Pressure at the tip of the anvil, $p = \dfrac{\text{Force}}{\text{Area}}$

$\therefore \quad p = \dfrac{F}{\pi r^2} = \dfrac{50000}{3.14 \times (2.5 \times 10^{-4})^2} = 2.5 \times 10^{11}$ Pa

97 (*b*) Given, pressure, $p = 10\,\text{atm} = 10 \times 1.013 \times 10^5$ Pa

$(\because 1\text{ atm} = 1.013 \times 10^5\text{ Pa})$

$= 1.013 \times 10^6$ Pa

Bulk modulus for glass, $B = 37 \times 10^9\ \text{Nm}^{-2}$

(Using value from table given in book)

Fractional change in volume $\left(\dfrac{\Delta V}{V}\right) = ?$

Bulk modulus, $|B| = \dfrac{p}{\Delta V/V} = \dfrac{pV}{\Delta V}$

$$\therefore \quad \frac{\Delta V}{V} = \frac{p}{B} = \frac{1.013 \times 10^6}{37 \times 10^9} = \frac{101.3}{37} \times 10^{-5}$$

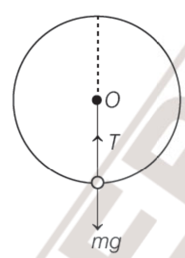
$= 2.74 \times 10^{-5}$

98 (*a*) Given, mass, $m = 14.5$ kg

Length of wire, $l = 1$m

Angular frequency, $\nu = 2\ \text{revs}^{-1}$

Angular velocity, $\omega = 2\pi\nu = 2\pi \times 2 = 4\pi\ \text{rads}^{-1}$



Area of cross-section of wire,

$A = 0.065\ \text{cm}^2 = 6.5 \times 10^{-6}\ \text{m}^2$

Young's modulus for steel, $Y = 2 \times 10^{11}\ \text{Nm}^{-2}$

At lowest point of the vertical circle,

$$T - mg = ml\omega^2$$

$\Rightarrow T = mg + ml\omega^2$

$= (14.5 \times 9.8) + [14.5 \times 1 \times (4\pi)^2]$

$= 14.5\,(9.8 + 16\pi^2)$

$= 14.5\,(9.8 + 16 \times 9.87) \qquad (\because \pi^2 = 9.87)$

$= 14.5 \times 167.72$ N $= 2431.94$ N

Young's modulus, $Y = \dfrac{\text{Stress}}{\text{Strain}} = \dfrac{T/A}{\Delta l / l} = \dfrac{Tl}{A\Delta l}$

$$\therefore \quad \Delta l = \frac{Tl}{AY} = \frac{2431.94 \times 1}{6.5 \times 10^{-6} \times 2 \times 10^{11}}$$

$= 1.87 \times 10^{-3}$ m $= 1.87$ mm

99 (*b*) Given, for steel wire

Length, $l_1 = 4.7$ m

Area of cross-section, $A_1 = 3.0 \times 10^{-5}\ \text{m}^2$

For copper wire, length, $l_2 = 3.5$ m

Area of cross-section, $A_2 = 4.0 \times 10^{-5}\ \text{m}^2$

Let F be the given load under which steel and copper wires be stretched by the same amount Δl.

Young's modulus,

$$Y = \frac{F/A}{\Delta l / l} = \frac{F \times l}{A \times \Delta l}$$

For steel, Young's modulus, $Y_s = \dfrac{F \times l_1}{A_1 \times \Delta l}$ ...(i)

For copper, Young's modulus, $Y_c = \dfrac{F \times l_2}{A_2 \times \Delta l}$ ...(ii)

On dividing Eq. (i) by Eq. (ii), we get

$$\frac{Y_s}{Y_c} = \frac{F \times l_1}{A_1 \times \Delta l} \times \frac{A_2 \times \Delta l}{F \times l_2}$$

$$= \frac{l_1}{l_2} \times \frac{A_2}{A_1} = \frac{4.7}{3.5} \times \frac{4.0 \times 10^{-5}}{3.0 \times 10^{-5}}$$

$$= \frac{18.8}{10.5} = 1.79 = 1.8$$

100 (*c*) Density of water at the surface, $\rho = 1.03 \times 10^3\ \text{kgm}^{-3}$

Pressure, $p = 80.0\ \text{atm} = 80.0 \times 1.013 \times 10^5$ Pa

$(\because 1\text{ atm} = 1.013 \times 10^5\text{ Pa})$

Compressibility of water $= 45.8 \times 10^{-11}\ \text{Pa}^{-1}$

Let V and V' be the volumes of certain mass of water at the surface and at a given depth. The density of water at the given depth be ρ'.

Volume of water at the surface, $V = m/\rho$

$[\because$ where, m = mass$]$

At the given depth, $V' = m/\rho'$

$\therefore$ Change in volume, $\Delta V = V - V' = m\left(\dfrac{1}{\rho} - \dfrac{1}{\rho'}\right)$

Volumetric strain $= \dfrac{\Delta V}{V} = m\left(\dfrac{1}{\rho} - \dfrac{1}{\rho'}\right) \times \dfrac{\rho}{m} = \left(1 - \dfrac{\rho}{\rho'}\right)$ ...(i)

$$|\text{Compressibility}| = \frac{1}{|\text{Bulk modulus } B|} = \frac{1}{\dfrac{\Delta p}{\Delta V/V}} = \frac{\Delta V}{\Delta p V}$$

where, Δp is per unit increase in pressure.

On putting the value of $\dfrac{\Delta V}{V}$ from Eq. (i)

$$45.8 \times 10^{-11} = \left(1 - \frac{\rho}{\rho'}\right) \times \frac{1}{80 \times 1.013 \times 10^5}$$

$$45.8 \times 10^{-11} \times 80 \times 1.013 \times 10^5 = 1 - \frac{1.03 \times 10^3}{\rho'}$$

$$\Rightarrow \quad 3.712 \times 10^{-3} = 1 - \frac{1.03 \times 10^3}{\rho'}$$

$$\Rightarrow \quad \frac{1.03 \times 10^3}{\rho'} = 1 - 3.712 \times 10^{-3}$$

$$\therefore \quad \rho' = \frac{1.03 \times 10^3}{1 - 0.003712} = 1.034 \times 10^3\ \text{kgm}^{-3}$$

101 (*b*) Given, initial volume, $V_1 = 100$ L

Final volume, $V_2 = 100.5$ L

$\therefore$ Increase in volume, $\Delta V = V_2 - V_1 = 100.5 - 100.0$

$= 0.5\ \text{L} = 0.5 \times 10^{-3}\ \text{m}^3$

$(\because 1\,\text{L} = 10^{-3}\ \text{m}^3)$

Increase in pressure, $\Delta p = 100.0$ atm

$= 100.0 \times 1.013 \times 10^5$ Pa

$(\because 1 \text{ atm} = 1.013 \times 10^5 \text{ Pa})$

$= 1.013 \times 10^7$ Pa

Bulk modulus of water, $|B_w| = \dfrac{\Delta p}{(\Delta V/V)} = \dfrac{\Delta p V}{\Delta V}$

$$= \frac{1.013 \times 10^7 \times 100 \times 10^{-3}}{0.5 \times 10^{-3}}$$

$$= \frac{10.13}{5} \times 10^9 = 2.026 \times 10^9 \text{ Pa}$$

Bulk modulus of air, $|B_a| = 1.0 \times 10^5$ Pa

$$\therefore \frac{\text{Bulk modulus of water } |B_w|}{\text{Bulk modulus of air } |B_a|} = \frac{2.026 \times 10^9}{1.0 \times 10^5} = 2.026 \times 10^4$$

102 (*d*) Given, total mass supported by cylindrical columns,

$m = 50000$ kg

Total weight supported by cylindrical columns $= mg$

$= 50000 \times 9.8 = 490000$ N

$\therefore$ Load acting on each cylindrical support,

$$F = \frac{mg}{4} = \frac{490000}{4} = 122500 \text{ N}$$

Area of cross-section of each cylindrical column,

$$A = \pi r_2^2 - \pi r_1^2 = \pi(r_2^2 - r_1^2)$$

where, r_1 and r_2 are the inner and outer radius of each column, respectively.

$\therefore \quad A = 3.14[(0.6)^2 - (0.3)^2]$

$[\because r_1 = 0.3 \text{ cm}, r_2 = 0.6 \text{ cm}]$

$= 3.14 \times 0.27 \text{ m}^2$

Young's modulus, $Y = 2 \times 10^{11}$ Pa

$$\text{Compressional strain} = \frac{\text{Compressional stress}}{\text{Young's modulus}} = \frac{F}{AY}$$

$$= \frac{122500}{(3.14 \times 0.27) \times 2 \times 10^{11}} = 7.22 \times 10^{-7}$$

103 (*c*) Given, diameter of each rivet, $D = 6$ mm

$\therefore$ Radius, $r = \dfrac{D}{2} = 3 \text{ mm} = 3 \times 10^{-3}$ m

Maximum shearing stress on each rivet $= 6.9 \times 10^7$ Pa.

Let w be the maximum load that can be subjected to the riveted strip. As each rivet carry one-quarter of the load, therefore

Load on each rivet (maximum shearing force) $= w/4$

$$\text{Maximum shearing stress} = \frac{\text{Maximum shearing force}}{\text{Area}}$$

$$\therefore 6.9 \times 10^7 = \frac{w/4}{\pi r^2} \Rightarrow w = 6.9 \times 10^7 \times 4\pi r^2$$

$= 6.9 \times 10^7 \times 4 \times 3.14 \times (3 \times 10^{-3})^2$

$= 6.9 \times 4 \times 3.14 \times 9 \times 10^{-6} \times 10^7$

$= 7.8 \times 10^3$ N

104 (*b*) Given, change in volume, $\Delta V = V \times \dfrac{0.10}{100}$

or $\dfrac{\Delta V}{V} = \dfrac{0.10}{100} = 1 \times 10^{-3}$

Bulk modulus of water, $B = 2.2 \times 10^9 \text{ Nm}^{-2}$

$\because$ Bulk modulus of water, $|B| = \dfrac{\Delta p}{\Delta V/V}$

or pressure on water, $\Delta p = |B| \times \dfrac{\Delta V}{V}$

$= 2.2 \times 10^9 \times 1 \times 10^{-3}$

$= 2.2 \times 10^6 \text{ Nm}^{-2}$

105 (*b*) Given, each side of cube, $l = 10 \text{ cm} = 0.1$ m

Hydraulic pressure, $p = 7 \times 10^6$ Pa

Bulk modulus for copper, $B = 140 \times 10^9$ Pa

Volume of contraction, $\Delta V = ?$

Volume of the cube,

$$V = l^3 = (0.1)^3 = 1 \times 10^{-3} \text{ m}^3$$

$\because$ Bulk modulus for copper,

$$|B| = \frac{p}{\Delta V/V} = \frac{pV}{\Delta V} \text{ or } \Delta V = \frac{pV}{|B|}$$

Contraction of a solid copper cube,

$$\Delta V = \frac{7 \times 10^6 \times 1 \times 10^{-3}}{140 \times 10^9} = \frac{1}{20} \times 10^{-6} \text{ m}^3$$

$= 0.05 \times 10^{-6} \text{ m}^3 = 5 \times 10^{-8} \text{ m}^3$

106 (*c*) Given, radius of steel cable

$r = 1.5 \text{ cm} = 1.5 \times 10^{-2}$ m

Maximum stress $= 10^8 \text{ Nm}^{-2}$

Area of cross-section of steel cable, $A = \pi r^2$

$= 3.14 \times (1.5 \times 10^{-2})^2 \text{ m}^2$

$= 3.14 \times 2.25 \times 10^{-4} \text{ m}^2$

$$\text{Maximum stress} = \frac{\text{Maximum force or load}}{\text{Area of cross-section}}$$

Maximum force or load = Maximum stress $\times$ Area of cross-section

$= 10^8 \times (3.14 \times 2.25 \times 10^{-4})$

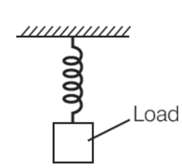
$= 7.065 \times 10^4 = 7.1 \times 10^4$ N

108 (*d*) $\because$ Breaking stress $= \dfrac{\text{Breaking force}}{\text{Area of cross-section}}$

When length of the wire changes, area of cross-section remains same. Hence, breaking force will be same.

Thus, when the length of the wire is reduced to half of its original length, then the maximum load it can withstand without breaking remains same.

109 (*c*) Consider the diagram shown alongside, where a spring is stretched by applying a load to its free end. Clearly the length and shape of the spring changes.



Thus, the change in length corresponds to longitudinal strain and change in shape corresponds to shearing strain.

110 (*b*) As, Young's modulus, $Y = \frac{\text{Stress}}{\text{Strain}} = \frac{FL}{A\Delta L}$

$$= \frac{F}{\pi(D/2)^2} \times \frac{L}{\Delta L} = \frac{4FL}{\pi D^2 \Delta L}$$

where, D is the diameter of wire.

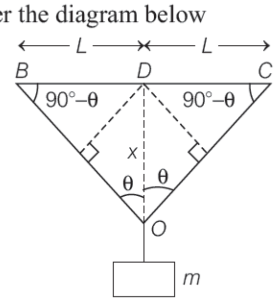
$$D^2 = \frac{4FL}{\pi \Delta L Y} \Rightarrow D = \sqrt{\frac{4FL}{\pi \Delta L Y}}$$

Hence, $D \propto \sqrt{\frac{1}{Y}}$ (because F and $\frac{L}{\Delta L}$ are constants)

Then, ratio of diameters of copper and iron is

$$\frac{D_{\text{copper}}}{D_{\text{iron}}} = \sqrt{\frac{Y_{\text{iron}}}{Y_{\text{copper}}}}$$

111 (*a*) Consider the diagram below



Given, length of wire = $2L$

Cross-section area of wire = A

Length, $DO = x$

Hence, change in length,

$$\Delta L = BO + OC - (BD + DC)$$
$$= 2BO - 2BD \quad (\because BO = OC, BD = DC)$$
$$= 2(BO - BD) = 2[(x^2 + L^2)^{1/2} - L]$$

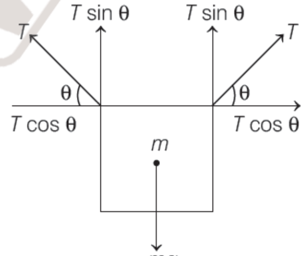
[$\because$ In $\Delta ABDO$, $BO^2 = BD^2 + DO^2$ and $BD = L$]

$$= 2L\left[\left(1 + \frac{x^2}{L^2}\right)^{1/2} - 1\right]$$

$$= 2L\left[1 + \frac{1}{2}\frac{x^2}{L^2} - 1\right] = \frac{x^2}{L} \quad (\because x << L)$$

$$\therefore \quad \text{Strain} = \frac{\Delta L}{2L} = \frac{x^2/L}{2L} = \frac{x^2}{2L^2}$$

112 (*c*) Consider the FBD diagram of the rectangular frame.



From above figure,

Balancing vertical forces $2T\sin\theta - mg = 0$

(T is tension in the string)

$$\Rightarrow \quad 2T\sin\theta = mg \quad \text{...(i)}$$

Now, total horizontal force = $T\cos\theta - T\cos\theta = 0$

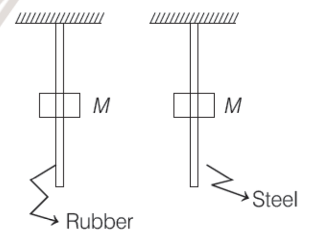
Now, from Eq. (i), $T = \frac{mg}{2\sin\theta}$

So, $T \propto \frac{1}{\sin\theta}$

As $\sin\theta$ in maximum in case (b) (given in question), so tension is minimum in (b).

113 (*d*) Consider the diagram,

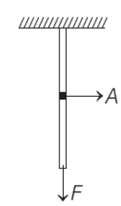
A mass M is attached at the centre of the two cylindrical rods as shown below. As the mass is attached to both the rods, both rods will be elongated, but due to different elastic properties of material, there is no change in shape of steel rod, while for rubber rod, the shape of the bottom edge tappered to a tip at the centre.



114 (*c*) It is clear from the two graphs, the ultimate tensile strength for material (ii) is greater, hence material (ii) is elastic over larger region as compared to material (i).

For material (ii) fracture point is nearer, so it is more brittle.

115 (*d*) A wire is suspended from the ceiling and stretched under the action of a weight F suspended from its other end. As shown in the diagram,



Clearly, force at cross-section is F.

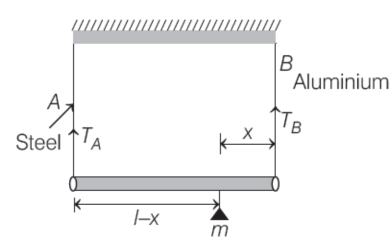
$$\text{Stress} = \frac{\text{Tension}}{\text{Area}} = \frac{F}{A}$$

where, A is cross-section area of the wire.

Tension at any cross-section A of the wire

= Applied force = F

116 (*b*) Let the mass m is placed at x from the end B.



Let T_A and T_B be the tension in wire A and wire B, respectively.

For the rotational equilibrium of the system,

$$\Sigma\tau = 0 \qquad \text{(total torque = 0)}$$

$$\Rightarrow \quad T_B x - T_A(l - x) = 0 \Rightarrow \frac{T_B}{T_A} = \frac{l - x}{x}$$

Stress in wire A, $\quad S_A = \dfrac{T_A}{a_A}$

Stress in wire B, $\quad S_B = \dfrac{T_B}{a_B}$

where, a_A and a_B are cross-sectional areas of wire A and B, respectively.

According to question, $a_B = 2a_A$

Now, for equal stress, $S_A = S_B$

$$\Rightarrow \quad \frac{T_A}{a_A} = \frac{T_B}{a_B} \Rightarrow \frac{T_B}{T_A} = \frac{a_B}{a_A} = 2$$

$$\Rightarrow \quad \frac{l - x}{x} = 2$$

$$\Rightarrow \quad \frac{l}{x} - 1 = 2 \qquad \left[\because \frac{T_B}{T_A} = \frac{l - x}{x}\right]$$

$$\Rightarrow \quad x = \frac{l}{3}$$

$$\therefore \quad l - x = l - l/3 = \frac{2l}{3}$$

Hence, mass m should be placed closer to wire B.

For equal strain, $(\text{strain})_A = (\text{strain})_B$

$$\Rightarrow \quad \frac{S_A}{Y_A} = \frac{S_B}{Y_B}$$

(where, Y_A and Y_B are Young's moduli)

$$\Rightarrow \quad \frac{T_A / a_A}{Y_{\text{steel}}} = \frac{T_B / a_B}{Y_{\text{Al}}}$$

$$\Rightarrow \quad \frac{Y_{\text{steel}}}{Y_{\text{Al}}} = \frac{T_A}{T_B} \times \frac{a_B}{A_B} = \left(\frac{x}{l - x}\right)\left(\frac{2a_A}{a_A}\right)$$

$$\Rightarrow \quad \frac{200 \times 10^9}{70 \times 10^9} = \frac{2x}{l - x} \Rightarrow \frac{20}{7} = \frac{2x}{l - x}$$

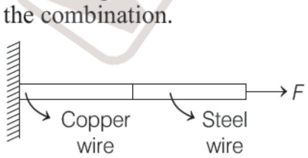
$$\Rightarrow \quad \frac{10}{7} = \frac{x}{l - x} \quad \Rightarrow \quad 10l - 10x = 7x$$

$$\Rightarrow \quad 17x = 10l \quad \Rightarrow \quad x = \frac{10l}{17}$$

$$l - x = l - \frac{10l}{17} = \frac{7l}{17}$$

Hence, mass m should be placed closer to wire A.

