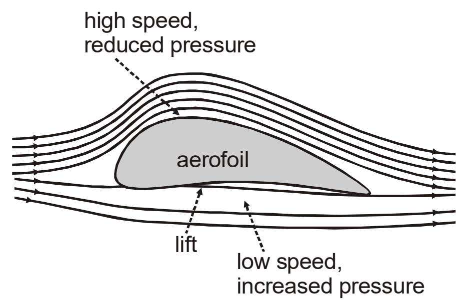
If we blow air at one end of a narrow tube, the air emerges from the other end at high speed and so the pressure falls there. If a ping-pong ball is left free slightly below this end, it does not fall down due to the large pressure (atmospheric) below the ball. Similarly, if we blow air in between two ping-pong balls suspended by light threads near each other, the balls come close to each other due to the decrease of air pressure between them. Same is the reason that when air is blown below a pan of a physical balance the pan is depressed down.



5. **Aerofoil :** This is a device which is shaped in such a way so that the relative motion between it and a fluid produces a force perpendicular to the flow. As shown in the figure the shape of the aerofoil section causes the fluid to flow faster over the top surface than over the bottom.

Therefore according to Bernoulli's theorem the pressure above is reduced and that underneath is increased. Thus a resultant upward force is created normal to the flow and this force provides *lift* (upward force) for an aeroplane.

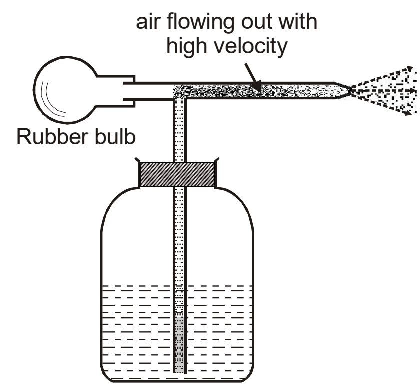
Examples of aerofoils are aircraft wings and propellers.



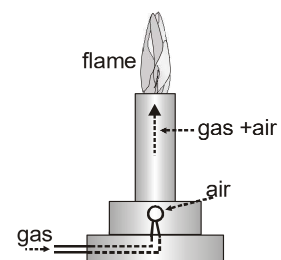
Principle of an aerofoil

6. **Sprayer or Atomizer :** This is an instrument used to spray a liquid in the form of small droplets (fine spray). It consists of a vertical tube whose lower end is dipped in the liquid to be sprayed, filled in a vessel. The upper end opens in a horizontal tube. At one end of the horizontal tube there is a rubber bulb and at the other end there is a fine hole. When the rubber bulb is squeezed, air rushes out through the horizontal tube with very high velocity and thus the pressure reduces (according to Bernoulli's theorem). So the liquid in the vessel rises up and mixes with air in the form of small droplets which is sprayed out.

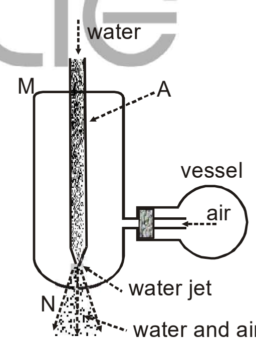
Example : paint guns, scent sprayer, etc.



7. **Bunsen's Burner :** It consists of a long tube having a fine hole O at the bottom. The gas enters the tube through O and burns in the form of a flame at the top of the tube. To produce a flame, the air of the atmosphere is mixed with the gas. Since the nozzle O is fine, the gas enters with a large velocity and so the pressure inside the tube is lowered than the outer atmospheric pressure. Therefore, air from outside rushes into the tube through a hole and is mixed with the burning gas.

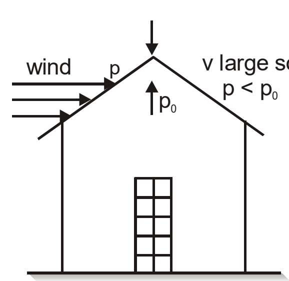


8. **Filter Pump :** It is used to create partial vacuum in a vessel. It consists of a wide tube M N in the upper part of which there is another tube A. The upper end of A is connected to a water tank, while its lower end has a fine hole through which water comes out in the form of a jet. The vessel which is to be evacuated is connected to the tube M N as shown. The velocity of the emerging water jet is very large. Therefore, the pressure of the air near the jet becomes less than the pressure in the vessel. Hence air from the vessel rushes into the tube MN and is carried out along with the water jet. Thus partial vacuum is created in the vessel.



9. **Blowing-off of Tin Roof Tops in Wind Storm :**

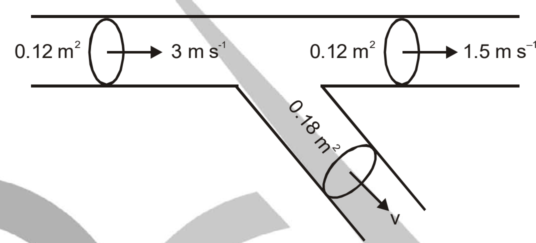
When wind blows with a high velocity above a tin roof, it causes lowering of pressure above the roof, while the pressure below the roof is still atmospheric. Due to this pressure-difference the roof is lifted up.



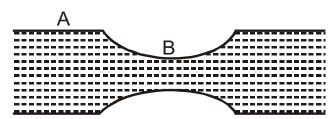
10. **Pull-in or Attraction Force by Fast Moving Trains :** If we are standing on a platform and a train passes through the platform with very high speed we are pulled towards the train. This is because as the train comes at high speed, the pressure between us and the train decreases. Thus the air behind us which is still at atmospheric pressure pushes us towards the train. The reason behind flying-off of small papers, straws and other light objects towards the train is also the same.

QUESTIONS FOR PRACTICE

Q.1 An incompressible liquid travels as shown in figure. Calculate the speed of the fluid in lower branch.



Q.2 Water flows in a horizontal tube as shown in figure. The pressure of water changes by 600 N/m^2 between A and B where the areas of cross-section are 30 cm^2 and 15 cm^2 respectively. Find the rate of flow of water through the tube.



Q.3 In a vessel of water a hole is made at a depth of 3.5 m from the free surface. What would be the velocity of efflux ?

Pinnacle

VISCOSITY

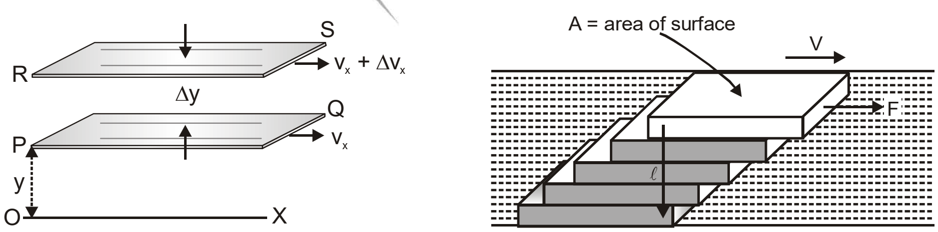
Viscosity is the property of the fluid (liquid or gas) by virtue of which it opposes the relative motion between its adjascent layers. It is the *fluid friction* or *internal friction*.
The internal tangential force which try to retard the relative motion between the layers is called *viscous force*.

