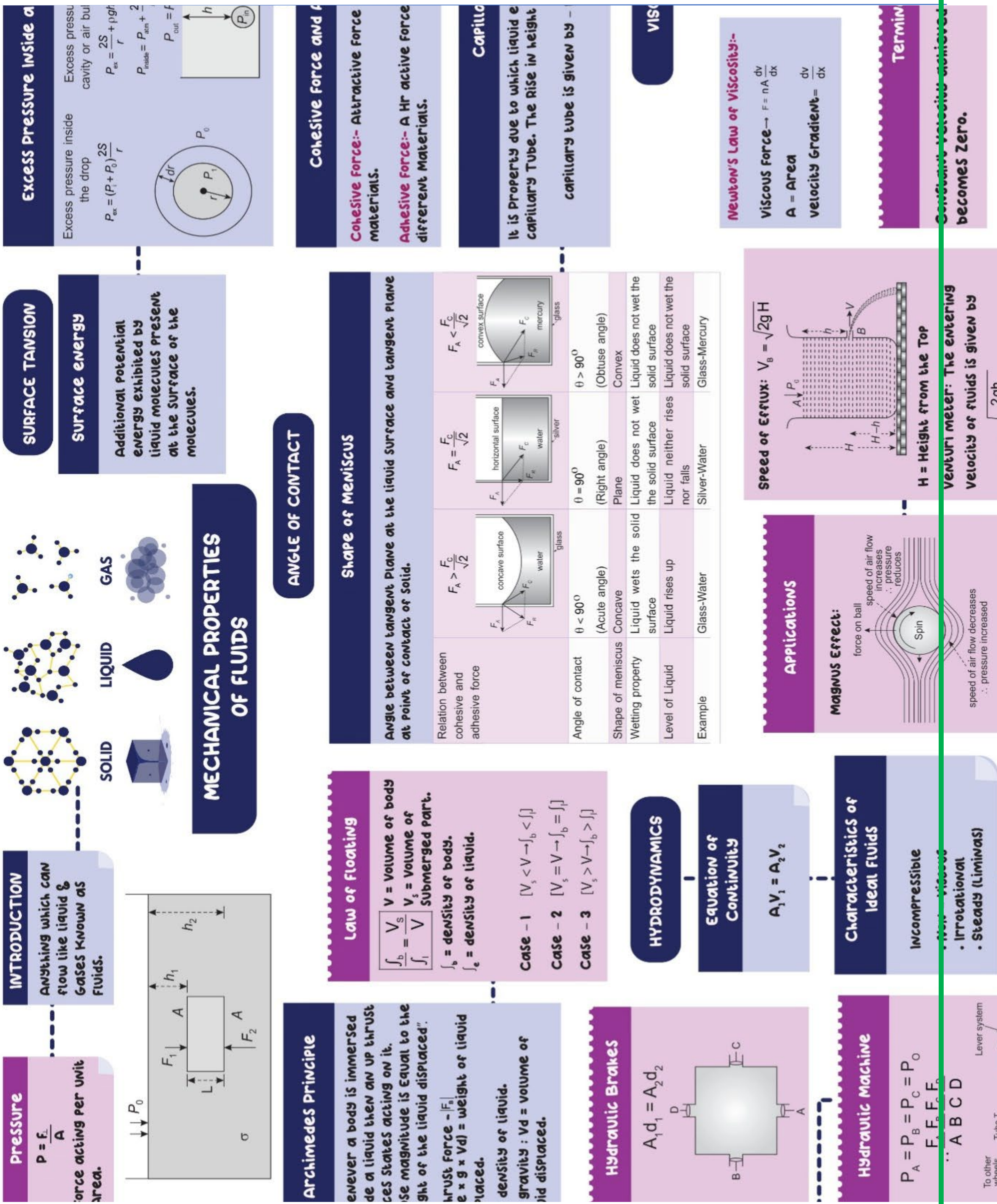
10.Mechanical Properties of Fluids

Ramanujan School of Mathematics and Physics

Theory + NCERT MCQs + Topic Wise Practice MCQs + NEET PYQs



Mechanical Properties of Fluids

Hydrostatics

1. **Fluid:** Liquids and gases are collectively called fluids for they have some common properties.
2. **Properties (or characteristics) of a fluid:**
   (a) It can flow since it cannot sustain a tangential force, i.e., shearing stress.
   (b) It has no shape of its own.
   (c) It exhibits the phenomenon of viscosity.
   (d) It exerts pressure on surfaces with which it is in contact.

3. **Pressure:** It is the ratio of the force exerted normally on a surface to the area of the surface. $P=\frac{F}{A}$,

F$\rightarrow$ constant normal force over an area A.

Pressure at a point in a fluid is $P=\frac{dF}{dA}$

The SI unit of pressure is $N.m^{-2}$, called the **pascal** (pa)

1 Pa = 1 N. m^{-2}

The dimensional formula for pressure is $[M^1L^{-1}T^{-2}]$

(a) **Atmospheric pressure (P)**: It is the pressure of the atmosphere at sea level. It is usually expressed in atmosphere (atm). It is the weight of air acting per unit area of a surface.

$$1\text{ atm}=1.01\times10^5\text{ Pa}$$

(b) **Hydrostatic pressure** (P_g) : It is the pressure exerted at a point by a column of fluid over it. It is also called the gauge pressure. It is the weight of stationary liquid acting per unit area of a surface.

$$P_g=\rho gh$$

$\rho\rightarrow$ density of the fluid, h$\rightarrow$height of the fluid column

(c) **Absolute (or total) pressure** (P_a): It is the sum of the atmospheric and gauge pressures.

$$P_a=P+P_g$$

☞

- Pressure is a scalar quantity (why?)
- The pressure at any point in a fluid is the same in all directions. That is, the orientation of the sensor at the point is immaterial.
- A barometer is used to measure atmospheric pressure
- A manometer is used to measure gauge pressure,since it is proportional to the difference in the levels of the manometer liquid.
- Absolute pressure in inflated tyres or the human circulatory system is more than the atmospheric pressure. So, P_g is + ve, sometimes called the **overpressure.**
- $P_a<P$ in your lung when you suck in a straw to pull liquid up the straw. So, P_g is –ve.
- Lying on a bed of nails is much more comfortable than sitting on a bed of nails (why?)
- **Fluid thrust** is the force exerted normally on a surface with which it is in contact.
- The torr is a unit of pressure.
  1 torr = 1 mm of Hg = 133.3 Pa
- In meteorology the bar is a common unit for pressure 1 bar = 10^5 Pa

4. **Pascal's principle:** Pressure applied to an enclosed incompressible static fluid is transmitted undiminished to all parts of the fluid (including the walls of the enclosure)

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

- The pressure at a point in a fluid in static equilibrium depends on the depth of that point but not on any horizontal dimension of the fluid or its container.
- Pressure exerted is same in all directions in a body at rest (It again reminds us that like other types of stress), pressure is not a vector quantity it is a scalar quantity. No direction can be assigned to it. The force against any area within a fluid at rest and under pressure is normal to the area, regardless of the orientation of the area.

5. **Buoyant force:** It is the vertical resultant upward force exerted by the liquid on an object immersed partially or wholly in a fluid. Its magnitude is given by Archimedes' principle.

6. **Archimedes principle:** A body immersed wholly or partially in a fluid is buoyed up by a force (the buoyant force) equal to the weight of the fluid it displaces.

$F_b = \rho_f V_f g$

where, $\rho_f \rightarrow$ density of the fluid

$V_f \rightarrow$ volume of the displaced fluid (or of the submerged portion of the body)

7. **Floatation:** Two forces acting on a floating body are

(i) The weight W ($=\rho Vg$) of the body, vertically down and (ii) the buoyant force $F_b (= \rho_f V_f g)$ vertically up. Depending upon their resultant a body can float, just float or just sink, and sink to the bottom.

(a) If $W < F_b$, i.e., $\rho < \rho_f$, the body floats with a part above the fluid surface.

(b) If $W = F_b$, i.e., $\rho = \rho_f$, the body just floats or just sinks, i.e. it remains wherever it is within the body of the fluid.

(c) If $W > F_b$, i.e. $\rho > \rho_f$, the body sinks to the bottom. A body with $\rho > \rho_f$ can also float.

☞

- The centre of gravity of the displaced fluid is called the centre of **buoyancy**
- The line through the centre of gravity and the centre of buoyancy is called the **central line**.
  It is vertical when the body is in static equilibrium. It gets tilted when the body is tiltedwith respect to the vertical.
- When a floating body is tilted, the central line also gets tilted and the centre of buoyancy gets shifted. The line of action of the buoyant force through the new centre of buoyancy intersects the central line at a point called the **metacentre.**
- For a body to be in stable equilibrium the metacentre M should always be at a higher level than that of the centre of gravity of the body. If it is below the centre of gravity it gets capsized. The body, is in **unstable equilibrium**.

8. **Density**

(a) Density of a rock (or any solid material)

$$\rho = \left(\frac{w}{w - w_w}\right)\rho_w$$

where $w \rightarrow$ weight in air, $w_w \rightarrow$ weight in water, $\rho_w \rightarrow$ density of water (or liquid)

(b) Density of a mixture of two solids or fluids

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

when, $\rho_1 \rightarrow$ density of a substance of mass m_1

$\rho_2 \rightarrow$ density of a substance of mass m_2

(i) If the two are of different volumes, say V_1 and V_2 respectively,

$$\rho = \frac{V_1\rho_1 + V_2\rho_2}{V_1 + V_2}$$

(ii) If they are of the same volume $(V_1 = V_2)$,

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

(iii) If they are of the same mass $(m_1 = m_2)$,

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

(c) **Relative density:** It is the density of a substance relative to that of water.

$$\rho_r = \frac{\text{Density of a substance}}{\text{Density of water}}$$

It is unit less and dimensionless.

(i) Relative density of a solid: $\rho_r = \dfrac{W'}{W - W'}$

$W \rightarrow$ weight in air; $W' \rightarrow$ weight in water

(ii) Relative density of a liquid:

$$\rho_r = \frac{W - W_l}{W - W'}$$

W→weight of a solid in air; W_l→ in a liquid; W′→ in water

9. A floating ice cube in a liquid :

(a) **Cube of ice only:**

Let M → mass of ice cube.

Volume of water formed, when ice melts, is $V_w = M/\rho_w$

Volume of the liquid displaced by floating ice cube is $V_l = M/\rho_l$

(i) If $\rho_l > \rho_W$, then $V_l < V_W$. So, the level of the liquid together with water formed is more than the level of the liquid with the floating ice cube. In other words, the level rises.

(ii) If $\rho_l < \rho_W$, then $V_l > V_W$. So, the level falls.

(iii) If the liquid is water, the level does not change.

(b) **An ice cube with a cavity in water:**

When the cube is floating, volume of water it displaces is $V_w = \dfrac{M+m}{\rho_w}$

M→ mass of ice, m→ mass of the cavity substance

Volume of water formed, when ice cube melts, is $V'_w = \dfrac{M}{\rho_w}$

(i) If the cavity contains air, m = 0. So, $V_w = V'_w$. The level of water remains the same, when ice cube melts.

(ii) If the cavity is filled with a floating object, such as cork, the volume of water displaced by it is

$$V''_W = \frac{m}{\rho_W}$$

It is obvious that the volume of water formed and the volume of water displaced by the cork equals the volume of water displaced by the floating ice cube. So, the level of water remains the same, when ice melts.

(iii) If the cavity is filled with a heavy object, such as iron, the volume of water displaced is

$$V''_W = \frac{m'}{\rho_{iron}}$$

$$V'_W + V''_W = \left(\frac{M}{\rho_w} + \frac{m}{\rho_{iron}}\right) < \frac{M}{\rho_w} + \frac{m}{\rho_w}$$

Since, $\rho_{iron} > \rho_w$. So, the volume of water formed and that displaced by iron is less than the volume displaced by the floating ice cube. Thus, the level of water falls, when the ice cube melts.

☞

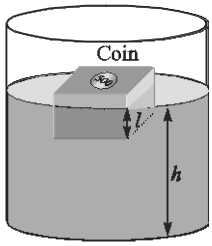
- The fraction of the total volume of a solid piece of density ρ, floating in a liquid of density ρ_l, above the liquid level is $f = \dfrac{V_{out}}{V_{total}} = \left(1 - \dfrac{\rho}{\rho_l}\right)$
- If a man in a floating boat, loaded with rocks, in the middle of a swimming pool throws the rocks into the pond, the water level in the pond will come down.

- For a floating body, the weight of the body is balanced by the upthrust. It is worth-while to note that the two forces do not act at the same point and still balance each other. The weight of the body acts at its centre of gravity, while the upthrust acts at the centre of gravity of the displaced liquid.
- If a body of volume 'V' and density 'ρ' is immersed in liquid of density 'σ', then apparent weight of the body = V(ρ−σ) g.

- If a body of density 'ρ' is allowed to fall in a liquid of density 'σ', then its acceleration is given by $a = \left(\frac{\rho - \sigma}{\rho}\right)g$.

Illustrations

1. A wooden block, with a coin placed on the top, floats in water as shown in figure. The distance *l* and h are shown there. After sometime the coin falls into the water. Then,



(A) *l* decreases and h increases
(B) *l* increases and h decreases
(C) both *l* and h increase
(D) both *l* and h decrease

Ans (D)
l will decrease because the block moves up, h will decrease because the coin will displace the volume of water (V_1), equal to its own volume when it is in the water, whereas, when it is on the block it will displace, the volume of water (V_2) whose weight is equal to weight of coin and since density of coin is greater than the density of water $V_1 < V_2$.

2. A cubical block is floating in a liquid with half of its volume immersed in the liquid. When the whole system accelerates upwards with a net acceleration of g/3, what fraction of its volume is immersed in the liquid ?
(A) $\frac{1}{2}$ (B) $\frac{3}{8}$ (C) $\frac{2}{3}$ (D) $\frac{3}{4}$

Ans (A)

$$\frac{\text{Volume submerged}}{\text{Volume}} = \frac{\rho_S}{\rho_L} = \frac{1}{2}.$$

The result is independent of the value of g_{eff}

3. The time period of a simple pendulum is T. The pendulum is oscillated with its bob immersed in a liquid of density σ. If the density of the bob is ρ and viscous effect is neglected, the time period of the pendulum will be
(A) $\left(\frac{\rho}{\rho-\sigma}\right)^{1/2} T$ (B) $\left(\frac{\sigma}{\rho-\sigma}\right)^{1/2} T$ (C) $\left(\frac{\rho}{\sigma}\right)^{1/2} T$ (D) $\left(\frac{\sigma}{\rho}\right)^{1/2} T$

Ans (A)
The net downawrd force acting on the bob is

$$ma = F = (\rho - \sigma)Vg \Rightarrow \left(\frac{\rho-\sigma}{\rho}\right)g = a \ (\because \ m = \rho V)$$

This is the effective acceleration due to gravity

$$T' = 2\pi\sqrt{\frac{l}{g_{eff}}} = 2\pi\sqrt{\frac{\rho l}{(\rho-\sigma)g}} = \left(\frac{\rho}{\rho-\sigma}\right)^{1/2} T \quad \left(\because T = 2\pi\sqrt{\frac{l}{g}}\right)$$

4. A vessel cotnains oil (density = 0.8 g cm^{-3}) over mercury (density = 13.6 g cm^{-3}). A homogeneous sphere floats with half its volume immersed in mercury and the other half in oil. The density of the material of the sphere in g cm^{-3} is
(A) 3.3 (B) 6.4 (C) 7.2 (D) 12.8

Ans (C)
Let density of material of sphere (in g cm^{-3}) be ρ
Applying the condition of floatation,

$$\text{Weight} = \text{Upthrust} \Rightarrow \rho V g = \frac{V}{2}\rho_{oil} g + \frac{V}{2}\rho_{Hg} g$$

$$\rho = \frac{\rho_{oil}}{2} + \frac{\rho_{Hg}}{2} = \frac{0.8}{2} + \frac{13.6}{2} = 7.2 \text{ g cm}^{-2}$$

5. An ideal fluid is one

(A) which is incompressible
(B)which offers no force of friction
(C) which is compressible
(D) which is incompressible and non-viscous.

Ans(D)

An ideal fluid is characterized by steady, incompressible, non-viscous flow.

6. "An object completely immersed in a fluid displaces its own volume of the fluid". This is the statement of

(A)Pascal'sprinciple
(B)Archimedes' principle
(C)Bernoulli'sprinciple
(D) Vernier principle

Ans(B)

Archimedes' principle: When a body is immersed either completely or partially in a liquid at rest, the body experiences an apparent loss of weight which is equal to the weight of liquid displaced.

7. A block of ice with a piece of iron frozen in it is floating on the water inside a vessel. When the ice melts, the level of water inside the vessel

(A) will rise
(B) will fall
(C) will remain same as before
(D) will fall at first and then will rise when the iron piece sinks to the bottom.

Ans(B)

Let m_1 and m_2 be the mass of ice and the iron piece respectively, from $(m_1 + m_2)g = V\rho g$. The volume of water displaced is $V = \frac{m_1 + m_2}{\rho} = \frac{m_1}{\rho} + \frac{m_2}{\rho}$. When the ice melts, the additional volume of water obtained is $V_1 = \frac{m_1}{\rho}$ and the volume of water displaced by the iron piece is equal to its own volume. $V_2 = \frac{m_2}{\rho_2}$, where ρ_2 is the density of iron.

Total volume of the extra water $V' = V_1 + V_2 = \frac{m_1}{\rho} + \frac{m_2}{\rho_2}$.

$$\therefore \frac{V'}{V} = \frac{1 + \left(\frac{m_2}{m_1}\right)\frac{\rho}{\rho_2}}{1 + \left(\frac{m_2}{m_1}\right)} < 1 \quad \text{since } \rho_2 > \rho. \text{ Hence } V' < V.$$

8. Equal masses of two substances A and B having densities ρ_A and ρ_B are mixed together. The density of the mixture would be

(A) $\sqrt{\rho_A \rho_B}$
(B) $\frac{\rho_A \rho_B}{(\rho_A + \rho_B)}$
(C) $\frac{2\rho_A \rho_B}{(\rho_A + \rho_B)}$
(D) $\frac{1}{2}(\rho_A + \rho_B)$

Ans(C)

$$\rho_{mix} = \frac{\text{total mass}}{\text{total volume}} = \frac{m_A + m_B}{V_A + V_B}$$

$$\rho_{mix} = \frac{m_A + m_B}{\left(\frac{m_A}{\rho_A}\right) + \left(\frac{m_B}{\rho_B}\right)}.$$

But $m_A = m_B = m$. Therefore $\rho_{mix} = \frac{2}{\frac{1}{\rho_A} + \frac{1}{\rho_B}}$

$$\rho_{mix} = \frac{2\rho_A\rho_B}{(\rho_A + \rho_B)}$$

9. A boat having a length of 5 m and breadth 1 m is floating on a lake. If a man gets on to the boat, the boat sinks by 0.1 cm. The weight of the man is (Take g = 10 m s^{-2})

(A) 50 N (B) 9 N (C) 35 N (D) 75 N

Ans(A)

Let V be the volume of water displaced by the man on the boat

$V = 5 \times 1 \times 0.1 \times 10^{-2}\ m^3 = 5 \times 10^{-3}\ m^3$

Weight of the man $W = V\rho_w g = 5\times10^{-3}\times10^3\times10 = 50$ N .