117 (*a*) Consider the diagram where a deforming force F is applied to the combination.



For steel wire, $Y_{\text{steel}} = \dfrac{\text{Stress}}{\text{Strain}} = \dfrac{F/A}{\text{Strain}}$

where, F is tension in each wire and A is cross-section area of each wire.

As F and A are same for both the wires, hence stress will be same for both the wires.

$$(\text{Strain})_{\text{steel}} = \frac{\text{Stress}}{Y_{\text{steel}}}, (\text{Strain})_{\text{copper}} = \frac{\text{Stress}}{Y_{\text{copper}}}$$

As, $\quad Y_{\text{steel}} \neq Y_{\text{copper}}$

Hence, the two wires will have different strains.

118 (*a*) Given, length of wires, $L_1 = L$ and $L_2 = 2L$

Radius of wires, $r_1 = r$ and $r_2 = 2r$

Force on the wires, $F_1 = F$ and $F_2 = 2F$

Young's modulus, $Y = \dfrac{FL}{Al}$

[where, F = force, L = length, A = area and l = expansion in length]

$$l = \frac{FL}{\pi r^2 Y}$$

Ratio of expansion for both the wires

$$\frac{l_2}{l_1} = \frac{F_2}{F_1}\frac{L_2}{L_1}\left(\frac{r_1}{r_2}\right)^2$$

$$= 2 \times 2 \times \left(\frac{1}{2}\right)^2 = 1$$

$\therefore\ l_2 = l_1$, i.e. the increament in length will be same, i.e. l.

119 (*a*) As the ivory ball is more elastic than wet clay ball, therefore it will tend to regain its shape instantaneously after the collision. Hence, there will be a large energy and momentum transfer compared to the wet clay.

Thus, the ivory ball will rise higher after the collision.

120 (*c*) Given, decreament in volume $\dfrac{\Delta V}{V} = 0.1\ \%$

Density of sea water $= 10^3\ \text{kg m}^{-3}$

Bulk modulus of rubber $= 9 \times 10^8\ \text{Nm}^{-2}$

Gravitational acceleration, $g = 10\ \text{ms}^{-2}$

Let h be the depth at which the rubber ball be taken, then $\quad p = h\rho g \qquad$ ...(i)

By definition of bulk modulus,

$$B = -\frac{p}{\Delta V / V}$$

The negative sign shows that with increase in pressure, a decrease in volume occurs.

$$\therefore \quad p = |B|\frac{\Delta V}{V}$$

Using Eq. (i), we get $h\rho g = |B|\dfrac{\Delta V}{V}$ or $h = \dfrac{|B|}{\rho g}\dfrac{\Delta V}{V}$

Substituting the given values, we get

$$h = \frac{9 \times 10^8\ \text{Nm}^{-2}}{10^3\ \text{kgm}^{-3} \times 10\ \text{ms}^{-2}}\left(\frac{0.1}{100}\right) = 90\ \text{m}$$

CHAPTER > 10

Mechanical Properties of Fluids

KEY NOTES

- Fluids are those substances which can flow. Liquids and gases falls in the category of fluids.

Pressure and Pascal's Law

- When an object is submerged in a fluid at rest, the fluid exerts a force on its surface. This force is perpendicular to the surface in contact with it.
- The force exerted by a liquid at rest per unit area of the surface in contact with the liquid is called as **pressure**.

$$\text{Pressure } (p) = \frac{\text{Force } (F)}{\text{Area } (A)}$$

It is a scalar quantity and its SI unit is Nm^{-2}.

- **Density** is defined as the ratio of the mass of a body to its volume.

$$\rho = \frac{m}{V}$$

where, ρ = density, V = volume and m = mass.

- It is a scalar quantity and its SI unit is kg m^{-3}.
- **Pascal's law** It states that, the change in pressure at one point of the enclosed liquid in equilibrium at rest is transmitted equally to all other points of the liquid in all directions.
- Pressure exerted by a liquid column,

$$p = \rho g h$$

where, h = height of liquid column,
g = acceleration due to gravity
and ρ = density of liquid.

- **Variation of pressure with depth** The pressure p at depth below the surface of a liquid open to the atmosphere is greater than atmospheric pressure p_a by an amount ρgh.
i.e. Pressure $p = p_a + \rho gh$
- The excess of pressure, $p - p_a$ at depth h is called a **gauge pressure**.
- The liquid pressure is the same at all points at the same horizontal level (same depth). The result is appreciated through the example of hydrostatic paradox.
- The pressure of the atmosphere (**atmospheric pressure**) at any point is equal to the weight of a column of air of unit cross-sectional area extending from that point to the top of the atmosphere.
- Atmospheric pressure is measured with mercury barometer accurately. The mercury column in the barometer has a height of about 76 cm at sea level equivalent to one atmosphere (1 atm).

$$1 \text{ atm} = 1.013 \times 10^5 \text{ Pa}$$

$$1 \text{ torr} = 133 \text{ Pa}, \ 1 \text{ bar} = 10^5 \text{ Pa}$$

- An open tube manometer is a useful instrument for measuring pressure differences.

Hydraulic Machines

- When external pressure is applied on any part of a fluid contained in a vessel, it is transmitted undiminished and equally in all directions. This is another form of the Pascal's law and it has many applications in daily life.

- **Hydraulic lift** and **hydraulic brakes** are based on the Pascal's law, in which fluids are used for transmitting pressure.
- **Hydraulic lift** is used to support or lift heavy objects based on the application of Pascal's law. It is a force multiplying device with a multiplication factor equal to the ratio of the areas of the two pistons.

Archimedes' Principle

- When a body is immersed partially or fully in a liquid, then resultant upward force on the body is called **buoyant force**.
- According to Archimedes' principle, "when a body is partially or fully immersed in a fluid at rest, the fluid exerts an upward force of buoyancy which is equal to the weight of the displaced fluid.
- Due to this upward force, the weight of the body appear to be decreased.
- If total volume of object is V_s and a part V_p of it is submerged in the fluid, then

  weight of displaced fluid = weight of object

$$\rho_s g V_s = \rho_f g V_p \Rightarrow \frac{\rho_s}{\rho_f} = \frac{V_p}{V_s}$$

Flow of Liquids

- If the velocity of fluid particles at any time does not vary with time, the flow is said to be **steady** or **streamline flow**.
- The path followed by a fluid particle in streamline flow is known as **streamlines**.
- Velocity of particles in streamline is along the tangent to the curve at that point.
- The flow of fluid in which velocity of all particles crossing a given point is not same and the motion of the fluid is irregular is called **turbulent flow**.
- If the liquid flows over a horizontal surface in the form of layers of different velocities, then the flow of liquid is called **laminar flow**.
- **Equation of continuity** It states that "when an incompressible and non-viscous fluid flows steadily through a tube of non-uniform cross-section, then the product of area of cross-section and velocity of flow is same at every point in the tube, i.e. $A_1 v_1 = A_2 v_2$

  where, A = area of cross-section and v = velocity of flow.

Bernoulli's Principle

- According to this principle, 'if an ideal fluid is flowing in streamlined flow, then total energy, i.e. sum of pressure energy, kinetic energy and potential energy per unit volume of the liquid remains constant at every cross-section of the tube."

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

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

where, $\frac{p}{\rho g}$ = pressure head, $\frac{v^2}{2g}$ = velocity head

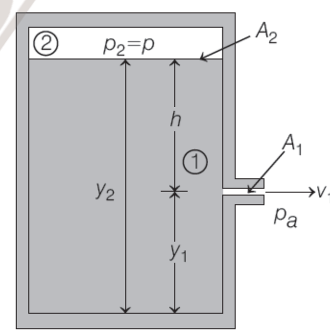
and h = gravitational head.

- Bernoulli's equation ideally applies to fluids with zero viscosity or non-viscous fluids.

Speed of Efflux : Torricelli's Law

- The outflow of a fluid is called efflux and the speed of the fluid coming out is called speed of efflux.
- When tank as shown below is closed, the speed of efflux is given by $v_1 = \sqrt{2gh + \frac{2(p - p_a)}{\rho}}$

  where, ρ = density of liquid.



Special case

When the tank is open to the atmosphere, then

$$p = p_a$$

$$\therefore \quad v_1 = \sqrt{2gh}$$

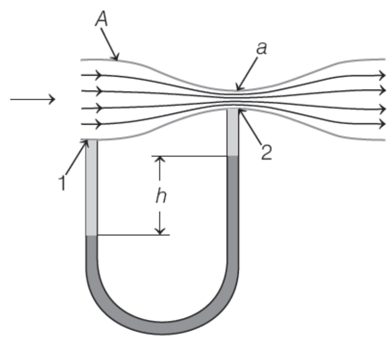
This is also the speed of a freely falling body and this equation represents **Torricelli's law**.

- The horizontal distance covered by the liquid coming out of the hole is called **range** and is given by

$$R = 2\sqrt{h(y_2 - y_1)}$$

Venturi-meter

It is a device which is used to measure the flow speed of incompressible fluid. According to given figure, speed of fluid at wide neck is given as



$$v_1 = \sqrt{\frac{2\rho_m gh}{\rho}} \cdot \left[\left(\frac{A}{a}\right)^2 - 1\right]^{-1/2}$$

where, ρ_m = density of liquid contained in U-tube,

ρ = density of fluid

and h = difference in height in U-tube.

Blood Flow and Heart Attack

Bernoulli's principle helps in explaining blood flow in artery. The artery may get constricted due to the accumulation of plaque on its inner surface. Due to this, the flow of blood increases in this region, resulting in decrease in pressure. The decreasing pressure makes the artery to collapse, resulting in heart attack.

Dynamic Lift

- It is the force that acts on a body, such as airplane wing, a hydrofoil or a spinning ball by virtue of its motion through a fluid. There arises following two cases, which can be explained on the basis of Bernoulli's principle.
  (i) **When ball is moving without spin in air**, then speed of air above and below to the ball is streamline, hence pressure difference above and below the ball is zero. The air, therefore exerts no upward or downward force on the ball.
  (ii) **When ball is moving with spin in air**, then speed of air above and below to the ball is not streamline, hence pressure difference above and below the ball is not zero. Due to difference in velocities of fluid (air) exerts, a net upward force on the ball.
- **Magnus Effect** When a ball is moving in air with spin, then due to difference in the velocities of air results in the pressure difference between the lower and upper faces and there is net upward force on the ball.

  This dynamic lift due to spinning is called Magnus effect.
- **Aerofoil or Lift on Aircraft Wing** An aerofoil is solid piece shaped to provide an upward dynamic lift when it moves horizontally through air. The cross-section of the wings of an aeroplane looks like the aerofoil.

Viscosity

- The property of a fluid by virtue of which an internal frictional force acts between its different layers, which opposes their relative motion is called viscosity.
- The velocities of layers increase uniformly from bottom (zero velocity) to the top layer (velocity v).
- The **coefficient of viscosity** for a fluid is defined as the ratio of shearing stress to the strain rate.

$$\eta = \frac{F/A}{v/l} = \frac{Fl}{vA}$$

  Its SI unit is poiseuille (PI).
- The viscosity of liquids decreases with temperature, while it increases in the case of gases.
- **Stokes' Law** There is a viscous drag force F on a sphere of radius r moving with velocity v through a fluid of viscosity η. It can be expressed as

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

- **Terminal Velocity** The maximum constant velocity acquired by the body while falling through a viscous fluid is called terminal velocity.

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

  where, r = radius of the spherical body,
  v = terminal velocity,
  η = coefficient of viscosity of fluid,
  ρ = density of the spherical body
  and σ = density of fluid.

Surface Tension

- It is the property of liquid at rest by virtue of which a liquid surface tends to occupy a minimum surface area and behaves like a stretched membrane.
- The **surface energy** may be defined as the amount of work done in increasing the area of the surface film through unity. It is expressed as

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

- **Surface tension and Surface energy** Surface tension is force per unit length (or surface energy per unit area) acting in the plane of the interface between the plane of the liquid and any other substance. It is also the extra energy that the molecules at the interface have as compared to molecules in the interior.
- The value of surface tension depends on temperatue.
- Like viscosity, the surface tension of a liquid usually falls with temperature.

KEY NOTES

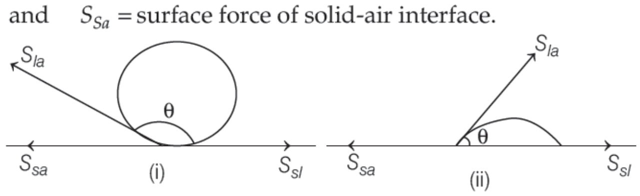
Angle of Contact

- The angle subtended between the tangent drawn at liquid's surface and tangent drawn at solid surface inside the liquid at the point of contact is called angle of contact.
- At the line of contact, the surface forces between three media as shown in Figs. (i) and (ii) must be in equilibrium, if

$$S_{la} \cos\theta + S_{sl} = S_{sa}$$

where,

S_{la} = surface force of liquid-air interface,
S_{sl} = surface force of solid-liquid interface
and S_{Sa} = surface force of solid-air interface.



(i) If $S_{sl} > S_{la}$, i.e. angle of contact is an obtuse angle for solid-liquid interface, then liquid does not wet the solid.
(ii) If $S_{sl} < S_{la}$, i.e. angle of contact is an acute angle for solid-liquid interface, then liquid wet the solid.
(iii) If $S_{la} = S_{sa}$, i.e. angle of contact is right angle for solid-liquid interface.

Drops and Bubbles

One consequence of surface tension is that, the pressure inside p_i a spherical drop is more than the pressure outside p_o.

Excess pressure inside a liquid drop, $(p_i - p_o) = \frac{2S}{R}$

Excess pressure inside a soap bubble, $(p_i - p_o) = \frac{4S}{R}$

Capillary Rise

- The phenomenon of rising or falling of liquid in a capillary tube is called **capillarity**.
- The height of liquid column in a capillary tube is given by

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

where, r is the radius of the capillary tube, θ is the angle of contact and ρ is density of liquid.

In capillary, there arises following cases

(i) When the angle of contact between the liquid and glass is acute, then surface of liquid in the capillary is concave. The pressure of the liquid inside the tube, just at the meniscus (air-liquid interface) is less than the atmospheric pressure.
(ii) When the angle of contact between the liquid and glass is obtuse, then surface of liquid in the capillary is convex. The pressure of liquid inside the tube, just at the meniscus (air-liquid interface) is greater than the atmospheric pressure.
(iii) When the angle of contact between the liquid and glass is right angle, the surface of liquid in the capillary tube is plane.
The pressure of liquid inside the tube, just at the meniscus (air-liquid interface) is equal to the atmospheric pressure.

- **Detergents and Surface Tension** By addition of detergents in water, surface tension decreases.
- It is favourable to form interfaces like globs of dirt surrounded by detergents and then by water. This kind of process using surface active detergents or surfactants is important not only for cleaning, but also in recovering oil, mineral ores, etc.

Mastering NCERT

MULTIPLE CHOICE QUESTIONS

TOPIC 1 ~ *Pressure and Pascal's Law*

1 The key property of fluids is that
(a) they offer very little resistance to shear stress
(b) their shape changes
(c) they offer very large resistance to shear stress
(d) Both (a) and (b)

2 Metal nails and metal pins are made to have pointed ends because
(a) it transmit large pressure
(b) it transmit large force
(c) it can easily penetrate the surface
(d) All of the above

3 When an object is submerged in a fluid at rest, then fluid exerts a force on its surface. This force is always
(a) normal to the objects surface
(b) parallel to the objects surface
(c) along 45° to the objects surface
(d) None of the above

4 The two thin bones (femurs), each of cross-sectional area 10 cm^2 support the upper part of human body of mass 40 kg. Estimate the average pressure sustained by the femurs.

(a) 2×10^5 Nm^{-2} (b) 3×10^4 Nm^{-2}
(c) 2.5×10^3 Nm^{-2} (d) 6×10^4 Nm^{-2}

5 If two forces in the ratio 1 : 7 act on two pistons of areas in the ratio 3 : 2, then the pressure exerted by the forces is in ratio

(a) 2 : 21 (b) 3 : 14 (c) 6 : 7 (d) 4 : 21

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

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

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

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

(d) $\rho=\dfrac{\rho_1\rho_2}{\rho_1+\rho_2}$

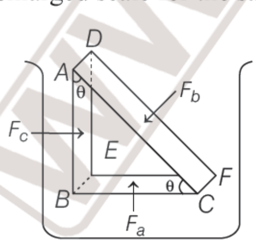
7 Pressure at a point inside a liquid does not depend on

(a) the depth of the point below the surface of the liquid
(b) the nature of the liquid
(c) the acceleration due to gravity at that point
(d) total weight of fluid in the beaker

8 Pascal's law states that pressure in a fluid at rest is the same at all points, if

(a) they are at the same height
(b) they are along same plane
(c) they are along same line
(d) Both (a) and (b)

9 Figure given below shows an element in the interior of a fluid at rest. This elemental volume is in the shape of a right angled prism. Let the elemental volume is small enough that we can ignore the effect of gravity, but it is drawn in an enlarged scale for the sake of clarity.



For equilibrium of elemental volume, which of these are correct?