1. COMPARISON OF VISCOSITY AND SOLID FRICTION

S.No.	Viscosity	Solid friction
	Similarities	
1.	It opposes relative motion.	It opposes relative motion.
2.	It acts tangentially in a direction opposite to that of motion.	It acts tangentially in a direction opposite to that of motion.
3.	It comes into play when the two layers of a liquid are in relative motion.	It comes into play when the two bodies are in relative motion.
	Differences	
1.	It is internal friction as the layer exerting the friction force is internal to the liquid.	It is external friction as the friction force is due to an external body.
2.	The viscous force is directly proportional to the surface area of contact of liquid layers.	It is independent of the area of solid surfaces in contact.
3.	The viscous force is directly proportional to the relative velocity between two layers of a liquid.	It is independent of the relative velocity of one body with respect to another body in contact.
4.	It does not depend upon the normal reaction between the two layers of the liquid.	It is directly proportional to the normal reaction between the surfaces in contact.

2. NEWTON'S LAW OF VISCOSITY

Suppose a liquid is flowing in stream-lined motion on a horizontal surface OX. The liquid layer in contact with the surface is at rest while the velocity of other layers increases with increasing distance from the surface OX. The highest layer flows with maximum velocity.



Let us consider two parallel layers PQ and RS at distances y and $y + \Delta y$ from OX. Thus the change in velocity in a perpendicular distance Δy is Δv_x. The rate of change of velocity with distance perpendicular to the direction of flow i.e. $\frac{\Delta v_x}{\Delta y}$, is called ***velocity-gradient.***

According to Newton, the viscous force F acting between two layers of a liquid flowing in stream-lined motion depends upon following two factors :

(i) $F \propto$ Contact-area (A) of the layers i.e. $F \propto A$

(ii) $F \propto$ Velocity-gradient $\left(\frac{\Delta v_x}{\Delta y}\right)$ between layers i.e. $F \propto \frac{\Delta v_x}{\Delta y}$.

From (i) and (ii) $F \propto A\frac{\Delta v_x}{\Delta y}$ or $F = \eta A\frac{\Delta v_x}{\Delta y}$

Where η is a constant called ***coefficient of viscosity*** of the liquid.

In above formula if A = 1 and $\frac{\Delta v_x}{\Delta y} = 1$, then $F = \eta$. i.e. the coefficient of viscosity of a liquid is defined as the viscous force per unit area of contact between two layers having a unit velocity gradient.

Dimension of η : $M^1L^{-1}T^{-1}$

S I Unit : 1 poiseuille (Pl) = $1\frac{N \times Sec}{m^2}$ = deca poise

C G S Unit : dyne-sec/cm^2 or poise such that 1 decapoise = 10 poise.

QUESTION FOR PRACTICE

Q.1 A large wooden plate of area $10m^2$ floating on the surface of a river is made to move horizontally with a speed of 2 m/s by applying a tangential force. If the river is 1 m deep and the water in contact with the bed is stationary, find the tangential force needed to keep the plate moving. Coefficient of viscosity of water at the temperature of the river = 10^{-2} poise.

3. DEPENDENCY OF VISCOSITY OF FLUIDS

(i) On Temperature of Fluid :

(a) Viscosity of a liquid is due to cohesive forces. Since cohesive forces decrease with increase in temperature. Therefore *with the rise in temperature, the viscosity of liquids decreases*.

(b) The viscosity of gases is the result of diffusion of gas molecules from one moving layer to other moving layer. Now with increase in temperature, the rate of diffusion increases. So, the viscosity also increases. Thus, *the viscosity of gases increases with the rise of temperature*.

(ii) On Pressure of Fluid :

(a) The viscosity of liquids increases with the increase of pressure.

(b) The viscosity of gases is practically independent of pressure.

(iii) On Nature of Fluid

4. STEADY FLOW IN CAPILLARY TUBE

Poiseuille's Formula : In case of steady flow of liquid of viscosity (η) in a capillary tube of length (L) and radius (r) under a pressure difference (P) across it, the volume of liquid flowing per second is given by :

$$Q = \frac{dV}{dt} = \frac{\pi.P.r^4}{8\eta L}$$

Note : With the help of poiseuille's formula, the coefficient of viscosity of a liquid can be determined.

QUESTIONS FOR PRACTICE

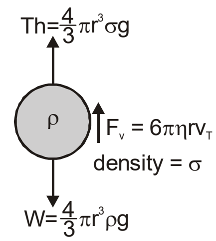
Q.2 A liquid flows through two capillary tubes connected in series. Their lengths are ℓ and 2ℓ and radii r and 2r respectively. Then the pressure difference across the first and second tubes are in the ratio **[CPMT 1991]**

Q.3 The rate of flow of a liquid through a capillary tube of radius r is V when the pressure difference is P. If the radius is reduced to r/2 and the pressure increases to 2P, then the rate of flow becomes **[JIPMER 1993]**

5. STOKE'S LAW AND TERMINAL VELOCITY

Stoke showed that if a small sphere of radius r is moving with a velocity v through a stationary medium (liquid or gas) of viscosity η then the viscous force acting on the sphere is $F_v = 6\pi\eta rv$.

Terminal Velocity : When a solid sphere falls in a liquid then its accelarating velocity is controlled by the viscous force of liquid and hence it attains a constant velocity which is known as *terminal velocity* (v_T).
As shown in figure when the body moves with constant velocity i.e. terminal velocity (zero acceleration) the net upward force (upthrust Th + viscous force F_v) balances the downward force (weight of body W)



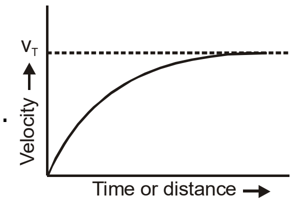
Therefore $\quad Th + F_v = W$

or $\quad \frac{4}{3}\pi r^3\sigma g + 6\pi\eta rv_T = \frac{4}{3}\pi r^3\rho g$

or $\quad v_T = \frac{2}{9}\frac{r^2(\rho-\sigma)}{\eta}g$ ....(4)

where $\quad$ r = radius of body $\quad \rho$ = density of body
σ = density of liquid $\quad \eta$ = coefficient of viscosity

Graph :
The variation of velocity with time (or distance) is shown in the adjascent graph.



SOLVED EXAMPLES

Ex.1 A drop of water of radius 0.0015 mm is falling in air. If the co-efficient of viscosity of air is 1.8×10^{-5} kg m^{-1} s^{-1}. What will be the terminal velocity of the drop. Density of air can be neglected.

Sol. $V_T = \frac{2}{9}\frac{r^2(\rho-\sigma)g}{\eta}$

Given r = 0.0015 mm, $\rho = 10^3$ kg m^{-3}, $\sigma \approx 0$, $\eta = 1.8 \times 10^{-5}$ kg m^{-1} s^{-1}

$$V_T = \frac{2\times\left(\frac{15\times10^{-4}}{1000}\right)^2\times10^3\times9.8}{9\times1.8\times10^{-5}}$$

$V_T = 2.72 \times 10^{-4}$ m/sec.

Ex.2 The velocity of a small ball of mass M and density d_1, when dropped in a container filled with glycerine becomes constant after some time. If the density of glycerine is d_2, the viscous force acting on the ball will be :

(1) $\frac{Md_1g}{d_2}$ $\quad$ (2) $Mg\left(1-\frac{d_2}{d_1}\right)$ $\quad$ (3) $\frac{M(d_1+d_2)}{g}$ $\quad$ (4) Md_1d_2

Sol. [2]
Since Effective force = $Vd_1g - Vd_2g$ $\quad = V(d_1 - d_2)\, g$

$$= \frac{M}{d_1}(d_1 - d_2)g = Mg\left(1-\frac{d_2}{d_1}\right) \quad [\because V = M/d_1]$$

QUESTIONS FOR PRACTICE

Q.4 Find the terminal velocity of a rain drop of radius 0.01 mm. The coefficient of viscosity of air is 1.8×10^{-5} N-s/m^2 and its density is 1.2 kg/m^3. Density of water = 1000 kg/m^3. Take g = 10 m/s^2. (Force of buoyancy due to air is neglected)

6. REYNOLDS NUMBER (R_e)

The type of flow pattern (laminar or turbulent) is determined by a non-dimensional number called *Reynolds number (R_e).* Which is defined as

$$\boxed{R_e = \frac{\rho v d}{\eta}} \qquad ....(5)$$

where ρ is the density of the fluid having viscosity η and flowing with mean speed v. d denotes the diameter of tube.