10. A cylindrical jar has a radius r. To what height h should it be filled with a liquid so that the force exerted by the liquid on the sides of the jar equals the force exerted on the bottom?

(A) $h = \frac{r}{2}$ (B) h = r (C) h = 2r (D) h = 4r

Ans (B)

Let us consider a cylinder with radius of cross-section r be filled with a homogeneous liquid of density ρupto a height h.

Pressure at the bottom of the cylinder, $P_1 = \rho gh$

Pressure at the top of the liquid surface, $P_2 = 0$

Average pressure on the sides of the cylinder, $P = \frac{P_1 + P_2}{2} \Rightarrow P = \frac{\rho gh + 0}{2} = \frac{\rho gh}{2}$

Force on the sides of the vessel = average pressure × area

$$= \frac{\rho gh}{2} \times 2\pi rh = \pi r\rho gh^2$$

Force on the bottom of the vessel $= P_1 \times \pi r^2 = \rho gh \times \pi r^2$

The two forces will be equal if $\pi r\rho gh^2 = \rho gh\pi r^2 \Rightarrow h = r$

11. Two identical cylindrical vessels, each of base area A, have their bases at the same horizontal level. They contain a liquid of density ρ. In one vessel the height of the liquid is h_1 and in the other $h_2 > h_1$. When the two vessels are connected, the work done by gravity in equalizing the levels is

(A) $2\rho Ag(h_2 - h_1)^2$ (B) $\rho Ag(h_2 - h_1)^2$ (C) $\frac{1}{2}\rho Ag(h_2 - h_1)^2$ (D) $\frac{1}{4}\rho Ag\,(h_2 - h_1)^2$

Ans (D)

After the levels in the two vessels become equal, the increase in height of the liquid in one vessel is $\frac{1}{2}(h_2 - h_1)$ with the same decrease in height in the other.

Thus, effectively a slab of liquid $\frac{1}{2}(h_2 - h_1)$ in thickness falls a vertical distance equals to its thickness under the action of gravity.

$\therefore$ Workdone by the gravity = W = mg $\times \frac{1}{2}(h_2 - h_1)$

Where m is the mass of the slab which is given by

$m = \rho \times V = \rho \times \frac{1}{2}(h_2 - h_1) \times A \qquad \therefore\ W = \rho \times \frac{1}{2}(h_2 - h_1) \times A \times g \times \frac{1}{2}(h_2 - h_1)$

$W = \frac{1}{4}\rho Ag\,(h_2 - h_1)^2$

12. A solid shell loses half its weight in water. Relative density of shell is 5. What fraction of its volume is hollow?

(A) $\frac{3}{5}$ (B) $\frac{2}{5}$ (C) $\frac{1}{5}$ (D) $\frac{4}{5}$

Ans (A)

Let x fraction of its volume is hollow.

Then the weight of the shell = (V –xV) × 5 × 1000 × g

Weight of the water displaced = V × 1000 × g

Weight of the water displaced = loss in weight

$$V \times 1000 \times g = \frac{1}{2} \times (V - xV) \times 5 \times 1000 \times g$$

$$V = \frac{1}{2}(5V - 5xV) \Rightarrow 2V = 5V - 5xV \Rightarrow 5xV = 3V \Rightarrow x = \frac{3}{5}$$

13. A spring balance reads 10 kg when a bucket of water is suspended from it. What will be the reading of the balance when an iron piece of mass 7.2 kg suspended by a string is immersed with half its volume inside the water in the bucket? Relative density of iron is 7.2.

(A) 10 kg (B) 10.5 kg (C) 13.6 kg (D) 17.2 kg

Ans (B)

Density of iron = $7.2 \times 10^3 kg / m^3$

Volume of the iron piece, $V = \frac{7.2}{7.2 \times 10^3} = 10^{-3}\ m^3$

Now, the volume of the iron piece under water is $\frac{V}{2}$, which is the volume of water displaced.

Hence, weight of water displaced = volume of water displaced × density of water × g

$$= \frac{V}{2} \times 1000 \times g = \frac{10^{-3}}{2} \times 1000 \times g = \frac{g}{2} \text{Newton}$$

= weight of 0.5 kg

This is the upthrust exerted by water on the iron piece. Hence, the iron piece will exert an equal and opposite force on water in the downward direction, which will increase the reading of the balance by 0.5 kg.

14. A tank with a square base of area 2 m^2 is divided into two compartments by a vertical partition in the middle. There is a small hinged door of face area 20 cm^2 at the bottom of the partition. Water is filled in one compartment and an acid of relative density 1.5 in the other, both to a height of 4m. If g = 10 m s^{-2}, the force necessary to keep the door closed is

(A) 10 N (B) 20 N (C) 40 N (D) 80 N

Ans (C)

Lateral pressure exerted by water on the face of the door in contact with water is

$P_W = h\rho_W g = 4 \times 1000 \times 10 = 4 \times 10^4\ N/m^2$

Lateral pressure exerted by acid on the face of the door in contact with acid is

$P_a = h\rho_a g = 4 \times 1500 \times 10 = 6 \times 10^4\ N/m^2$

∴ net pressure on the door = $P_a - P_w = 2 \times 10^4\ N/m^2$

Face area of the door = 20 cm^2 = $20 \times 10^{-4}\ m^2$

∴ Force on the door = pressure × area

$= 2 \times 10^4 \times 20 \times 10^{-4} = 40$ N

Hence, a force of 40 N must be applied on the door inorder to counter balance the force due to the two liquids.

15. A sample of metal weighs 210 g in air, 140 g in water and 120 g in an unknown liquid. Then

(A) the density of the metal is 3 g cm^{-3}

(B) the density of the metal is 7 g cm^{-3}

(C) the density of the metal is 4 times the density of the unknown liquid

(D) the density of the metal is 10 g cm^{-3}

Ans(A)

Specific gravity = $\dfrac{\text{weight of the body in air}}{\text{weight of the water displaced}} = \dfrac{210}{210-140} = 3$

Density of the body = specific gravity × density of water = 3 × 1 = 3 g cm^{-3}

16. When a crown of mass 14.7 kg made of an alloy of gold is submerged in water, an accurate scale reads only 13.4 kg. The specific gravity of alloy is

(A) 11.3 (B) 10.6 (C) 8.5 (D) 7.3

Ans(A)

The apparent weight of the submerged object W′ equals its actual weight W(= mg) minus the buoyant force B.

$W' = T = W - B = \rho_0 gV - \rho_F gV$

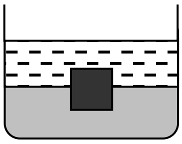
where V is the volume of the object, ρ_0 is the density of the object and ρ_F is the density of the fluid.

$\therefore\ B = W - W' = \rho_F gV$

$\therefore\ \dfrac{W}{W-W'} = \dfrac{\rho_0 gV}{\rho_F gV} = \dfrac{\rho_0}{\rho_F}$

$\therefore$ Specific gravity = $\dfrac{W}{W-W'} = \dfrac{14\cdot7}{14\cdot7-13\cdot4} = 11\cdot3$

17. An ice cube floats partly in water and partly in oil. Find the ratio of the volume of ice immersed in water to that in the oil. (Specific gravity of the oil is 0.8 and that of ice is 0.9).



(A) 0.5 (B) 1

(C) 1.5 (D) 2

Ans(B)

Let V_O be the volume of the cube in oil and V_W be the volume of the cube in water.

$V_O + V_W = V$ … (1)

where V is the volume of the cube.

Now for equilibrium of the cube, $B_O + B_W = mg$ … (2)

where B_O = Buoyancy due to displaced oil

B_W = Buoyancy due to displaced water and

mg = weight of the cube

From (2), $V_O\rho_O g + V_W\rho_W g = V\rho_{ice}g$

$V_O\dfrac{\rho_O}{\rho_W} + V_W = V\dfrac{\rho_{ice}}{\rho_W}$

$0.8\ V_O + V_W = 0.9\ V$ … (3)

Solving (1) and (3) for V_O and V_W, we get $\dfrac{V_O}{V_W} = \dfrac{1}{1}$

18. When equalvolumes of two metals are mixed together, the specific gravity of the alloy is 4. When equal masses of the same two metals are mixed together, the specific gravity of the alloy is 3. The specific gravity of each metal is

(A) 1, 2 (B) 2, 3 (C) 1, 3 (D) 2, 6

Ans(D)

Let ρ_1 and ρ_2 be the specific gravities of the two metals.

Then $\dfrac{\rho_1+\rho_2}{2} = 4$ … (1)

and $\dfrac{2\rho_1\rho_2}{\rho_1+\rho_2} = 3$ … (2)

Solving equations (1) and (2) we get $\rho_1 = 2$ and $\rho_2 = 6$.

19. What is the minimum area of a block of thick ice floating on water that will hold up an automobile weighing 1134 kg if the thickness of block of ice is 0.3 m?

(A) 32 m^2 (B) 42 m^2 (C) 56 m^2 (D) 87 m^2

Ans (B)

Let A be the minimum area of the ice block. Then the volume of the ice block is $(A\times 0.3)m^3$ and its weight is $(A\times 0.3\times 910)g$.

It will displace (0.3 A) m^3 of water whose weight is $(0.3A\times 1000)g$

To make the block float, $(0.3A\times 910)g + 1134\ g = (0.3A\times 1000)g$

Solving which we get, A = 42 m^2.

20. The fraction of a floating object of volume V_o and density ρ_o above the surface of liquid of density ρ will be

(A) $\dfrac{\rho_0}{\rho-\rho_0}$ (B) $\dfrac{\rho-\rho_0}{\rho}$ (C) $\dfrac{\rho_0}{\rho}$ (D) $\dfrac{\rho_0\rho}{\rho+\rho_0}$

Ans(B)

Let f be the fraction of volume of the object floating above the surface of the liquid.

According to the Archimedes' principle, weight of liquid displaced = weight of the object

$(V_0 - fV_0)\rho g = V_0\rho_0 g$

Solving which we get $(1 - f)\,\rho = \rho_0$ or $f = 1 - \dfrac{\rho_0}{\rho} = \dfrac{\rho-\rho_0}{\rho}$.

21. A beaker containing a liquid of density ρ moves up with an acceleration a. The pressure due to the liquid at a depth h below the free surface of the liquid is

(A) ρgh (B) $\rho h(g - a)$ (C) $\rho h(g + a)$ (D) $2h\rho g\left(\dfrac{g+a}{g-a}\right)$

Ans(C)

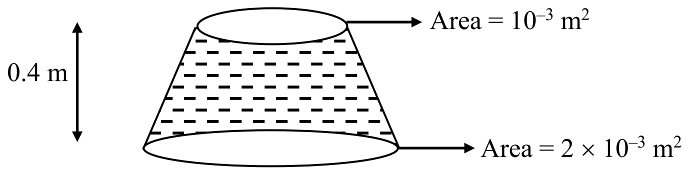
22. In order that a floatingobject be in a stable equilibrium, its centre of buoyancy should be

(A) vertically above its centre of gravity (B)below its centre of gravity

(C) horizontally in line with its centre of gravity (D)may be anywhere

Ans (A)

23. A uniformly tapered vessel, shown in the figure, is filled with a liquid of density 900 kg m^{-3}. The force that acts on the base of the vessel due to the liquid is (take g = 10 m s^{-2})



(A)3.6 N (B) 7.2 N (C) 9 N (D) 12.6 N

Ans (B)

$F = p \times A = \rho gh \times A = 900 \times 10 \times 0.4 \times 2 \times 10^{-3} = 7.2$ N.

24. A beaker containing water is placed on the pan of a common balance. A solid of specific gravity 1 and mass 5 g is tied to the arm of the balance and immersed in water contained in the beaker. The scale pan with the beaker

(A)goes down (B) goes up

(C) remains unaffected (D)none of these

Ans (C)

Effective weight of a solid of specific gravity 1 when immersed in water is zero.

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

(A) 6 × 6 × 5 × 5 g (B) 4 × 4 × 4 × 7 g (C) 5 × 5 × 5 × 7 g (D) 5 × 5 × 5 × 6 g

Ans (D)

Weight of the block of steel in air = 5 × 5 × 5 × 7 g

Weight of water displaced by steel = 5 × 5 × 5 × 1 g

∴ Apparent weight = 5 × 5 × 5 × 7 g – 5 × 5 × 5 × 1 g = 5 × 5 × 5 × 6 g

26. A body floats with one third of its volume outside water and $\frac{3}{4}$ of its volume outside another liquid. The density of the other liquid is

(A) 9·4 g cc^{-1} (B) 4 g cc^{-1} (C) $\frac{8}{3}$ g cc^{-1} (D) $\frac{3}{8}$ g cc^{-1}

Ans (C)

Let V be the volume of the body. Weight of the body is equal to weight of the water displaced.

Weight of the liquid displaced = $\frac{2}{3}V \times 1 \times g$

In another liquid, weight of the liquid displaced = $\frac{1}{4}V\rho g$

$\therefore \frac{2}{3}Vg = \frac{1}{4}V\rho g \Rightarrow \rho = \frac{8}{3}$ g cc^{-1}

27. A body is just floating in a liquid (their densities are equal). If the body is slightly pressed down and released, it will

(A) start oscillating (B)sink to the bottom

(C) come back to the same position immediately (D)come back to the same position slowly

Ans (B)

28. The gate of a canal is 8 m wide. The level of water on one side is 30 m and on the other side is 15 m. The resultant force on the gate is

(A) 270×10^5 N (B) 270×10^6 N (C) 540×10^5 N (D) 540×10^6 N

Ans(A)

$F = \frac{1}{2}\rho g h_1 A_1 - \frac{1}{2}\rho g h_2 A_2 = \frac{1}{2} \times 10^4[30 \times 30 \times 8 - 15 \times 15 \times 8] = 270 \times 10^5$ N

29. A block of ice is floating in a liquid of specific gravity 1.3 contained in a beaker. When the ice melts completely, level of liquid in the beaker

(A) remains same (B) increases (C) decreases (D) data is insufficient

Ans(B)

When ice is floating $m_i = v_1\rho_l \Rightarrow v_1 = \frac{m_i}{1300}$

When ice melts, $m_i = m_\omega = v_2\rho_\omega \Rightarrow v_2 = \frac{m_i}{1000}$

$\Rightarrow v_2 > v_1$ ∴ level of water increases.

30. An object floatshalf submerged in a beaker containing liquid at rest on the earth. When the beaker is taken to Mars,

(A) object completely sinks in (B) object raises up

(C) object sinks further slightly
(D) object floats half submerged only

Ans(D)

Weight of the body = weight of liquid

$V\rho_s g = V'\rho_l g \Rightarrow \frac{V'}{V} = \frac{\rho_s}{\rho_l}$

$\Rightarrow$ ratio of the submerged volume to the total volume is independent of the acceleration due to gravity.

31. A block of wood floats in a bucket of water in a lift, when the lift starts accelerating up,

(A) block sinks further
(B) block raises up
(C) block will float at the same level
(D) block oscillates in water

Ans(C)

Equilibrium of floating body is unaffected by variation in g. However thrust and weight increases.

32. Weightless bag is filled with water and weighed in water, then its weight will be

(A)equal to weight of water taken in bag
(B) zero
(C)greater than weight of water taken in the bag
(D) less than weight of water taken in the bag

Ans(B)

upthrust = $V\rho_\omega g \Rightarrow \omega_{app} = \omega_0 -$ upthrust = 0

33. A cubical block of steel of side 'a' and density ρ floats on mercury of density σ with a part of it being submerged. The height of the block above the mercury level is given by

(A) $a\left(1-\frac{\rho}{\sigma}\right)$
(B) $a\left(1+\frac{\sigma}{\rho}\right)$
(C) $a\left(1-\frac{\sigma}{\rho}\right)$
(D) $a\left(1+\frac{\rho}{\sigma}\right)$

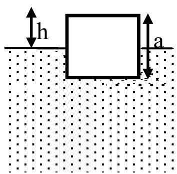
Ans (D)

Let h be the height of the cubical block over the surface of the mercury weight of the cube as in the figure.

From the Archimedes principle we can write,

mg = weight of the mercury displaced.

$mg = V\sigma g$ or, $a^3\rho g = (a-h)a^2\sigma g$ gives $h = a\left(1+\frac{\rho}{\sigma}\right)$.



34. The tension in a string holding a solid block of density ρ_s below the surface of a liquid of density ρ_l ($\rho_l > \rho_s$) is T_0 when the beaker is at rest. Tension in the string when beaker moves up with acceleration a is

(A) $T = 0$
(B) $T = T_0$
(C) $T = T_0\left[1+\frac{a}{g}\right]$
(D) $T = T_0\left[1-\frac{a}{g}\right]$

Ans(C)

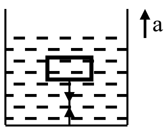
When beaker is at rest, upthrust = $T_0 + mg$

$T_0 =$ upthrust $- mg = V[\rho_l - \rho_s]g$

When lift is accelerating up, $g \to g + a$

$T = V[\rho_l - \rho_s]\,(g + a)$

$\therefore \frac{T}{T_0} = \frac{g+a}{g} \Rightarrow T = T_0\left[1+\frac{a}{g}\right]$



35. A plastic sphere has a volume V and density $(1/10)^{th}$ of water. Force required to hold it completely submerged under water is

(A) $V\rho_\omega g$ downwards
(B) $\frac{1}{10}V\rho_\omega g$ downwards

(C) $\frac{9}{10}V\rho_P g$ downwards (D) $\frac{9}{10}V\rho_\omega g$ downwards

Ans(D)

Given $\rho_p = \frac{1}{10}\rho_\omega$:

$F_{req} = V\rho_\omega g - V\rho_P g = V\left[1-\frac{1}{10}\right]\rho_\omega g \Rightarrow F_{req} = \frac{9}{10}V\rho_\omega g$

36. An object hangs from a spring balance. The balance registers 40 N in air, 30 N when the object is immersed in water. Then density of the object is

(A) 4×10^3 kg m^{-3} (B) 4×10^{-3} kg m^{-3} (C) 3×10^3 kg m^{-3} (D) 3×10^{-3} kg m^{-3}

Ans(A)

$F_B = 10\text{ N} = V_0\rho_\omega g \Rightarrow V_0 = \frac{10}{10^3 \times 10} = 10^{-3}\text{ m}^3$

$m_0 g = 40 \Rightarrow m_0 = 4$ kg $\therefore \rho_0 = \frac{4}{10^{-3}} = 4 \times 10^3$ kg m^{-3}

37. An object weighs 240 g in air and 210 g in water. Then relative density of metal is

(A) 3 (B) 8 (C) $\frac{1}{8}$ (D) $\frac{1}{3}$

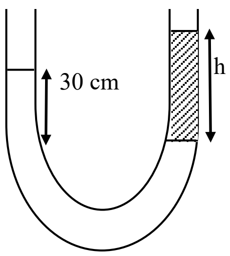
Ans(B)

$m_\omega g = m_a g - F_B$

$210g = 240g - V\rho_\omega g \Rightarrow V\rho_\omega = 30$ also $V\rho_0 = 240$

$\therefore \frac{\rho_0}{\rho_\omega} = \frac{240}{30} = 8$

38. A U-tube is partially filled with water. Liquid which does not mix with water is poured into one side until water rises by 15 cm on the other side. If the density of liquid is 0.8; the liquid level will stand higher than the water level by



(A) 37.5 cm
(B) 30 cm
(C) 7.5 cm
(D) 15 cm

Ans(C)

$\rho_\omega g\,(30\text{ cm}) = \rho_l g\,(h) \Rightarrow h = 30\text{ cm}\left(\frac{\rho_\omega}{\rho_l}\right)$

$h = \frac{30}{0.8} = 37.5$ cm $\therefore$ Height of liquid above the water level = 7.5 cm

Fluid Dynamics

1. **Properties of an ideal fluid under ideal flow:**

   (a) **Incompressible fluid:** A fluid is incompressible if its density has a constant value at all times regardless of the pressure in the fluid.