(a) $F_b\sin\theta=F_c$ (b) $F_c\cos\theta=F_b$
(c) $F_b\cos\theta=F_c$ (d) $F_a\cos\theta=F_b$

10 A uniformly tappering vessel is filled with a liquid of density 900 kgm^{-3}. The force that acts on the base of the vessel due to the liquid is (take, $g=10$ ms^{-2})

(a) 3.6 N (b) 7.2 N (c) 9.0 N (d) 14.4 N

11 The heart of a man pumps 5 L of blood through the arteries per minute at a pressure of 150 mm of mercury. If the density of mercury be 13.6×10^3 kg m^{-3} and $g=10$ ms^{-2}, then the power of heart in watt is **CBSE AIPMT 2015**

(a) 1.70 (b) 2.35
(c) 3.0 (d) 1.50

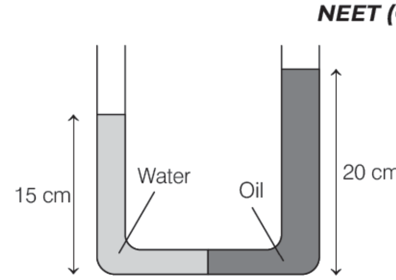
12 The approximate depth of an ocean is 2700 m. The compressibility of water is 45.4×10^{-11} Pa^{-1} and density of water is 10^3 kg m^{-3}. What fractional compression of water will be obtained at the bottom of the ocean? **CBSE AIPMT 2015**

(a) 0.8×10^{-2} (b) 1.0×10^{-2} (c) 1.2×10^{-2} (d) 1.4×10^{-2}

13 A long cylindrical vessel is half-filled with a liquid. When the vessel is rotated about its own vertical axis, the liquid rises up near the wall. If the radius of vessel is 5 cm and its rotational speed is 2 rotations per second, then the difference in the heights between the centre and the sides (in cm) will be **JEE Main 2019**

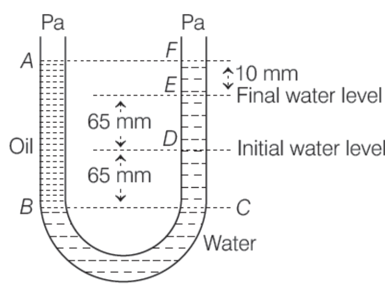
(a) 0.1 (b) 1.2
(c) 0.4 (d) 2.0

14 In a U-tube as shown in a figure, water and oil are in the left side and right side of the tube, respectively. The heights from the bottom for water and oil columns are 15 cm and 20 cm, respectively. The density of the oil is [take $\rho_{water}=1000$ kgm^{-3}] **NEET (Odisha) 2019**



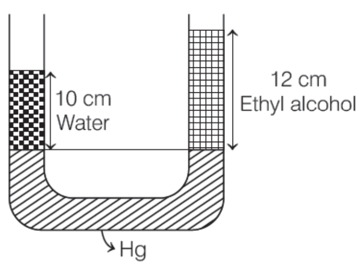
(a) 1200 kgm^{-3} (b) 750 kgm^{-3}
(c) 1000 kgm^{-3} (d) 1333 kgm^{-3}

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



(a) 650 kg m^{-3} (b) 425 kg m^{-3}
(c) 800 k g m^{-3} (d) 928 kg m^{-3}

16 Find density of ethyl alcohol. Using information given in the diagram below ***JIPMER 2018***

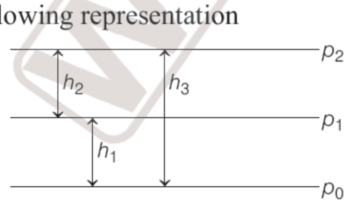


(a) 0.83 gcm^{-3} (b) 0.5 gcm^{-3} (c) 1.83 gcm^{-3} (d) 0.12 gcm^{-3}

17 A liquid of density ρ is coming out of a hose pipe of radius a with horizontal speed v and hits a mesh. 50% of the liquid passes through the mesh unaffected 25% losses all of its momentum and, 25% comes back with the same speed. The resultant pressure on the mesh will be ***JEE Main 2019***

(a) ρv^2 (b) $\frac{1}{2}\rho v^2$ (c) $\frac{1}{4}\rho v^2$ (d) $\frac{3}{4}\rho v^2$

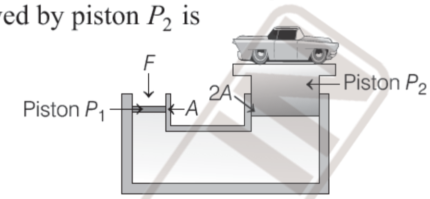
18 A student measures pressure of a gas in a container using a mercury manometer and she also measures atmospheric pressure using a mercury barometer. She gave following representation



If $p_1 =$ atmospheric pressure,
and $p_2 =$ absolute pressure, then

(a) gauge pressure $= h_1 + h_2$ (b) gauge pressure $= h_3 - h_1$
(c) gauge pressure $= h_3$ (d) absolute pressure $= h_1$

19 A hydraulic lift has 2 limbs of areas A and $2A$. Force F is applied over limb of area A to lift a heavy car. If distance moved by piston P_1 is x, then distance moved by piston P_2 is



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

20 Two syringes of different cross-sections (without needles) filled with water are connected with a tightly fitted rubber tube filled with water. Diameters of the smaller piston and larger piston are 1.0 cm and 3.0 cm, respectively. If the smaller piston is pushed in through 6.0 cm, how much does the larger piston move out?

(a) 0.67 cm (b) 0.5 cm (c) 0.75 cm (d) 1.00 cm

21 A car of mass 500 kg is lifted by a hydraulic jack that consist of two pistons. If the diameter of large and small pistons are 2 m and 20 cm respectively, then force required to lift the car by smaller piston is (take, $g = 10\text{ m/s}^2$)

(a) 5000 N (b) 25 N (c) 500 N (d) 50 N

22 Consider a solid sphere of radius R and mass density $\rho(r) = \rho_0\left(1-\frac{r^2}{R^2}\right), 0 < r \le R$. The minimum density of a liquid in which it will float is ***JEE Main 2020***

(a) $\frac{\rho_0}{3}$ (b) $\frac{2\rho_0}{5}$ (c) $\frac{2\rho_0}{3}$ (d) $\frac{\rho_0}{5}$

23 An ice cube floats on water in a beaker with $(9/10)$th of its volume submerged under water. What fraction of its volume will be submerged, if the beaker of water is taken to the moon where the gravity is $(1/6)$th that on the earth?

(a) $\frac{9}{10}$ (b) $\frac{27}{50}$ (c) $\frac{2}{3}$ (d) Zero

24 A cubical block of steel of each side equal to l is floating on mercury in a vessel. The densities of steel and mercury are ρ_s and ρ_m. The height of the block above the mercury level is given by

(a) $l\left(1+\frac{\rho_s}{\rho_m}\right)$ (b) $l\left(1-\frac{\rho_s}{\rho_m}\right)$ (c) $l\left(1+\frac{\rho_m}{\rho_s}\right)$ (d) $l\left(1-\frac{\rho_m}{\rho_s}\right)$

25 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 ***NEET 2016***

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

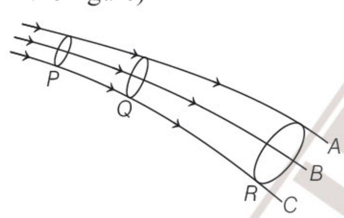
TOPIC 2 ~ Flow of Liquids and Bernoulli's Principle

26 In a streamline flow,
(a) the speed of a particle always change
(b) the velocity of each particle always remains same at a given point
(c) the kinetic energies of all the particles arriving at a given point are the same
(d) the potential energies of all the particles arriving at a given point are the same

27 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

28 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

29 In case of streamline flow of a fluid (which is incompressible), consider these streamlines A, B and C (as shown in the figure)

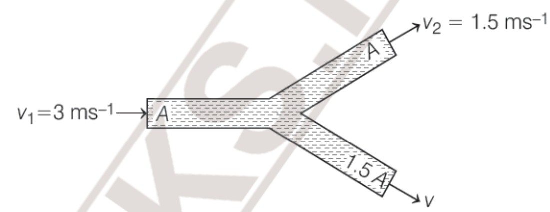


Let, P, Q and R are 3 planes perpendicular to the direction of flow of streamlines, then which of the following is correct?
(a) $m_P > m_Q > m_R$, where m = mass flow per second.
(b) $v_P > v_Q > v_R$
(c) $n_P > n_Q > n_R$, where n = number of fluid particles crossing area per unit time.
(d) $m_P < m_Q < m_R$

30 An ideal fluid flows (laminar flow) through a pipe of non-uniform diameter. The maximum and minimum diameters of the pipes are 6.4 cm and 4.8 cm, respectively. The ratio of the minimum and the maximum velocities of fluid in this pipe is **JEE Main 2020**
(a) $\frac{9}{16}$ (b) $\frac{81}{256}$ (c) $\frac{\sqrt{3}}{2}$ (d) $\frac{3}{4}$

31 A liquid flows through a pipe of varying diameter. The velocity of the liquid is 2 ms^{-1} at a point, where the diameter is 6 cm. The velocity of the liquid at a point, where the diameter is 3 cm will be
(a) 1 ms^{-1} (b) 4 ms^{-1} (c) 8 ms^{-1} (d) 16 ms^{-1}

32 An incompressible liquid flows through a horizontal tube as shown (areas of tubes is marked), then the velocity v of the fluid is



(a) 3.0 ms^{-1} (b) 1.5 ms^{-1} (c) 1.0 ms^{-1} (d) 2.25 ms^{-1}

33 The cylindrical tube of a spray pump has radius R, one end of which has n fine holes, each of radius r. If the speed of the liquid in the tube is v, the speed of the ejection of the liquid through the holes is **CBSE AIPMT 2015**
(a) $\frac{vR^2}{n^2r^2}$ (b) $\frac{vR^2}{nr^2}$ (c) $\frac{vR^2}{n^3r^2}$ (d) $\frac{v^2R}{nr}$

34 According to Bernoulli's equation,

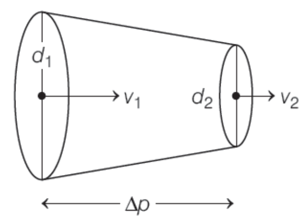
$$\frac{p}{\rho g} + h + \frac{1}{2}\frac{v^2}{g} = \text{constant}$$

The terms, $\frac{p}{\rho g}$, h and $\frac{1}{2}\frac{v^2}{g}$ 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

35 Air is streaming past a horizontal airplane's wing such that its speed is 120 ms^{-1} over the upper surface and 90 ms^{-1} at the lower surface. If the density of air is 1.3 kgm^{-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 is
(a) 4095.0 Pa (b) 409.50 Pa
(c) 40.950 Pa (d) 4.0950 Pa

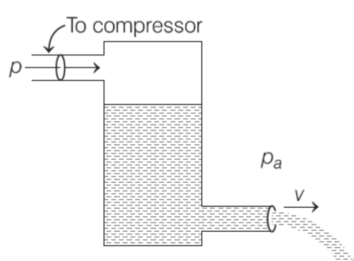
36 A wind with speed 40 ms^{-1} blows parallel to the roof of a house. The area of the roof is 250 m^2. Assuming that the pressure inside the house is atmospheric pressure, the force exerted by the wind on the roof and the direction of the force will be (ρ_{air} = 1.2 kgm^{-3}) **CBSE AIPMT 2015**
(a) 2.4×10^5 N, downwards (b) 4.8×10^5 downwards
(c) 4.8×10^5 N, upwards (d) 2.4×10^5 N, upwards

37 Determine the pressure difference in tube of non-uniform cross sectional area as shown in figure. $\Delta p = ?$, $d_1 = 5$ cm, $v_1 = 4$ m/s, $d_2 = 2$ cm. ***AIIMS 2019***



(a) 304200 Pa (b) 304500 Pa
(c) 302500 Pa (d) 303500 Pa

38 A sealed tank has 2-openings as shown below. One at near top and other at near bottom. Let height of water filled above the bottom opening is h and a compressor producing a pressure p is connected to top opening. Velocity of water obtained from lower opening is (take, atmospheric pressure p_a such that $p - p_a = \rho g h$)

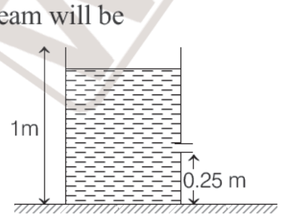


(a) $\sqrt{2gh}$ (b) $\sqrt{gh}$
(c) $2\sqrt{gh}$ (d) 0

39 Water stands at a depth H in a tank whose side walls are vertical. A hole is made in one of the walls at a height h below the water surface. The stream of water emerging from the hole strikes the floor at a distance R from the tank, where R is given by

(a) $R = \sqrt{h(H-h)}$ (b) $R = \sqrt{h(H+h)}$
(c) $R = 2\sqrt{h(H-h)}$ (d) $R = 2\sqrt{h(H+h)}$

40 If a small orifice is made at a height of 0.25 m from the ground as shown in figure below, the horizontal range of water stream will be ***AIIMS 2019***



(a) 46.5 cm (b) 56.6 cm
(c) 76.6 cm (d) 86.6 cm

41 A small hole of area of cross-section 2 mm^2 is present near the bottom of a fully filled open tank of height 2 m. Taking $g = 10$ m/s^2, the rate of flow of water through the open hole would be nearly ***NEET (National) 2019***

(a) $8.9 \times 10^{-6} m^3/s$ (b) 2.23×10^{-6} m^3/s
(c) 6.4×10^{-6} m^3/s (d) 12.6×10^{-6} m^3/s

42 A cylinder of height 20 m is completely filled with water. The velocity of efflux of water (in ms^{-1}) through a small hole on the side wall of the cylinder near its bottom is

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

43 A hole is made at the bottom of the tank filled with water (density 1000 kgm^{-3}). If the total pressure at the bottom of the tank is 3 atm (1 atm $= 10^5$ Nm^{-2}), then the velocity of efflux is

(a) $\sqrt{200}$ ms^{-1} (b) $\sqrt{400}$ ms^{-1}
(c) $\sqrt{500}$ ms^{-1} (d) $\sqrt{800}$ ms^{-1}

44 The applications of venturimeter is/are

(a) carburetor of an automobile
(b) sprayers
(c) filter pumps
(d) All of the above

45 The flow of blood in a large artery of an anesthetised dog is diverted through a venturimeter. The wider part of the meter has a cross-sectional area equal to that of the artery, $A = 8$ mm^2.

The narrower part has an area, $a = 4$ mm^2 and density of blood, $\rho = 1.06 \times 10^3$ kgm^{-3}.

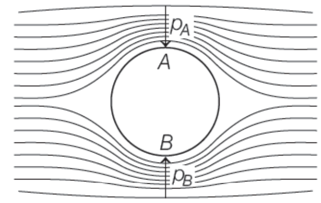
The pressure drop in the artery is 24 Pa, then what is the speed of the blood in the artery?

(a) 0.5 ms^{-1} (b) 0.125 ms^{-1}
(c) 1.25 ms^{-1} (d) 2.5 ms^{-1}

46 Just before "Heart attack", velocity of blood flow through the affected "artery"

(a) increases (b) decreases
(c) remains same (d) stopped

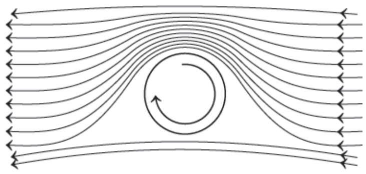
47 A ball is moving without spinning in a straight line through a fluid (as shown)



If p_A and p_B are pressure values at A and B, then

(a) $p_A < p_B$ (b) $p_B < p_A$
(c) $p_A \times p_B = 1$ (d) $p_A / p_B = 1$

48 A ball is moving in a straight line through a fluid which is spinning around its own centre of mass as shown.



Then, the ball experiences

(a) an upward force (b) a downward force
(c) a leftward force (d) no force at all

49 A fully loaded boeing aircraft has a mass of 3.3×10^5 kg. Its total wing area is 500 m^2. It is in level flight with a speed of 960 kmh^{-1}. (i) Estimate the pressure difference between the lower and upper surfaces of the wings (ii) Estimate the fractional increase in the speed of the air on the upper surface of the wing relative to the lower surface. The density of air is $\rho = 1.2\ kgm^{-3}$.

(a) $6.5\times 10^{+3}\ Nm^{-2}$, 0.01 (b) $6.5\times 10^3\ Nm^{-2}$, 0.09
(c) $6.5\times 10^3\ Nm^{-2}$, 0.08 (d) $2.5\times 10^3\ Nm^{-2}$, 0.02

TOPIC 3 ~ *Viscosity*

50 As the temperature of water increases, its viscosity

(a) remains unchanged
(b) decreases
(c) increases
(d) increases or decreases depending on the external pressure

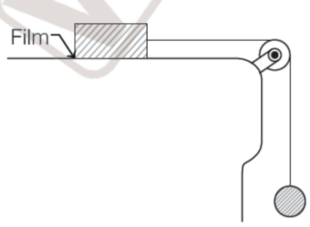
51 The coefficient of viscosity for hot air is

(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

52 We have three beakers A, B and C containing three different liquids. They are stirred vigorously and placed on a table, then liquid which is

(a) most viscous comes to rest at the earliest
(b) most viscous comes to rest at the last
(c) most viscous slows down earliest but comes to rest at the last
(d) All of them come to rest at the same time

53 A metal block of area 0.10 m^2 is connected to a 0.010 kg mass *via* a string that passes over an ideal pulley (considered massless and frictionless), as in figure. A liquid with a film thickness of 0.30 mm is placed between the block and the table. When released the block moves to the right with a constant speed of 0.085 ms^{-1}, find the coefficient of viscosity of the liquid.

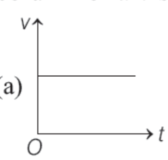


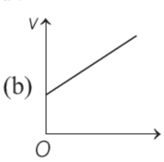
(a) 4×10^{-2} Pa-s (b) 3.45×10^{-3} Pa-s
(c) 5×10^{-2} Pa-s (d) 7×10^{-7} Pa-s

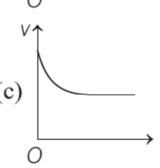
54 A rain drop of radius 0.3 mm has a terminal velocity in air 1 ms^{-1}. The viscosity of air is 18×10^{-5} poise. Find the viscous force on the rain drops. ***JIPMER 2018***

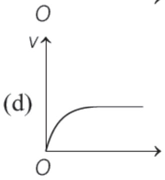
(a) 5.02×10^{-7} N (b) 1.018×10^{-7} N
(c) 1.05×10^{-7} N (d) 2.058×10^{-7} N

55 Which one shows the variation of the velocity v with time t for a small sized spherical body falling in a column of a viscous liquid?

(a) 

(b) 

(c) 

(d) 

56 A small drop of water falls from rest through a large height h in air, the final velocity is proportional to

(a) $\sqrt{h}$ (b) h (c) $1/h$ (d) h^0

57 The terminal velocity of a copper ball of radius 2.0 mm falling through a tank of oil at 20°C is 6.5 cms^{-1}. Compute the viscosity of the oil at 20°C. Density of oil is $1.5\times 10^3\ kgm^{-3}$ and density of copper is $8.9\times 10^3\ kg\ m^{-3}$.