Although there is not a perfect demarkation for value of R_e for laminar and turbulent flow but some authentic references take the value as

R_e	< 1000	> 2000	between 1000 to 2000
Type of flow	laminar	often turbulent	may be laminar or turbulent

on gradually increasing the speed of flow at certain speed transition from laminar flow to turbulent flow takes place. This speed is called **critical speed.** For lower density and higher viscosity fluids laminar flow is more probable.

LEVEL-I

1. A boy is carrying a bucket of water in one hand and a piece of plaster in the other. After transfering the plaster piece to the bucket (in which it floats) the boy will carry -
(A) same load as before
(B) more load than before
(C) less load than before
(D) either less or more load, depending on the density of the plaster

2. A beaker containing water is balanced on the pan of a common balance. A solid of specific gravity 1 and mass 5 g is tied to the arm of the balance and immersed in water contained in the beaker. The scale pan with the beaker -
(A) goes down
(B) goes up
(C) remains unchanged
(D) none of these

3. A sample of metal weighs 210 g in air, 140 g in water and 120 g in an unknown liquid. Then -
(A) the density of the metal is 3 g/cm^3
(B) The density of the metal is 7 g/cm^3
(C) density of the metal is 4 times the density of unknown liquid
(D) the metal still float in water

4. A body is just floating in a liquid (their densities are equal) If the body is slightly pressed down and released it will -
(A) start oscillating
(B) sink to the bottom
(C) come back to the same position immediately
(D) come back to the same position slowly

5. Two stretched membranes of areas 2 and 3 m^2 are placed in a liquid at the same depth. The ratio of the pressure on them is -
(A) 1 : 1 (B) 2 : 3
(C) $\sqrt{2} : \sqrt{3}$ (D) $2^2 : 3^2$

6. 1 kg of cotton and iron are weighed in vacuum, then -
(A) cotton and iron will weight same
(B) iron will weight more than cotton
(C) cotton will weight more than iron
(D) both have zero weight

7. An ice block floats in a liquid whose density is less than water. A part of block is outside the liquid. When whole of ice has melted, the liquid level will -
(A) rise
(B) go down
(C) remain same
(D) first rise then go down

8. A small lead shot is embedded in a big lump of ice floating in a jar of water. The level of water in the jar is noted. When all the ice melts down, the level of water in the jar would
(A) be raised
(B) go down
(C) remain unchanged
(D) none of the above

9. The height of a barometer filled with a liquid of density 3.4 g/cc under normal condition is approximately -
(A) 8 m (B) 5 m
(C) 3 m (D) 1 m

10. A weightless base is filled with 5 kg of water and then weighed in water. The reading of spring balance is -
(A) 5 kg f (B) 2.5 kg f
(C) 1.25 kg f (D) zero

11. A cube of iron whose sides are of length L, is put into mercury. The weight of iron cube is W. The density of iron is ρ_I, that of mercury is ρ_M. The depth to which the cube sinks is given by the expression -
(A) $WL^2\rho_I$ (B) $WL^2\rho_M$
(C) $\frac{W}{L^2\rho_I}$ (D) $\frac{W}{L^2\rho_M g}$

12. To what height should a rectangular cylinder having square base of length 10 cm be filled so that the total force on the bottom is equal to that on the sides -
(A) 5 cm (B) 10 cm
(C) 20 cm (D) 6.67 cm

13. A metallic sphere with an internal cavity weighs 40 gm in air and 20 gm in water. If the density of the material with the cavity = 8 gm/c.c., then the volume of the cavity is -
(A) 15 c.c. (B) 20 c.c.
(C) 25 c.c. (D) 30 c.c.

14. If 1 g of substance of realtive density 2 and 4g of another substance of relative density 3 are mixed together, then the relative density of the mixture is -
(A) 2.4 (B) 2.5
(C) 2.7 (D) 2.8

15. A bucket contains water filled upto a height = 15 cm. The bucket is tied to a rope which is passed over a frictionless light pulley and the other end of the rope is tied to a weight of mass which is half of that of the (bucket + water). The water pressure above atmosphere pressure at the bottom is
(A) 0.5 kPa (B) 1 kPa
(C) 5 kPa (D) None

16. A U-tube having horizontal arm of length 20 cm, has uniform cross-sectional area = 1 cm^2. It is filled with water of volume 60 cc. What volume of a liquid of density 4 g/cc should be poured from one side into the U-tube so that no water is left in the horizontal arm of the tube?
(A) 60 cc (B) 45 cc
(C) 50 cc (D) 35 cc

17. The pressure at the bottom of a tank of water is 3P where P is the atmospheric pressure. If the water is drawn out till the level of water is lowered by one fifth., the pressure at the bottom of the tank will now be
(A) 2P (B) (13/5) P
(C) (8/5) P (D) (4/5) P

18. An incompressible fluid flows steabily through a cylindrical pipe which has radius 2R at point A and radius R at point B further along the flow direction. If the velocity at point A is ν, its velocity at point B will be –
(A) 2ν (B) ν
(C) $\nu/2$ (D) 4ν

19. Water is flowing in a horizontal pipe of non-uniform cross - section. At the most contracted place of the pipe –
(A) Velocity of water will be maximum and pressure minimum
(B) Pressure of water will be maximum and velocity minimum
(C) Both pressure and velocity of water will be maximum
(D) Both pressure and velocity of water will be minimum

20. Water is flowing in a tube of non-uniform radius. The ratio of the radii at entrance and exit ends of tube is 3 : 2. The ratio of the velocities of water entering in and exiting from the tube will be –
(A) 8 : 27 (B) 4 : 9
(C) 1 : 1 (D) 9 : 4

21. Water from a tap emerges vertically downward with an initial speed of 1.0 ms^{-1}. The cross-section area of the tap is $10^{-4}m^2$. Assumed at the pressure is constant throughout the stream of water and that the flow is steady. The cross-sectional areal of the stream 0.15 m below the tap is (g = 10 m/s^2)
(A) 5.0×10^{-4} m^2 (B) 1.0×10^{-5} m^2
(C) 5.0×10^{-5} m^2 (D) 2.0×10^{-5} m^2

22. The velocity of a small ball of mass M and density d_1, when dropped in a container filled with glycerine becomes constant after some time. If the density of glycerine is d_2, the viscous force acting on the ball will be –
(A) $\frac{Md_1g}{d_2}$ (B) $\frac{M(d_1+d_2)}{g}$
(C) $Mg\left(1-\frac{d_2}{d_1}\right)$ (D) M d_1 d_2

23. Bernoulli's theorem based upon –
(A) Conservation of momentum
(B) Conservation of energy
(C) Conservation mass
(D) None of these
(D) Faraday's law

24. A tank has an orifice near its bottom. The volume of the liquid flowing per second out of the orifice does not depend upon –
(A) Area of the orifice
(B) Height of the liquid level above the orifice
(C) Density of liquid
(D) Acceleration due to gravity

25. The rate of flowing of water from the orifice in a wall of a tank will be more if the orific is –
(A) Near the bottom
(B) Near the upper end
(C) Exactly in the middle
(D) Does not depend upon the position of orific