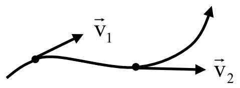
   (b) **Nonviscous fluid:** A fluid is non-viscous if an object moving through it does not experience any viscous drag or force, i.e., no resistive force due to viscosity.

   The above two assumptions are the properties of an ideal fluid.

(c) **Steady (or laminar) flow:** The flow is steady if the velocity of a fluid element at any fixed point does not vary with time. If it does, the flow becomes **turbulent** (nonsteady).

(d) **Irrotational flow:** The flow is irrotational if an object in it does not rotate about an axis through its centre of mass. There is no angular momentum of the fluid about any point. The last two are the descriptions the way that the fluid flows.

2. **Streamline:** It is the path followed by a fluid element when the fluid is under steady flow. It is defined as a curve whose tangent at any point is in the direction of the fluid velocity at that point.



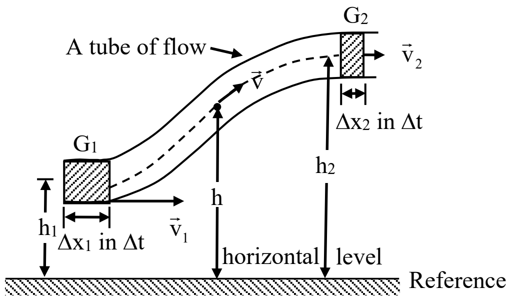
A stream line

3. **Tube of flow:** It is an imaginary tubular region bounded by streamlines. It acts like a pipe since fluid elements cannot leave through its boundary.

4. **Equation of continuity:** The rate of volume flow of a fluid in steady flow is a constant. $a_1v_1 = a_2v_2$

Equivalently av = constant Equation of continuity expresses **conservation of mass** in steady state.

Steady flow is achieved at low flow speeds. Beyond a limiting value, called critical speed, this flow loses steadiness and becomes turbulent.



A tube of flow and Bernoullis' equation and equation of continuity

5. **Bernoulli's equation (or theorem):** It is the reformulation of the **principle of conservation of mechanical** energy, more suitable for fluid mechanics.

Equivalent forms of Bernoulli's equation

(a) $P_1 + \rho g h_1 + \frac{\rho v_1^2}{2} = P_2 + \rho g h_2 + \frac{\rho v_2^2}{2}$

(b) $P + \rho g h + \frac{\rho v^2}{2} = \text{a constant}$

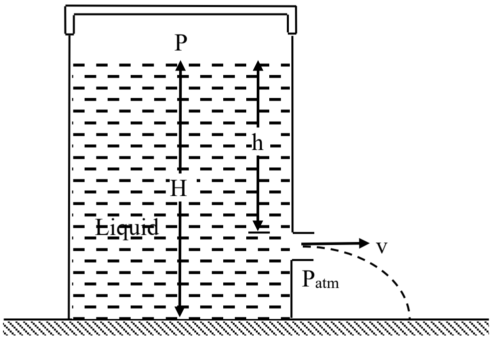
If the steady flow is horizontal, $h_1 = h_2$. Hence $P + \frac{\rho v^2}{2} = \text{a constant}$

In words, the Bernoullis relation may be stated as follows: As we move along a streamline the sum of the pressure, (P), the K.E $\left(\frac{\rho v^2}{2}\right)$ and the P.E (ρgh), all per unit volume remains constant.

☞

- In applying the energy conservation principle, there is an assumption that no energy is lost due to friction. But in fact, when fluids flow, some energy does get lost due to internal friction. This arises due to the fact that in a fluid flow, the different layers of the fluid flow with different velocities. These layers exert frictional forces on each other resulting ρ_{wa} loss of energy. This property of the fluid is called viscosity. The lost K.E of the fluid gets converted into heat energy. Thus, Bernoulli's equation ideally applies to fluids with zero viscosity or non-viscous fluids.
- Another restriction on application of Bernoulli's theorem is that the fluid must be incompressible, as the elastic energy of the fluid is also not taken into consideration. In practice, it has a large number of useful applications and can help to explain a wide variety of phenomena for low viscosity incompressible fluids. Bernoulli's equation also does not hold for non-steady or turbulent flows, because in that situation velocity and pressure are constantly varying with time.

6. **Torricelli's theorem:** A large (closed vessel containing a liquid of density ρ has a small hole (of cross-section << than that of the vessel). The air above the liquid is maintained at a constant pressure. The speed with which the liquid leaves the hole, (usually called the **velocity of efflux**) when the liquid level is at a distance h above the hole, is



(a) $v = \sqrt{\dfrac{2(P - P_{atm})}{\rho} + 2gh}$ – (Bernoulli's equation)

(b) If the liquid surface is open to atmosphere, $v = \sqrt{2gh}$

(i) Time taken by the liquid to reach the base is

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

(ii) The range is a maximum, $R_{max} = H$, when $h = \dfrac{H}{2}$

(iii) The range is the same for the liquid leaving two holes separated by y = H – 2h, i.e., when one hole is as much above the base as the other is below the free surface.

(iv) Time taken for the level to fall form H to H′ and $t = \dfrac{A}{a}\sqrt{\dfrac{2}{g}}\left[\sqrt{H} - \sqrt{H'}\right]$

If the hole is at the bottom, $t = \dfrac{A}{a}\sqrt{\dfrac{2H}{g}}$

A→ cross-sectional area of the vessel ;a→ cross-sectional area of the hole.

☞
- The velocity of a fluid element along a streamline may or may not change
- No two streamlines can intersect
- A fluid element nearing the narrow region of a tube of flow is accelerated by the high pressure behind it whereas it is retarded by the high pressure ahead of it when nearing a wide region.

Bernoulli's theorem offers explanation for the following:

(a) Heart and blood pressure:

(i) During each pulse (takes a little less than a second), the pressure in the heart and the circulatory system goes through a maximum (**systolic**) as the blood is pumped by the heart and a minimum (**diastolic**) as the heart relaxes.

(ii) The blood pressure is almost the same at the lower and upper parts when the person is lying down, but is quite different when the person is standing, being the least at the brain.

(iii) The blood pressure of a human is measured using an instrument, called the **sphygnomanometer,** and a stethoscope. The upper arm is used for the same because it is at the same level as the heart and the single bone in it facilitates the compression of the artery there, called the **brachial artery.**

(iv) The sphygnomanometer works on the principle that the **blood flow in the brachial artery can be made to go from laminar to turbulent by suitable compression.** The sound caused by turbulent flow, a dissipative one, is picked on the stethoscope.

The pressure in the air sack, wrapped around the upper arm, is first increased till the brachial artery is closed. The pressure in the sack is slowly reduced using the release valve. When the pressure in the sack is just below the systolic valve, a **tapping sound** is heard on the stethoscope. When the pressure is reduced to diastolic valve, a continuous roar is heard on the stethoscope. For a resting healthy adult, the typical systolic and diastolic pressures are respectively is 120 mm of Hg (16.0 kPa) and 80mm of Hg (10.6 kPa)

(v) **Vascular flutter:** One symptom of advanced arteriosclerosis (hardening of artery walls) is the vascular flutter as a result of accumulation of the plague (a combination of fat, cell debris, connective tissue, and sometimes calcium) on the inner walls of the artery. The accumulation causes the constriction of the artery. This makes the heart to put in more effort to pump the blood, and the blood flow through this region with greater speed. From Bernoulli's theorem, the pressure in the constricted region falls. If the blood speed is sufficiently high in this region, the artery may collapse under larger external pressure, causing monetary interruption in blood flow. At this point, the speed of blood decreases to zero, its pressure rises again, and the artery reopens. This irregular collapsing and revival of the artery is called the vascular flutter and can be heard on the stethoscope. The vascular flutter can lead to cardiac arrest, usually called heart attack.

(b) **Venturimeter**(also called the venture tube or flow meter), the carburetor, the ordinaryspray gun, and the atomizer work on Bernoulli's theorem.

(c) For the explanation of motion of two suspended pingpong balls toward each other, when air is blown between them.

(d) Doors and windows are almost always blown out and the house roof is lifted off the house during a tornedo.

Illustrations

1. The largest average velocity of blood flow in an artery of radius 2×10^{-3} m if the flow must remain laminar? (Take viscosity of blood to be 2.084×10^{-3} Pa s and $\rho_{blood} = 1.06 \times 10^3$ kg m^{-3}).

(A) 2.12 ms^{-1} (B) 0.49 ms^{-1} (C) 1.72 ms^{-1} (D) 0.62 ms^{-1}

Ans (B)

The maximum value of Reynolds number for flow to be laminar is 1000. If $v_c$is the average velocity of flow, then

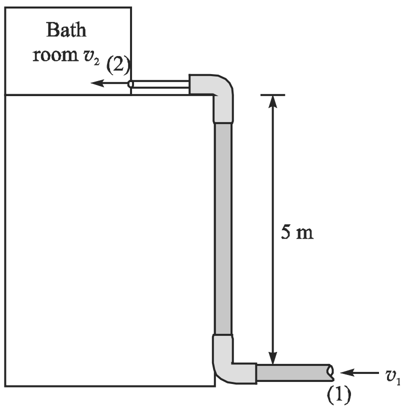
$$R_e = \frac{\rho v_c D}{\eta}$$

$$\therefore v_c = \frac{\eta R_e}{\rho D} = \frac{\eta R_e}{\rho(2r)} = \frac{2.084 \times 10^{-3} \times 1000}{1.06 \times 10^3 \times 2 \times 2 \times 10^{-3}} = 0.49 \text{ ms}^{-1}$$

2. Water enters a house through a pipe with 2.0 cm inside diameter, at an absolute pressure of 4×10^5 Pa. The pipe leading to the second-floor bathroom 5 m above is 1.0 cm in diameter. When the flow velocity at the inlet pipe is 4 ms^{-1}, find the flow velocity and pressure in the bathroom in ms^{-1} and Pa respectively

(A) 16, 2.3×10^5 (B) 16, 3.2×10^5 (C) 132, 2.3×10^5 (D) 32, 3.2×10^5

Ans (A)



By continuity equation, the flow velocity

$$v_2 = \frac{A_1 v_1}{A_2} = \frac{\pi(0.01)^2}{\pi(0.005)^2} \times 4 = 16 \text{ ms}^{-1}$$

Using Bernoulli's equation between 1 and 2, we have

$$p_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = p_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

$$\text{Or } p_2 = p_1 - \frac{1}{2}\rho\left(v_2^2 - v_1^2\right) - \rho g\left(h_2 - h_1\right)$$

$$= 4 \times 10^5 - \frac{1}{2} \times 1000(16^2 - 4^2) - 1000 \times 9.8 \times 5 = 2.3 \times 10^5 \text{ Pa}$$

3. A cylindrical tank has a hole of 1 cm^2 at its bottom. If the water is allowed to flow into the tank from a tube above it at the rate of 70 cm^3 s^{-1}, then find the maximum height upto which water can rise in the tank?

(A) 1.5 cm (B) 3.5 cm (C) 3 cm (D) 2.5 cm

Ans (D)

As height of water in the tank increases, the efflux velocity and hence rate of flow of emerging water also increases. At a certain height h the output become equal to input and the level of water becomes constant. $\therefore Q_{in} = Q_{out}$

$Q = a\sqrt{2gh}$

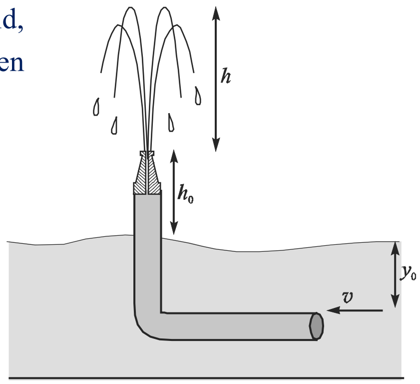
$$h = \frac{Q^2}{2ga^2} = \frac{(70\times10^{-6})^2}{2\times9.8\times(1\times10^{-4})^2} = 2.5 \times 10^{-2}\text{ m}$$

4. A bent tube is lowered into a water stream as shown in figure. The velocity of stream relative to the tube is equal to v = 2.5 m s^{-1}. The closed upper end of the tube located at the height h_0 = 12 cm as a small orifice. To what height h will the water jet spurt?

(A) 0.1 m (B) 0.2 m (C) 0.3 m (D) 0.5 m

Ans (B)

Consider two points 1 and 2, Point (1) is y_0 below the free surface of the liquid, Point 2 is the point of maximum height. Applying Bernoulli's equation between (1) and (2), we have



$$(p_a + y_0\rho g) + \frac{1}{2}\rho v^2 + 0 = p_a + 0 + \rho\,(y_0 + h_0 + h)g$$

$$\frac{1}{2}\rho v^2 = \rho(h_0 + h)g$$

$$\frac{1}{2}\times 2.5^2 = (0.12 + h)\times 9.8$$

$\therefore$ h = 0.2 m

5. Streamline flow is more likely for liquids with

(A) high density and low viscosity (B) high density and high viscosity

(C) low density and high viscosity (D) low density and low viscosity

Ans (C)

For the flow to be streamline, the velocity of the liquid must be less than the critical velocity.

But the critical velocity $v_C \propto \dfrac{\eta}{\rho}$.

Hence if η is high ρ is small, v_c will be large and the flow will be streamline.

6. A hole is made at the bottom of the tank filled with water. If the total pressure at the bottom of the tank is three atmosphere, the velocity of efflux is

(A) 30 m s^{-1} (B) 20 m s^{-1} (C) $\sqrt{40}$ m s^{-1} (D) $\sqrt{30}$ m s^{-1}

Ans (B)

$$\frac{1}{2}\rho v^2 = p_1 - p_2 \Rightarrow \frac{1}{2}\times10^3\times v^2 = 2\times10^5 \Rightarrow v^2 = 4\times10^2 \Rightarrow v = 20\text{ m s}^{-1}$$

7. Water from a tap emerges vertically down with an initial speed of 1.0 ms^{-1}. The cross-sectional area of the tap is 10^{-4} m^2. The cross-sectional area of the stream 0.15 m below the tap is (take g = 10 m s^{-2})

(A) 5.0×10^{-5} m^2 (B) 50×10^{-4} m^2

(C) 5×10^{-6} m^2 (D) 5.0×10^{-4} m^2

Ans (A)

Velocity of water at 0.15m below the tap is given by $v^2 = u^2 + 2gh$

$$v = \sqrt{u^2 + 2gh} = \sqrt{(1)^2 + 2(10)(0.15)} = \sqrt{4} = 2\text{ m s}^{-1}$$

From the equation of continuity $A_1v_1 = A_2v_2$

$(10^{-4})\ (1) = A_2(2)$

$\therefore A_2 = 0.5\times10^{-4}\ m^2 = 5.0\times10^{-5}\ m^2$

8. Water is flowing through a horizontal pipe in stream line flow. At the narrowest part of the pipe

(A) velocity is max; pressure is minimum

(B) velocity is minimum; pressure is maximum

(C) both velocity and pressure are maximum

(D) both velocity and pressure are minimum

Ans (A)

From the equation of continuity, $av = \text{constant}$. If a is minimum, v is maximum

From Bernoullis theorem, $p+\frac{1}{2}\rho v^2 = \text{constant}$; If v is maximum, p is minimum.

9. The rate of flow of a liquid through an orifice at the bottom of a tank does not depend on

(A) The area of cross-section of the orifice
(B) The height of the liquid above the orifice

(C) The acceleration due to gravity
(D) the density of the liquid

Ans (D)

Rate of flow of liquid = av = $a\sqrt{2gh}$

Rate of flow is independent of density.

10. A cylindrical tank of height H is completely filled with water on its vertical side there are two tiny holes, one above the middle at a height h_1 and the other below the middle at a depth h_2. If the jets of water from the holes meet at the same point at the horizontal plane through the bottom of the tank, then the ratio $\frac{h_1}{h_2}$ is

(A) 1
(B) 2
(C) 3
(D) 4

Ans (A)

The horizontal range of a jet of water emerging from a hole at a height h below the surface of water is given by $R = 2\sqrt{h(H-h)}$

The upper hole is at a height $\left(\frac{H}{2}+h_1\right)$ from the bottom and the lower hole is at a height $\left(\frac{H}{2}-h_2\right)$ from the bottom.