(a) $1\times 10^{-1}\ kg\,ms^{-1}$ (b) $9.9\times 10^{-1}\ kg\,ms^{-1}$
(c) $24.3\times 10^{-2}\ kg\,ms^{-1}$ (d) $2\times 10^{-2}\ kg\,ms^{-1}$

58 If ratio of terminal velocity of two drops falling in air is 3 : 4, then what is the ratio of their surface area?
JIPMER 2018

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

59 Consider two solid spheres P and Q each of density $8\ \text{g cm}^{-3}$ and diameters 1 cm and 0.5 cm, respectively. Sphere P is dropped into a liquid of density $0.8\ \text{g cm}^{-3}$ and viscosity $\eta = 3$ poiseuille. Sphere Q is dropped into a liquid of density $1.6\ \text{g cm}^{-3}$ and viscosity $\eta = 2$ poiseiulle. The ratio of the terminal velocities of P and Q is
(a) 3 : 1 (b) 9 : 1
(c) 2 : 4 (d) 4 : 2

60 Two small spherical metal balls, having equal masses are made from materials of densities ρ_1 and ρ_2 $(\rho_1 = 8\rho_2)$ and have radii of 1 mm and 2 mm, respectively. They are made to fall vertically (from rest) in viscous medium whose coefficient of viscosity equals η and whose density is $0.1\ \rho_2$. The ratio of their terminal velocities would be
NEET (Odisha) 2019

(a) $\frac{79}{72}$ (b) $\frac{19}{36}$ (c) $\frac{39}{72}$ (d) $\frac{79}{36}$

61 A small sphere of radius r falls from rest in a viscous liquid. As a result, heat is produced due to viscous force. The rate of production of heat when the sphere attains its terminal velocity, is proportional to
NEET 2018

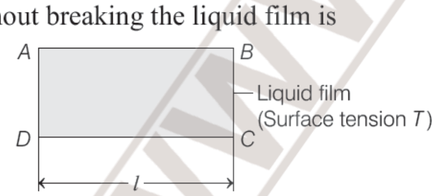
(a) r^5 (b) r^2
(c) r^3 (d) r^4

TOPIC 4 ~ *Surface Tension*

62 Surface tension is due to
(a) frictional forces between molecules
(b) cohesive forces between molecules
(c) adhesive forces between molecules
(d) Both (b) and (c)

63 The surface tension of a liquid at its boiling point
(a) becomes zero
(b) becomes infinity
(c) is equal to the value at room temperature
(d) is half to the value at room temperature

64 A liquid film is formed over a frame $ABCD$ as shown in figure. Wire CD can slide without friction. Maximum value of mass that can be hanged from CD without breaking the liquid film is



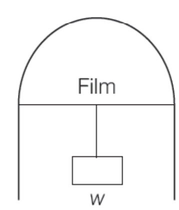
(a) $\frac{Tl}{g}$ (b) $\frac{2Tl}{g}$
(c) $\frac{g}{2Tl}$ (d) $T \times l$

65 The force required to separate two glass plates of $10^{-2}\ \text{m}^2$ with a film of water 0.05 mm thick between them, is (surface tension of water is $70 \times 10^{-3}\ \text{Nm}^{-1}$)
(a) 28 N (b) 14 N (c) 50 N (d) 38 N

66 A 10 cm long wire is placed horizontally on the surface of water and is gently pulled up with a force of 2×10^{-2} N. To keep the wire in equilibrium, the surface tension in Nm^{-1} of water is
(a) 0.1 (b) 0.2
(c) 0.001 (d) 0.002

67 A wooden stick 2 m long is floating on the surface of water. The surface tension of water is $0.07\ \text{Nm}^{-1}$. By putting soap solution on one side of the stick, the surface tension is reduced to $0.06\ \text{Nm}^{-1}$. The net force on the stick will be
(a) 0.07 N (b) 0.06 N
(c) 0.01 N (d) 0.02 N

68 A thin liquid film is formed between a U-shaped wire and a light slider, supporting a weight of 1.5×10^{-2} N as shown in the figure. The length of the slider is 30 cm and its weight is negligible. The surface tension of the liquid film is ***JEE Main 2014***



(a) $0.0125\ \text{Nm}^{-1}$ (b) $0.1\ \text{Nm}^{-1}$
(c) $0.05\ \text{Nm}^{-1}$ (d) $0.025\ \text{Nm}^{-1}$

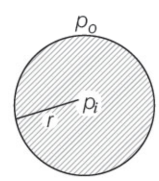
69 The shape of drops and bubbles are spherical due to its
(a) surface with minimum energy
(b) surface with maximum energy
(c) high pressure
(d) low pressure

70 A spherical drop of radius r is in equilibrium. The extra surface energy, if radius of bubble is increased by Δr, is (S = surface tension)

(a) $4\pi r\,\Delta r\,S$ (b) $8\pi r\,\Delta r\,S$
(c) $2\pi r\,\Delta r\,S$ (d) $10\pi r\,\Delta r\,S$

71 In figure below, pressure inside a spherical drop is more than pressure outside.

If a liquid drop is in equilibrium, then the pressure difference between the inside and outside of the drop is



(a) $\frac{2S_{la}}{r}$ (b) $\frac{S_{la}}{r}$ (c) $\frac{4S_{la}}{r}$ (d) $\frac{2r}{S_{la}}$

72 A small spherical droplet of density d is floating exactly half immersed in a liquid of density ρ and surface tension T. The radius of the droplet is (take note that the surface tension applies an upward force on the droplet) ***JEE Main 2020***

(a) $r = \sqrt{\frac{3T}{(2d-\rho)g}}$ (b) $r = \sqrt{\frac{T}{(d-\rho)g}}$
(c) $r = \sqrt{\frac{T}{(d+\rho)g}}$ (d) $r = \sqrt{\frac{2T}{3(d+\rho)g}}$

73 A soap bubble of radius r is blown up to form a bubble of radius $3r$ under isothermal conditions. If σ is the surface tension of soap solution, the energy spent in blowing is

(a) $3\pi\sigma r^2$ (b) $6\pi\sigma r^2$ (c) $12\pi\sigma r^2$ (d) $64\pi\sigma r^2$

74 Two small drops of mercury, each of radius r, coalesce to form a single large drop of radius R. The ratio of the total surface energies before and after the change is

(a) $1:2^{1/3}$ (b) $2^{1/3}:1$
(c) $2:1$ (d) $1:2$

75 A certain number of spherical drops of a liquid of radius r coalesce to form a single drop of radius R and volume V. If T is the surface tension of the liquid, then ***CBSE AIPMT 2014***

(a) energy $= 3VT\left(\frac{1}{r}-\frac{1}{R}\right)$ is released
(b) energy is neither released nor absorbed
(c) energy $= 4VT\left(\frac{1}{r}-\frac{1}{R}\right)$ is released
(d) energy $= 3VT\left(\frac{1}{r}+\frac{1}{R}\right)$ is absorbed

76 In a soap bubble, pressure difference is

(a) $\frac{2S_{la}}{r}$ (b) $\frac{4S_{la}}{r}$ (c) $\frac{S_{la}}{r}$ (d) $\frac{8S_{la}}{r}$

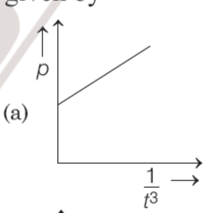
77 The excess pressure inside an air bubble of radius r just below the surface of water is p_1. The excess pressure inside a drop of the same radius just outside the surface is p_2. If T is the surface tension, then

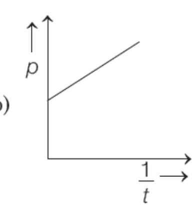
(a) $p_1 = 2p_2$ (b) $p_1 = p_2$
(c) $p_2 = 2p_1$ (d) $p_2 = 0,\ p_1 \neq 0$

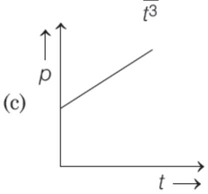
78 The surface tension of water at temperature of the experiment is $7.30 \times 10^{-2}\ \text{Nm}^{-1}$. (1 atm pressure $= 1.01 \times 10^5$ Pa, density of water $= 1000\ \text{kgm}^{-3}$ and $g = 9.80\ \text{ms}^{-2}$). Calculate the pressure inside a bubble of radius 1mm.

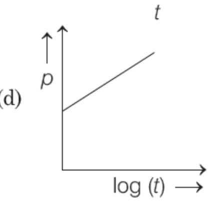
(a) 3×10^2 Pa (b) 8×10^4 Pa
(c) 1.01×10^5 Pa (d) 7×10^3 Pa

79 A soap bubble, blown by a mechanical pump at the mouth of a tube, increases in volume, with time, at a constant rate. The graph that correctly depicts the time dependence of pressure inside the bubble is given by ***JEE Main 2019***

(a)


(b)


(c)


(d)


80 A soap bubble having radius of 1 mm is blown from a detergent solution having a surface tension of 2.5×10^{-2} N/m. The pressure inside the bubble equals at a point Z_0 below the free surface of water in a container. Taking, $g = 10\ \text{m/s}^2$ and density of water $= 10^3\ \text{kg/m}^3$, the value of Z_0 is ***NEET (National) 2019***

(a) 10 cm (b) 1 cm (c) 0.5 cm (d) 100 cm

81 If the air bubble of radius r is formed at a depth h inside the container of soap solution of density ρ, the total pressure inside the bubble is (here, p_o denotes the atmospheric pressure and σ denotes surface tension) ***JEE Main 2013***

(a) $\frac{2\sigma}{r} + h\rho g$ (b) $\frac{2\sigma}{r} - h\rho g$
(c) $\frac{2\sigma}{r} + p_o + h\rho g$ (d) $\frac{2\sigma}{r} + p_o - h\rho g$

82 The lower end of a capillary tube of diameter 2.00 mm is dipped 8.00 cm below the surface of water in a beaker. What is the pressure required in the tube in order to blow a hemispherical bubble at its end in water?

(a) 2×10^5 Pa
(b) 1.01784×10^5 Pa
(c) 3×10^3 Pa
(d) 2.438×10^5 Pa

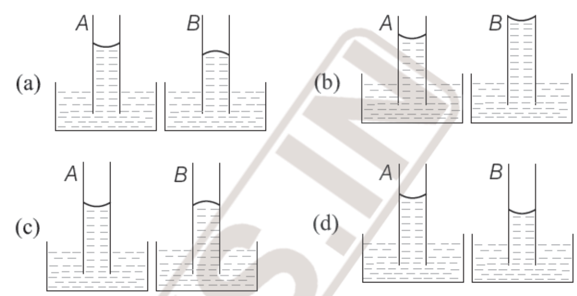
83 Water rises to a height h in capillary tube. If the length of capillary tube above the surface of water is less than h, then **CBSE AIPMT 2015**

(a) water rises upto the tip of capillary tube and then starts overflowing like a fountain
(b) water rises upto the top of capillary tube and stays there without overflowing
(c) water rises upto a point a little below the top and stays there
(d) water does not rise at all

84 Find the height of liquid in capillary tube, if surface tension of liquid $= S$, radius of capillary tube $= r$ and acceleration due to gravity $= g$. **JIPMER 2019**

(a) $\frac{2S\cos\theta}{\rho rg}$ (b) $\frac{2S}{\rho rg\cos\theta}$
(c) $\frac{2S\sin\theta}{\rho rg}$ (d) None of these

85 A capillary tube A is dipped in water. Another identical tube B is dipped in soap-water solution. Which of the following shows the relative nature of the liquid columns in the two tubes?



86 Two capillaries made of same material but of different radii are dipped in a liquid. The rise of liquid in one capillary is 2.2 cm and that in the other is 6.6 cm. The ratio of their radii is

(a) 9 : 1 (b) 1 : 9 (c) 3 : 1 (d) 1 : 3

87 If M is the mass of water that rises in a capillary tube of radius r, then mass of water which will rise in a capillary tube of radius $2r$ is **JEE Main 2019**

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

88 The lower end of a capillary tube of radius r is placed vertically in water. Then, with the rise of water in the capillary, heat evolved is

(a) $+\frac{\pi^2 r^2 h^2}{2}dg$ (b) $\frac{\pi r^2 h^2 dg}{2}$
(c) $-\frac{\pi^2 h^2 dg}{2}$ (d) $-\frac{\pi r^2 h^2 dg}{2}$

SPECIAL TYPES QUESTIONS

I. Assertion and Reason

■ **Direction** (Q. Nos. 89-105) *In the following questions, a statement of Assertion is followed by a corresponding statement of Reason. Of the following statements, choose the correct one.*

(a) Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) Both Assertion and Reason are correct but Reason is not the correct explanation of Assertion.
(c) Assertion is correct but Reason is incorrect.
(d) Assertion is incorrect but Reason is correct.

89 **Assertion** Pressure is not a vector quantity.
Reason No direction can be assigned to pressure.

90 **Assertion** In steady flow, the velocity of each passing fluid particle remains constant in time.
Reason Each particle follows a smooth path and the paths of the particle do not cross each other.

91 **Assertion** In streamline flow, $A\times v$ is constant.
Reason For incompressive flow, mass in = mass out.

92 **Assertion** The stream of water flowing at high speed from a garden horse pipe tend to spread like a fountain when held vertically up, but tends to narrow down when held vertically down.
Reason Speed of upstream decreases as its area of cross-section increases and speed of downstream increases as its area of cross-section decreases.

93 **Assertion** The steady flow of a liquid over a horizontal surface in the form of layers of different velocity is called turbulent flow.

Reason When a fluid is flowing in a pipe, then velocity of the liquid layer along the axis of tube is maximum and decreases gradually as it move towards wall.

94 **Assertion** The shape of an automobile is so designed that its front resembles the streamline pattern of the fluid through which it moves.

Reason The resistance offered by the fluid is not maximum.

95 **Assertion** The machine parts are jammed in winter.

Reason The viscosity of the lubricants used in the machine increases at low temperature.

96 **Assertion** Water flows faster than honey.

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

97 **Assertion** All the rain drops hit the surface of the earth with the same constant velocity.

Reason An object falling through a viscous medium eventually attains a terminal velocity.

98 **Assertion** No net force acts on a body falling in a liquid with a velocity equal to the terminal velocity.

Reason The weight of the body is balanced by the upward buoyant force.

99 **Assertion** A fluid will stick to a solid surface.

Reason Surface energy between fluid and solid is smaller than the sum of surface energies between solid-air and liquid-air interface.

100 **Assertion** Sometimes insects can walk on the surface of water.

Reason The gravitational force on insect is balanced by force due to surface tension. *AIIMS 2019*

101 **Assertion** A bubble differs from a drop as it has two interfaces.

Reason Excess pressure inside a drop is directly proportional to its surface area.

102 **Assertion** The surface of water in the capillary tube is concave.

Reason The pressure difference between two sides of the top surface of water is $\frac{2S}{a}\cos\theta$.

103 **Assertion** Smaller drop of water resist deformation forces better than the larger drops.

Reason Excess pressure inside drop is inversely proportional to its radius. *AIIMS 2018*

104 **Assertion** Ploughing a field reduces evaporation of water from the ground beneath.

Reason Ploughing results in lowering of surface area open to sunlight.

105 **Assertion** Washing with water does not remove grease stains.

Reason Water does not wet greasy dirt.

II. Statement Based Questions

106 I. Atoms or molecules in a fluid are arranged in a random manner.
II. A fluid can withstand tangential or shearing stress for an indefinite period.
III. A fluid has no definite shape of its own.

Which of the following statement (s) is/are correct?

(a) Only I (b) Both I and III
(c) Only III (d) I, II and III

107 In streamline flow, which of the following statement(s) is/are correct?
I. Every fluid particle follows the path of its preceding particle with same velocity.
II. Eddies and whirls are formed.
III. Speed of particle is less than the critical speed.

(a) Only I (b) Both I and III
(c) Only III (d) Both II and III

108 I. Turbulence dissipates kinetic energy in the form of heat.
II. Turbulence like friction is sometimes desirable.
III. Turbulence promotes mixing and increases the rate of transfer of mass, momentum and energy.

Which of the following statement(s) is/are correct?

(a) Only I (b) Both II and III
(c) Only III (d) I, II and III

109 I. Bernoulli's equation ideally applies to non-viscous fluids.
II. Fluid must be compressible in Bernoulli's theorem.
III. Bernoulli's equation does not hold for non-steady flow.

Which of the following statement(s) is/are correct?

(a) Both I and II (b) Only I
(c) Both I and III (d) Only II

110 For an aerofoil, which of the following are correct?
I. The orientation of the wing relative to flow direction causes the streamlines to crowd above wing surface.
II. Flow speed on top is lower than that below it.
III. Upward force results in a dynamic lift of the wings.

(a) Only I (b) Both I and II
(c) Only III (d) Both I and III

111 I. Stress depends on the rate of change of strain or strain rate.
II. The coefficient of viscosity for a fluid is defined as the ratio of shearing stress to the strain rate.
III. The SI unit of viscosity is Poiseuille (PI).

Which of the following statement(s) is/are correct?
(a) Only I (b) Both I and II
(c) Only II (d) I, II and III

112 I. Viscous force is proportional to the velocity of the object.
II. Viscous is a dragging force which acts opposite to the direction of motion.
III. Viscous force depends on viscosity η of the fluids and radius r of the sphere.

Which of following statement(s) is/are correct?
(a) Only I (b) Both I and II
(c) Only III (d) I, II and III

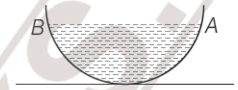
113 A thin uniform cylindrical sheet, closed at both ends,is partially filled with water. It is floating vertically in water in half-submerged state.
If ρ_c is the relative density of the material of the shell with respect to water, then the correct statement is that the shell is
(a) more than half filled, if ρ_c is less than 0.5.
(b) more than half filled, if ρ_c is more than 1.0.
(c) half filled, if ρ_c is more than 0.5.
(d) less than half filled, if ρ_c is less than 0.5.

114 A hydraulic lift has limbs of areas A_1 and A_2 ($A_1 >> A_2$). A piston creates a force F_2 in small limb to balance a large force F_1. Which of the following statement is correct?
(a) $F_2 \propto \frac{A_1}{A_2}$.
(b) Work done by F_1 > Work done by F_2.
(c) Pressure in small area limb is more than pressure in large area limb.
(d) If piston of small area limb has velocity v_2 and piston of large area limb as velocity v_1, then $\frac{v_2}{v_1} = \frac{A_1}{A_2}$.

115 Which amongst the following statement is incorrect?
(a) A jet of air striking a plate placed perpendicular to it is an example of turbulent flow.
(b) The carburetor of automobile has a venturi channel (nozzle) through which air flows with a high speed.
(c) Ball moving without spinning inside a fluid experiences a net upward force.
(d) None of the above

116 An object is moving through a viscous fluid. Which of the following statement is incorrect?
(a) Viscous force on object decreases with increase in temperature.
(b) Viscous force depends on velocity of object.
(c) Viscous force decreases if object is made pointed.
(d) Viscous force is directed anti-parallel to velocity of flow.

117 A liquid is kept in a bowl opened to atmosphere.



Consider two consecutive layers A and B as shown above,
which of the following statement(s) is/are correct?
(a) Total energy of surface A = Total energy of surface B.
(b) Number of molecules in surface A > Number of molecules in surface B.
(c) Energy of a molecule of layer B is nearly half of energy of layer A.
(d) Net force on a molecule of surface B is zero.

118 A small drop is formed using a dropper over a clean solid surface, then which of the following statement(s) is/are correct?
Where, S_{la} = surface force of liquid and air,
S_{sa} = surface force of solid and air
and S_{ls} = surface force of liquid and solid.
(a) If $S_{ls} > S_{la}$, then angle of contact is less than 90°.
(b) If $S_{ls} > S_{la}$, then angle of contact is equal to 90°.
(c) If $S_{ls} > S_{la}$, then liquid spreads over solid surface.
(d) If $S_{ls} > S_{la}$, then liquid does not spread on solid surface.

III. Matching Type

119 Match the Column I (terms or quantities) with Column II (dimensions) and select the correct answer from the codes given below.

	Column I		Column II
A.	Coefficient of viscosity	1.	$[ML^0T^{-2}]$
B.	Density	2.	$[M^0L^0T^0]$
C.	Surface tension	3.	$[ML^{-1}T^{-1}]$
D.	Reynold's number	4.	$[ML^{-3}T^0]$

	A	B	C	D		A	B	C	D
(a)	2	3	4	1	(b)	1	3	4	3
(c)	3	4	1	2	(d)	1	2	3	4

120 Match the Column I (situation) with Column II (reason or principle) and select the correct answer from the codes given below.