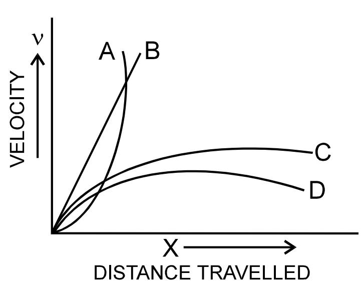
26. A tank is filled with water to a height H. A hole is made in one of the walls at a depth D below the water surface. The distance x from the foot of the wall at which the stream of water coming out of the tank strikes the ground is given by –
(A) $x = 2\ [D(H - D)]^{1/2}$
(B) $x = 2\ (gD)^{1/2}$
(C) $x = 2\ [D(H + D)]^{1/2}$
(D) None of these

27. A small lead ball is falling freely in a viscous liquid. The velocity of the ball –
(A) goes on increasing
(B) goes on decreasing
(C) remains constant
(D) first increases and then becomes constant

28. The terminal velocity of a spherical ball of radius r falling through a viscous liquid is proportional to –
(A) r (B) r^2
(C) r^3 (D) r^{-1}

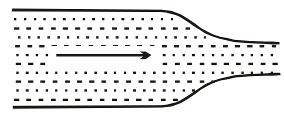
29. The viscous force acting on a solid ball moving in air with terminal velocity ν is directly proportional to–
(A) $\sqrt{\nu}$ (B) ν
(C) $\frac{1}{\sqrt{\nu}}$ (D) ν^2

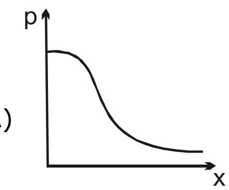
30. A small spherical solid ball is dropped in a viscous liquid. Its journey in the liquid is best described in the figure by

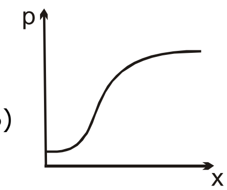


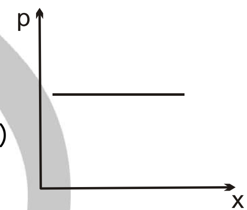
(A) Curve A (B) Curve B
(C) Curve C (D) Curve D

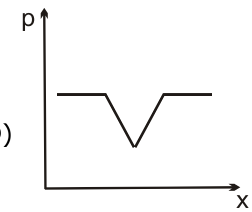
31. Water flows through a frictionless duct with a cross-section varying as shown in figure. Pressure p at points along the axis is represented by



(A)


(B)


(C)


(D)


32. Two water pipes P and Q having diameters 2×10^{-2} m and 4×10^{-2} m, respectively, are joined in series with the main supply line of water. The velocity of water flowing in pipe P is
(A) 4 times that of Q
(B) 2 times that of Q
(C) 1/2 times of that of Q
(D) 1/4 times that of Q

33. A laminar stream is flowing vertically down from a tap of cross-section area 1 cm^2. At a distane 10 cm below the tap, the cross-section area of the stream has reduced to 1/2 cm^2. The volumetric flow rate of water from the tap must be about
(A) 2.2 litre/min (B) 4.9 litre/min
(C) 0.5 litre/min (D) 7.6 litre/min

Pinnacle

LEVEL-II

HYDROSTATICS

1. A tank 5 metre high is half-filled with water and then is filled to the top with oil of density 0.8 gm/cm^3. The pressure at the bottom of the tank, due to these liquid is
(A) 1.85 gm cm^{-2}
(B) 89.25 gm cm^{-2}
(C) 462.5 gm cm^{-2}
(D) none of the above

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

3. A body of volume 100 c.c. is immersed just completely in water contained in a jar. The weight of water and the jar before immersion of the body was 600 g. After immersion, the weight of the water and jar will be -
(A) 500 g (B) 700 g
(C) 100 g (D) 800 g

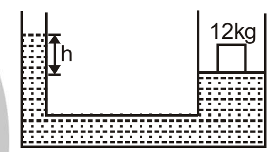
4. The density of ice is 0.9 g/c.c. and that of sea water is 1.1 g/c.c. An ice berg of volume V is floating in sea water. The fraction of ice berg above water level is -
(A) 1/11 (B) 2/11
(C) 3/11 (D) 4/11

5. A piece of steel floats in mercury. The specific gravity of mercury and steel are 13.6 and 7.8 respectively. For covering the whole piece some water is filled above the mercury. What part of the piece is inside the mercury -
(A) 0.54 (B) 0.50
(C) 0.47 (D) 0.62

6. A metal ball immersed in alcohol weighs W_1 at 0ºC and W_2 at 59ºC. The coefficient of cubical expansion of the metal is less than that of alcohol. Assuming that the density of the metal is large compared to that of alcohol, it can be shown that -
(A) $W_1 > W_2$ (B) $W_1 < W_2$
(C) $W_1 = W_2$ (D) $W_1 = 2\ W_2$

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 a net acceleration of g/4, the fraction of volume immersed in the liquid will be -
(A) $\frac{1}{2}$ (B) $\frac{1}{4}$
(C) $\frac{3}{4}$ (D) $\frac{3}{8}$

8. The area of cross-section of the wider tube shown in figure is 800 cm^2. If a mass of 12 kg is placed on the massless piston, the difference in heights h in the level of water in the two tubes is :



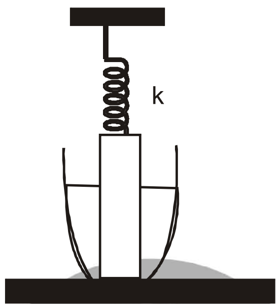
(A) 10 cm (B) 6 cm
(C) 15 cm (D) 2 cm

9. Two cubes of size 1.0 m sides, one of relative density 0.60 and another of relative density = 1.15 are connected by weightless wire and placed in a large tank of water. Under equilibrium the lighter cube will project above the water surface to a height of
(A) 50 cm (B) 25 cm
(C) 10 cm (D) zero

10. A cork of density 0.5 gcm^{-3} floats on a calm swimming pool. The fraction of the cork's volume which is under water is
(A) 0% (B) 25%
(C) 10% (D) 50%

11. A small wooden ball of density ρ is immersed in water of density σ to depth h and then released. The height H above the surface of water up to which the ball will jump out of water is
(A) $\frac{\sigma h}{\rho}$ (B) $\left(\frac{\sigma}{\rho} - 1\right)h$
(C) h (D) zero

12. A block of mass 2kg and specific gravity 5/2 is attached with a spring of force constant K = 100 N/m and is half dipped in the water. If extension in the spring is 1 cm, the force exerted by the bottom of the tank on block is– (Take g = 10 m/s^2)

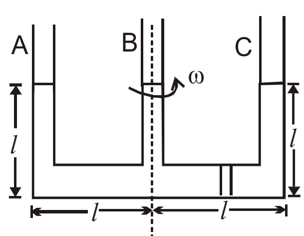


(A) 20N (B) 19N
(C) 15N (D) 16N

13. A stone is placed inside a container. The normal reaction between the stone and the container is N_1. Now a liquid is poured inside the container such that normal reaction between stone and the container is N_2 then (Assume no liquid between stone and container at the contace surface) –

(A) $N_2 < N_1$ (B) $N_2 > N_1$
(C) $N_2 = N_1$ (D) None of these

14. Figure shows a three arm tube in which a liquid is filled upto levels of height l. It is now rotated at an angular frequency ω about an axis passing through arm B. The angular frequency ω at which level of liquid of arm B becomes zero.