Their depths from the surface are respectively $\left(\frac{H}{2}-h_1\right)$ and $\left(\frac{H}{2}+h_2\right)$

The horizontal ranges will be equal if

$$2\sqrt{\left(\frac{H}{2}+h_1\right)\left(\frac{H}{2}-h_1\right)} = 2\sqrt{\left(\frac{H}{2}+h_2\right)\left(\frac{H}{2}-h_2\right)} \quad \Rightarrow h_1 = h_2$$

11. A horizontal pipe line carries water in a streamline flow. At a joint along the pipe, where the cross sectional area is 10 cm^2, the water velocity is 1 m s^{-1} and the pressure is 2000 Pa. The pressure of water at another point where the cross-sectional area is 5 cm^2 is (ρ_w = 1000 kg/m^3)

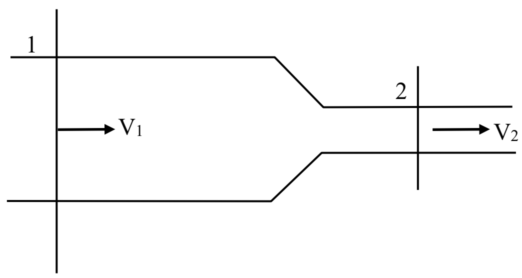
(A) 500 Pa
(B) 1000 Pa
(C) 1500 Pa
(D) 2000 Pa

Ans (A)

From the equation of continuity, $A_1v_1 = A_2v_2$

$$\Rightarrow v_2 = \left(\frac{A_1}{A_2}\right)v_1 = \left(\frac{10}{5}\right)\times1$$

$$v_2 = 2\ ms^{-1}$$



Applying Bernoulli's theorem at 1 and 2,

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

$$\Rightarrow P_2 = P_1 + \frac{1}{2}\left(v_1^2 - v_2^2\right)$$

$$= 2000 + \frac{1}{2} \times \left[1000\,(1-4)\right]$$

$P_2 = 500$ Pa

12. A rectangular tank is filled to the brim with water when a hole at its bottom is unplugged, the tank is emptied in time T. If the tank is filled with water, it will be emptied in time

(A) $\frac{T}{\sqrt{2}}$ (B) $\frac{T}{\sqrt{3}}$ (C) $\frac{T}{2}$ (D) $\frac{T}{2\sqrt{2}}$

Ans (A)

The velocity of efflux through a hole is given by $v = \sqrt{2gh}$, where $h \rightarrow$ is the height of the tank.

If the hole is at the top of the tank, v is obviously zero.

$\therefore$ The average velocity of efflux, $v_a = \frac{1}{2} \times \sqrt{2gh} = \sqrt{\frac{gh}{2}}$

If the volume of water in the tank when it is full, is V and A, the cross-sectional area of the hole, then the time taken by the tank to be emptied is $T = \frac{V}{Av_a} = \frac{\sqrt{2}V}{A\sqrt{g\,h}}$

When the tank is half full, V – is replaced by $\frac{V}{2}$ and h-is replaced by $\frac{h}{2}$.

$\therefore$ The time taken now is $T' = \frac{\sqrt{2}\,\frac{V}{2}}{A\sqrt{\frac{gh}{2}}} = \frac{V}{A\sqrt{gh}}$ $\qquad \therefore\ T' = \frac{T}{\sqrt{2}}$

13. Water is flowing through a tube of non-uniform cross-section. If the radius of the tube at the entrance and exit is 3 : 2, the ratio of velocity of liquid entering and leaving the tube is

(A) 8 : 27 (B) 4 : 9 (C) 1 : 1 (D) 9 : 4

Ans (B)

From equation of continuity, $a_1v_1 = a_2v_2$

$$\frac{v_1}{v_2} = \frac{a_2}{a_1} = \frac{\pi r_2^2}{\pi r_1^2} = \frac{4}{9}$$

14. A hole is made at the bottom of the tank filled with water. If the total pressure at the bottom of the tank is 3 atmosphere, then the velocity of efflux is

(A) $\sqrt{200}$ m s^{-1} (B) $\sqrt{300}$ m s^{-1} (C) $\sqrt{400}$ m s^{-1} (D) $\sqrt{600}$ m s^{-1}

Ans (C)

Total pressure = 3 atmosphere

$\therefore$ Fluid pressure = 2 atmosphere

$$\frac{1}{2}\rho v^2 = P \quad \Rightarrow \frac{1}{2}(10^3)v^2 = 2\times10^5$$

$\therefore\ v^2 = 400 \quad \therefore\ v = \sqrt{400}\ \text{m s}^{-1}$

15. A drum of radius R full of liquid of density d is rotated at ω rad s^{-1}. The increase in pressure at the centre of the drum is

(A) $\frac{\omega Rd}{4}$ (B) $\frac{\omega^2R^2d^2}{2}$ (C) $\frac{\omega Rd}{2}$ (D) $\frac{\omega^2R^2d}{2}$

Ans (D)

From Bernoulli's principle

$$\left(P+\frac{1}{2}dv^2\right)_{center}=\left(P+\frac{1}{2}dv^2\right)_{edge}$$

$$P_c+0=P_e+\frac{1}{2}d(R\omega)^2 \qquad \therefore P_c-P_e=\frac{1}{2}dR^2\omega^2$$

16. A tank is filled with water (density 1000 kg m^{-3}) and oil (density 900 kg m^{-3}). The height of water layer is 1.0 m and that of the oil layer is 4.0 m. The velocity of efflux from an opening at the bottom of the tank is

(A) 10 m s^{-1} (B) 9.5 m s^{-1} (C) 0.95 m s^{-1} (D) 100 m s^{-1}

Ans (B)

$$h_0d_0g+h_\omega d_\omega g=\frac{1}{2}d_\omega v^2$$

$$(4)(900)(9.8)+(1)(1000)(9.8)=\frac{1}{2}(1000)v^2$$

On simplifying we get v = 9.5 m s^{-1}

17. A water tank resting on the floor has two small holes vertically one above the other. The holes are h_1 and h_2 cm above the floor. How high does the water stand in the tank if the jets from the holes hit the floor at the same point?

(A) $h_1 + h_2$ (B) $h_1 - h_2$ (C) $\frac{h_1^2+h_2^2}{2}$ (D) h_1h_2

Ans (A)

Let H be the height to which water stands

Then $H - h_1 = h_2$

$\therefore$ $H = h_1 + h_2$

18. A tank is filled with water to a height of 2 m. A small hole is made in one of the walls of the tank at a depth 40 cm below the water surface. The distance from the foot of the wall at which the water jet coming out through the hole strikes the ground is

(A) 80 cm (B) 160 cm (C) 28.3 cm (D) 200 cm

Ans (B)

$$R=2\sqrt{h(H-h)}=2\sqrt{(40(200-40)}=2\sqrt{40\times160}=160\text{ cm}$$

19. Water contained in a tank flows through an orifice of diameter 2 cm, under a constant pressure difference of 10 cm of water column. The rate of flow of water through the orifice is

(A) 44 cc/s (B) 4.4 cc/s (C) 476 cc/s (D) 4400 cc/s

Ans (C)

$$V=\sqrt{2gh}=\sqrt{2\times980\times10}=140\text{ cm/s}$$

Volume of water flowing out of the orifice = $(\pi r^2)V = (3.4)(1)^2(140) = 476$ cc/s

Viscosity

1. **Viscosity:** It is a property of the fluid. It can be thought of as internal friction between adjacent layers of a fluid in motion that opposes the relative motion between them.
2. **Velocity gradient:** It is the rate of change of velocity of a fluid with distance normal to its propagation direction.

   Velocity gradient = $\frac{dv}{dz}$
3. **Viscous drag:** (a) It is the retarding force exerted by one layer on another adjacent layer of a fluid in motion.

(b) It is tangential to the surfaces of the layers in contact

(c) Its magnitude is found to be

$$F = \eta A \frac{dv}{dz}$$

A $\rightarrow$ area of the layers in contact

$\frac{dv}{dz} \rightarrow$ velocity gradient in the fluid

$\eta \rightarrow$ a proportionality constant, called coefficient of viscosity.

(d) The SI unit of η is Nsm^{-2} and its dimensional formula is $[M^1L^{-1}T^{-1}]$.

(e) The cgs unit of η is poise. 1 poise = 0.1 Nsm^{-2}.

4. **Poiseuille's formula (or equation):** It is an expression for the rate of steady fluid flow through a narrow horizontal cylindrical tube. The rate at which volume of a fluid flows steadily is given by $Q = \frac{V}{t} = \frac{\pi P r^4}{8\eta l}$

   r$\rightarrow$ radius of the tube, $l \rightarrow$ length of the tube

   P$\rightarrow$ pressure difference between the ends of the tube.

   $\eta \rightarrow$ coefficient viscosity of the fluid.

   V $\rightarrow$ volume of the fluid flowing for a time t.

5. **Stokes' law:** The viscous force on a solid ball of radius r moving through a fluid with velocity v is given by $F = 6\pi\eta r v$

6. **Terminal speed (v_0):** A solid sphere falling through a viscous fluid attains a constant speed, called terminal speed, after which it continues to fall with that speed. The forces acting on the sphere are

   (i) its weight vertically downward, (ii) viscous force vertically upward and (iii) buoyant force vertically upward. The net force on the sphere becomes zero, when it starts falling with terminal speed, given by $6\pi\eta r v_o$ = [weight – buoyant force].

   It can be shown that

   $$v_o = \frac{2gr^2(\rho - \sigma)}{9\eta}$$

   r $\rightarrow$ radius of the solid sphere,

   g $\rightarrow$ acc. due to gravity.

   $\rho \rightarrow$ density of the material of the sphere.

   $\sigma \rightarrow$ density of the fluid.

   $\eta \rightarrow$ coefficient of viscosity of the fluid.

☞

- η of liquids decreases with temperature because its molecules become more mobile. $\eta \propto \frac{1}{T}$
- η of gases increases with temperature because random motion of its molecules increases.
- η of liquids increases with density.
- η of gases decreases with density.
- η of liquids (except water) increases with pressure.
- η of gases is practically independent of pressure.
- Viscosity represents, from the point of view of kinetic theory, transportation of momentum.
- The profile of advancing liquid in a capillary is a parabola.

Reynolds Number

Osborne Reynolds (1842 – 1912) observed that turbulent flow is less likely for visions fluid flowing at low rates. He defined a dimensionless number, whose value gives are an approximate idea whether the flow would be turbulent. This number is called the Reynolds Number 'R_e'.

$$R_e = \frac{\rho v d}{n}$$

where ρ – is the density of the fluid flowing with a speed 'v'.

d – stands for the dimension of the pipe and

n – is the viscosity of the fluid.

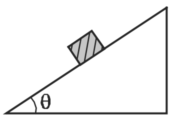
- 'R_e' is a dimensionless number and therefore, it remains some in any system of units.
- (i) If $R_e < 1000$, then the flow is streamline or laminar.
- (ii) If $R_e > 2000$, then the flow is turbulent.
- (iii) The flow becomes unsteady for 'R_e' between 1000 and 2000.
- The critical value of 'R_e' (called as critical Reynolds number), at which turbulence sets, is found to be the same for the geometrically similar flows.
- 'R_e' can also be written as $R_e = \dfrac{\rho v^2}{\left(\dfrac{nv}{d}\right)} = \dfrac{\rho A v^2}{\left(\dfrac{nAv}{d}\right)} = \dfrac{\text{inertial force}}{\text{force of viscosity}}$
- ∴ Thus 'R_e' represents the ratio of inertial force (force due to inertia is … mass of moving fluid or due to inertia of obstacle in its path) to viscous force.

Illustrations

1. A cubical block of side *a* and density ρ slides over a fixed inclined plane with constant velocity *v*. There is a thin film of viscous fluid of thickness *t* between the plane and the block. Then the coefficient of viscosity of the thin fill will be

(A) $\eta = \dfrac{\rho a g t \sin\theta}{v}$ (B) $\dfrac{\rho g t \sin\theta}{a v}$

(C) $\dfrac{v}{\rho\, a g t \sin\theta}$ (D) None of these



Ans (B)

$$mg\sin\theta = \eta A\left(\frac{v}{t}\right) \text{ or } \rho a^3 g\sin\theta = \eta a^2\left(\frac{v}{t}\right) \quad \therefore \eta = \frac{\rho\, a g t\sin\theta}{v}$$

2. Find the viscosity of glycerine (having density 1.3 g cc^{-1}) if a steel ball is 2 mm radius (density = 8 g cc^{-1}) acquires a terminal velocity of 4 cm s^{-1} in falling freely in the tank of glycerine

(A) 14.6 poise (B) 12.2 poise (C) 10.4 poise (D) 9.8 poise

Ans (A)

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

i.e., $\eta = \frac{2}{9}\frac{g(\rho-\sigma)r^2}{v_T}$

So $\eta = \frac{2}{9}\times\frac{980\times(8-1.3)\times(0.2)^2}{4} = 14.6$ poise

3. The terminal speed of a rain drop of radius 0.3 mm in air is 1 ms^{-1}. The coefficient of viscosity of air is 18×10^{-5} poise, the viscous force on the drop is nearly

(A) 10^{-6} N (B) 10^{-5} N (C) 10^{-7} N (D) 10^{-4} N

Ans (A)

$F = 6\pi\eta rv = 6 \times 3.14 \times 18 \times 10^{-5} \times 0.3 \times 10^{-3} \times 1 = 1.01 \times 10^{-6}$ N

4. Two liquids flowing through similar pipes under similar pressure heads have viscosities 0.002 S.I unit and 0.012 S.I. unit. If the rate of flow of the first liquid is 1.2 litres per minute, that of the other is

(A) 2 litre (B) 0.72 litre (C) 0.2 litre (D) 7.2 litre

Ans (C)

Rate of flow, $V = \frac{\pi pr^4}{8\eta l}$; $V \propto \frac{1}{\eta}$; $\frac{V_2}{V_1} = \frac{\eta_1}{\eta_2}$;

$\frac{V_2}{1.2} = \frac{0.002}{0.012} \therefore V_2 = 1.2\frac{0.002}{0.012} = \frac{1.2\times0.2}{1.2} = 0.2$ litre

5. A drop of a liquid of radius 2 mm has a terminal velocity of 20 cm s^{-1} in a viscous medium. The terminal velocity of a drop of radius 1 mm in the same medium is

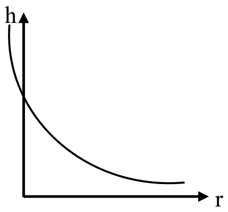
(A) 10 cm s^{-1} (B) 5 cm s^{-1} (C) 40 cm s^{-1} (D) 15 cm s^{-1}

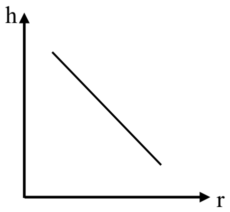
Ans (B)

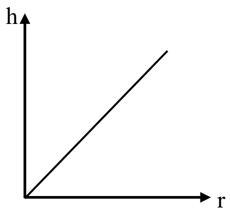
Terminal velocity is given by $V_t = \frac{2r^2}{9\eta}(\rho-\sigma)g$

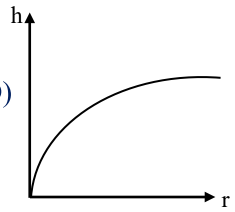
$V_t \propto r^2 \qquad \therefore \frac{v'_t}{v_t} = \frac{r'^2}{r^2} \Rightarrow \frac{v'_t}{20} = \left(\frac{1}{2}\right)^2 \Rightarrow v'_t = 5 \text{ cm s}^{-1}$

6. Which of the following graphs best represent the variation of velocity of a body dropped in a viscous liquid with time

(A) 

(B) 

(C) 

(D) 

Ans (D)

The body attains terminal velocity after some time and then after its velocity remains constant

7. If viscosity of air is taken into account, then the orbital velocity of the satellite moving close to the earth

(A) increases till the satellite falls back on the earth

(B) increases till the satellite overcomes earth's gravitational pull

(C) decreases continuously

(D) remains unaffected

Ans (A)

Energy of satellite at radius r is $E = -\frac{GMm}{2r}$

Due to friction losses (due to air) energy of the satellite goes on decreasing or r goes on increasing.

Now, the orbital velocity $v_0 \propto \frac{1}{\sqrt{r}}$

(or) it goes on increasing till it finally falls back on the earth.

8. A solid ball of density ρ_1 and radius r falls vertically through a liquid of density ρ_2. Assume that the viscous forceacting on the ball is F = Krv, where K is a constant and v is its velocity. What is the terminal velocity of the ball?

(A) $\frac{4\pi g r^2(\rho_1-\rho_2)}{3K}$ (B) $\frac{2\pi g r^2(\rho_1-\rho_2)}{3gK}$ (C) $\frac{2\pi g(\rho_1+\rho_2)}{3gr^2K}$ (D) none of these

Ans (A)

Net force on the ball = 0; when terminal velocity is attained

Hence, weight = up thrust + viscous force

$$\frac{4}{3}\pi r^3\rho_1 g = \frac{4}{3}\pi r^3\rho_2 g + Krv_t$$

$$\Rightarrow v_t = \frac{4\pi g r^2}{3K}(\rho_1-\rho_2)$$

9. Two capillary tubes A and B of equal radii $r_A = r_B = r$ and $l_A = 2l$ and $l_B = l$. If a pressure difference P is maintained across tube A, the rate of flow of water in it is Q. If the tubes are connected in series and the same pressure difference P is maintained across the combination, the rate of flow through the combination will be

(A) $\frac{Q}{3}$ (B) $\frac{2Q}{3}$ (C) Q (D) $\frac{4Q}{3}$

Ans (B)

Since pressure difference across a tube is directly proportional to its length and the lengths of tubes A and B are in the ratio 2 : 1, the pressure difference across A and B is

$$P_A = \frac{2P}{3} \text{ and } P_B = \frac{P}{3}$$

If l is the equivalent length of the series combination, we have

$$Q' = Q_A + Q_B$$

$$\Rightarrow \frac{Pr^4}{8\eta l^1} = \frac{2P}{3}\times\frac{r^4}{8\eta(2l)} + \frac{P}{3}\times\frac{r^4}{8\eta l}$$

$$\Rightarrow \frac{1}{l'} = \frac{1}{3l} + \frac{1}{3l} = \frac{2}{3l} \Rightarrow l' = \frac{3l}{2}$$

$$\therefore Q' = \frac{Pr^4}{8\eta l'} = \frac{Pr^4}{8\eta\left(\frac{3l}{2}\right)} = \frac{2}{3}\left(\frac{Pr^4}{8\eta l}\right) \quad Q' = \frac{2}{3}Q$$

10. A wide vessel of uniform cross-section with a small hole in the bottom is filled with 40 cm thick layer of water and 30 cm thick layer of kerosene. The relative density of kerosene is 0.8. The initial velocity of flow of water streaming out of the hole is (take g = 10 m s^{-2})

(A) $\frac{2}{\sqrt{5}}$ m s^{-1} (B) $\frac{4}{\sqrt{5}}$ m s^{-1} (C) $\frac{6}{\sqrt{5}}$ m s^{-1} (D) $\frac{8}{\sqrt{5}}$ m s^{-1}

Ans (D)

Let ρ_w and ρ_k be the densities of water and kerosene.

The initial weight of the liquid in vessel = $h_w\rho_w ag + h_k\rho_k ag$

where h_w and h_k are the thickness of water and kerosene layers and a is the cross-sectional area of the vessel.