	Column I		Column II
A.	Hydraulic lift	1.	Archimedes' principle
B.	A razor blade can be made to float on water surface in a tray.	2.	Pascal's law
C.	The dam of water reservoir is made thick at the bottom level.	3.	Surface tension
D.	Ship is floating on ocean water.	4.	Pressure

	A	B	C	D
(a)	2	3	4	1
(b)	4	3	4	1
(c)	4	1	3	4
(d)	1	2	3	4

121 Match the Column I (situation) with Column II (value or changes) and select the correct answer from the codes given below.

	Column I		Column II
A.	When a single drop splits into *n*-identical drops, then	1.	Zero
B.	When a *n*-identical drops combine to form a single drop, then	2.	Temperature increase
C.	The surface tension of a liquid drop decreases, for	3.	Energy absorbed
D.	The surface tension of water at boiling temperature is	4.	Energy released

	A	B	C	D		A	B	C	D
(a)	3	4	1	2	(b)	3	4	2	1
(c)	4	3	1	2	(d)	1	2	3	4

NCERT & NCERT Exemplar

MULTIPLE CHOICE QUESTIONS

NCERT

122 A 50 kg girl wearing high heel shoes balances on a single heel. The heel is circular with the diameter 1.0 cm. What is the pressure exerted on the horizontal floor?

(a) 3×10^6 Pa (b) 2×10^4 Pa
(c) 6.24×10^6 Pa (d) 9×10^3 Pa

123 Toricelli's barometer used mercury. Pascal duplicated it using French wine of density 984. Determine the height of the wine column for normal atmospheric pressure.

(a) 9 m (b) 10.5 m (c) 11.5 m (d) 7.5 m

124 A vertical off-shore structure is built to withstand a maximum stress of 10^9 Pa. What is the suitable pressure exerted by water column? Take, the depth of the ocean to be roughly 3 km and ignore ocean current.

(a) 4×10^4 Pa (b) 2.94×10^7 Pa
(c) 2.0×10^6 Pa (d) 3×10^5 Pa

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

(a) 9×10^5 Pa (b) 6.92×10^5 Pa
(c) 5×10^5 Pa (d) 3×10^4 Pa

126 A U-tube contains water and methylated spirit separated by mercury. The mercury columns in the two arms are in level with 10 cm of water in one arm and 12.5 cm of spirit in the other, what is the specific gravity of spirit?

(a) 0.6 (b) 0.7 (c) 0.8 (d) 0.9 m

127 In a U-tube, mercury column in the two arms are in level, with 10 cm of water in one arm and 12.5 cm of spirit in the other. If 15 cm of water and spirit each are further poured into the respective arms of the tube, then what is the difference in the levels of mercury in the two arms? (Specific gravity of mercury = 13.6)

(a) 0.106 cm (b) 0.221 cm (c) 0.302 cm (d) 0.136 cm

128 Glycerin flows steadily through a horizontal tube of length 1.5 m and radius 1.0 cm. If the amount of glycerin flowing per second at one end is 4.0×10^{-3} kg s^{-1}, then what is the pressure difference between two ends of the tube? (Density of glycerin = 1.3×10^3 kgm^{-3} and viscosity of glycerin = 0.83 Pa-s).

(a) 5×10^2 Pa (b) 9.75×10^2 Pa
(c) 4×10^4 Pa (d) 2×10^2 Pa

129 In a test experiment on a model aeroplane in a wind tunnel, the flow speeds on the upper and lower surfaces of the wing are 70 ms^{-1} and 63 ms^{-1}, respectively. What is the lift on the wing, if its area is 2.5 m^2? (Take, the density of air to be 1.3 kgm^{-3})

(a) 2×10^3 N (b) 4×10^2 N
(c) 1.51×10^3 N (d) 6×10^3 N

130 The cylindrical tube of a spray pump has a cross-section of 8.0 cm^2, one end of which has 40 fine holes each of diameter 1.0 mm. If the liquid flow inside the tube is 1.5 m/min, what is the speed of ejection of the liquid through the holes?
(a) 0.94 ms^{-1} (b) 0.64 ms^{-1} (c) 0.25 ms^{-1} (d) 0.50 ms^{-1}

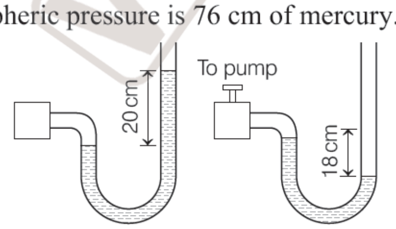
131 A U-shaped wire is dipped in a soap solution and removed. The thin soap film formed between the wire and a light slider supports a weight of 1.5×10^{-2} N (which includes the small weight of the slider). The length of the slider is 30 cm, then what is the surface tension of the film?
(a) $2.5 \times 10^{-2} \text{ Nm}^{-1}$ (b) $5 \times 10^{-3} \text{ Nm}^{-1}$
(c) $6 \times 10^{-4} \text{ Nm}^{-1}$ (d) $9 \times 10^{-2} \text{ Nm}^{-1}$

132 The drop of mercury has radius 3.00 mm at room temperature. Surface tension of mercury at that temperature is $4.65 \times 10^{-1} \text{ Nm}^{-1}$. The atmospheric pressure is 1.01×10^5 Pa, then what is the excess pressure inside the drop at that temperature?
(a) 410 Pa (b) 210 Pa (c) 540 Pa (d) 310 Pa

133 What is the excess pressure inside a bubble of soap solution of radius 5.00 mm, given that the surface tension of soap solution at the temperature 20° C is $2.50 \times 10^{-2} \text{ Nm}^{-1}$? If an air bubble of the same dimension were formed at a depth of 40.0 cm inside a container containing the soap solution (relative density is 1.20), what would be the pressure inside the bubble? (1 atmospheric pressure is 1.01×10^5 Pa)
(a) 10 Pa, 2×10^4 Pa (b) 20 Pa, 1.06×10^5 Pa
(c) 20 Pa, 3×10^4 Pa (d) 30 Pa, 5×10^3 Pa

134 A tank with a square base of area 1.0 m^2 is divided by a vertical partition in the middle. The bottom of the partition has a small hinged door of area 20 cm^2. The tank is filled with water in one compartment and an acid (of relative density 1.7) in the other, both to a height of 4.0 m. Compute the force necessary to keep the door closed.
(a) 55 N (b) 27 N (c) 20 N (d) 60 N

135 A manometer reads the pressure of a gas in an enclosure as shown in Fig. (a). When a pump removes some of the gas, the manometer reads as in Fig. (b). The liquid used in the manometers is mercury and the atmospheric pressure is 76 cm of mercury.



(a) (b)

Give the absolute and gauge pressure of the gas in the enclosure for cases (a) and (b) in units of cm of mercury.
(a) 96 and 20, 58 and –18 cm
(b) 84 and 10, 40 and –20 cm
(c) 30 and 20, 30 and 40 cm
(d) 85 and 40, 20 and 40 cm

136 During blood transfusion, the needle is inserted in a vein where the gauge pressure is 2000 Pa. At what minimum height must the blood container be placed so that blood may just enter the vein? The density of whole blood is $1.06 \times 10^3 \text{ kgm}^{-3}$.
(a) 0.6 m (b) 0.5 m
(c) 0.3 m (d) 0.2 m

137 (i) What is the largest average velocity of blood flow in an artery of radius 2×10^{-3} m, if the flow must remain laminar?
(ii) What is the corresponding flow rate?
(Take, viscosity of blood to be 2.084×10^{-3} Pa-s and density of blood is $1.06 \times 10^3 \text{ kgm}^{-3}$.)
(a) 0.98 ms^{-1}, $1.23 \times 10^{-5} \text{ m}^3\text{s}^{-1}$
(b) 2 ms^{-1}, $1.23 \times 10^{-5} \text{ m}^3\text{s}^{-1}$
(c) 1.2 ms^{-1}, $2 \times 10^{-5} \text{ m}^3\text{s}^{-1}$
(d) 3 ms^{-1}, $1.23 \times 10 \text{ m}^3\text{s}^{-1}$

138 A plane is in level flight at constant speed and each of its two wings has an area of 25 m^2. If the speed of the air is 180 kmh^{-1} over the lower wing and 234 kmh^{-1} over the upper wing surface, determine the mass of plane. (Take, air density to be 1 kgm^{-3}.)
(a) 4000 kg (b) 5400 kg (c) 4400 kg (d) 5000 kg

139 In Millikan's oil drop experiment, what is the terminal speed of an uncharged drop of radius of 2.0×10^{-5} m and density $1.2 \times 10^3 \text{ kgm}^{-3}$? Take the viscosity of air at the temperature of the experiment to be 1.8×10^{-5} Pa-s and how much is the viscous force on the drop at that speed? Neglect buoyancy of the drop due to air.
(a) $3.9 \times 10^{-3} \text{ ms}^{-1}$, 4×10^{-2} N
(b) $5.8 \times 10^{-2} \text{ ms}^{-1}$, 3.93×10^{-10} N
(c) $2 \times 10^{-3} \text{ ms}^{-1}$, 6×10^{-3} N
(d) $5.8 \times 10^{-2} \text{ ms}^{-1}$, 7×10^{-4} N

140 Mercury has an angle of contact equal to 140° with sodalime glass. A narrow tube of radius 1.00 mm made of this glass is dipped in a trough containing mercury.
By what amount does the mercury dip down in the tube relative to the liquid's surface outside? Surface

tension of mercury at the temperature of the experiment is 0.465 Nm^{-1}. (Density of mercury is $13.6 \times 10^3 \text{ kgm}^{-3}$ and $\cos 140° = -0.7660$)

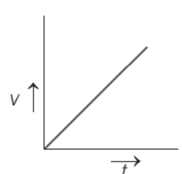
(a) 2.34 mm (b) 4.34 mm (c) 5.34 mm (d) 6.34 mm

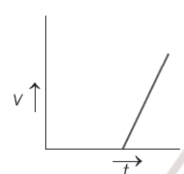
141 Two narrow bores of diametres 3.0 mm and 6.0 mm are joined together to form a U-tube opened at both ends. If the U-tube contains water, what is the difference in its levels in the two limbs of the tube? Surface tension of water at the temperature of the experiment is $7.3 \times 10^{-2} \text{ Nm}^{-2}$. Take the angle of contact to be zero, density of water to be $1.0 \times 10^3 \text{ kgm}^{-3}$ and $g = 9.8 \text{ ms}^{-2}$.

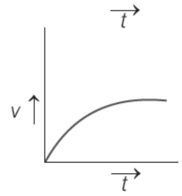
(a) 2.4 mm (b) 5.4 mm (c) 4.9 mm (d) 6.3 mm

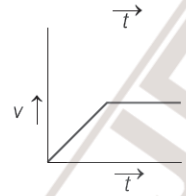
NCERT Exemplar

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

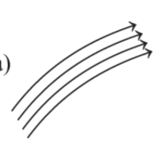
(a) 

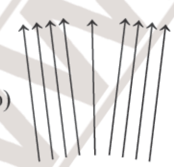
(b) 

(c) 

(d) 

143 Which of the following diagram does not represent a streamline flow?

(a) 

(b) 

(c) 

(d) 

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

145 An ideal fluid flows through a pipe of circular cross-section made of two sections with diameters 2.5 cm and 3.75 cm. The ratio of the velocities in the two pipes is
(a) 9 : 4 (b) 3 : 2
(c) $\sqrt{3} : \sqrt{2}$ (d) $\sqrt{2} : \sqrt{3}$

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

147 For a surface molecule,
(a) the net force on it is zero
(b) there is a net downward force
(c) the potential energy is less than that of a molecule inside
(d) the potential energy is equal to that of a molecule inside

148 Pressure is a scalar quantity, because
(a) it is the ratio of force to area and both force and area are vectors
(b) it is the ratio of the magnitude of the force to area
(c) it is the ratio of the component of the force parallel to the area
(d) it does not depend on the size of the area chosen

149 With increase in temperature, the viscosity of liquids
(a) decreases
(b) increases
(c) remains same
(d) None of the above

150 Streamline flow is more likely for liquids with
(a) high density (b) high viscosity
(c) low density (d) Both (b) and (c)

151 If a drop of liquid breaks into smaller droplets, it results in lowering temperature of the droplets. Let a drop of radius R breaks into N small droplets each of radius r. Estimate the drop in temperature.

(a) $\dfrac{3S}{\rho s}\left(\dfrac{1}{R^2} - \dfrac{1}{r^2}\right)$ (b) $\dfrac{3S}{\rho s}\left(\dfrac{1}{R} - \dfrac{1}{r}\right)$

(c) $\dfrac{2S}{\rho s}\left(\dfrac{1}{R} - \dfrac{1}{r}\right)^2$ (d) $\dfrac{4S}{\rho s}\left(\dfrac{1}{R^2} - \dfrac{1}{r^2}\right)$

152 The surface tension and vapour pressure of water at 20°C is $7.28 \times 10^{-2} \text{ Nm}^{-1}$ and 2.33×10^3 Pa, respectively. What is the radius of the smallest spherical water droplet which can be formed without evaporating at 20°C?
(a) 5×10^{-4} m (b) 6.25×10^{-5} m
(c) 9×10^{-2} m (d) 3×10^{-5} m

Answers

> Mastering NCERT with MCQs

1 (d)	2 (d)	3 (a)	4 (a)	5 (a)	6 (c)	7 (d)	8 (a)	9 (a)	10 (b)
11 (a)	12 (c)	13 (d)	14 (d)	15 (d)	16 (a)	17 (d)	18 (b)	19 (c)	20 (a)
21 (d)	22 (b)	23 (a)	24 (b)	25 (c)	26 (b)	27 (d)	28 (a)	29 (b)	30 (a)
31 (c)	32 (c)	33 (b)	34 (c)	35 (a)	36 (d)	37 (b)	38 (c)	39 (c)	40 (d)
41 (d)	42 (b)	43 (b)	44 (d)	45 (b)	46 (a)	47 (d)	48 (a)	49 (c)	50 (b)
51 (a)	52 (a)	53 (b)	54 (b)	55 (d)	56 (d)	57 (b)	58 (b)	59 (a)	60 (d)
61 (a)	62 (d)	63 (a)	64 (b)	65 (a)	66 (a)	67 (d)	68 (d)	69 (a)	70 (b)
71 (a)	72 (a)	73 (d)	74 (b)	75 (a)	76 (b)	77 (b)	78 (c)	79 (b)	80 (b)
81 (c)	82 (b)	83 (b)	84 (a)	85 (d)	86 (c)	87 (a)	88 (b)		

> Special Types Questions

89 (a)	90 (a)	91 (a)	92 (a)	93 (d)	94 (b)	95 (a)	96 (a)	97 (b)	98 (c)
99 (a)	100 (a)	101 (c)	102 (a)	103 (a)	104 (c)	105 (a)	106 (b)	107 (b)	108 (d)
109 (c)	110 (d)	111 (d)	112 (d)	113 (a)	114 (d)	115 (c)	116 (a)	117 (d)	118 (d)
119 (c)	120 (a)	121 (b)							

> NCERT & NCERT Exemplar MCQs

122 (c)	123 (b)	124 (b)	125 (b)	126 (c)	127 (b)	128 (b)	129 (c)	130 (b)	131 (a)
132 (d)	133 (b)	134 (a)	135 (a)	136 (d)	137 (a)	138 (c)	139 (b)	140 (c)	141 (c)
142 (c)	143 (d)	144 (b)	145 (a)	146 (c)	147 (b)	148 (b)	149 (a)	150 (d)	151 (b)
152 (b)									

Hints & Explanations

2 (*d*) The pointed ends of metal nails and metal pins have very small area.

When a force is applied over head of a pin or a nail, it transmits a large pressure (= force/area) on the surface and hence easily penetrate the surface.

4 (*a*) Total cross-sectional area of the femurs is $A = 2\times 10\ \text{cm}^2 = 20\times 10^{-4}\ \text{m}^2$.

The force acting on them is $F = 40$ kg-wt $= 400$ N (take, $g = 10\ \text{ms}^{-2}$).

This force is acting vertically downwards, so acts, normally on the femurs.

Thus, the average pressure is

$$p_{\text{av}} = \frac{F}{A} = \frac{400}{20\times 10^{-4}} = 2\times 10^5\ \text{Nm}^{-2}$$

5 (*a*) Given, $F_1 : F_2 = 1:7$ and $A_1 : A_2 = 3:2$

$\therefore$ Pressure, $p = \dfrac{F}{A}$

$$\therefore \quad \frac{p_1}{p_2} = \frac{F_1/A_1}{F_2/A_2} = \frac{F_1}{F_2}\cdot\frac{A_2}{A_1} = \frac{1}{7}\cdot\frac{2}{3} = \frac{2}{21} = 2:21$$

6 (*c*) Density, $\rho = \dfrac{\text{Total mass}}{\text{Total volume}}$

$$= \frac{2m}{V_1 + V_2} = \frac{2m}{m\left(\dfrac{1}{\rho_1} + \dfrac{1}{\rho_2}\right)}$$

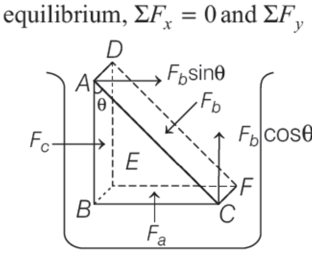
$$\therefore \quad \rho = \frac{2\rho_1\rho_2}{\rho_1 + \rho_2}$$

7 (*d*) $\because$ Pressure at a point inside a liquid, $p = \dfrac{F}{A} = \rho g h$

$\therefore$ It does not depend on the weight of fluid.

9 (*a*) The forces on this element are those exerted by the rest of the fluid and they must be normal to the surfaces of the element. Thus, the fluid exerts pressure p_a, p_b and p_c normal to the forces F_a, F_b and F_c.