(A) $\sqrt{\frac{2g}{3l}}$ (B) $\sqrt{\frac{g}{l}}$

(C) $\sqrt{\frac{3g}{l}}$ (D) $\sqrt{\frac{3g}{2l}}$

15. A cuboidal piece of wood has dimensions a, b and c. Its relative density is d. It is floating in a larger body of water such that side a is vertical. It is pushed down a bit and released. The time period of SHM executed by it is :

(A) $2\pi\sqrt{\frac{abc}{g}}$ (B) $2\pi\sqrt{\frac{g}{da}}$

(C) $2\pi\sqrt{\frac{bc}{dg}}$ (D) $2\pi\sqrt{\frac{da}{g}}$

16. Two bodies having volumes V and 2V are suspended from the two arms of a common balance and they are found to balance each other. If larger body is immersed in oil (density d_1 = 0.9 gm/cm^3) and the smaller body is immersed in an unknown liquid, then the balance remain in equilibrium. The density of unknown liquid is given by :

(A) 2.4 gm/cm^3 (B) 1.8 gm/cm^3
(C) 0.45 gm/cm^3 (D) 2.7 gm/cm^3

17. A sphere of radius R and made of material of relative density σ has a concentric cavity of radius r. It just floats when placed in a tank full of water. The value of the ratio R/r will be

(A) $\left(\frac{\sigma}{\sigma-1}\right)^{1/3}$ (B) $\left(\frac{\sigma-1}{\sigma}\right)^{1/3}$

(C) $\left(\frac{\sigma+1}{\sigma}\right)^{1/3}$ (D) $\left(\frac{\sigma-1}{\sigma+1}\right)^{1/3}$

18. A uniform solid cylinder of density 0.8 g/cm^3 floats in equilibrium in a combination of two non-mixing liquid A and B with its axis vertical. The densities of liquid A and B are 0.7 g/cm^3 and 1.2 gm/cm^3. The height of liquid A is h_A = 1.2 cm and the length of the part of cylinder immersed in liquid B is h_B = 0.8 cm. Then the length of the cylinder in air is

(A) 0.21 m (B) 0.25 cm
(C) 0.35 cm (D) 0.4 cm

FLUID MECHANICS

19. Velocity of flow of water in a horizontal pipe is 10.0 m/s. Find the velocity- head or water ($g = 10.00\ m/s^2$)
(A) 9.00 m (B) 5.00 m
(C) 3.00 m (D) None of these

20. Water is flowing through a cylindrical pipe of cross- section area $0.09\ \pi\ m^2$ at a speed of 1.0 m/s. If the diameter of the pipe is halved, then find the speed of flow of water through it-
(A) 4.0 m/s (B) 6.0 m/s^2
(C) 4.0 m/s^2 (D) 6.0 m/s

21. Water is flowing through a horizontal tube of non- uniform cross- section. At a place the radius of the tube is 0.5 cm and the velocity of water there is 20 cm/s. What will be the velocity at another place where the radius of the tube is 1.0 cm?
(A) 3 cm/s (B) 7 cm/s
(C) 5 cm/s (D) 0.5 cm/s

22. Water is flowing in a horizontal pipe of non-uniform area of cross- section. The velocity of water at a place, where the radius of pipe is 0.01 m is 25 m/s. What will be the velocity of water where the radius of pipe is 0.02 m?
(A) 7.25 m/s (B) 6.75 m/s
(C) 6.25 m/s (D) None of these

23. Water is flowing through a horizontal pipe of non- uniform cross- section. The speed of water is 30 cm/s at a place where pressure is 10 cm(of water). Calculate the speed of water at the other place where the pressure is half of that of the first place-
(A) 100.4 cm/s (B) 101.4 cm/s
(C) 102.4 cm/s (D) 103.4 cm/s

24. Water enters a horizontal pipe of non-uniform cross-section with a velocity of 0.5 m/s and leaves the other end with a velocity of 0.7 m/s. The pressure of water at the first end is $10^3\ N/m^2$. Calculate pressure at the other end. (Density of water = $1.0 \times 10^3\ kg/m^3$)-
(A) 980 N/m^2 (B) 880 N/m^2
(C) 800 N/m (D) None of these

25. A water tank has a hole in its wall at a distance of 40 m below the free surface of water. Compute the velocity of flow of water from the hole. If the radius of the hole is 1 mm., find the rate of flow of water-
(A) 26 m/s , $8.8 \times 10^{-5}\ m^3/s$
(B) 28 m/s, $8.8 \times 10^{-5}\ m^3/s$
(C) 28 m/s, $6.8 \times 10^{-5}\ m^3/s$
(D) 26 m/s, $9.8 \times 10^{-5}\ m^3/s$

26. The relative velocity between two parallel layers of water is 8 cm/s and the perpendicular distance between them is 0.1 cm. Calculate the velocity- gradient-
(A) 90/s (B) 80.5 /s
(C) 80 /s. (D) None of these

27. There is a 1 mm thick layer of oil between a flat plate of area $10^{-2}\ m^2$ and a big plate. How much force is required to move the plate with a velocity of 1.5 cm/s^2? The coefficient of viscosity of oil is 1 poise-
(A) 1.5×10^{-3} N (B) 1.3×10^{-5} N
(C) 1.5×10^{-2} N (D) 1.5×10^{2} N

28. A steel shot of diameter 2 mm is dropped in a viscous liquid filled in a drum. Find the terminal speed of the shot. Density of the material of the shot = $8.0 \times 10^3\ kg/m^3$, density of liquid = $1.0\times 10^3\ kg/\ m^3$. Coefficient of viscosity of liquid = 1.0 kg/(m-s), g= 10 m/s^2
(A) 1.55 cm/s (B) 1.455 cm/s
(C) 5.1 cm/s (D) None of these

29. An air bubble (radius 0.4 mm) rises up in water. If the coefficient of viscosity of water be 1×10^{-3} kg/(m–s), then determine the terminal speed of the bubble density of air is negligible-
(A) 0.843 m/s (B) 3.048 m/s
(C) 0.483 m/s (D) 0.348 m/s

30. If an oil drop of density $0.95 \times 10^3\ kg/\ m^3$ and radius 10^{-4} cm is falling in air whose density is 1.3 km/m^3 and coefficient of viscosity is 18×10^{-6} kg/(m–s). Calculate the terminal speed of the drop.
(A) 0.00015 cm/s (B) 0.0005 cm/s
(C) 0.0115 cm/s (D) None of these

31. The terminal velocity of a ball in air is v, where acceleration due to gravity is g. Now the same ball is taken in a gravity free space where all other conditions are same. The ball is now pushed at a speed vv, then –

(A) The terminal velocity of the ball will be v/2

(B) The ball will move with a constant velocity

(C) The initial acceleration of the ball is 2g in opposite direction of the ball's velocity

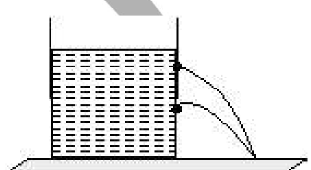
(D) The ball will finally stop (Given that density of the ball ρ = 2 times the density of air σ)

32. A tank is filled up to a height 2H with a liquid and is placed on a platform of height H from the ground. The distance x from the ground where a small hole is punched to get the maximum range R is –

(A) H (B) 1.25 H

(C) 1.5 H (D) 2H

33. In a cylindrical vessel containing liquid of density ρ, there are two holes in the side walls at heights of h_1 and h_2 respectively such that the range of efflux at the bottom of the vessel is same. The height of a hole, for which the range of efflux would be maximum, will be –