Let this weight be equivalent to water layer of thickness h, then

$$h\rho_w ag = h_w\rho_w ag + h_k\rho_k ag \Rightarrow h = h_w + h_k\left(\frac{\rho_k}{\rho_w}\right)$$

$= 0.4 + 0.3 \times 0.8 = 0.64$ m

From Toricelli's theorem, the velocity of efflux is

$$v = \sqrt{2gh} = \sqrt{2\times10\times0.64} = \frac{8}{\sqrt{5}}\ \text{m s}^{-1}$$

11. A small metal sphere of radius r and density ρ falls from rest in a visions liquid of density σ and coefficient of viscosityη. Due to friction, heat is produced. The rate of production of heat when the sphere has acquired the terminal velocity is proportional to

(A) r^2 (B) r^3 (C) r^4 (D) r^5

Ans (D)

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

The rate of production of heat (or power dissipated) is given by

$P = fv_t$ where $f = 6\pi\eta r v_t$

$\therefore$ $P = 6\pi\eta r v_t \times v_t$

$$= 6\pi\eta r\left[\frac{2r^2}{9\eta}(\rho-\sigma)g\right]^2$$

$$= 6\pi\eta\left[\frac{2}{9\eta}(\rho-\sigma)g\right]^2 \cdot r^5$$

$\therefore$ $P\ \alpha\ r^5$

12. A small spherical ball of radius r falls freely under gravity through a distance h before entering a tank of water. If after enteringthe water, the velocity of the ball does not change, then h is proportional to

(A) r^2 (B) r^3 (C) r^4 (D) r^5

Ans (C)

As indicated in the question as the ball enters the water it has already attained the terminal velocity.

Terminal velocity is reached when the viscous force (acting upwards) balances the weight mg of the ball.

$\therefore$ $6\pi\eta r v = mg$

where $6\pi\eta r v \rightarrow$ is the viscous force on the ball.

Here $v \rightarrow$ is the terminal velocity and

$\eta \rightarrow$ is the coefficient of viscosity of water.

If ρ is the density of the material of the ball, we have $m = \frac{4}{3}\pi r^3\rho$

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

$$\Rightarrow v = \frac{2r^2\rho g}{9\eta} \qquad \ldots(1)$$

Now $v^2 - 0 = 2gh$

$$\Rightarrow h = \frac{v^2}{2g} \qquad \ldots(2)$$

Substituting (1) in (2)

$$\Rightarrow h = \frac{\left(\frac{2r^2\rho g}{9\eta}\right)^2}{2g} \Rightarrow h \,\alpha\, r^4$$

13. Under a constant pressure head, the rate of flow of liquid through a capillary tube is V. If the length of the capillary is doubled and the diameter of the bore is halved, the rate of flow would become

(A) $\frac{V}{4}$ (B) 16 V (C) $\frac{V}{8}$ (D) $\frac{V}{32}$

Ans (D)

$$V = \frac{\pi P r^4}{8\eta l};\ V' = \frac{\pi P(r/2)^4}{8\eta(2l)} = \frac{1}{2^5}\frac{\pi P r^4}{8\eta l} = \frac{V}{2^5} = \frac{V}{32}$$

14. The terminal velocity of small sized spherical body of radius r falling vertically in a viscous liquid is proportional to

(A) r (B) r^2 (C) $\frac{1}{r}$ (D) $\frac{1}{r^2}$

Ans (B)

$$6\pi\eta v_t r = mg = \rho\left(\frac{4}{3}\pi r^3\right)g \Rightarrow v_t \propto r^2$$

15. Two drops of same radius are falling through air with steady velocity v. If the two drops coalesce, its terminal velocity would be

(A) $2^{1/3}$ v (B) $4^{1/3}$ v (C) $4^{2/3}$ v (D) 2v

Ans (B)

$v \propto r^2$; $v' \propto R^2$; but $R = 2^{1/3}$ r

$\therefore$ $v' \propto (2^{1/3} r)^2 = 2^{2/3} r^2$

$\therefore$ $v' \propto 2^{2/3}v$ or $v' \propto 4^{1/3}$ v

16. Hot and cold syrup of similar type are poured on the top of a table. Then

(A) hot syrup will flow faster

(B) cold syrup will flow faster

(C) both hot and cold syrup flow equally fast

(D) which flows how depends on the nature of the syrup

Ans (A)

Viscosity decreases as the temperature is increased.

17. A liquid flows at the rate of 320 cc per minute through a horizontal pipe of radius r. The rate of flow if the same liquid be made to flow over the same pressure gradient through a similar pipe of radius $\frac{r}{2}$ is

(A) 160 cc/min (B) 80 cc/min (C) 40 cc/min (D) 20 cc/min

Ans (D)

$$V \propto r^4 \quad \text{i.e., } 320 \propto r^4;\ V' \propto \left(\frac{r}{2}\right)^4 = \frac{r^4}{16}$$

$$\therefore \frac{V'}{320} = \frac{1}{16} \quad \therefore V' = \frac{320}{16} = 20 \text{ cc/min}$$

18. The coefficient of viscosity of hot air is

(A) greater than that of cold air (B) smaller than that of cold air
(C) same as that of cold air (D) dependent on the external pressure

Ans (A)

$\eta \propto \sqrt{T}$

19. A river flowing smoothly over a hard bed, experience a shearing stress of 2 mPa. If the coefficient of viscosity of water be 1.0×10^{-2} poise, find the velocity gradient there.

(A) 1 ms^{-1} (B) 2 ms^{-1} (C) 3 ms^{-1} (D) 4 ms^{-1}

Ans (B)

From $F = \eta A \frac{dv}{dy}$; $\frac{dv}{dy} = \frac{F/A}{\eta} = \frac{2\times10^{-3}}{1\times10^{-3}} = 2 \text{ m s}^{-1}$

20. Calculate the limiting velocity of a rain drop weighing 1.1×10^{-3} g falling freely in air. Coefficient of viscosity η for air is 1.8×10^{-4}c.g.s unit (ignore the density of air).

(A) 29.6 ms^{-1} (B) 6.5 ms^{-1} (C) 49.6 ms^{-1} (D) 13 ms^{-1}

Ans (C)

Mass of the rain drop, $m = \frac{4}{3}\pi r^3 \rho$

$\therefore r = \left(\frac{3m}{4\pi\rho}\right)^{1/3} = \left(\frac{3\times1.1\times10^{-3}}{4\times3.14\times1}\right)^{1/3} = 6.4\times10^{-2} \text{ cm}$

The terminal velocity, $v_t = \frac{2}{9}\frac{r^2(\rho-\sigma)g}{\eta} = \frac{2}{9}\frac{(6.4\times10^{-2})^2(1-0)980}{1.8\times10^{-4}} = 49.6 \text{ m s}^{-1}$

21. Water is escaping from a cistern through a horizontal capillary tube 10 cm long and 4 mm in diameter and at a depth of 0·50 m below the free surface of water in the cistern. Calculate the rate of flow of water. Coefficient of viscosity of water = 14 milli poise.

(A) 10×10^{-6} m^3s^{-1} (B) 22×10^{-6} m^3s^{-1} (C) 30×10^{-6} m^3s^{-1} (D) 41×10^{-6} m^3s

Ans (B)

Rate of flow of water $V = \frac{p\pi r^4}{8\eta l} = \frac{0\cdot5\times10^3\times9\cdot8\times\pi\times(2\times10^{-3})^4}{8\times0\cdot014\times0\cdot10}$

$= 22 \times 10^{-6} \text{ m}^3 \text{ s}^{-1}$

22. A solid sphere falls with a terminal velocity of 10 m s^{-1} in air. If it is allowed to fall in vacuum,

(A) terminal velocity will be more than 10 m s^{-1} (B) terminal velocity will be less than 10 m s^{-1}
(C) terminal velocity will be 10 m s^{-1} (D) there will be no terminal velocity

Ans (D)

There is no viscous force in vacuum.

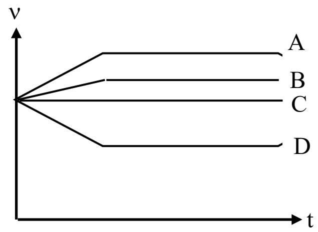
23. A small steel ball falls through a syrup at constant speed of 10 cm s^{-1}. If the steel ball is pulled upwards with a force equal to twice its effective weight, it moves upwards with a speed of

(A) 10 cm s^{-1} (B) 20 cm s^{-1} (C) 5 cm s^{-1} (D) –5 cm s^{-1}

Ans (A)

When a body is falling downwards with a constant speed v, then weight of body = viscous force. When body is pulled upwards with a force equal to twice its effective weight, it will be opposed by weight of body and viscous force, due to which, the resultant force on body is zero. Thus the upward terminal velocity of body is same as downward terminal velocity = 10 cm s^{-1}.

24. A small spherical solid ball is dropped from a great height into a viscous liquid. Its journey in the liquid is best described, in the diagram given below (v = velocity and t = time), by the



(A) curve A (B) curve B

(C) curve C (D) curve D

Ans (D)

As the solid sphere falls from a greater height, it acquires a large velocity before entering the viscous liquid. As it enters liquid, it experiences a viscous drag which opposes its motion due to which the velocity of the body goes on decreasing. This situation continues till the body attains terminal velocity. At that stage, viscous force is balanced by weight of body and net force on body is zero. Hence curve 'D' is correct.

25. Two identical drops of water fall through air with a terminal velocity 2 m s^{-1}. If the drops merge to form a single drop its terminal velocity is

(A) 3.17 m s^{-1} (B) 1.58 m s^{-1} (C) 2.52 m s^{-1} (D) 4 m s^{-1}

Ans (A)

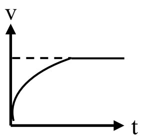
When two drops merge let R be the radius, then

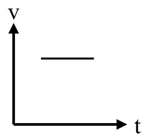
$$\frac{4}{3}\pi R^3 = 2\left(\frac{4}{3}\pi r^3\right) \Rightarrow R = 2^{1/3} r$$

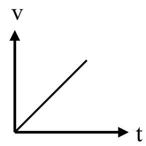
$$v_T \propto (\text{radius})^2 \Rightarrow \frac{v_T}{v_T^1} = \frac{r^2}{2^{2/3} r^2}$$

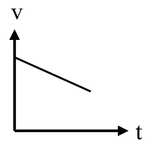
$$v_T^1 = 4^{1/3} v_T \quad = 4^{1/3} \times 2 = 3.17 \text{ m s}^{-1}$$

26. A small sphere is falling from rest through a large column of viscous liquid. The variation of the velocity v of the sphere with time is

(A) 

(B) 

(C) 

(D) 

Ans (A)

Initially sphere moves with an acceleration and after certain instant it moves with constant velocity (Terminal velocity)

27. Liquid is flowing through two tubes of length L and 3 L and radius r and 3 r respectively are connected in series. The pressure difference across first and second tube are in the ratio

(A) 3 : 1 (B) 1 : 3 (C) 27 : 1 (D) 9 : 1

Ans (C)

As tubes are in series, rate of flow will be same.

$$Q = \frac{\pi \Delta P_1 r^4}{8\eta L} = \frac{\pi \Delta P_2 (3r)^4}{8\eta 3L} \Rightarrow \frac{\Delta P_1}{\Delta P_2} = \frac{81}{3} = 27$$

28. A liquid is flowing through a horizontal capillary tube. The tube has a diameter 2 mm. The flow is at a rate of 3.14 × 10^{-8} m^3 s^{-1}. The velocity of liquid at a point on the axis of capillary tube is

(A) 0.02 m s^{-1} (B) 0.01 m s^{-1} (C) 0.03 m s^{-1} (D) 0.04 m s^{-1}

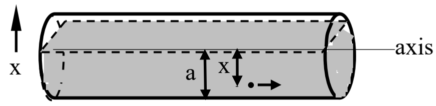
Ans (A)

The velocity v of part of the fluid flowing through a capillary tube of length L and radius a at a distance x from one of the walls of the tube as shown in the fig is

$v = \frac{P}{4\eta L}(a^2 - x^2)$; P being the pressure difference across the capillary tube.

Volume flow per second, $V = \frac{\pi P a^4}{8\eta L}$

And therefore $\frac{v}{V} = \frac{2(a^2 - x^2)}{\pi a^4}$



This gives $v = \frac{2V}{\pi a^2}\left(1 - \frac{x^2}{a^2}\right)$

On the axis, x = 0.

So, $v = \frac{2V}{\pi a^2} = \frac{2(3.14 \times 10^{-8}\ m^3 s^{-1})}{(3.14)(1 \times 10^{-3}\ m)^2} = 0.02\ m\ s^{-1}$.

29. A plate of area 100 cm^2 is placed on the upper surface of castor oil 2 mm thick. Taking the coefficient of viscosity of castor oil to be 15 poise, the horizontal force required to move the plate with a constant velocity 3 cm s^{-1} is

(A) 0.5 N (B) 0.45 N (C) 0.35 N (D) 0.225 N

Ans (D)

The magnitude of the viscous force on the plate is

$|F| = \eta A \frac{dv}{dx} = (15 \times 10^{-1} Pa.s)(100 \times 10^{-4}\ m^2)\left(\frac{3 \times 10^{-2}\ m s^{-1}}{2 \times 10^{-3}\ m}\right) = 0.225$ N.

30. Two tubes A and B are connected to each other. A has a length of 1 m and radius 0.1 mm whereas B has a length of 0.5 m and radius 0.2 mm. If a liquid is passing through the two tubes entering A at a pressure of 0.8 m of mercury and leaving B at a pressure of 0.76 m, the pressure at the junction of A and B is

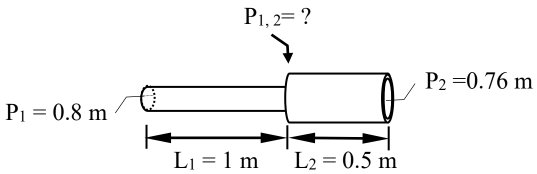
(A) 0.6612 m (B) 0.5612 m (C) 0.7611 m (D) 0.8612 m

Ans (C)

The volume flow rates at the ends of A and B must be the same and thus $V_1 = V_2$

$\frac{\pi(\Delta P_1)a_1^4}{8\eta L_1} = \frac{\pi(\Delta P_2)a_2^4}{8\eta L_2}$ gives

$\frac{\Delta P_1}{\Delta P_2} = \frac{L_1}{L_2}\left(\frac{a_2}{a_1}\right)^4 = \left(\frac{1\,m}{0.5\,m}\right)\left(\frac{0.2\,mm}{0.1\,mm}\right)^4 = 8$



If $P_{1,2}$ is the pressure at junction, then $\frac{0.8 - P_{1,2}}{P_{1,2} - 0.76} = 8$

Solving for $P_{1,2}$, we get $P_{1,2}$ = 0.7644 m (of mercury).

31. The terminal velocity of a tiny brass sphere of radius r falling in a viscous liquid is v_t. What will be the terminal velocity of a brass sphere of radius 2r falling in the same liquid?

(A) $\frac{v_t}{2}$ (B) v_t (C) 2 v_t (D) 4 v_t

Ans (D)

The terminal velocity of a sphere of radius r and density ρ falling in a fluid of density σ and viscosity η is given by

$v_1 = \frac{2}{9}\frac{(\rho - \sigma)r^2 g}{\eta}$

Since ρ, σ and η are the same, $v_t \propto r^2$. Therefore, if r is doubled, v_t becomes 4 times.

32. Eight spherical rain drops of equal size are falling vertically through air with a terminal velocity of $0.1\ m\ s^{-1}$. What should be the velocity if these drops were to combine to form a large spherical drop?

(A) $0.4\ ms^{-1}$ (B) $0.3\ ms^{-1}$ (C) $0.2\ ms^{-1}$ (D) $0.1\ ms^{-1}$

Ans (A)

Let r be the radius of each of the small rain drop and R be the radius of big rain drop formed.

As, volume of big drop = 8 × volume of each drop

$\frac{4}{3}\pi R^3 = 8 \times \frac{4}{3}\pi r^3 \qquad R = 2r$

Let the terminal velocity of small drop be v_1 and of big drop be v_2

$v = \frac{2r^2(\rho - \rho_0)g}{9\eta}$

$v \propto r^2; \frac{v_2}{v_1} = \frac{R^2}{r^2}; \quad v_2 = v_1\frac{R^2}{r^2} = 0.1\left(\frac{2r}{r}\right)^2 = 0.1 \times 4 = 0.47\ m\ s^{-1}$

33. Water flows through a capillary tube of radius r and length l at a rate of 40 ml per second when connected to a pressure difference of h cm of water. Another tube of the same length but radius $\frac{r}{2}$ is connected in series with this tube and the combination is connected to the same pressure head. The rate of flow of water through the combination is

(A) $\frac{10}{17}ccs^{-1}$ (B) $\frac{20}{17}ccs^{-1}$ (C) $\frac{30}{17}ccs^{-1}$ (D) $\frac{40}{17}ccs^{-1}$

Ans (D)

The volume of water flowing per second through a tube of length l and radius r under a pressure difference p is given by $\quad V = \frac{\pi p r^4}{8\eta l}$ where η = coefficient of viscosity

Given that pressure difference = h cm of water i.e., $p = \rho gh$.

Volume of water flowing per second = 40 ml.

Hence, $40 = \frac{\pi(\rho gh)r^4}{8\eta l}$ … (1)

When another tube of same length but radius $\frac{r}{2}$ is connected in series with this tube, let p_1 and p_2 be the pressure differences across there tubes, respectively. They are connected to the same pressure head.

Hence, $v = \frac{\pi p_1 r^4}{8\eta l} = \frac{\pi p_2 (r/2)^4}{8\eta l}$ … (2)

or $p_2 = 16\ p_1$, … (3)

Also, $p_1 + p_2 = \rho gh$ … (4)

Solving (3) and (4), we get $p_1 = \frac{\rho gh}{17}$ and $p_2 = \frac{16}{17}\rho gh$

Divide (1) by (2), $\frac{40}{v} = \frac{\rho gh}{p_1} = \frac{\rho gh}{(\rho gh/17)}$ or $v = \frac{40}{17}$ cc s^{-1}.

34. A plate of area $100 \times 10^{-4}\ m^2$ is placed on the upper surface of castor oil, 2 mm thick. Taking the coefficient of viscosity to be $15.5 \times 10^{-1}\ kg\ m^{-1}\ s^{-1}$, calculate the horizontal force necessary to move the plate with a velocity $3 \times 10^{-2}\ m\ s^{-1}$.

(A) 0.132 N (B) 0.232 N (C) 0.332 N (D) 0.432 N

Ans (B)

Viscous force is given by

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

$n = 15.5 \times 10^{-1}$ kg m^{-1} s^{-1}

$A = 100 \times 10^{-4}$ m^2

$$\frac{dv}{dx} = \frac{v_2 - v_1}{x_2 - x_1} = \left(\frac{0-3}{2-0}\right)\frac{\times 10^2}{\times 10^{-3}} = -15 \text{ sec}^{-1}$$

$$F = -\eta A \frac{dv}{dx} = -1.55 \times 10^{-2}(-15) = 0.232 \text{ N}$$

35. Water is escaping from cistern by way of a horizontal capillary tube, 0.01 m long and 4 mm in diameter at a distance of 0.50 m below the free surface of water in the cistern? Calculate the rate of flow of water, (η for water = 0.014 poise).