Thus, in equilibrium, $\Sigma F_x = 0$ and $\Sigma F_y = 0$



$$\Rightarrow \quad F_b \sin\theta = F_c \text{ and } F_b \cos\theta = F_a$$

10 (*b*) Force acting on the base, $F = p \times A = h\rho g A$

$$= 0.4 \times 900 \times 10 \times 2 \times 10^{-3} = 7.2 \text{ N}$$

11 (*a*) Given, pressure = 150 mm of Hg = 0.15 m of Hg

$$\rho = 13.6 \times 10^3 \text{ kg m}^{-3}, g = 10 \text{ ms}^{-2}$$

$$h = 0.15 \text{ m}, V = 5 \times 10^{-3} \text{ m}^3 \text{ and } t = 60 \text{ s}$$

Pumping rate of heart of a man $= \dfrac{dV}{dt} = \dfrac{5 \times 10^{-3}}{60} \text{ m}^3\text{s}^{-1}$

Power of heart $= p \cdot \dfrac{dV}{dt} = \rho g h \cdot \dfrac{dV}{dt}$ $\quad (\because p = \rho g h)$

$$= \frac{(13.6 \times 10^3 \text{ kg m}^{-3})(10) \times (0.15 \times 5 \times 10^{-3})}{60}$$

$= 1.70$ W

12 (*c*) Given, $d = 2700$ m and $\rho = 10^3 \text{ kgm}^{-3}$

Compressibility $= 45.4 \times 10^{-11} \text{ Pa}^{-1}$

The pressure at the bottom of ocean is given by

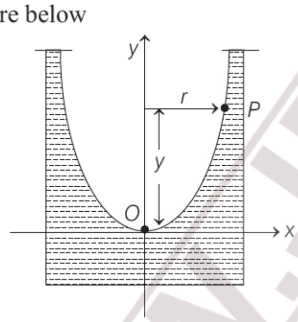
$$p = \rho g d = 10^3 \times 10 \times 2700 = 27 \times 10^6 \text{ Pa}$$

So, fractional compression = compressibility × pressure

$$= 45.4 \times 10^{-11} \times 27 \times 10^6$$

$$= 1.2 \times 10^{-2}$$

13 (*d*) When liquid filled vessel is rotated the liquid profile becomes a paraboloid due to centripetal force, as shown in the figure below



Pressure at any point P due to rotation is

$$p_R = \frac{1}{2}\rho r^2 \omega^2$$

Gauge pressure at depth y is $p_G = -\rho g y$

If p_0 is atmospheric pressure, then total pressure at point P is

$$p = p_0 + \frac{1}{2}\rho r^2 \omega^2 - \rho g y$$

For any point on surface of rotating fluid,

$$p = p_0$$

Hence, for any surface point;

$$p_0 = p_0 + \frac{1}{2}\rho r^2 \omega^2 - \rho g y$$

or $\quad \dfrac{1}{2}\rho r^2 \omega^2 = \rho g y$

or $\quad y = \dfrac{r^2 \omega^2}{2g}$ $\quad \ldots$ (i)

In the given case,

Angular speed, $\omega = 2\pi s = 2 \times 2\pi = 4\pi \text{ rad s}^{-1}$

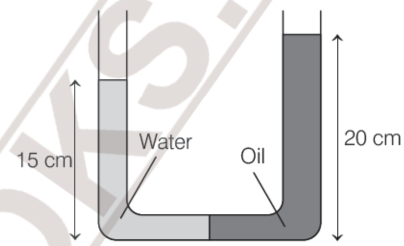
Radius of vessel, $r = 5 \text{ cm} = 0.05 \text{ m}$

and $g = 10 \text{ ms}^{-2}$

Hence, substituting these values in Eq. (i), we get

$$y = \frac{\omega^2 r^2}{2g} = \frac{(4\pi)^2 (0.05)^2}{2 \times 10} = 0.02 \text{ m} = 2 \text{ cm}$$

14 (*b*) In the given situation as shown in the figure below



According to Pascal's law,

Pressure due to water column of height 15 cm

= Pressure due to oil column of height 20 cm

$\Rightarrow \quad h_w \rho_w g = h_o \rho_o g$

$$15\rho_w = 20\rho_o \quad \Rightarrow \quad \rho_o = \frac{15}{20}\rho_\omega$$

$$\rho_o = \frac{15}{20} \times 1000 \quad (\because \text{given}, \rho_w = 1000 \text{ kg m}^{-3})$$

$$= 750 \text{ kgm}^{-3}$$

15 (*d*) As we know, the liquid pressure is the same at all points at the same horizontal level.

Since in the given situation in the problem, both ends of the U-tube are open and the level of the fluid is same, so the pressure on both the free surfaces must be equal.

i.e. $\quad p_1 = p_2$

$$h_{\text{oil}} \cdot \rho_{\text{oil}} \cdot g = h_{\text{water}} \cdot \rho_{\text{water}} \cdot g \quad (\because p = \rho g h)$$

$$\rho_{\text{oil}} = \frac{h_{\text{water}} \cdot \rho_{\text{water}} \cdot g}{h_{\text{oil}} \cdot g}$$

From figure, $\rho_{\text{oil}} = \dfrac{(65 + 65) \times 1000}{(65 + 65 + 10)} = 928 \text{ kgm}^{-3}$

$$[\because \rho_{\text{water}} = 1000 \text{ kgm}^{-3}]$$

16 (*a*) Pressure at left arm of U-tube,

$$p_1 = p_0 + \rho_1 g h_1 = p_0 + \rho_1 10 (10 \times 10^{-2})$$

or $\quad p_1 = p_0 + \rho_1$

Pressure at right arm of U-tube,

$$p_2 = p_0 + \rho_2 g h_2 = p_0 + \rho_2 10 (12 \times 10^{-2})$$

or $\quad p_2 = p_0 + 1.2 \rho_2$

The mercury column in both arms of U-tube are at same level, therefore pressure in both arms will be same.

i.e. $\quad p_1 = p_2 \Rightarrow p_0 + \rho_1 = p_0 + 1.2\rho_2$

∴ Density of ethyl alcohol,

$$\rho_2 = \frac{\rho_1}{1.2} = \frac{1000}{1.2} = 833.3 \text{ kg/m}^3$$

$$= 0.83 \text{ gcm}^{-3}$$

17 (*d*) Mass per unit time of a liquid flow is given by

$$\frac{dm}{dt} = \rho A v$$

where, ρ is density of liquid, A is area through which it is flowing and v is velocity.

$\therefore$ Rate of change in momentum of the 25% of liquid which loses all momentum is

$$\frac{dp_1}{dt} = \frac{1}{4}\left(\frac{dm}{dt}\right) v = \frac{1}{4}\rho A v^2 \quad \ldots\text{(i)}$$

and the rate of change in momentum of the 25% of the liquid which comes back with same speed.

$$\frac{dp_2}{dt} = \frac{1}{4}\left(\frac{dm}{dt}\right) \times 2v = \frac{1}{2}\rho A v^2 \quad \ldots\text{(ii)}$$

[$\because$ Net change in velocity is $= 2v$]

$\therefore$ Net pressure on the mesh is

$$p = \frac{F_{\text{net}}}{A} = \frac{(dp_1/dt + dp_2/dt)}{A} \quad \left[\because F = \frac{dp}{dt}\right]$$

$\therefore$ From Eqs. (i) and (ii), we get

$$p = \frac{3}{4}\rho v^2 A / A = \frac{3}{4}\rho v^2$$

18 (*b*) As we know that, if p_1 represents the atmospheric pressure, then absolute pressure $p' = p_1 + \rho g h$

and gauge pressure, $p'' = p' - p_1 = \rho g h$

From the given figure, we can write, $p_1 = \rho g h_1$

$\Rightarrow p' = p_2 = \rho g h_1 + \rho g h_2 = \rho g (h_1 + h_2) = \rho g h_3$

Similarly, $p'' = p_2 - p_1 = \rho g h_3 - \rho g h_1$

$= \rho g (h_3 - h_1) = \rho g h_2$

$\therefore$ In terms of height, we can write,

Absolute pressure $= h_3 = h_1 + h_2$

Gauge pressure $= h_2 = h_3 - h_1$

19 (*c*) Since, the fluid in the lift is perfectly incompressible.

$\therefore$ Volume covered by the movement of piston P_1 inwards by a distance x_1 is equal to volume moved outwards due to the piston P_2 by a distance x_2 (say).

$\therefore \quad V_1 = V_2 \Rightarrow A_1 x_1 = A_2 x_2$

$\Rightarrow \quad x_2 = \dfrac{A_1}{A_2} x_1 = \dfrac{Ax}{2A}$ (Given, $A_1 = A$ and $A_2 = 2A$)

$= \dfrac{x}{2}$

Thus, the distance moved by piston P_2 is $\dfrac{x}{2}$.

20 (*a*) Water is considered to be perfectly incompressible. Volume covered by the movement of smaller piston inwards is equal to volume moved outwards due to the larger piston.

$$L_1 A_1 = L_2 A_2$$

$$L_2 = \frac{A_1}{A_2} L_1 = \frac{\pi(1/2 \times 10^{-2})^2}{\pi(3/2 \times 10^{-2})^2} \times 6 \times 10^{-2}$$

$= 0.67\,\text{cm}$

(Atmospheric pressure is common to both pistons and has been ignored.)

21 (*d*) Given, mass of car = 500 kg

Weight of car, $w = mg = 500 \times 10 = 5 \times 10^3$ N,

$d_1 = 2\text{m} \Rightarrow r_1 = 1\text{m}, d_2 = 20$ cm

$\Rightarrow \quad r_2 = 10$ cm $= 0.1$ m

According to Pascal's law,

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

$$\Rightarrow \quad \frac{F_2}{\pi r_2^2} = \frac{w}{\pi r_1^2}$$

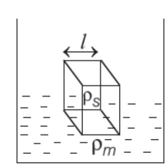
$$\Rightarrow \quad F_2 = w\left(\frac{r_2}{r_1}\right)^2 = 5 \times 10^3 \left(\frac{0.1}{1}\right)^2 = 50\text{ N}$$

23 (*a*) The buoyant force acting on the ice cube inside the beaker depends on the value of g.

However, the fraction of the cube submerged under a liquid is independent of the value of g but depends only on the density of the ice cube relative to that of the liquid on which it floats. Therefore, if the beaker of water is taken to the moon, where the gravity is $(1/6)$th as that on earth, then the buoyant force acting on the cube will be affected, but the fraction of the volume submerged will remain same.

$\therefore$ On moon also, the ice cube floats on water in the beaker with $\left(\dfrac{9}{10}\right)$th of its volume submerged under water.

24 (*b*) According to the question, the situation can be drawn as



Volume of block $= l^3$

Let h be the height of the block above the surface of mercury and volume of mercury displaced $= (l - h) \cdot l^2$.

$\therefore$ Weight of mercury displaced $= (l - h) \cdot l^2 \cdot \rho_m \cdot g$

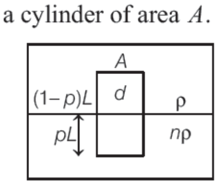
This is equal to the weight of the block which is $\rho_s \cdot l^3 \cdot g$

Thus, according to Archimedes' principle,

$$(l - h)\, l^2 \cdot \rho_m \cdot g = \rho_s \cdot l^3 \cdot g$$

which gives, $h = l\left(1 - \dfrac{\rho_s}{\rho_m}\right)$

25 (*c*) According to question, the situation can be drawn as following for a cylinder of area A.



Hints & Explanations

Applying Archimedes' principle,

Weight of cylinder = $(\text{Upthrust})_1 + (\text{Upthrust})_2$

i.e. $$ALdg = (1-p)LA\rho g + (pLA)n\rho g$$

$$\Rightarrow \quad d = (1-p)\rho + pn\rho = \rho - p\rho + n\,p\rho$$

$$d = \rho + (n-1)\,p\rho = \rho\,\{1 + (n-1)\,p\}$$

29 (*b*) Mass of fluid flowing out is equals the mass flowing in, therefore $\Delta m_P = \Delta m_Q = \Delta m_R$, we have

$$A_P v_P\, \rho_P \Delta t = A_Q v_Q \rho_Q \Delta t = A_R v_R \rho_R \Delta t \quad \ldots\text{(i)}$$

For flow of incompressible fluids, we have,

$$\rho_P = \rho_R = \rho_Q$$

Thus, Eq. (i) reduces to,

$$\Rightarrow \quad A_P v_P = A_R v_R = A_Q v_Q$$

Also, from the given figure we can also say that,

$$A_R > A_Q > A_P$$

So, at narrower portions, where the streamlines are closely spaced, velocity increases.

i.e. $$v_p > v_Q > v_R$$

31 (*c*) Given, $d_1 = 6\text{ cm} \Rightarrow r_1 = 3\text{ cm}$

$$d_2 = 3\text{ cm} \Rightarrow r_2 = \frac{3}{2}\text{ cm}$$

$$v = 2\text{ ms}^{-1}$$

According to equation of continuity of flow,

$$A_1 v_1 = A_2 v_2$$

$$\therefore \quad v_2 = \frac{A_1 v_1}{A_2} = \frac{\pi r_1^2 v_1}{\pi r_2^2}$$

$$(\because A_1 = \pi r_1^2 \text{ and } A_2 = \pi r_2^2)$$

$$= v_1 \left(\frac{r_1}{r_2}\right)^2 = 2 \times \left(\frac{3}{3/2}\right)^2 = 2 \times 2^2 = 8\text{ ms}^{-1}$$

32 (*c*) If the liquid is incompressible, then according to Bernoulli's principle mass of liquid entering through left end, should be equal to mass of liquid coming out from the right end.

$$\therefore \quad M = m_1 + m_2 \Rightarrow Av_1 = Av_2 + 1.5A\,v$$

$$\Rightarrow \quad A \times 3 = A \times 1.5 + 1.5A\,v \Rightarrow v = 1.0\text{ ms}^{-1}$$

33 (*b*) Consider a cylindrical tube of a spray pump of radius R, one end having n fine holes, each of radius r and speed of liquid in the tube is v as shown in figure.

According to equation of continuity, Av = constant where, A is area of the cylindrical tube and v is velocity of liquid in the tube.

Volume of inflow rate = Volume of outflow rate

$$\pi R^2 v = n\,\pi r^2 v' \quad \Rightarrow \quad v' = \frac{vR^2}{nr^2}$$

Thus, speed of the ejection of the liquid through the holes is $\frac{vR^2}{nr^2}$.

35 (*a*) From the Bernoulli's theorem,

$$p_1 - p_2 = \frac{1}{2}\rho(v_2^2 - v_1^2)$$

Given, $\rho = 1.3\text{ kgm}^{-3}$

$$v_2 = 120\text{ ms}^{-1}$$

$$v_1 = 90\text{ ms}^{-1}$$

$$\Rightarrow \quad p_1 - p_2 = \frac{1}{2} \times 1.3 \times [(120)^2 - (90^2)]$$

$$= 4095\text{ Nm}^{-2} \text{ or Pa}$$

36 (*d*) From Bernoulli's equation, $p = p_0 + \frac{1}{2}\rho v^2$

Given, $v = 40\text{ ms}^{-1}$, $A = 250\text{ m}^2$, $\rho_{\text{air}} = 1.2\text{ kgm}^{-3}$

Force will act due to pressure difference

$$\therefore \quad p - p_0 = \frac{1}{2}\rho v^2 = \frac{1}{2} \times 1.2 \times (40)^2$$

$$= 960\text{ Pa}$$

$\therefore$ Force acting upwards, F

= Pressure difference × Area

$= 960 \times 250 = 2.4 \times 10^5$ N, upwards

37 (*b*) Given, diameter of tube at first end, $d_1 = 5\text{ cm}$

$$\therefore \text{ Radius, } r_1 = \frac{d_1}{2} = 2.5\text{ cm} = 2.5 \times 10^{-2}\text{ m}$$

Diameter of tube at second end, $d_2 = 2\text{ cm}$

$$\therefore \text{ Radius, } r_2 = \frac{d_2}{2} = 1\text{ cm} = 10^{-2}\text{ m}$$

Velocity of fluid at first end, $v_1 = 4$ m/s

By the principle of continuity,

$$A_1 v_1 = A_2 v_2$$

$$\pi r_1^2 v_1 = \pi r_2^2 v_2$$

$$(2.5 \times 10^{-2})^2 \times 4 = (10^{-2})^2 \cdot v_2$$

$$\Rightarrow \quad v_2 = 25\text{ m/s}$$

From Bernoulli's theorem,

$$p_1 + \frac{1}{2}\rho v_1^2 = p_2 + \frac{1}{2}\rho v_2^2$$

$$p_1 - p_2 = \frac{1}{2}\rho(v_2^2 - v_1^2)$$

$$[\because \text{density of water, } \rho = 10^3\text{ kg/m}^3]$$

$$= \frac{1}{2} \times 10^3 (25^2 - 4^2)$$

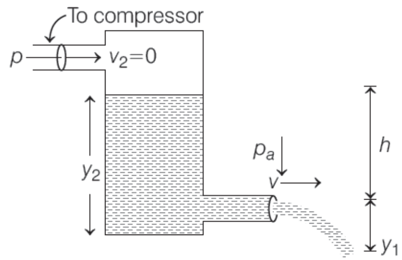
$$= 304500\text{ Pa}$$

38 (*c*) Applying Bernoulli's theorem, at different parts of figure given below,

$$p_a + \frac{1}{2}\rho v_1^2 + \rho g y_1 = p + \frac{1}{2}\rho v_2^2 + \rho g y_2$$

$$= p + \rho g y_2 \qquad [\because v_2 = 0]$$

$$v_1^2 = \frac{2}{\rho}(p - p_a + \rho g(y_2 - y_1)) \quad \ldots\text{(i)}$$



Given, $\quad y_2 - y_1 = h$

Substituting the given value in Eq. (i), we get

$$v_1 = \sqrt{2gh + \frac{2(p - p_a)}{\rho}} = \sqrt{2gh + \frac{2(\rho gh)}{\rho}} = 2\sqrt{gh}$$

39 (*c*) Let h be the depth of the hole below the free surface of water. According to Torricelli's theorem, the velocity of the efflux v of water through the hole is given by

$$v = \sqrt{2gh} \quad \text{...(i)}$$

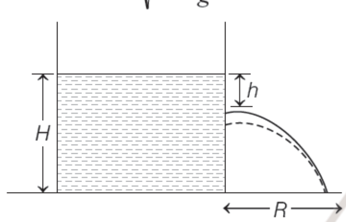
The height through which the water falls is

$$s = H - h$$

If t is the time taken by water to strike the floor, then

$$s = \frac{1}{2}gt^2 \quad \text{or} \quad (H - h) = \frac{1}{2}gt^2$$

$$\Rightarrow \quad t = \sqrt{\frac{2(H-h)}{g}} \quad \text{...(ii)}$$

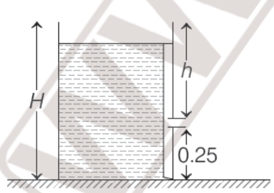


The distance R, where the emerging stream strikes the floor is given by $R = vt$

Substituting the value of v and t from Eqs. (i) and (ii), we get

$$R = \sqrt{2g \cdot h} \times \sqrt{\frac{2(H-h)}{g}} = 2\sqrt{h(H-h)}$$

40 (*d*) Given, height of small orifice from ground $(H–h)$ = 0.25 m



Total height of water tank, $H = 1$ m

$\therefore$ Range of water stream,

$$R = 2\sqrt{h(H-h)} = 2\sqrt{(H - 0.25)(0.25)}$$
$$= 2\sqrt{(1 - 0.25)0.25}$$
$$= 2\sqrt{0.75 \times 0.25}$$
$$= 0.866 \text{ m} = 86.6 \text{ cm}$$

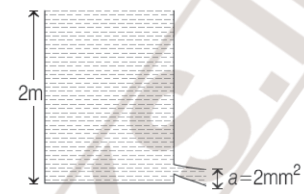
41 (*d*) The rate of liquid flow moving with velocity v through an area a is given by

Rate (R) = Area $(A) \times$ Velocity (v)

Given, area of hole, $A = 2 \text{ mm}^2 = 2 \times 10^{-6} \text{ m}^2$

Height of tank, $h = 2$ m

The given situation can also be depicted as shown in the figure below



As the velocity of liquid flow is given as $v = \sqrt{2gh}$

$$\therefore \quad R = Av = A\sqrt{2gh}$$

Substituting the given values, we get

$$R = 2 \times 10^{-6} \times \sqrt{2 \times 10 \times 2}$$
$$= 2 \times 10^{-6} \times 6.32 = 12.64 \times 10^{-6} \text{ m}^3/\text{s}$$
$$\simeq 12.6 \times 10^{-6} \text{ m}^3/\text{s}$$

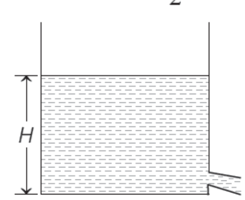
42 (*b*) According to Torricelli's theorem, the velocity of efflux of water, $v = \sqrt{2gh} = \sqrt{2 \times 10 \times 20} = 20 \text{ ms}^{-1}$.