(A) $h_2 - h_1$ (B) $h_2 + h_1$

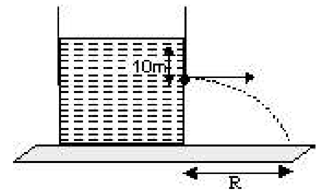
(C) $\frac{h_2 - h_1}{2}$ (D) $\frac{h_2 + h_1}{2}$

34. Two drops of same radius are falling through air with steady speed v. If the two drops coalesce, what would be the terminal speed

(A) 4v (B) 2v

(C) 3v (D) None of these

35. A large tank is filled with water (density = 10^3 kg/m^3). A small hole is made at a depth 10m below water surface. The range of water issuing out of the hole is R on ground. What extra pressure must be applied on the water surface so that the range becomes 2R (take 1 atm = 10^5 Pa and g = 10 m/s^2) :



(A) 9 atm (B) 4 atm

(C) 5 atm (D) 3 atm

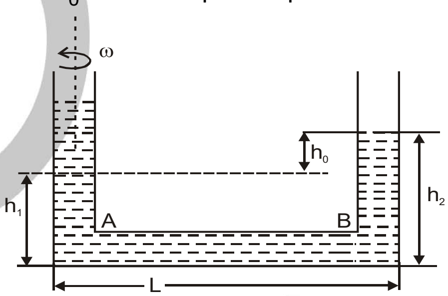
36. A ball of relative density 0.8 falls into water from a height of 2m. The depth to which the ball will sink is (neglect viscous forces) –

(A) 8m (B) 2 m

(C) 6m (D) 4 m

Passage (37 to 39)

A U-tube of base length L contains a liquid of density ρ in it. The tube is rotated about one of its vertical end with angular velocity ω as shown. The diameter of the tube is negligible. Take P_0 as atmospheric presure.



Answer the following questions : -

37. What is the force at B due to rotations of the u-tube ?

(A) A $\rho\omega^2$ (B) A $\rho\omega^2L^2$

(C) $\frac{A\rho\omega^2L^2}{2}$ (D) $\frac{A\rho\omega^2L^2}{4}$

38. What is the presure at B from left hand side.

(A) $P_0 + h_1 \rho g$ (B) $P_0 + \frac{h_1 \rho g}{2}$

(C) $2P_0 + h_1 \rho g$ (D) $P_0 + h_1 \rho g + \frac{\rho\omega^2 L^2}{2}$

39. The value of h_0 is -

(A) $\frac{\omega^2 L}{2g}$ (B) $\frac{\omega^2 L^2}{2g}$

(C) $\frac{\omega^2 L^2}{3g}$ (D) $\frac{\omega^2 L^2}{4g}$

40. A rectangular tank is placed on a horizontal ground and is filled with water to a height H above the base. A small hole is made on one vertical side at a depth D below the level of the water in the tank. The distance x from the bottom of the tank at which the water jet from the tank will hit the ground is

(A) $2\sqrt{D(H-D)}$ (B) $2\sqrt{DH}$

(C) $2\sqrt{D(H+D)}$ (D) $\frac{1}{2}\sqrt{DH}$

41. Water is flowing steadily through a horizontal tube of non uniform cross-section. If the pressure of water is 4×10^4 N/m^2 at a point where cross-section is 0.02 m^2 and velocity of flow is 2 m/s, what is pressure at a point where cross-section reduces to 0.01 m^2

(A) 1.4×10^4 N/m^2 (B) 3.4×10^4 N/m^2

(C) 2.4×10^{-4} N/m^2 (D) none of these

42. 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 H/η, ($\eta > 1$) and it takes T_2 time to take out the rest of water. If $T_1 = T_2$, then the value of η is :

(A) 2 (B) 3

(C) 4 (D) $2\sqrt{2}$

43. A cylindrical vessel open at the open at the top is 20 cm high and 10 cm in diameter. A circular hole whose cross-sectional area 1 cm^2 is cut at the centre of the bottom of the vessel. Water flows from a tube above it into the vessel at the rate 100 cm^{3}s^{-1}. The height of water in the vessel under state is (Take g = 1000 cms^{-2})

(A) 20 cm (B) 15 cm

(C) 10 cm (D) 5 cm

44. A vertical tank, open at the top, is filled with a liquid and rests on a smooth horizontal surface. A small hole is opened at the centre of one side of the tank. The area of cross-section of the tank is N times the area of the hole, where N is a large number. Neglect mass of the tank itself. The initial acceleration of the tank is

(A) $\frac{g}{2N}$ (B) $\frac{g}{\sqrt{2}N}$

(C) $\frac{g}{N}$ (D) $\frac{g}{2\sqrt{N}}$

45. A horizontal pipe line carries water in a streamline flow. At a point along the tube where the cross-sectional area is 10^{-2}m^2, the water velocity is 2 ms^{-1} and the pressure is 8000 Pa. The pressure of water at another point where the cross-sectional area is 0.5×10^{-2} m^2 is :

(A) 4000 Pa (B) 1000 Pa

(C) 2000 Pa (D) 3000 Pa

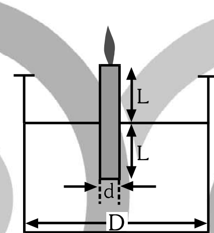
LEVEL – III | PREVIOUS YEARS

1. A sphere of mass M and radius R is falling in a viscous fluid. The terminal velocity attained by the falling object will be proportional to

(A) R^2 (B) R
(C) 1/R (D) $1/R^2$

2. Bernoulli's equation is a consequence of conservation of :–
(A) energy
(B) linear momentum.
(C) angular momentum.
(D) mass

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



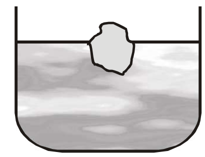
(A) remain at the same height
(B) fall at the rate of 1 cm/hour
(C) fall at the rate of 2 cm/hour
(D) go up at the rate of 1 cm/hour

4. By sucking through a straw, a student can reduce the pressure in his lungs to 750 mm of Hg (density = 13·6 gm/cm^3). Using the straw, he can drink water from a glas upto a maximum depth of
(A) 10 cm (B) 75 cm
(C) 13·6 cm (D) 1·36 cm

5. Which one of the following would a hydrogen balloon find easiest to lift :-
(A) One kg. of steel
(B) One kg. of lightly packed feathers
(C) One kg. of water
(D) All the same

6. A body is just floating in a liquid (their densities are equal). If the body is slightly pressed down and released then it will :-
(A) Start oscillating
(B) Sink to the bottom
(C) Come back to the same position immediately
(D) Come back to the same position slowly.

7. A body floats in a liquid contained in a beaker. The whole system is shown in fig. falling under gravity. The upthrust on the body due to liquid is



(A) Zero
(B) Equal to weight of liquid displaced
(C) Equal to weight of the body in air
(D) Equal to the weight of the immersed body.