(A) 2.2×10^{-5} m^{3}s^{-1} (B) 3.2×10^{-5} m^{3}s^{-1} (C) 4.2×10^{-5} m^{3}s^{-1} (D) 5.2×10^{-5} m^{3}s^{-1}

Ans (A)

Pressure, $p = \rho gh = 0.5 \times 10^3 \times 9.8$ Pa

$R = 2 \times 10^{-3}$ m, $l = 0.01$ m

$\eta = 0.014$ poise $= 0.0014$ kg m^{-1} s^{-1}

Rate of flow of water

$$V = \frac{p}{R} = \frac{p}{8\eta l/\pi r^4} = \frac{\pi p r^4}{8\eta l} = \frac{3.14 \times 0.50 \times 10^3 \times 9.8 \times (2 \times 10^{-3})^{-4}}{8 \times 0.0014 \times 0.10} = 2.2 \times 10^{-5} \text{ m}^3 \text{ s}^{-1}$$

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

(A) 2 v (B) v (C) v/2 (D) 4 v

Ans (D)

From equation of continuity $A_1v_1 = A_2v_2$

$\pi(2R)^2 v = \pi R^2 v' \Rightarrow v' = 4v$

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

(A) zero (B) maximum

(C) equal to critical velocity (D) in between zero and critical velocity

Ans (A)

Surface Tension

1. Cohesion and Adhesion

(a) **Cohesive force :**It is the force between the molecules of the same substance. E.g: Force between two water molecules or two glass molecules.

(b) **Adhesive force :**It is the force between the molecules of different substances. E.g: Force between the molecule of a container and the molecule of a liquid near it.

(c) **Molecular range :** It is the distance over which a molecule attracts any other molecule within that distance. It is of the order of 10^{-9} m (10-15 molecular diameters)

(d) Surface film is a layer of liquid of thickness approximately equal to the molecular range.

☞

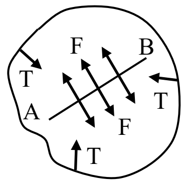
- Interatomic or intermolecular forces can be attractive or repulsive. It is attractive beyond a certain separation, called equilibrium separation (r_o), and it becomes repulsive if the separation becomes less than r_o.
- Potential energy of a system of two atoms or molecules at the equilibrium separation is a minimum and the

mutual force is zero.

- Interatomic or intermolecular forces are electrical in nature.
- A liquid molecule inside the liquid experiences no net force because of symmetric distribution of similar molecules about it.
- Free surface of a liquid cannot be perfectly sharp as the liquid density drops rapidly to zero over a distance of a few molecular size across the liquid surface (usually air).
- A molecule in the surface film experiences a net downward force because of asymmetric distribution of molecules above and below the surface. Thus, the surface film is in microscopic turbulence. Molecular transportation from the surface to the rest of the liquid and vice versa is continuously taking place since the thickness of the film is approximately fixed.

2. **Surface Tension:** It is a surface phenomenon that is due to asymmetric distribution of molecular forces about a molecule in the surface film.

(a)It is defined as the force per unit length of an imaginary line on the surface of the liquid, tending to pull the surface apart along the line.



$$T = \frac{F}{L}$$

F→ magnitude of the force perpendicular to AB of length L, tending to tear apart along it. The SI unit of surface tension is Nm^{-1}. Its dimensional formula is $[M^1L^0T^{-2}]$

(b) It may also be defined as the work done per unit area of the surface created under isothermal condition.

$$T = \frac{\Delta W}{\Delta T}$$

Surface tension may also be expressed in Jm^{-2}

Surface film

A thin film of the liquid near its surface and having thickness equal to the molecular range for that liquid is called surface film. The molecules present in the surface film possess addition P.E.

Surface Energy: The P.E per unit area of the surface film is called the surface energy.

$$\text{Mathematically, surface energy} = \frac{\text{workdone in increasing the surface area}}{\text{increase in surface area}}$$

Surface energy of a liquid is numerically equal to the surface tension of the liquid.

☞

- Surface tension is a property of the interface because a surface molecule interacts with its own molecules below and the molecules of other kind (air, its own vapour, another liquid, or a solid) above.
- A molecule in the surface film has more potential energy than the one in the rest of the liquid.
- When the surface film (soap film) is stretched, the film tends to get cooled since work is done against the forces due to surface tension. Therefore, $S = E - Q = W$,

  where $E \rightarrow$ total energy per unit area created

  $Q \rightarrow$ heat absorbed per unit area created

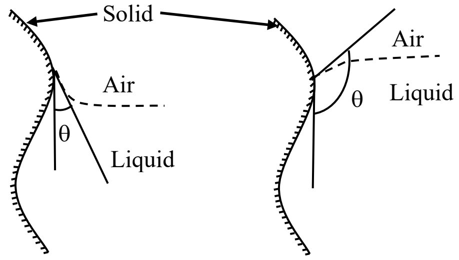
  $W \rightarrow$ work done per unit area created
- Force due to surface tension does not depend on the area of the surface.
- Small amounts of liquid assume the shape of a sphere due to surface tension. Surface tension and gravity determine the shape of a liquid drop
- Immiscible liquids (like kerosene) reduces the surface tension of water considerably. Insects capable of walking on water effortlessly get drowned when kerosene in sprayed on it.
- Highly soluble inorganic salts (like NaCl and $ZnSO_4$) increase the surface tension of water. Freelly soluble impurities

(like soap, detergent and phenol) decrease the surface tension considerably.

- Surface tension of liquids decreases with increase in temperature. Surface tension of water is found to disappear at 647 K. Surface tension of molten Cu and Cd is found to increase with increase in temperature.

3. **Angle of contact :** Liquid surface in contact with a solid is generally curved. The angle (within the liquid) between the tangent lines to the liquid and the solid planes at their point of contact is called the angle of contact.

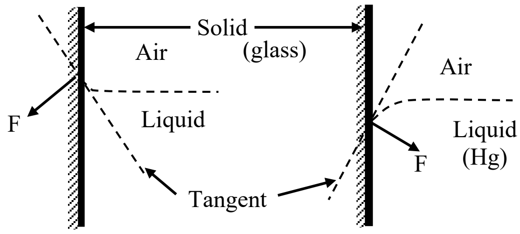
$\theta = 0$ for pure water-clean glass
$\approx 8°$ for tap water- clean glass
$\approx 101°$ for tap water- paraffin
$\approx 140°$ for pure mercury –clean glass



θ is acute   θ is obtuse

- Angle of contact does not depend on the shape of the solid
- Angle of contact is defined for a liquid-solid pair.
- A soluble impurity decreases with temperature
- A liquid wets a surface for which the angle of contact is acute
- A liquid spreads on a solid for which $\theta = 0°$
- A liquid which does not wet a surface, the angle of contact is abtuse.

4. **Theshape of a liquid surface:** A liquid element near its container experiences three forces, (a) its own weight (W), (b) net adhesive force (F_a) normal to the container and (c) net cohesive force (F_c) that lies within the liquid. The resultant $\vec{F}$ of $\vec{W}$, $\vec{F}_a$ and $\vec{F}_c$ must be normal to the liquid surface for it to be in equilibrium. Thus, the resultant $\vec{F}$ determines the shape of the liquid near the contact.



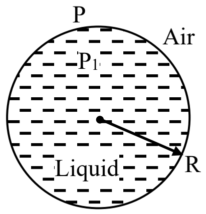
(i) $\theta < 90°$ (ii) $\theta > 90°$

(i) If $\vec{F}$ passes through the solid, the liquid rises along the solid and the surface is concave upward.
(ii) If $\vec{F}$ passes through the liquid, it gets depressed along the solid and the surface is convex upward.
(iii) If the liquid surface is neither raised nor depressed along the solid, F_c must from symmetry, make, an angle of 45° with either surface. Consequently, $F_a = \frac{F_c}{\sqrt{2}}$.

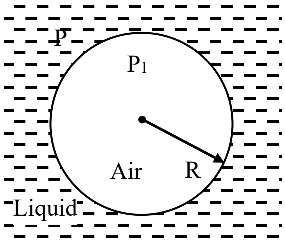
So, $F_a / F_c / \sqrt{2}$ for convex surface and $> \frac{F_c}{\sqrt{2}}$ for concave surface.

- The crescent shaped liquid surface near its container is called the meniscus (convex or concave)
- The shape of a liquid drop is determined by surface tension and gravity together.
- Liquid globules are almost spherical since surface tension effects predominate over gravity. If the liquid amount is more, gravity predominates over surface tension effects.
- For a given volume (of a liquid) surface area is the least for a spherical shape.
- A liquid tends to have minimum possible surface area

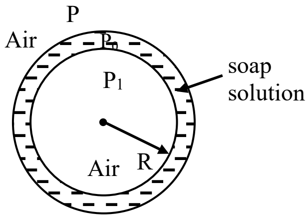
5. **Excess pressure :** Pressure inside a liquid drop, an air bubble in a liquid, or a (soap) bubble in air is more than that outside it.



Liquid drop
(much exaggerated size)



Air bubble in a liquid



Soap bubble in air
(much exaggerated thickness)

(a) For a liquid drop or an air bubble; $p = (P_1 - P) = \dfrac{2S}{R}$

(b) For a soap (or similar) bubbles;

$(P_1 - P_0) = \dfrac{2S}{R}$;

$(P_0 - P) = \dfrac{2S}{R}$;

$p = (P_1 - P) = \dfrac{4S}{R}$

- When two plates, each of area 'A', are separated by a thin film of a liquid of thickness 't' and surface tension 'T', the force required to separate the two plates is given by $F = \dfrac{2TA}{t}$.
- The work done (W) in blowing a soap bubble of radius 'r' is $W = 8\pi r^2 T$.
- Workdone in increasing the area of circular soap film from radius 'r_1' to 'r_2';

  $W = 2\pi T(r_2^2 - r_1^2)$

  Work done in increasing the radius of a bubble from 'r_1' to 'r_2' is given by $W = 8\pi(r_2^2 - r_1^2)T$
- When a number of small liquid drops coalesce to form a large drop, energy is released (since surface area decreases).
- Energy is required to break a liquid drop into smaller drops (since surface area increases).
- The work done by an agent to split a liquid drop of radius 'R' into in identical drops is $W = 4\pi R^2 T\left(n^{\frac{1}{3}} - 1\right)$.
- The amount of energy evolved when 'n' dropped of a liquid of radius 'r' combine to form a large drop is $E = 4\pi r^2 T\left(n - n^{\frac{2}{3}}\right)$
- 'n' drops each of radius 'r' continue to form a big drop of radius 'R'. Then the work done (or) the energy expended is $4\pi T\,(nr^2 - R^2)$.

☞

- Excess pressure on the concave side of a liquid surface is inversely proportional to its radius.
- When two soap bubbles are put into communication, the larger one grows and two bubbles acquire the same curvature (equilibrium states)
- On spraying a large drop of a liquid into n identical droplets (i) the resulting surface area in $\sqrt[3]{n}$ times that of the drop, (ii) energy is expended and (iii) temperature of the droplets is less than that of the drop.
- Soap bubble expands on charging
- Two glass plates with a drop of water spread between them experience attractive force. Similarly, two glass plates with a drop of mercury spread between them experience repulsive force.
- A double bubble is formed when a small bubble of radian r_1 comes in contact with a large bubble of radius r_m. The common surface is concave toward smaller bubble and its radius is given by

$$r = \frac{r_1 r_2}{r_2 - r_1}$$

6. **Capillarity:** The rise or fall of a liquid in a capillary tube dipped in the liquid is called the capillarity.
(a) A liquid that wets the capillary tube (θ< 90°) rises in it, whereas the one that does not wet falls
(b) The amount by which a liquid level rises or falls in a capillary tube is given by $h = \frac{2S\cos\theta}{\rho g r}$
$r \to$ radius of the capillary tube
$\theta \to$ angle of contact, $\rho \to$ density of the liquid.
Radius of the meniscus is $r_m = r/\cos\theta$

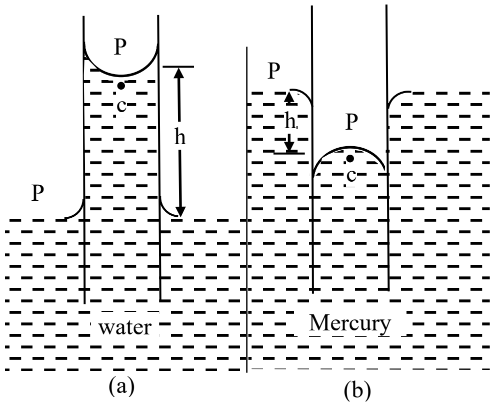


Fig. Capillary rise and fall

☞
- Pressure at point C is $p = P - \frac{2S}{r_m}$ for concave meniscus
- $= p = \frac{2S}{r_m}$ for convex meniscus
- Height of the liquid in Fig. (a) is $h + \frac{r}{3}$ and that in Fig. (b) is $h - \frac{r}{3}$
- If the length of the capillary tube is insufficient (l< h), the radius of curvature of the meniscus of the liquid $(\theta < 90°)$ changes from r to r^1 such that $hr = lr^1$, nature of the meniscus being intact.
- If a capillary tube is inclined to the vertical at an angle α, then length of the liquid (θ< 90°) column in the capillary is $l = h / \cos\theta$ where h is the liquid column if the capillary were vertical.
- If the angle of contact θ= 90°menisus becomes plane, and the capillarity disappears.

Turin's law: According to Turin's law, inversely the height of the liquid (h) rise or fall in a capillary tube is, inversely proportional to the radius (r).

i.e., $h \propto \frac{1}{r}$ or hr = constant

- A graph between 'h' and 'r' is a rectangular hyperbola.
- If a capillary tube is dipped in water in a satellite, the water level will rise to the full length of the tube.
- For the liquids of low S.T, wetting property is more. (ST – Surface Tension)
- **Critical Temperature:** The temperature at which S.T. of the liquid becomes zero is known as C.T.
- In case of molten copper and molten cadmium, S.T. increases with increase of temperature.
- S.T. of liquid metals is very very high and S.T. of a liquid is zero at its B.P.
- Over small ranges of temperature the S.T of a liquid decreases linearly with the rise of temperature.
- $T = T_0 (1 - \alpha T)$
  Where $T \to$ S.T. at t°d
  $T_0 \to$ S.T at 0°d
  and $\alpha \to$ coefficient of S.T
- When two soap bubbles of radii 'a' and 'b' coalesce molar isothermal condition, the resultant bubble has a radius 'R' such that $R = \sqrt{a^2 + b^2}$.

Illustrations

1. A capillary tube of radius 0.50 mm is dipped vertically in a pot of water. Find the difference between the pressure of the water in the tube 5.0 cm below the surface and atmospheric pressure. Surface tension of water = 0.075 N m^{-1}

(A) 160 Pa (B) 190 Pa (C) 200 Pa (D) 220 Pa

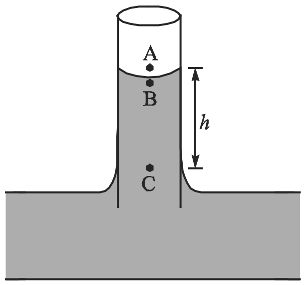
Ans (B)

$p_A = pa$

$p_B = p_a - \frac{2T}{r}$

and$p_C = p_B + h\rho g = \left(p_a - \frac{2T}{r}\right) + h\rho g$

$\therefore p_C - p_a = h\rho g - \frac{2T}{r} = 0.05 \times 10^3 \times 9.8 - \frac{2\times 0.075}{0.5\times 10^{-3}} = 190\ \mathrm{N\,m^{-2}}$



2. Two soap bubbles of radii r_1 and r_2 coalesce to form a single bubble under isothermal condition. Find the radius of resulting bubble.

(A) $\sqrt{r_1^2 + r_2^2}$ (B) $\sqrt{r_1 r_2}$ (C) $\frac{\sqrt{r_1^2 + r_2^2}}{2}$ (D) $2\sqrt{r_1 r_2}$

Ans (A)

As the process is isothermal, by Boyle's law, we have $p_1V_1 + p_2V_2 = pV$

If r is the radius of the resulting bubble, then

$$\left(\frac{4T}{r_1}\right)\times\frac{4}{3}\pi r_1^3 + \left(\frac{4T}{r_2}\right)\times\frac{4}{3}\pi r_2^3 = \left(\frac{4T}{r}\right)\times\frac{4}{3}\pi r^3$$

$r_1^2 + r_2^2 = r^2 \therefore r = \sqrt{r_1^2 + r_2^2}$

3. When there are no external forces, the shape of a liquid drop is determined by

(A) surface tension of the liquid (B) the density of the liquid

(C) viscosity of the liquid (D) the mass of the liquid drop

Ans (A)

4. The amount of work done in increasing the size of a soap film from 10 cm × 6 cm to 10 cm × 10 cm is (surface tension of soap solution = 30 × 10^{-3} Nm^{-1})

(A) 1.2 × 10^{-4} J (B) 2.4 × 10^{-4} J (C) 2.4 × 10^{-5} J (D) 1.2 × 10^{-5} J

Ans (B)

Work done = Surface Tension × increase in area = T ΔA.

Since a soap solution has two surfaces, work done = 2 (T ΔA)

W = 2 × 30 × 10^{-3} × (100 – 60)10^{-4} = 2.4 × 10^{-4} J

5. The excess of pressure inside one soap bubble is three times that inside another bubble. Then the ratio of volume of the first bubble to that of the second is

(A) $1:\sqrt{3}$ (B) 1 : 9 (C) 1 : 3 (D) 1 : 27

Ans (D)

$p = \frac{2T}{r}$; $\frac{p_1}{p_2} = \frac{r_2}{r_1} = \frac{3}{1}$; $\frac{V_1}{V_2} = \frac{r_1^3}{r_2^3} = \frac{1}{27}$

6. In a capillary tube, water rises by 1.2 mm. The height to which water will rise in another capillary tube having half the radius of the first is

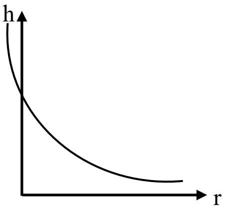
(A) 0.4 mm (B) 0.6 mm (C) 2.4 mm (D) 1 .2 mm

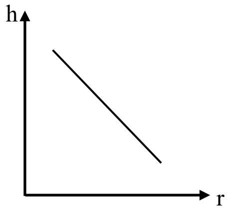
Ans (C)

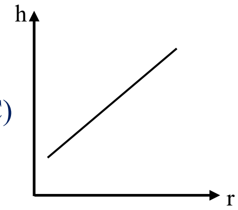
$$T = \frac{1}{2}\rho g r_1 h_1 = \frac{1}{2}\rho g r_2 h_2 \qquad \therefore r_2 h_2 = r_1 h_1$$

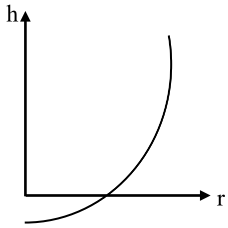
$$\left(\frac{1}{2}r\right)h_2 = r(1.2) \qquad \therefore h_2 = 2.4 \text{ mm}$$

7. Which of the following graphs best represent the variation of capillary rise 'h' with radius of the capillary tube r?

(A) 

(B) 

(C) 

(D) 

Ans (A)

$T = \frac{1}{2}\rho g h r$; graph of h versus r is a rectangular hyperbola.