43 (*b*) Given, $\rho = 1000 \text{ kgm}^{-3}$, $p_1 = 3 \times 10^5 \text{ Nm}^{-2}$

and $\quad p_2 = 1 \times 10^5 \text{ Nm}^{-2}$ (for air)

Applying Bernoulli's theorem, we get

$$p_1 + 0 + \rho gH = p_2 + \frac{1}{2}\rho v^2 + \rho gH$$



$$p_1 - p_2 = \frac{1}{2}\rho v^2$$
$$3 \times 10^5 - 1 \times 10^5 = \frac{1}{2}\rho v^2$$
$$2 \times 10^5 = \frac{1}{2}\rho v^2$$
$$2 \times 10^5 = \frac{1}{2} \times 10^3 \times v^2$$
$$v^2 = 400$$
$$v = \sqrt{400} \text{ ms}^{-1}$$

45 (*b*) Given, cross-sectional area of wider part of the meter, $A = 8 \text{ mm}^2$, area of narrower part, $a = 4 \text{ mm}^2$ and density of blood, i.e. ρ is $1.06 \times 10^3 \text{ kgm}^{-3}$.

The ratio of the areas is $\frac{A}{a} = 2$.

The pressure drop in artery $= \rho_m gh = 24$ Pa

So, the speed of the blood in the artery,

$$v = \sqrt{\frac{2\rho_m gh}{\rho}\left[\left(\frac{A}{a}\right)^2 - 1\right]^{-1/2}}$$

$$\Rightarrow \quad v = \sqrt{\frac{2 \times 24}{1.06 \times 10^3 \times (2^2 - 1)}} \simeq 0.125 \text{ ms}^{-1}$$

46 (*a*) According to Bernoulli's principle, just before heart attack as velocity increases due to constriction of artery, pressure is reduced and finally artery collapses.

47 (*d*) As the ball is not spinning, then by Bernoulli's theorem, $p_A = p_B$.
$\Rightarrow (p_A / p_B) = 1$

48 (*a*) A ball which is spinning drags the fluid along with it. The given figure shows the streamlines of fluid and spinning at the same time.

The ball is moving forward and relative to it, the fluid is moving backwards.

Therefore, the velocity of the fluid above to the ball is larger and below is smaller. This difference in the velocity of fluid results in pressure difference between the lower and upper faces and there is a net upward force on the ball.

49 (*c*) The weight of the boeing aircraft is balanced by the upward force due to the pressure difference.

$$\Delta p \times A = mg$$
$$\Delta p \times A = 3.3 \times 10^5 \times 9.8$$
$$\Delta p = (3.3 \times 10^5 \times 9.8)/500$$
$$= 6.5 \times 10^3 \text{ Nm}^{-2}$$

We ignore the small height difference between the top and bottom sides in Bernoulli's equation,

i.e. $$p_1 + \left(\frac{1}{2}\right)\rho v_1^2 + \rho g h_1 = p_2 + \left(\frac{1}{2}\right)\rho v_2^2 + \rho g h_2$$

The pressure difference between them is

$$\Delta p = p_1 - p_2 = \frac{\rho}{2}(v_2^2 - v_1^2)$$

where, v_2 is the speed of air over the upper surface and v_1 is the speed under the bottom surface.

$$\Delta p = \frac{\rho}{2}(v_2 - v_1)(v_2 + v_1)$$

$$v_2 - v_1 = \frac{2\Delta p}{\rho(v_2 + v_1)} \quad \ldots\text{(i)}$$

Taking the average speed,

$$v_{\text{av}} = (v_2 + v_1)/2 = 960 \text{ kmh}^{-1} = 267 \text{ ms}^{-1}$$

Dividing both sides of Eq. (i) by v_{av}, we get

$$v_2 - v_1 / v_{\text{av}} = \frac{\Delta p}{\rho v_{\text{av}}^2}$$

where, $\frac{v_2 - v_1}{v_{\text{av}}}$ represents the fractional increase in speed.

$$\Rightarrow \quad \frac{v_2 - v_1}{v_{\text{av}}} = \frac{6.5 \times 10^3}{1.2 \times (267)^2} \approx 0.08$$

51 (*a*) For gases, viscosity increases with temperature.
Hence, coefficient of viscosity for hot air is greater than coefficient of viscosity for cold air.

52 (*a*) Most viscous liquid comes to rest quickly due to dissipation of energy at a larger rate.
Hence, most viscous liquid comes to rest at the earliest.

53 (*b*) Given, $A = 0.10 \text{ m}^2$, $m = 0.010 \text{ kg}$, $l = 0.30 \text{ mm}$
$$= 0.30 \times 10^3 \text{ m and } v = 0.085 \text{ ms}^{-1}.$$

The metal block moves to the right, because of the tension in the string. The tension T is equal to the magnitude of the weight of the suspended mass m.

Thus, the shear force,

$$F = T = mg = 0.010 \times 9.8 = 9.8 \times 10^{-2} \text{ N}$$

$$\text{Shear stress on the fluid} = F/A = \frac{9.8 \times 10^{-2}}{0.10}$$

$$\text{Velocity gradient} = \frac{v}{l} = \frac{0.085}{0.30 \times 10^{-3}}$$

$$\Rightarrow \text{Coefficient of viscosity, } \eta = \frac{\text{Stress}}{\text{Velocity gradient}}$$

$$= \frac{(9.8 \times 10^{-2})(0.30 \times 10^{-3})}{(0.085)\ (0.10)}$$

$$= 3.45 \times 10^{-3} \text{ Pa-s}$$

54 (*b*) Given, $r = 0.3 \text{ mm} = 0.3 \times 10^{-3} \text{ m}$, $v = 1 \text{ ms}^{-1}$
$\eta = 18 \times 10^{-5}$ poise $= 18 \times 10^{-6}$ decapoise

Viscous force, $F = 6\pi\eta r v$

$$= 6 \times \frac{22}{7} \times (18 \times 10^{-6}) \times (0.3 \times 10^{-3}) \times 1$$

$$= 1.018 \times 10^{-7} \text{ N}$$

55 (*d*) According to Stoke's law, the retarding force is proportional to velocity.

Initially, when the spherical body is released in the fluid, it accelerates due to gravity. As the velocity increases, the retarding force also increases.

Finally, when viscous force plus buoyant force become equal to the force of gravity, the net force and hence acceleration become zero. The sphere then moves with a constant velocity called terminal velocity. This situation is correctly described by the v-t graph of option (d).

56 (*d*) Final velocity is terminal velocity, it does not depend on the height of fall.

57 (*b*) Given, $v_T = 6.5 \times 10^{-2} \text{ ms}^{-1}$, $a = 2 \times 10^{-3}$ m
$g = 9.8 \text{ ms}^{-2}$, $\rho = 8.9 \times 10^3 \text{ kgm}^{-3}$
$\sigma = 1.5 \times 10^3 \text{ kgm}^{-3}$

So, terminal velocity, $v_T = \frac{2a^2(\rho - \sigma)g}{9\eta}$

$$\Rightarrow \quad \eta = \frac{2}{9} \times \frac{(2 \times 10^{-3})^2 \times (8.9 - 1.5) \times 10^3 \times 9.8}{6.5 \times 10^{-2}}$$

$$= 9.9 \times 10^{-1} \text{ kg ms}^{-1}$$

58 (*b*) Terminal velocity is given by $v = \dfrac{2r^2\,(\rho - \sigma)}{9\eta}\,g$

where, r = radius of drop,
ρ = density of medium of drop,
σ = density of surrounding medium
and η = coefficient of viscosity of drop medium.

$\Rightarrow v \propto r^2$ and we know, area of drop $\propto r^2$

$$\Rightarrow \quad v \propto A \text{ (area)}$$

$$\Rightarrow \quad \frac{v_1}{v_2} = \frac{A_1}{A_2} = \frac{3}{4} \Rightarrow \frac{A_1}{A_2} = \frac{3}{4}$$

59 (*a*) Terminal velocity is given by

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

$$\frac{v_P}{v_Q} = \frac{r_P^2}{r_Q^2} \times \frac{\eta_Q}{\eta_P} \times \frac{(d-\rho_P)}{(d-\rho_Q)}$$

Given, $d = 8\ \text{gcm}^{-3}$

$$r_P = (1/2)\ \text{cm},\ r_Q = \frac{0.5}{2}\ \text{cm}$$

$$\rho_P = 0.8\ \text{gcm}^{-3}$$

$$\rho_Q = 1.6\ \text{gcm}^{-3}$$

$$\eta_P = 3 \text{ poise}$$

$$\eta_Q = 2 \text{ poise}$$

$$\Rightarrow \quad \frac{v_P}{v_Q} = \left(\frac{1}{0.5}\right)^2 \times \left(\frac{2}{3}\right) \times \frac{(8-0.8)}{(8-1.6)} = 4 \times \frac{2}{3} \times \frac{7.2}{6.4} = 3$$

$$\Rightarrow \quad v_P : v_Q = 3:1$$

60 (*d*) The terminal velocity achieved by ball in a viscous fluid is

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

where, ρ = density of metal of ball,
σ = density of viscous medium,
r = radius of ball
and η = coefficient of viscosity of medium.

Terminal velocity of first ball,

$$v_{t_1} = \frac{2(\rho_1 - \sigma) r_1^2 g}{9\eta} = \frac{2(8\rho_2 - \sigma) r_1^2 g}{9\eta} \quad \ldots\text{(i)}$$

$$[\because \rho_1 = 8\rho_2]$$

Similarly, for second ball, $v_{t_2} = \dfrac{2(\rho_2 - \sigma) r_2^2 g}{9\eta}$ ...(ii)

From Eqs. (i) and (ii), we get

$$\frac{v_{t_1}}{v_{t_2}} = \frac{2(8\rho_2 - \sigma) r_1^2 g}{2(\rho_2 - \sigma) r_2^2 g} \times \frac{9\eta}{9\eta}$$

$$= \left(\frac{8\rho_2 - 0.1\rho_2}{\rho_2 - 0.1\rho_2}\right)\left(\frac{r_1}{r_2}\right)^2 \quad \ldots\text{(iii)} \ [\because \sigma = 0.1\rho_2]$$

Given, $r_1 = 1$ mm and $r_2 = 2$ mm

Substituting these values in Eq. (iii), we get

$$\Rightarrow \quad \frac{v_{T_1}}{v_{T_2}} = \left(\frac{7.9\rho_2}{0.9\rho_2}\right)\left(\frac{1}{2}\right)^2 = \frac{79}{36}$$

61 (*a*) The rate of heat generation is equal to the rate of work done by the viscous force which in turn is equal to its power.

$$\text{Rate of heat produced, } \frac{dQ}{dt} = F \times v_T$$

where, F is the viscous force and v_T is the terminal velocity.

As, $\quad F = 6\pi\eta r v_T$

$$\Rightarrow \quad \frac{dQ}{dt} = 6\pi\eta r v_T \times v_T = 6\pi\eta r v_T^2 \quad \ldots\text{(i)}$$

From the relation for terminal velocity,

$$v_T = \frac{2}{9}\frac{r^2\,(\rho - \sigma)}{\eta} g, \text{ we get}$$

$$v_T \propto r^2 \quad \ldots\text{(ii)}$$

From Eq. (ii), we can rewrite Eq. (i) as

$$\frac{dQ}{dt} \propto r \cdot (r^2)^2 \text{ or } \frac{dQ}{dt} \propto r^5$$

Hence, the rate of production of heat is proportional to r^5.

64 (*b*) A liquid film has two surfaces, so upward force $= 2Tl$

According to question,

Weight of the body hanged from wire (mg)
= Upward force due to surface tension $(2Tl)$

$$\Rightarrow \quad m = \frac{2Tl}{g}$$

65 (*a*) Given, $T = 70 \times 10^{-3}\ \text{Nm}^{-1}$, $A = 10^{-2}\ \text{m}^2$

and $\quad t = 0.05$ mm $= 0.05 \times 10^3$ m

Force required to separate the two glass plates,

$$F = \frac{2TA}{t} = \frac{2 \times 70 \times 10^{-3} \times 10^{-2}}{0.05 \times 10^{-3}} = 28\ \text{N}$$

66 (*a*) Given, $F = 2 \times 10^{-2}$ N and $l = 10$ cm $= 10 \times 10^{-2}$ m

$$\text{Surface tension, } T = \frac{F}{2l} = \frac{2 \times 10^{-2}}{2 \times 10 \times 10^{-2}} = 0.1\ \text{Nm}^{-1}$$

67 (*d*) Given, $T_1 = 0.07\ \text{Nm}^{-1}\text{m}$, $T_2 = 0.06\ \text{Nm}^{-1}$

and $\quad L = 2$ m

Force on one side of the stick $F_1 = T_1 \times L$
$= 0.07 \times 2 = 0.14$ N

and force on other side of the stick

$$F_2 = T_2 \times L = 0.06 \times 2 = 0.12\ \text{N}$$

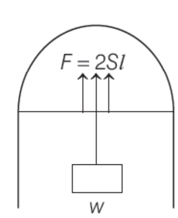
So, net force on the stick $= F_1 - F_2 = 0.14 - 0.12$
$= 0.02$ N

68 (*d*) Given, $w = 1.5 \times 10^{-2}$ N

$$l = 30\ \text{cm} = 30 \times 10^{-2}\ \text{m}$$

A liquid film has two free surfaces.

A slider will support the weight, when the force of surface tension acting upwards on the slider $(= 2Sl)$ balances the downward force due to weight (w) as shown below



$$\therefore \quad 2\,Sl = w$$

$$\Rightarrow \quad S = w/\,2l$$

$$\Rightarrow \quad S = \frac{1.5 \times 10^{-2}}{2 \times 30 \times 10^{-2}}$$

$$\therefore \quad S = 0.025 \text{ Nm}^{-1}$$

69 (*a*) A liquid air interface has energy. So, for a given volume the surface with minimum energy is the one with the least area.

Since, amongst the various shapes of objects, sphere has the minimum area.

Thus, sphere (shape of drop and bubbles) will have minimum energy associated with it.

Therefore free liquid drops and bubbles are spherical in shape, due to its surface with minimum energy, if effects of gravity can be neglected.

70 (*b*) Suppose a spherical drop of radius r is in equilibrium. If its radius increases by Δr, then the extra surface energy is

ΔE_S = final surface energy – initial surface energy

$$= (SA)_f - (SA)_i$$

where, $S =$ surface tension and A is the surface area.

$$= |4\pi (r + \Delta r)^2 - 4\pi r^2| S$$

$$= (4\pi r^2 + 4\pi r^2 + 8\pi r \Delta r - 4\pi r^2) S = 8\pi r \Delta r S$$

(neglecting Δr^2 as it is very small)

71 (*a*) If a liquid drop is in equilibrium, then energy lost is balanced by the energy gain due to expansion under the pressure difference $(p_i - p_o)$ between the inside of the drop and the outside.

Initial surface area of liquid drop $= 4\pi r^2$

Final surface area of the liquid drop $= 4\pi (r + \Delta r)^2$

$$= 4\pi r^2 + 8\pi r \Delta r$$

(Δr^2 is very small and hence neglected)

Increase in the surface area of liquid drop

$$= 4\pi r^2 + 8\pi r \Delta r - 4\pi r^2 = 8\pi r \Delta r$$

External work done is increasing the surface area of the drop

$$w = 8\pi r \Delta r S_{la} \quad \ldots \text{(i)}$$

where, S_{la} is the surface tension of liquid air interface.

However, work done is $W = (p_i - p_o) 4\pi r^2 \Delta r \quad \ldots$(ii)

$\therefore$ From Eqs. (i) and (ii), we get

$$p_i - p_o = \frac{2S_{la}}{r}$$

73 (*d*) Surface area of bubble of radius $r = 4\pi r^2$

Surface area of bubble of radius $3r = 4\pi (3r)^2 = 36\pi r^2$

Therefore, increase in surface area

$$= 36\pi r^2 - 4\pi r^2 = 32\pi r^2$$

Since, a bubble has two surfaces, the total increase in surface area $= 64\pi r^2$.

$\therefore$ Energy spent = Work done = Surface tension $\times$ Area

$$= 64\pi \sigma r^2$$

74 (*b*) As, radius of bigger drop $R = n^{1/3} r = 2^{1/3} r$

$$\Rightarrow \quad R^2 = 2^{2/3} r^2$$

$$\Rightarrow \quad \frac{r^2}{R^2} = 2^{-2/3}$$

$$\frac{\text{Initial surface energy}}{\text{Final surface energy}} = \frac{2(4\pi r^2 T)}{(4\pi R^2 T)} = 2\left(\frac{r^2}{R^2}\right)$$

$$= 2 \times 2^{-2/3} = 2^{1/3} = 2^{1/3} : 1$$

75 (*a*) Let n be the number of spherical drops of liquid of radius r, that coalesce to form a single drop of radius R.

$\therefore n \times$ volume of each spherical drop of radius $r =$ volume of spherical drop of radius R

$$\Rightarrow \quad nV_i = V \text{ or } V_i = \frac{V}{n}$$

As, $\quad V_{\text{sphere}} = \frac{4}{3}\pi r^3 \Rightarrow V \propto r^3$

As, $\quad V \propto \frac{1}{n} \Rightarrow r^3 \propto \frac{1}{n}$ or $r \propto \frac{1}{n^{1/3}}$

$$\Rightarrow \quad r_i = \frac{R}{n^{\frac{1}{3}}} \quad \Rightarrow \quad n^{\frac{1}{3}} = \frac{R}{r}$$

As we know, $\Delta U = U_f - U_i = T\, 4\pi (R^2 - nr^2)$

where, T is the surface tension of the liquid.

$$\Rightarrow \quad \Delta U = T 4\pi R^2 \left(1 - \frac{nr^2}{R^2}\right) = T\, 4\pi R^2 \left(1 - \frac{n}{n^{\frac{2}{3}}}\right)$$

$$= T \times 4\pi R^2 (1 - n^{1/3}) = T\, 4\pi R^2 \left(1 - \frac{R}{r}\right)$$

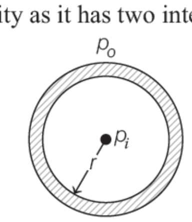
$$= T\, 4\pi R^3 \left(\frac{1}{R} - \frac{1}{r}\right) = T\, 3\left(\frac{4}{3}\pi R^3\right)\left(\frac{1}{R} - \frac{1}{r}\right)$$

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

As, $\quad R > r \Rightarrow \frac{1}{R} < \frac{1}{r}$

$\therefore \Delta U$ is negative, so energy released. $= 3VT\left(\frac{1}{r} - \frac{1}{R}\right)$

76 (*b*) A soap bubble is as shown in figure, differs from a drop and a cavity as it has two interfaces.