8. The most characteristic property of a liquid is

(A) Elasticity (B) Fluidity
(C) Formlessness (D) Volume conservation

9. A boat having a length of 3 metre and breadth 2 metre is floating on a lake. The boat sinks by one cm when a man gets on it. The mass of the man is
(A) 60 kg (B) 62 kg
(C) 72 kg (D) 128 kg

10. If M_1 gm of a substance with specific gravity S_1 is mixed with M_2 gm of a substance with specific gravity S_2 and then the substances are used to make an alloy. What will be the specific gravity of the alloy ?
(A) $(M_1 + M_2)/S_1S_2$
(B) $(M_1 + M_2)/(M_1/S_1 + M_2/S_2)$
(C) $(M_1/S_1) + (M_1/S_2)/(M_1 + M_2)$
(D) $(M_1/S_1) + (M_2/S_2)/(M_1M_2)$

11. A man of weight 40 kg floats on water in a lake. His apparent weight is
(A) 40 kg (B) 35 kg
(C) zero (D) 20 kg

12. The barometric pressure and height on the earth are 10^5 Pa and 760 mm respectively. If it is taken to moon, then barometric height will be

(A) 76 mm (B) 126.6 mm
(C) zero (D) 760 mm

13. The reading a spring balance when a block is suspended from it in air is 60 N. This reading is changed to 40 N when the block is submerged water. The specific gravity of the block must be therefore.
(A) 3 (B) 2
(C) 6 (D) 3/2

14. A solid of density D is floating in a liquid of density d. If υ is the volume of solid submerged in the liquid and V is the total volume of the solid, then $\frac{\upsilon}{V}$ is equal to

(A) $\frac{d}{V}$ (B) $\frac{D}{d}$

(C) $\frac{D}{(D+d)}$ (D) $\frac{D+d}{D}$

15. A body of volume 100 c.c. is immersed completely in water contained in a jar. The weight of water and the jar before immersion of the body was 700g wt. After immersion weight of water and jar will be.

(A) 700 g wt. (B) 800 g wt.
(C) 500 g wt. (D) 100 g wt.

16. 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 :

(A) H (B) 2H
(C) 7H (D) 8H

17. The total weight of a piece of wood is 6 kg. In the floating state in water its $\frac{1}{3}$ part remains inside the water. On this floating solid, what maximum weight is to be put such that whole of the piece of wood is drowned in the water ?
(A) 12 kg (B) 10 kg
(C) 14 kg (d) 15 kg

18. A sample of metal weights 210 gram in air, 180 gram in water and 120 gram in an unknown liquid. Then
(A) the density of metal is 3 g/cm^3
(B) the density of metal is 7 g/cm^3
(C) density of metal is 4 times the density of the unknown liquid
(D) the metal will float in water

19. A wooden cube just floats inside water when a 200 g mass is placed on it. When the mass is removed the cube is 2 cm above water level. The side of cube is
(A) 5 cm (B) 10 cm
(C) 15 cm (D) 20 cm

20. 'Torr' is the unit of :-
(A) Pressure (B) Density
(C) Volume (D) Flux

21. A sphere is floating in water its 1/3rd part is outside the water and when sphere is floating in unknown liquid, its $\frac{3}{4}$th part is outside the liquid then density of liquid is
(A) 4/9 gm/c.c. (B) 9/4 gm/c.c.
(C) 8/3 gm/c.c. (D) 3/8 gm/c.c.

22. Which of the following works on Pascal's law ?

(A) Sprayer (B) Venturimeter
(C) Hydraulic lift (D) Aneroid barometer

23. An object of weight W and density ρ is submerged in a fluid of density ρ_1. Its appearent weight will be

(A) $W(\rho-\rho_1)$ (B) $\frac{(\rho-\rho_1)}{W}$

(C) $W\left(1-\frac{\rho_1}{\rho}\right)$ (D) $W(\rho_1-\rho)$

24. Water stands upto a height h behind the vertical wall of a dam. What is the net horizontal force pushing the dam down by the stream, if width of the dam is σ ? (ρ = density of water)

(A) $2h\sigma g$ (B) $\frac{h^2\sigma\rho g}{2}$

(C) $\frac{h^2\sigma\rho g}{4}$ (D) $\frac{h\sigma\rho g}{4}$

25. A U-tube is partially filled with water. Oil which does not mix with water is next poured into one side, until water rises by 25 cm on the other side. If the density of the oil is 0.8 g/cc, the oil level will stand higher than the water level by
(A) 6.25 cm (B) 12.50 cm
(C) 18.75 cm (D) 25.00

26. Which law states that the magnitude of pressure within fluid is equal in all parts ?

(A) pascal's law (B) Gay-Lusac's law
(C) Dalton's law (D) None of these

27. A body measures 5 N in air and 2 N when put in water. The buoyant force is
(A) 7 N (B) 9 N

(C) 3 N (D) None of these

28. Hydraulic press is based upon
(A) Archimede's principle
(B) Bernoulli's theorem
(C) Pascal's law
(D) Reynold's number

29. A wooden block is taken to the bottom of a lake of water and then released. it rise up with a
(A) Constant acceleration
(B) Decreasing acceleration
(C) Constant velocity
(D) Decreasing velocity

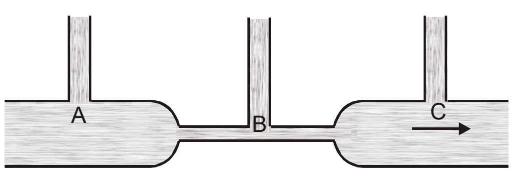
30. Magnus effect is very near to the
(A) magnetic field
(B) electric field
(C) Bernoulli's theorem
(D) magnetic effect of current

31. A cylinder is filled with non viscous liquid of density d to a height h_0 and a hole is made at a height h_1 from the bottom of the cylinder. The velocity of liquid issuing out of the hole is

(A) $\sqrt{(2gh_0)}$ (B) $\sqrt{2g(h_0 - h_1)}$
(C) $\sqrt{dgh_1}$ (D) $\sqrt{dgh_0}$

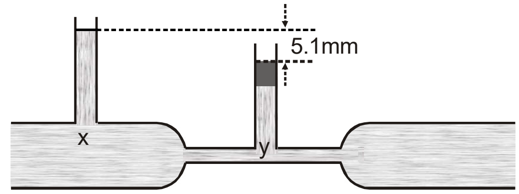
32. Sudden fall of atmospheric pressure by a large amount indicate
(A) Storm (B) Rain
(C) Fair weather (D) Cold wave

33. In the figure below 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

34. The diagram (fig.) shows a venturimeter, through which water is flowing. The speed of water at X is 2 cm/sec. The speed of water at Y (taking g = 1000 cm/sec^2) is :



(A) 23 cm/sec (B) 32 cm/sec
(C) 101 cm/sec (D) 1024 cm/sec

35. A cylindrical vessel is filled with water up to height H.A hole is bored in the wall at a depth h from the free surface of water. For maximum range, h is equal to

(A) $\frac{H}{4}$ (B) $\frac{H}{2}$

(C) $\frac{3H}{4}$ (D) H.

36. A tank of height 5 m is full of water. There is a hole of cross sectional area 1 cm^2 in its bottom. The initial volume of water that will come out from this hole per second is
(A) 10^{-3} m^3/s (B) 10^{-4} m^3/s
(C) 10 m^3/s (D) 10^{-2} m^3/s.

37. The gale blows over a house. The force due to gale on the roof is.
(A) in the downward direction
(B) in upward direction
(C) zero
(D) in the horizontal direction

38. In a streamline flow if the gravitational head is h. The kinetic and pressure heads are.

(A) v^2 / g and P / ρ (B) $v^2 / 2g$ and $P / \rho g$

(C) $v^2 / 2$ and P / ρ (D) $v^2 / 2$ and $P / \rho g$.

39. To calculate the rate of flow of a liquid, which of the following is used.?
(A) Stoke's law
(B) Bernouli Theorem
(C) Poissuelli's Law
(D) Conservation for pressure.