8. If a million tiny droplets of water of the same radius coalesce into one larger drop, the ratio of surface energy of the large drop to the total surface energy of all the droplets will be

(A) 1 : 10 (B) 1 : 10^2 (C) 1 : 10^4 (D) 1 : 10^6

Ans (B)

Let r be the radius of each droplet and R be the radius of the big drop which is made up of a million (10^6) tiny droplets. Since the total volume is the same, we have

$$V = 10^6 \times \frac{4}{3}\pi r^3 = \frac{4\pi R^3}{3}$$

$\Rightarrow R^3 = 10^6 r^3 \Rightarrow R = 100\ r$

Now, the surface energy of a drop of radius r is given by $S = 4\pi r^2\sigma$

where σ is the surface tension of water

The surface energy of one million drops will be $E_1 = 4\pi r^2\sigma \times 10^6$

The surface energy of one big drop is, $E_2 = 4\pi R^2\sigma$

$$\therefore \frac{E_2}{E_1} = \left(\frac{R}{r}\right)^2 \times \left(\frac{1}{10^6}\right) = \left(\frac{100r}{r}\right)^2 \times \frac{1}{10^6} = \frac{1}{10^2}$$

9. If W is the amount of work done in blowing a bubble of volume V, what will be the amount of work done to blow a bubble of volume 8V?

(A) 2 W (B) 4 W (C) 8 W (D) 16 W

Ans (B)

Work done to blow a bubble of radius r is, $W = 4\pi\sigma r^2$

In terms of volume $V = \frac{4}{3}\pi r^3$, we have $W = 4\pi\sigma\left(\frac{3V}{4\pi}\right)^{\frac{2}{3}}$

Now, work done to blow a bubble of volume 8 V is

$$W' = 4\pi\sigma\left(\frac{3\times 8V}{4\pi}\right)^{\frac{2}{3}} = 4\pi\sigma\left(\frac{3V}{4\pi}\right)^{\frac{2}{3}} \times \left(8^{\frac{2}{3}}\right) = W\left(8^{\frac{2}{3}}\right)$$

$$W' = 4W$$

10. A ring of external and internal radii r_1 and r_2 just touches the horizontal surface of a liquid of surface tension σ. The force required to pull the ring away from the surface is

(A) $2\pi(r_1 + r_2)\sigma$ (B) $2\pi(r_1 - r_2)\sigma$ (C) $4\pi(r_1 + r_2)\sigma$ (D) $4\pi(r_1 - r_2)\sigma$

Ans (A)

Force = surface tension ×length

Force = $\sigma \times 2\pi r$ $\therefore$ Force = $2\pi r_1\sigma + 2\pi r_2\sigma = 2\pi(r_1 + r_2)\sigma$

11. A capillary tube is immersed vertically in water and the height of the water column is x. When this arrangement is taken into a mine of depth d, the height of the water column is y. If R is the radius of the earth, the ratio $\frac{x}{y}$ is

(A) $\left(1-\frac{d}{R}\right)$ (B) $\left(1+\frac{d}{R}\right)$ (C) $\left(\frac{R-d}{R+d}\right)$ (D) $\left(\frac{R+d}{R-d}\right)$

Ans (A)

On the earth's surface, surface tension, $\sigma = \frac{x\rho rg}{2}$ … (1)

In the mine, $\sigma = \frac{y\rho rg_d}{2}$ … (2)

$$\frac{(1)}{(2)} \Rightarrow \frac{\sigma}{\sigma} = \frac{x\rho rg/2}{y\rho rg_d/2}$$

$$\Rightarrow 1 = \frac{xg}{yg_d} \Rightarrow \frac{g_d}{g} = \frac{x}{y} \Rightarrow \frac{x}{y} = \frac{g_d}{g}$$

$$\Rightarrow \frac{x}{y} = \frac{g\left(1-\frac{d}{R}\right)}{g} = \left(1-\frac{d}{R}\right)$$

12. If a number of identical droplets of water, each of radius r, coalesce to form a single drop of radius R, the resulting rise in temperature of water is given by (here ρ is the density of water, S is its specific heat and σ is the surface tension)

(A) $\frac{\sigma}{\rho S}\left(\frac{1}{r}-\frac{1}{R}\right)$ (B) $\frac{3\sigma}{\rho S}\left(\frac{1}{r}-\frac{1}{R}\right)$ (C) $\frac{\sigma}{\rho S}\left(\frac{1}{r}+\frac{1}{R}\right)$ (D) $\frac{3\sigma}{\rho S}\left(\frac{1}{r}+\frac{1}{R}\right)$

Ans (B)

Work done, $W = 4\pi R^2(n^{1/3} - 1)\sigma$

$$= 4\pi R^2\left(\frac{R}{r}-1\right)\sigma \quad \ldots (1) \quad \left[\because R = n^{\frac{1}{3}} \cdot r\right]$$

Heat produced, $Q = mS(\Delta T)$

$$= \left(\frac{4}{3}\pi R^3 \times \rho\right) \times S \times (\Delta T) \quad \ldots (2)$$

Equating (1) and (2)

$$4\pi R^2\left(\frac{R}{r}-1\right)\sigma = \frac{4}{3}\pi R^3 \times \rho \times S \times (\Delta T)$$

$$\Rightarrow \frac{3\left(\frac{R}{r}-1\right)\sigma}{R+S} = \Delta T$$

$$\Rightarrow \Delta T = \frac{3\sigma\left(\frac{R}{r}-1\right)}{R\rho S} = \frac{3\sigma}{\rho S}\left(\frac{\frac{R}{r}-1}{R}\right)$$

$$\Delta T = \frac{3\sigma}{\rho S}\left(\frac{1}{r} - \frac{1}{R}\right)$$

13. Eight spherical rain drops of the same mass and radius are falling down with a terminal speed of 6 cm s^{-1}. If they coalesce to from one big drop, what will be its terminal speed? Neglect the buoyancy due to air.

(A) 1.5 cm s^{-1} (B) 6 cm s^{-1} (C) 24 cm s^{-1} (D) 32 cm s^{-1}

Ans (C)

Let r be the radius of each small drop

The volume of each drop is $= \frac{4}{3}\pi r^3$

Let R be the radius of big drop formed when 8 small drops coalesce.

The volume of the big drop will be 8 times that of the small drop.

Hence, $\frac{4}{3}\pi R^3 = 8 \times \frac{4}{3}\pi r^3 \Rightarrow R = 2r$

That is the radius of the big drop is twice the radius of each small drop. Now if the buoyancy of the drop due to air is neglected, the terminal speed of the small drop is given by

$$v_t = \frac{2}{9\eta}\rho r^2 g \qquad \ldots (1)$$

Terminal speed of the big drop will be, $V_t = \frac{2}{9\eta}\rho R^2 g \qquad \ldots (2)$

$$\frac{(1)}{(2)} \Rightarrow \frac{V_t}{v_t} = \frac{R^2}{r^2} = \frac{(2r)^2}{r^2} = 4 \Rightarrow V_t = 4v_t = 4 \times 6 = 24\,cm/s$$

14. The surface tension of a liquid is 5 Nm^{-1}. If a film is held on a ring of area 0.02 m^2, its surface energy is about

(A) 5×10^{-2} J (B) 2.5×10^{-2} J (C) 2×10^{-2} J (D) 2×10^{-1} J

Ans (D)

A film has two free surfaces

$\therefore$ Surface energy = surface tension × area

$= T \times 2A = 5 \times 2 \times 0.02 = 0.2$ J

15. A capillary tube of radius r is immersed in water and capillary rise is found to be h. When another tube of radius $\frac{r}{2}$ is immersed, the capillary rise will be

(A) h (B) 2h (C) 3h (D) 4h

Ans (B)

$$T = \frac{1}{2}\rho g r h;\quad h \propto \frac{1}{r};\quad h' \propto \frac{1}{r/2} \propto \frac{2}{r} \qquad \therefore h' = 2h$$

16. Two soap bubbles have radii in the ratio 2 : 1. The ratio of excess pressure inside is

(A) 1 : 1 (B) 1 : 3 (C) 1 : 2 (D) 1 : 4

Ans (C)

$$p = \frac{4T}{r};\quad \frac{p_1}{p_2} = \frac{r_2}{r_1} = \frac{1}{2}$$

17. A child blows a soap bubble of radius 5 cm. The energy spent by the child is (S.T of soap solution = 3×10^{-2} N m^{-1})

(A) 9.42×10^{-2} J (B) 9.42×10^{-3} J (C) 1.884×10^{-4} J (D) 1.884×10^{-3} J

Ans (D)

Energy = (S.T)(Increase in area) = $T(2 \times 4\pi r^2)$

$= 2 \times 4 \times 3.14 \times (5 \times 10^{-2})^2 \times 3 \times 10^{-2} = 18.84 \times 10^{-4} = 1.884 \times 10^{-3}$ J.

18. The work done in blowing a soap bubble is W. In order to blow another bubble of half the diameter, the work required would be

(A) $\frac{W}{4}$ (B) $\frac{W}{2}$ (C) W (D) 4 W

Ans (A)

$$W = 2T(4\pi r^2); \quad W' = 2T\left(4\pi\left(\frac{r}{2}\right)^2\right) = \frac{W}{4}$$

19. If the work done in blowing a bubble of volume V is W, then the work done in blowing a soap bubble of volume 2 V is

(A) W (B) 2W (C) $2^{2/3}$ W (D) $2^{1/3}$ W

Ans (C)

$$W = 2T(4\pi R^2) = 2T\frac{3}{R}\left(\frac{4}{3}\pi R^3\right) = \frac{6TV}{R}$$

$$W' = \frac{6TV'}{R'} \qquad \therefore \frac{W'}{W} = \frac{V'}{V}\frac{R}{R'} = \frac{2V}{V}\frac{R}{2^{1/3}R} = \frac{2}{2^{1/3}} = 2^{2/3} \qquad \therefore W' = 2^{2/3} W$$

20. The work done in breaking a drop of radius R and surface tension T into eight spherical droplets is

(A) $4\pi R^2T$ (B) $8\pi R^2T$ (C) $2\pi R^2T$ (D) πR^2T

Ans (A)

$W = T[8(4\pi r^2) - 4\pi R^2] = 4\pi T[8r^2 - R^2]$

$$= 4\pi T\left[8\left(\frac{R}{8^{1/3}}\right)^2 - R^2\right] = 4\pi T\left[8\frac{R^2}{4} - R^2\right] = 4\pi TR^2$$

21. Two water droplets merge with each other to form a larger droplet. In this process

(A) energy is absorbed (B) energy is liberated

(C) energy is neither absorbed nor liberated (D) temperature neither increases nor decreases

Ans (B)

When small drops merge to form a bigger drop, energy is liberated and hence temperature increases.

22. A ring formed of iron is of diameter 10 cm, which is supported horizontally from a pan of a balance so that it just comes in contact with the surface of water. Find the surface tension of water, if an additional weight of 4.61 g is required to pull it away from water.

(A) 5.19×10^{-2} Nm^{-1} (B) 6.19 Nm^{-1}

(C) 7.19×10^{-2} Nm^{-1} (D) 5.19×10^{-3} Nm^{-1}

Ans (C)

The ring is in contact with water surface along its inner and outer periphery. Hence surface tension force acting downward is

$2(2\pi r)T = (2\pi d)T$. This is balanced by the additional weight.

Hence, $(2\pi d)T = mg$

$$\therefore T = \frac{mg}{2\pi d} = \frac{4.61 \times 10^{-3} \times 9.8}{2 \times 3.14 \times 0.1} = 7.19 \times 10^{-2} \text{ N m}^{-1}$$

23. Water rises to a height of 15 cm in a capillary of radius 0.1 mm. Calculate the surface tension of water.

(A) 73.5×10^{-3} Nm^{-1} (B) 73.5×10^{-2} Nm^{-1}

(C) 73.5×10^{-4} Nm^{-1} (D) 73.5×10^{-1} Nm^{-1}

Ans (A)

$$T = \frac{1}{2}\rho grh = \frac{1}{2}(10)^3(9.8)(0.1\times10^{-3})(15\times10^{-2})$$

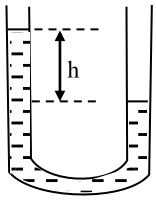
$$= 73.5 \times 10^{-3} \text{ N m}^{-1}$$

24. A U tube is made up of two capillary tubes of 2 mm and 4 mm diameter joined at the bottom. A liquid of density 0.8 g/cc and surface tension 70×10^{-3} Nm^{-1} is poured in it. Calculate the difference in heights between the liquid surfaces in the two limbs.

(A) 7.89 mm (B) 8.89 mm (C) 6.89 mm (D) 5.89mm

Ans (B)

Let h be the difference in heights between the liquid levels in the two limbs. Then the excess hydrostatic pressure hρg will balance the difference in pressure on either side of the surfaces.



$$\therefore h\rho g = 2T\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

$$\therefore h = \frac{2T}{\rho g}\left(\frac{1}{r_1} - \frac{1}{r_2}\right) = \frac{2\times70\times10^{-3}}{0.8\times10^3\times9.8}\left(\frac{1}{1\times10^{-3}} - \frac{1}{2\times10^{-3}}\right)$$

h = 8.89 mm

25. A mercury drop of radius 1 cm is sprayed into 10^6 droplets of equal size. Calculate the energy expended if surface tension of mercury is 4.35×10^{-3} N m^{-1}.

(A) 5.4×10^{-6} J (B) 5.4×10^{-2} J (C) 5.4×10^{-3} J (D) 5.4×10^{-4} J

Ans (D)

Let R be the radius of the big drop. Then its surface area is $4\pi R^2$. Let r be the radius of each droplet. Then its surface area is $4\pi r^2$. Total surface area of n drops is $n(4\pi r^2)$. Hence increase in area $\Delta A = n(4\pi r^2) - 4\pi R^2$.

Since the total volume of n droplets is the same as the volume of the initial drop

$$n\left(\frac{4}{3}\pi r^3\right) = \frac{4}{3}\pi R^3 \qquad \therefore \quad r = \frac{R}{n^{1/3}}$$

$$\therefore \Delta A = \left(n4\pi\frac{R^2}{n^{2/3}} - 4\pi R^2\right) = 4\pi R^2[n^{1/3} - 1]$$

Energy expended, $W = T\Delta A = 4\pi R^2 T[n^{1/3} - 1]$

$\therefore \quad W = 4 \times 3.14 \times (1 \times 10^{-2})^2 \times 4.35 \times 10^{-3}[(10^6)^{1/3} - 1]$

$= 4 \times 3.14 \times 4.35 \times 10^{-7} \times 99 = 5.4 \times 10^{-4}$ J

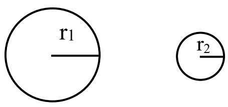
26. Two separate air bubbles of radii 0.002 m and 0.004 m, formed of the same liquid of surface tension 0.07 N m^{-1} come together to form a double bubble. Find the radius of curvature of the surface common to both bubbles.

(A) 0.004 m (B) 0.003 m (C) 0.002 m (D) 0.001 m

Ans (A)

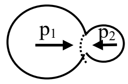
Let r_1 and r_2 be the radii of the bigger and smaller bubbles.

Let r be the radius of curvature of the surface common to both bubbles.



$$p_1 = p_0 + \frac{4T}{r_1}; \; p_2 = \left(p_0 + \frac{4T}{r_2}\right) \text{ and } p = \frac{4T}{r}$$

and $p=(p_2-p_1) \Rightarrow \frac{4T}{r}=4T\left(\frac{1}{r_2}-\frac{1}{r_1}\right)$ i.e., $\frac{1}{r}=\left(\frac{1}{r_2}-\frac{1}{r_1}\right)$



$$\therefore r=\left(\frac{r_1 r_2}{r_1-r_2}\right)=\frac{(0.002)(0.004)}{(0.002)}=0.004 \text{ m}$$

27. If the surface tension of soap solution is σ, what is the work done in blowing soap bubble of radius?

(A) $\pi r^2\sigma$ (B) $2\pi r^2\sigma$ (C) $4\pi r^2\sigma$ (D) $8\pi r^2\sigma$

Ans (D)

Since a bubble has two surfaces in contact with air, the total surface area of the bubble $= 2 \times (4\pi r^2) = 8\pi r^2$.

Now work done = surface tension × increase in surface area $= \sigma\times(8\pi r^2 - 0) = 8\pi r^2\sigma$.