When radius of bubble is increased by radius Δr, the increase in the surface area of the bubble $= 8\pi r \Delta r$.

So, effective increase in surface area of the soap bubble $= 2 \times 8\pi r \Delta r = 16\pi r \Delta r$

External work done in increasing the surface area of the soap bubble

= Increase in surface energy = $16\pi r\Delta r\, S_{la}$ ...(i)

where, S_{la} is the surface tension of liquid-air interface.

But, work done = $p \times 4\pi r^2\ \Delta r$ ...(ii)

From Eqs. (i) and (ii), we get

$$p = \frac{4S_{la}}{r}$$

$\therefore$ Pressure difference in a soap bubble is

$$p_i - p_0 = \frac{4S_{la}}{r}$$

77 (*b*) Excess pressure inside an air bubble just below the surface of water, $p_1 = \frac{2T}{r}$, due to only one free surface and excess pressure inside a drop, $p_2 = \frac{2T}{r}$

$\therefore$ $p_1 = p_2$

The excess pressure inside an air bubble below the surface of water is same as the excess pressure inside a drop of same radius outside the surface of water.

78 (*c*) Given, $p_0 = 1.01 \times 10^5$ Pa, $S = 7.30 \times 10^{-2}$ Nm^{-1}

and $r = 1\,\text{mm} = 1 \times 10^{-3}$ m

Pressure inside the bubble is

$$p_i = p_o + 2S/r$$

$$= 1.01 \times 10^5 + (2 \times 7.30 \times 10^{-2}/10^{-3})$$

$$= (1.01000 + 0.00146) \times 10^5 \text{ Pa} = 1.01146 \times 10^5 \text{ Pa}$$

79 (*b*) When soap bubble is being inflated and its temperature remains constant, then it follows Boyle's law, so

$$pV = \text{constant } (k) \Rightarrow p = \frac{k}{V}$$

Differentiating above equation with time, we get

$$\frac{dp}{dt} = k.\frac{d}{dt}\left(\frac{1}{V}\right) \Rightarrow \frac{dp}{dt} = k\left(\frac{-1}{V^2}\right).\frac{dV}{dt}$$

It is given that, $\frac{dV}{dt} = c$ (a constant)

So, $$\frac{dp}{dt} = \frac{-kc}{V^2} \qquad \text{... (i)}$$

Now, from $\frac{dV}{dt} = c$; we get

$$dV = cdt$$

or $$\int dV = \int cdt \text{ or } V = ct \qquad \text{... (ii)}$$

From Eqs. (i) and (ii), we get

$$\frac{dp}{dt} = \frac{-kc}{c^2t^2} \quad \text{or} \quad \frac{dp}{dt} = -\left(\frac{k}{c}\right)t^{-2}$$

$$\Rightarrow \quad dp = -\frac{k}{c}.t^{-2}dt$$

Integrating both sides, we get

$$\int dp = -\frac{k}{c}\int t^{-2}dt$$

$$p = -\frac{k}{c}.\left(\frac{t^{-2+1}}{-2+1}\right) = -\frac{k}{c}.\frac{-1}{t} = \frac{k}{ct} \Rightarrow p \propto \frac{1}{t}$$

Hence, p *versus* $\frac{1}{t}$ graph is a straight line, which is correctly represented in option (b).

80 (*b*) The excess pressure inside a soap bubble of radius r is given by

$$p = \frac{4T}{r}$$

where, T = surface tension.

If p_o be the pressure outside from the water, then total pressure inside the bubble becomes

$$p_i = p_o + \frac{4T}{r} \qquad \text{... (i)}$$

The pressure at the depth Z_0 below the water surface is

$$p_2 = p_o + Z_0\rho g \qquad \text{... (ii)}$$

As it is given that the pressure inside the bubble is same as the pressure at depth Z_0, then equating Eqs. (i) and (ii), we get

$$p_o + \frac{4T}{r} = p_o + Z_0\rho g \Rightarrow Z_0 = \frac{4T}{r\rho g} \qquad \text{... (iii)}$$

Given, $T = 2.5 \times 10^{-2}$ N/m, $\rho = 10^3$ kg/m^3,

$g = 10\,\text{m/s}^2$ and $r = 1\,\text{mm} = 1 \times 10^{-3}$ m

Substituting these values in Eq. (iii), we get

$$Z_0 = \frac{4 \times 2.5 \times 10^{-2}}{1 \times 10^{-3} \times 10^3 \times 10} = 10 \times 10^{-3}\text{ m} = 1\,\text{cm}$$

81 (*c*) If p_o is the atmospheric pressure, the pressure outside the air bubble when it is at a depth $h = p_o + h\rho g$. Therefore, the total pressure inside the air bubble is

$$p_t = p + p_o + h\rho g$$

$$= \frac{2\sigma}{r} + p_o + h\rho g \qquad \left(\because p = \frac{2\sigma}{r}\right)$$

82 (*b*) The excess pressure in a bubble of gas in a liquid is given by $2S/r$, where S is the surface tension of the liquid gas interface. There is only one liquid surface in this case.

Pressure outside the bubble,

p_o = Atmospheric pressure + Pressure due to 8 cm of water column

where, 1 atmospheric pressure = 1.01×10^5 Pa.

Pressure due to 8 cm of water column, $p = \rho gh$

Density of water, $\rho = 1000\,\text{kg/m}^3$, $g = 9.8\,\text{ms}^{-2}$

h = depth below the surface of water in a beaker

= $8.00\,\text{cm} = 0.08\,\text{m}$

$$\therefore \quad p_o = (1.01 \times 10^5\,\text{Pa} + 0.08 \times 1000 \times 9.8)$$

$$= 1.01784 \times 10^5 \text{ Pa}$$

83 (*b*) It is given that water rises to a height h in capillary tube. If the length of capillary tube above the surface water is made less than h, then height of water column > length of capillary tube.

So, water rises upto the top of capillary tube and stay there without overflowing.

85 (d) Soap solution has lower surface tension, T as compared to pure water and capillary rise in tube,

$$h = \frac{2T\cos\theta}{\rho rg}$$

so h is less for soap solution.

So, figure in option (d) shows the correct relative nature of liquid columns in the two tubes as water form concave surface with capillary tube.

86 (c) Given, $h_1 = 2.2$ cm and $h_2 = 6.6$ cm

As, $h \propto \frac{1}{r}$

$$\therefore \quad \frac{h_1}{h_2} = \frac{r_2}{r_1} \text{ or } \frac{r_1}{r_2} = \frac{h_2}{h_1} = \frac{6.6}{2.2} = \frac{3}{1}$$

87 (a) Height of liquid rise in capillary tube,

$$h = \frac{2T\cos\theta_c}{\rho rg} \Rightarrow h \propto \frac{1}{r}$$

So, when radius is doubled, height becomes half.

$$\therefore \quad h' = h/2$$

Now, density $(\rho) = \frac{\text{mass}(M)}{\text{volume}(V)}$

$$\Rightarrow \quad M = \rho \times \pi r^2 h$$

$$\therefore \quad M' = \rho\pi r'^2 h'$$

$$\therefore \quad \frac{M'}{M} = \frac{r'^2 h'}{r^2 h} = \frac{(2r)^2(h/2)}{r^2 h} = 2$$

$$\Rightarrow \quad M' = 2M$$

88 (b) When the tube is placed vertically in water, water rises through a height h is given by $h = \frac{2T\cos\theta}{rdg}$

However, the increase in potential energy ΔE_P, of the raised water column $= mg\frac{h}{2}$ ...(i)

where, m is the mass of the raised column of water,

i.e. $m = \pi r^2 hd$

From Eq. (i), we get

$$\Delta E_p = (\pi r^2 hd)\left(\frac{hg}{2}\right) = \frac{\pi r^2 h^2 dg}{2}$$

Further, heat evolved = increase in potential energy

$$\Delta W = \Delta E_p = \frac{\pi r^2 h^2 dg}{2}$$

89 (a) Pressure exerted is same in all directions in a fluid at rest. So, pressure is not a vector quantity.

No direction can be assigned to pressure. The force against any area within (or bounding) a fluid at rest and under pressure is normal to the area, regardless of the orientation of the area.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

90 (a) The flow of the fluid is said to be steady, if at any given point, the velocity of each passing fluid particle remains constant in time.

Every other particle which passes the second point behaves exactly as the previous particle that has just passed that point.

This is because, each particle follows a smooth path and the paths of the particles do not cross each other.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

91 (a) According to the equation of continuity, for the flow of incompressible fluids mass of liquid flowing out equals to the mass of the liquid flowing in, i.e. Av = constant.

So, Av gives the volume flux or flow rate and remains constant throughout the streamline flow.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

92 (a) As from equation of continuity, volume flow rate of fluid, i.e. $Q = Av$ = constant. So, speed of upstream decreases as its area of cross-section increases. Similarly, speed of downstream increase, as its area of cross-section decreases.

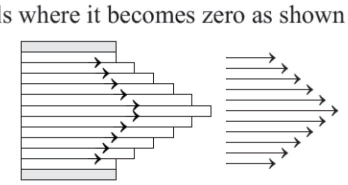
So, when a horse pipe is held vertically up, the speed of stream decreases and hence area of liquid flow increases and water spread like a fountain. Similarly, when it is held vertically down, the speed of stream increases , so area of liquid flow decreases and the water stream tends to narrow down.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

93 (d) In steady flow of a liquid over a horizontal surface, the velocities of layers increases uniformly from bottom (zero velocity) to the top layer (velocity $\mathbf{v}$).

For any layer of liquid, its upper layer pulls it forward while lower layer pulls it backward. This results in a force between the layers. This type of flow is known as laminar flow.

When a fluid is a flowing in a pipe or a tube, then velocity of the liquid layer along the axis of the tube is maximum and decreases gradually as we move towards the walls where it becomes zero as shown in figure.



Therefore, Assertion is incorrect but Reason is correct.

94 (b) When a body moves through a fluid, its motion is opposed by the force of fluid friction called resistance of fluid. It acts normal to the surface and increases with increasing speed of body.

It is due to this reason, the shape of an automobile is, so designed that it resembles the streamline pattern of the fluid through which it moves, so that air friction is minimum.

Also, the resistance offered by the fluid is not maximum.

Therefore, Assertion and Reason are correct but Reason is not the correct explanation of Assertion.

95 (*a*) The machine parts are jammed in winter because the viscosity of the lubricants used in the machines increases at low temperature.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

96 (*a*) Water flows faster than honey because the coefficient of viscosity of water is less than honey.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

97 (*b*) When an object falls through a viscous medium, finally it attains terminal velocity. At this velocity, the viscous force balances the weight of the rain drop.

So, all the rain drops hit the surface of the earth with the same constant velocity, but do not mutually attain same terminal velocity because it depends on the size of the drop.

Therefore, Assertion and Reason are correct but Reason is not the correct explanation of Assertion.

98 (*c*) The weight of the body is balanced by two upward forces, namely the buoyant force and viscous force.

No net force acts on a body falling in a liquid with a velocity equal to the terminal velocity, because this force (viscous) is balanced by the weight of body.

Therefore, Assertion is correct but Reason is incorrect.

99 (*a*) A fluid will stick to a solid surface, if the surface energy between fluid and the solid is smaller than the sum of surface energies between solid-air and liquid-air, interface.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

100 (*a*) Sometimes insects can walk on the surface of water due to surface tension, when legs of insects are not being wet.

In this situation, the gravitational force on insect is balanced by force due to surface tension.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

101 (*c*) The excess pressure inside a liquid drop is given by $p = \frac{2\sigma}{R}$

i.e. $p \propto \frac{1}{R}$

A bubble differs from a drop as it has two interfaces.

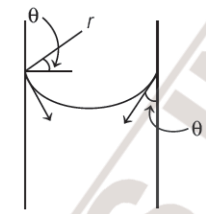
Therefore, Assertion is correct but Reason is incorrect.

102 (*a*) The pressure difference between the two sides of the top surface of a liquid in a capillary tube is given by

$$p_i - p_o = \frac{2S}{r} = \frac{2S}{a\sec\theta} = \frac{2S}{a}\cos\theta$$

where, θ = angle of contact.

In case of water is taken in the capillary tube, the contact angle between water and glass is acute. Thus, the pressure of water inside the tube, just at the meniscus (air-water interface) is less than the atmospheric pressure. So, the surface of water in the capillary is concave as shown below



Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

103 (*a*) As excess pressure inside a liquid drop is

$$p = \frac{2S}{R} \Rightarrow p \propto \frac{1}{R}$$

$\therefore$ Excess pressure inside the smaller drop is large due to which smaller drop of water resist deforming forces better than the larger drops.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

104 (*c*) The formation of capillaries take place in the field which is not ploughed for long. So, the water from beneath the ground reaches the surface and evaporates.

But if the fields are ploughed, the capillaries will break and water will not rise to surface and thus ploughing reduces evaporation.

On ploughing, more surface area of the field becomes open to the sunlight.

Therefore, Assertion is correct but Reason is incorrect.

105 (*a*) Washing with water does not remove grease stains. This is because water does not wet greasy dirt, i.e. there is very little area of contact between them.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

106 (*b*) Statements I and III are correct but II is incorrect and it can be corrected as,

A fluid cannot withstand tangential or shearing stress for an indefinite period. It begins to flow when a shearing stress is applied.

107 (*b*) Statements I and III are correct but II is incorrect and it can be corrected as,

Eddies and whirls are formed in turbulent flow.

109 (*c*) Statements I and III are correct but II is incorrect and it can be corrected as,

A restriction on application of Bernoulli's theorem is that the fluids must be incompressible as the elastic energy of the fluid is also not taken into consideration.

110 (*d*) Statements I and III are correct but II is incorrect and it can be corrected as,

The flow speed on top is higher than that below it.

113 (*a*) Let V_1 = total volume of material of shell

V_2 = total inside volume of shell,

and $\quad x$ = fraction of V_2 volume filled with water.

In floating condition,

Total weight = Upthrust

$$\therefore \quad V_1\rho_c g + (xV_2)(1)g = \left(\frac{V_1+V_2}{2}\right)(1)g$$

[As upthrust is on half part only]

$[\because \rho_{\text{water}} = 1\,\text{kgm}^{-3}]$

$$\Rightarrow \quad x = 0.5 + (0.5 - \rho_c)\frac{V_1}{V_2}$$

From here, we can see that, $x > 0.5$ if $\rho_c < 0.5$.

Thus, the statement given in option (a) is correct, rest are incorrect.

114 (*d*) Since, pressure is transmitted undiminished throughout the fluid in lift,

So, pressure in limb of area A_1 = pressure in limb of area A_2

$$\Rightarrow \quad \frac{F_1}{A_1} = \frac{F_2}{A_2} \Rightarrow F_2 = F_1\frac{A_2}{A_1} \Rightarrow F_2 \propto A_2/A_1$$

Since, the fluid used is considered to be perfectly incompressible.

Volume displaced by pistons in both limbs is same

$$\therefore \quad V_1 = V_2$$

$$\Rightarrow \quad A_1x_1 = A_2x_2$$

$$\Rightarrow \quad A_1\cdot\frac{d}{dt}x_1 = A_2\frac{d}{dt}x_2$$

$$\Rightarrow \quad A_1v_1 = A_2v_2$$

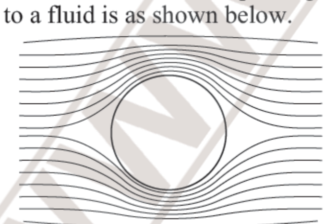
$$\Rightarrow \quad \frac{v_2}{v_1} = \frac{A_1}{A_2}$$

As pressure is same in both the limbs, so work done by force F_1 is equal to that of F_2.

Thus, the statement given in option (d) is correct, rest are incorrect.

115 (*c*) Statement given in option (c) is incorrect and it can be corrected as,

The streamlines around a non-spinning ball moving relative to a fluid is as shown below.



From the symmetry of streamlines, it is clear that the velocity of fluid above and below the ball at corresponding points is the same resulting in zero pressure difference. The fluid therefore, exerts no upward or downward force on the ball.

Rest statements are correct.

116 (*a*) Statement given in option (a) is incorrect and it can be corrected as,

Viscous force decreases with decrease in viscosity. If fluid is a gas, its viscosity increases with increase in temperature.

Thus, viscous force on object decreases with decrease in temperature.

Rest statements are correct.

117 (*d*) From the property of surface tension, there are least number of molecules in topmost layer of any liquid and for topmost layers of a fluid, energy is maximum.

So, total energy of surface A > total energy of surface B.

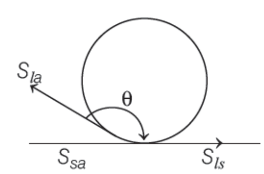
Number of molecules on surface A < Number of molecules in surface B.

The molecule on the surface of the liquid, i.e. layer A is surrounded from half side by liquid molecules. Thus, its potential energy is half that of a molecule inside the liquid, i.e. layer B.

However, as the liquid molecule inside the liquid is surrounded equally from all sides, so net force on a molecule of surface B will be zero.

Thus, the statement given in option (d) is correct, rest are incorrect..

118 (*d*) According to question, the situation can be depicted as below,



From, this we have,

$$\cos\theta + S_{ls} = S_{sa}$$

It is given that a small drop is formed, so the angle of contact should be greater than 90°, i.e. $\theta > 90°$ and $\cos\theta$ is negative.

This implies that $S_{ls} > S_{la}$. Hence, liquid does not spread on solid surface.

Thus, the statement given in option (d) is correct, rest are incorrect.

122 (*c*) Given, mass of girl, $m = 50$ kg

Diameter of circular heel, $2r = 1.0$ cm

$\therefore$ Radius, $r = 0.5\,\text{cm} = 5\times10^{-3}$ m

Area of circular heel, $A = \pi r^2 = 3.14\times(5\times10^{-3})^2\ \text{m}^2$

$$= 78.50\times10^{-6}\ \text{m}^2$$

$\therefore$ Pressure exerted on the horizontal floor,

$$p = \frac{F}{A} = \frac{mg}{A} = \frac{50\times9.8}{78.50\times10^{-6}}$$

$$= 6.24\times10^6\ \text{Pa}$$

123 (*b*) Pressure exerted by h height of wine column $(h\rho g)$

= Pressure exerted by 76 cm of Hg column $(h\rho g)$

or $\quad h\times984\times9.8 = 0.76\times13.6\times10^3\times9.8$

$$\therefore \quad h = \frac{0.76\times13.6\times10^3}{984} = 10.5\,\text{m}$$

124 (*b*) Given, depth of ocean, $h = 3\ \text{km} = 3000$ m

Density of water, $\quad \rho = 10^3\ \text{kgm}^{-3}$