40. Paint Gun depends upon :
(A) Bernoulli's principle
(B) Boyle's law
(C) Faraday's law
(D) Archimede's principle

41. An incompressible fluid flows steadily through a cylindrical pipe which has radius 2 R at point A and radius R at point B farther along the flow direction. If the velocity at point A is v, its velocity at point B is

(A) 2v (B) v

(C) $\frac{v}{2}$ (D) 4v

42. Water is flowing through a non-uniform radius tube. If ratio of the radius of entry and exit end of the pipe is 3 : 2 then the ratio of velocities of entring and exit liquid is :-

(A) 4 : 9 (B) 9 : 4

(C) 8 : 27 (D) 1 : 1

43. An aeroplane of mass 3×10^4 kg and total wing area of 120 m^2 is in a level flight at some height. The difference in pressure between the upper and lower surfaces of its wings in kilopascals is ($g=10m/s^2$)

(A) 2.5 (B) 5.0

(C) 10.0 (D) 12.5

44. A hole is there in the bottom of the tank having water. If total pressure at bottom is 3 atm (1 atm = 10^5 N m^{-2}), then velocity of water flowing from hole is

(A) $\sqrt{400}\ ms^{-1}$ (B) $\sqrt{600}\ ms^{-1}$

(C) $\sqrt{60}\ ms^{-1}$ (D) none of these

45. Scent sprayer is based on

(A) Charle's law

(B) Archimede's principle

(C) Boyle's law

(D) Bernoulli's theorem

46. Bernoulli's equation for steady, non-viscous, in-compressible flow expresses the

(A) Conservation of angular momentum

(B) Conservation of density

(C) Conservation of momentum

(D) Conservation of energy.

47. Application of Bernoulli's theorem can be seen in

(A) Dynamic lift to aeroplane

(B) Hydraulic press

(C) Helicopter

(D) None of these

48. Two drops of equal radius are falling through air with a steady velocity of 5cm/sec. If the two drops coalesce, then its terminal velocity will be –

(A) $4^{1/3} \times 5$ cm/Sec. (B) $4^{1/3}$ cm/Sec.

(C) $5^{1/3} \times 4$ cm/Sec. (D) $4^{2/3} \times 5$ cm/Sec.

49. The force F on a sphere of radius 'a' moving in a medium with velocity 'v' is given by $F = 6\pi\eta av$. The dimensions of η are

(A) $ML^{-1}T^{-1}$ (B) MT^{-1}

(C) MLT^{-2} (D) ML^{-3}

50. If V_1 and V_2 be the volumes of the liquids flowing out of the same tube in the same interval of time and η_1 and η_2 their coefficients of viscosity respectively, then

(A) $\frac{\eta_1}{\eta_2} = \frac{V_2}{V_1}$ (B) $\frac{\eta_1}{\eta_2} = \frac{V_1}{V_2}$

(C) $\frac{\eta_1}{\eta_2} = \frac{V_1^2}{V_2^2}$ (D) $\frac{\eta_1}{\eta_2} = \frac{V_2^2}{V_1^2}$

51. A copper ball of radius 'r' travels with a uniform speed 'v' in a viscous fluid. If the ball is changed with another ball of radius '2r', then new uniform speed will be.

(A) v (B) 2v

(C) 4v (D) 8v

52. More viscous oil is used in summer than in winter in motors due to

(A) rise in temperature in summer, the viscosity of oil decreases

(B) rise in temperatrue in summer, viscosity of oil increases

(C) S. T. of oil increases

(D) S. T. of oil decreases

53. The rate of flow of liquid through a capillary tube, in an experiment to determine the viscosity of the liquid, increases

(A) when the pressure of the tube is increased

(B) when the length of the tube is increased

(C) when the radius of the tube is increased

(D) none of the above

54. Speed of 2 cm radius ball in a viscous liquid is 20 cm s^{-1}. Then the speed of 1 cm radius ball

in the same liquid is
(A) 5 cm/s (B) 10 cm/s
(C) 40 cm/s (D) 80 cm/s

55. The velocity of falling rain drop attain limited value because of
(A) surface tension
(B) upthrust due to air
(C) viscous force exerted by air
(D) air current

56. Poise is the unit of
(A) Pressure (B) Friction
(C) Surface tension (D) Viscosity

57. Two rain drops falling through air have radii in the ratio 1:2. They will have terminal velocity in the ratio.
(A) 4 : 1 (B) 1 : 4
(C) 2 : 1 (D) 1 : 2

58. A wind with speed 40 m/s blows parallel to the roof of a house. The area of the roof is 250 m^2. Assuming that the pressure inside the house is atmospheric pressure, the force exerted by the wind on the roof and the direction of the force will be -
($P_{air} = 1.2\ kg/m^3$)
(A) 2.4×10^5 N, upwards
(B) 2.4×10^5 N, downwards
(C) 4.8×10^5 N, downwards
(D) 4.8×10^5 N, upwards

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

(A) $\{1 + (n + 1)p\}\rho$ (B) $\{2 + (n + 1)p\}\rho$
(C) $\{2 + (n - 1)p\}\rho$ (D) $\{1 + (n - 1)p\}\rho$

ANSWER-KEY

Level -I

1.	A	**2.**	C	**3.**	A	**4.**	B	**5.**	A	**6.**	A	**7.**	B
8.	B	**9.**	C	**10.**	D	**11.**	D	**12.**	A	**13.**	A	**14.**	C
15.	B	**16.**	D	**17.**	B	**18.**	D	**19.**	A	**20.**	B	**21.**	C
22.	C	**23.**	B	**24.**	C	**25.**	A	**26.**	A	**27.**	D	**28.**	B
29.	B	**30.**	C	**31.**	A	**32.**	A	**33.**	B				

Level -II

1	**C**	**2**	**A**	**3**	**B**	**4**	**B**	**5**	**A**	**6**	**B**	**7**	**A**
8	**C**	**9**	**B**	**10**	**D**	**11**	**B**	**12**	**B**	**13**	**B**	**14**	**C**
15	**D**	**16**	**B**	**17**	**A**	**18**	**B**	**19**	**B**	**20**	**A**	**21**	**C**
22	**C**	**23**	**D**	**24**	**B**	**25**	**B**	**26**	**C**	**27**	**C**	**28**	**A**
29	**D**	**30**	**C**	**31**	**D**	**32**	**C**	**33**	**D**	**34**	**A**	**35**	**D**
36	**A**	**37**	**C**	**38**	**D**	**39**	**D**	**40**	**A**	**41**	**B**	**42**	**C**
43	**D**	**44**	**C**	**45**	**C**								

Level -III

1.	**A**	**2.**	**A**	**3.**	**B**	**4.**	**C**	**5.**	**B**	**6.**	**B**	**7.**	**A**
8.	**D**	**9.**	**A**	**10.**	**B**	**11.**	**C**	**12.**	**C**	**13.**	**A**	**14.**	**B**
15.	**B**	**16.**	**C**	**17.**	**A**	**18.**	**B**	**19.**	**B**	**20.**	**A**	**21.**	**C**
22.	**C**	**23.**	**C**	**24.**	**B**	**25.**	**B**	**26.**	**A**	**27.**	**C**	**28.**	**C**
29.	**A**	**30.**	**C**	**31.**	**B**	**32.**	**A**	**33.**	**D**	**34.**	**B**	**35.**	**B**
36.	**A**	**37.**	**B**	**38.**	**B**	**39.**	**C**	**40.**	**A**	**41.**	**D**	**42.**	**A**
43.	**A**	**44.**	**A**	**45.**	**D**	**46.**	**D**	**47.**	**A**	**48.**	**A**	**49.**	**A**
50.	**A**	**51.**	**C**	**52.**	**A**	**53.**	**A,C**	**54.**	**A**	**55.**	**C**	**56.**	**D**
57.	**B**	**58.**	**A**	**59.**	**D**								