NCERT LINE BY LINE QUESTIONS

1. The energy required for having a molecule at the surface of liquid is [NCERT Pg. 261]

(1) Heat of evaporation

(2) Roughly half the heat of evaporation

(3) Heat capacity

(4) Roughly half of heat capacity of liquid

2. Which of the following conversion is correct? [NCERT Pg. 250]

(1) 1 atm = 1.0110^4 Pa (2) 1 mm of Hg= 133 Pa

(3) 1 bar= 10^7 Pa (4) 1 torr= $10^{?}$ Pa

3. Pressure is equal to [NCERT Pg. 247]

(1) It is product of force and area and both force and area are vectors

(2) It is the ratio of force which is a vector and parallel to area

(3) It is ratio of the component of force normal to area

(4) It depends on size of area chosen

4. Along a streamline in flow [NCERT Pg. 253)

(1) The velocity of a fluid particle remains constant

(2) The velocity of all fluid particles crossing a given position is constant

(3) The velocity of all fluid particles at a given instant is constant

(4) The speed of all fluid particle at any instant must be constant

5. Which of the following statements is incorrect? [NCERT Pg. 257]

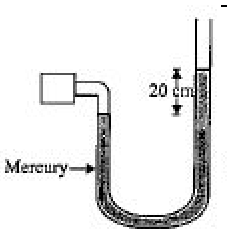
(1) Blood is more viscous than water

(2) The blood pressure in humans is greater at the feet than at the brain

(3) The angle of contact of mercury with glass is obtuse while that of water with glass is acute

(4) A spinning cricket ball in air follows a parabolic trajectory

6. A manometer reads the pressure of a gas in an enclosure as shown in figure. The absolute and gauge pressure of the gas (in cm of mercury) in the enclosure is



(Take atmospheric pressure = 76 cm of Hg) [NCERT Pg. 250]

(1) 76, 20 (2) 20, 76 (3) 96, 20 (4) 20, 96

7. Streamline flow is more likely for liquids with [NCERT Pg. 260]

(1) High density and high viscosity (2) Low density and low viscosity

(3) High density and low viscosity

(4) Low density and high viscosity

8. The ratio of inertial force to the viscous force represents [NCERT Pg. 260]

(1) Magnus effect (2) Reynold's number

(3) Relative density (4) Torricelli's law

9. The Onset Of turbulence in a liquid is determined by [NCERT Pg. 260]

(1) Pascal's law (2) Avogadro number

(3) Stoke's law (4) Reynold's number

10. A plane is in level flight and each of its wings has an area 20 m^2. If the speed of air on

upper and lower surfaces are 80 m/s and 70 m/s respectively, then the mass of plane is (density of air = 1 kg/m³) [NCERT Pg. 271]

(1) 1500 kg (2) 1700 kg (3) 1650 kg (4) 1750 kg

11. Which of the following instrument is used to measure blood pressure in humans? [NCERT Pg. 273)

(1) Sphygmomanometer

(2) Cardioverter defibrillator

(3) Barometer

(4) Syphnometer

12. When temperature increases, the viscosity of [NCERT Pg. 259]

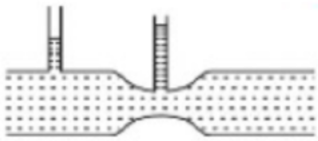
(1) Gases decreases and liquids increases

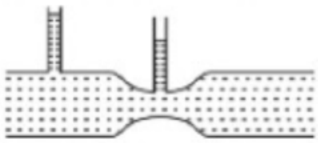
(2) Gases increases and liquid decreases

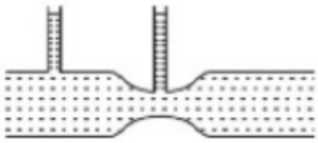
(3) Both gases and liquids increases

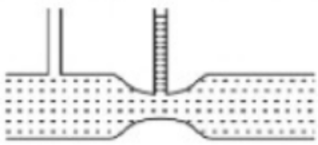
(4) Both gases and liquids decreases

13. Which of the following figure shown below is correct regarding the steady flow of an ideal liquid? [NCERT Pg. 269)

(1) 

(2) 

(3) 

(4) 

14. When a drop of water splits up into number Of droplets [NCERT Pg. 264]

(1) Surface area will increase (2) Volume decreases

(3) Energy is absorbed (4) Both (1) and (3)

15. Which of the following statement is not true about angle of contact? [NCERT Pg. 263]

(1) The angle of ccntact for pure water and glass is nearly zero

(2) Angle of contact may increase with increase in temperature

(3) if the angle of contact of a liquid and a solid surface is less than 90% then liquid spread on surface of solid

(4) Angle of contact depends upon the inclination of the solid surface to the liquid surface

16. A soap bubble is having internal and external radii as *R* and *2R* respectively. If surface tension of soap solution is *T*, then excess pressure inside bubble will be

[NCERT Pg. 264]

1) $\frac{4T}{R}$ 2) $\frac{3T}{R}$ 3) $\frac{2T}{R}$ 4) $\frac{4T}{3R}$

17. When a capillary tube is dipped in a liquid, the liquid rises to a height *h* in the tube. The free liquid surface in the tube is hemispherical in shape. The tube is now pushed down so the height of the tube outside the liquid is less than *h*. Then the [NCERT Pg. 265]

(1) Liquid will come out of the tube in the form of small fountain

(2) Liquid will ooze out of the tube slowly

(3) Free liquid surface inside the tube remain hemispherical

(4) Liquid will rise to the top of capillary tube increase the radius of curved surface and stay there

18 Dynamic lift due to spinning of a ball is [NCERT Pg. 257]

(1) Magnus effect (2) Doppler's effect

(3) Pascal effect (4) Torricelli effect

19. A solid sphere falls with a terminal velocity *v* in air. If it is allowed to fall in vacuum, then

[NCERT Pg. 260]

(1) Terminal velocity of sphere is equal to *v*

(2) Terminal velocity of sphere is greater than *v*

(3) Terminal velocity of sphere is less than *v*

(4) Sphere will never attain terminal velocity

20. The sap in tree rises in a system of capillaries of radius 2.5×10^{-5} m. The surface tension of sap is 7.28×10^{2} N/m and the angle of contact is 0°. The maximum heightto which sap can rise in a tree through capillary action is (density of sap is = 1×10^3 kg/m^3)

[NCERT Pg. 265]

(1) 0.21 m (2) 0.59 m (3) 0.87 m (4) 0.91 m

NCERT BASED PRACTICE QUESTIONS

1. Liquid pressure depends upon

(a) area of the liquid surface (b) shape of the liquid surface

(c) height of the liquid column (d) directions

2. Hydraulic lifts and hydraulic brakes are based on

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

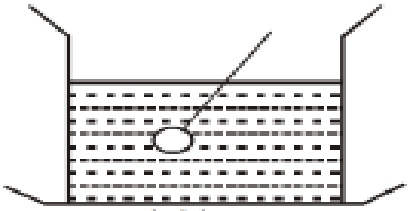
(c) Stoke's law (d) Pascal's law

3. According to archimedes' principle, loss of weight of a body immersed in a liquid is equal to

(a) weight of the liquid displaced (b) weight of the total liquid

(c) weight of the body (d) None of these

4. A vessel with water is placed on a weighing pan and it reads 600 g. Now a ball of mass 40 g and density 0.80 g cm–3 is sunk into the water with a pin of negligible volume,
as shown in figure keeping it sunk. The weighting pan will show a reading



(a) 600 g (b) 550 g (c) 650 g (d) 632 g

5. Pressure applied to enclosed fluid is

(a) increased and applied to every part of the fluid

(b) diminished and transmitted to wall of container

(c) increased in proportion to the mass of the fluid and then transmitted

(d) transmitted unchanged to every portion of the fluid and wall of containing vessel.

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

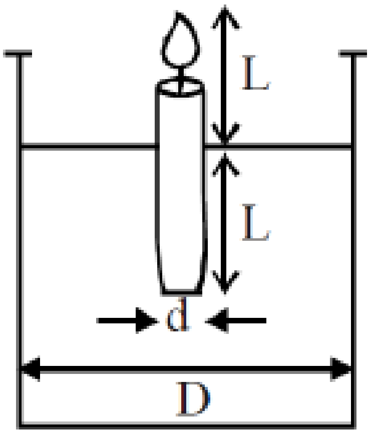
(a) acceleration due to gravity

(b) height of the liquid column

(c) area of the bottom surface

(d) nature of the liquid

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



(a) remain at the same height

(b) fall at the rate of 1 cm/hour

(c) fall at the rate of 2 cm/hour

(d) go up at the rate of 1 cm/hour

8. **Assertion:** A small iron needle sinks in water while a large iron ship floats.

Reason: The shape of iron needle is like a flat surface while the shape of a ship is that which makes it easier to float.

(a) Assertion is correct, reason is correct; reason is a correct explanation for assertion.

(b) Assertion is correct, reason is correct; reason is not a correct explanation for assertion

(c) Assertion is correct, reason is incorrect

(d) Assertion is incorrect, reason is correct.

9. Consider an iceberg floating in sea water. The density of sea water is 1.03 g/cc and that of ice is 0.92 g/cc. The fraction of total volume of iceberg above the level of sea water is near by

(a) 1.8% (b) 3% (c) 8% (d) 11%

10. **Assertion:** The apparent weight of a floating body is zero.

Reason: The weight of the block acting vertically
downwards is balanced by the buoyant force acting on the block upwards.

(a) Assertion is correct, reason is correct; reason is a correct explanation for assertion.

(b) Assertion is correct, reason is correct; reason is not a correct explanation for assertion

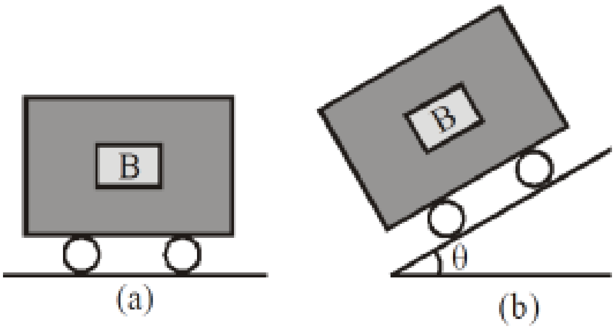
(c) Assertion is correct, reason is incorrect

(d) Assertion is incorrect, reason is correct.

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

(a) 8 (b) 4 (c) 3 (d) zero

12. A body B is capable of remaining stationary inside a liquid at the position shown in Fig. (a). If the whole system is gently placed on smooth inclined plane (Fig (b)) and is allowed to slide down, then (0 < q < 90°). The body will



(a) move up (relative to liquid)

(b) move down (relative to liquid)

(c) remain stationary (relative to liquid)

(d) move up for some inclination q and will move down for another inclination q

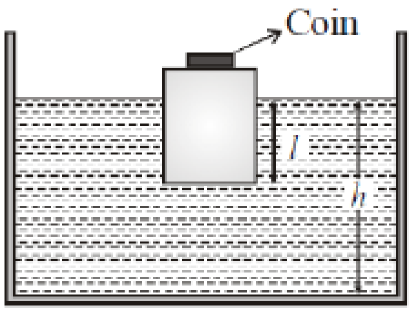
13. In rising from the bottom of a lake, to the top, the temperature of an air bubble remains unchanged, but its diameter gets doubled. If h is the barometric height (expressed in m of mercury of relative density r) at the surface of the lake, the depth of the lake is

(a) 8 rh m (b) 7rh m (c) 9 rh m (d) 12 rh m

14. A boy can reduce the pressure in his lungs to 750 mm of mercury. Using a straw he can drink water from a glass upto the maximum depth of (atmospheric pressure = 760
mm of mercury; density of mercury = 13.6 gcm–3)

(a) 13.6 cm (b) 9.8 cm (c) 10 cm (d) 76 cm

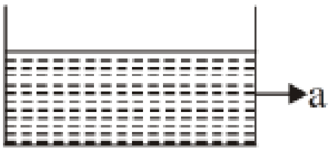
15. A wooden block, with a coin placed on its top, floats in water as shown in fig. the distance l and h are shown there. After some time the coin falls into the water. Then

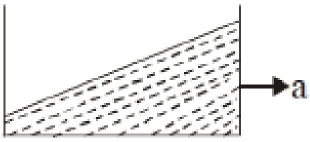


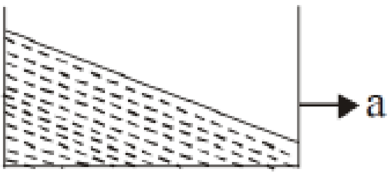
(a) l decreases and h increases (b) l increases and h decreases

(c) both l and h increases (d) both l and h decreases

16. A vessel containing water is given a constant acceleration '*a*' towards the right along a straight horizontal path. Which of the following diagrams represents the surface of the liquid ?

(a) 

(b) 

(c) 

(d) None of these

17. A cone full of water, is placed on its side on a horizontal table, the thrust on its base is x times the weight of the contained fluid, where 2α is the vertical angle of the cone.
Find the value of x.

(a) $3 \cos \alpha$ (b) $3 \sin\alpha$ (c) $2 \sin \alpha$ (d) $2 \cos \alpha$

18. **Assertion :**Imagine holding two identical bricks under water. Brick A is completely submerged just below the surface of water, while Brick B is at a greater depth. The magnitude of force exerted by the person (on the brick) to hold brick B in place is the same as magnitude of force exerted by the person (on the brick) to hold brick A in place.

Reason : The magnitude of buoyant force on a brick completely submerged in water is equal to magnitude of weight of water it displaces and does not depend on depth of brick in water.

(a) Assertion is correct, reason is correct; reason is a correct explanation for assertion.

(b) Assertion is correct, reason is correct; reason is not a correct explanation for assertion

(c) Assertion is correct, reason is incorrect

(d) Assertion is incorrect, reason is correct.

19. Beyond the critical speed, the flow of fluids becomes

(a) streamline (b) turbulent

(c) steady (d) very slow

20. Streamline flow is more likely for liquids with

(a) high density and low viscosity (b) low density and high viscosity
(c) high density and high viscosity (d) low density and low viscosity

21. For flow of a fluid to be turbulent
(a) fluid should have high density (b) velocity should be large
(c) reynold number should be less than 2000 (d) both (a) and (b)

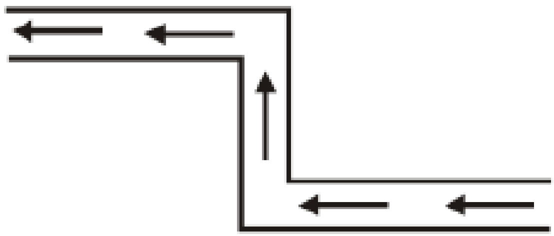
22. In Bernoulli's theorem which of the following is conserved?
(a) Mass (b) Linear momentum (c) Energy (d) Angular momentum

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

24. Which of the following statements are true about streamline flow?
I. Path taken by a fluid particle under a steady flow is a streamline
II. No two streamlines can cross each other
III. Velocity increases at the narrower portions where the streamlines are closely spaced
(a) I & II only (b) II & III only (c) I & III only (d) I, II & III

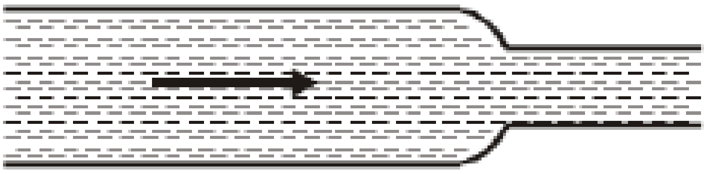
25. Consider the following statements : In a streamline flow of a liquid
I. the kinetic energies of all particles arriving at a given point are same.
II. the momenta of all particles arriving at a given point are same.
III. the speed of particles are below the critical velocity.
Which of the statements given above are correct?
(a) I & II only (b) II & III only (c) I &III only (d) I, II & III

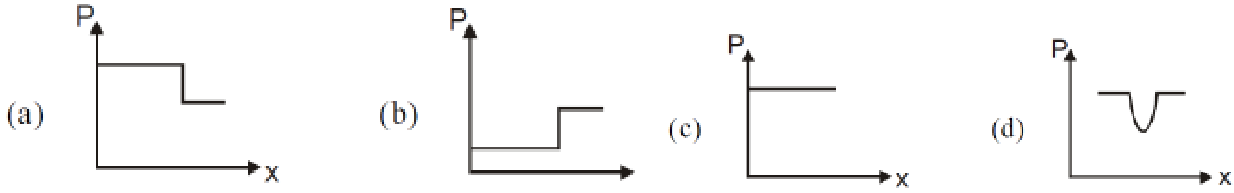
26. A liquid flows through a tube of uniform cross-section with a constant speed in the direction as shown by the arrows in fig. The liquid exerts on the tube



(a) a net force to the left (b) a net force to the right
(c) an anticlockwise torque (d) a clockwise torque

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





28. **Assertion :** Lifting of aircraft is caused by pressure difference brought by varying speed of air molecules.

Reason : As the wings/ aerofoils move against the wind, the streamlines crowd more above them than below, causing higher velocity above than below.

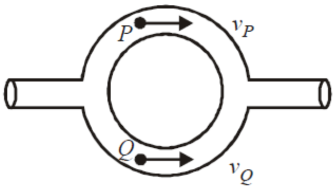
(a) Assertion is correct, reason is correct; reason is a correct explanation for assertion.

(b) Assertion is correct, reason is correct; reason is not a correct explanation for assertion

(c) Assertion is correct, reason is incorrect

(d) Assertion is incorrect, reason is correct.

29. Figure shows a liquid flowing through a tube at the rate of 0.1 m^3/s. The tube is branched into two semicircular tubes of cross-sectional area A/3 and 2A/3. The velocity of liquid at Q is (the cross-section of the main tube is $A = 10^{-2}$ m^2 and $v_P = 20$ m/s)



(a) 5 m/s (b) 30 m/s (c) 35 m/s (d) None of these

30. As the temperature of a liquid is raised, the coefficient of viscosity

(a) decreases (b) increases (c) remains the same

(d) may increase or decrease depending on the nature of liquid

31. After terminal velocity is reached, the acceleration of a body falling through a fluid is

(a) equal to g (b) zero (c) less than g (d) greater than g

32. Terminal velocity of ball depends on

(a) area of the ball (b) density of liquid only

(c) density of ball only (d) density difference of liquid and ball

33. A boat with base area $8m^2$ floating on the surface of a still river is intended to move with a constant speed of 2 m/s by the application of a horizontal force. If the river bed is 2m deep find the force needed, (assuming a constant velocity gradient) Coefficient of viscosity of water is 0.90×10^{-2} poise.

(a) 720 dyne (b) 620 dyne (c) 520 dyne (d) 360 dyne

34. Which of the following statements is/are true?

I. Solid friction is independent of area of surface in contact and viscous drag is also independent of area of layers in contact.

II. Solid friction depends on the relative velocity of one body on the surface of another body while viscous drag is independent of the relative velocity between two layers of the liquid.

III. Solid friction is directly proportional to the normal reaction while viscosity is independent of the normal reaction between two layers of the liquid.

(a) I, II & III (b) I & II (c) III only (d) II only

35. The relative velocity of two parallel layers of water is 8 cm/sec. If the perpendicular distance between the layers is 0.1 cm. Then velocity gradient will be

(a) 80/sec (b) 60 /sec (c) 50/sec (d) 40/sec

36. **Assertion :**Falling raindrops acquire a terminal velocity.

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

(a) Assertion is correct, reason is correct; reason is a correct explanation for assertion.

(b) Assertion is correct, reason is correct; reason is not a correct explanation for assertion

(c) Assertion is correct, reason is incorrect

(d) Assertion is incorrect, reason is correct.

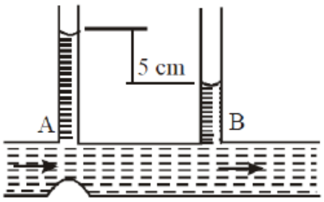
37. A liquid is filled upto a height of 20 cm in a cylindrical vessel. The speed of liquid coming out of a small hole at the bottom of the vessel is (g = 10 ms–2)

(a) 1.2 ms^{-1} (b) 1 ms^{-1} (c) 2 ms^{-1} (d) 3.2 ms^{-1}

38. A solid ball of volume V experiences a viscous force F when falling with a speed v in a liquid. If another ball of volume 8 V with the same velocity v is allowed to fall in the same liquid, it experiences a force

(a) F (b) l6 F (c) 4 F (d) 2 F

39. In the diagram shown, the difference in the two tubes of the manometer is 5 cm, the cross section of the tube at A and B is 6 mm2 and 10 mm2 respectively. The rate at which water flows through the tube is (g = 10 ms–2)



(a) 7.5 cc/s (b) 8.0 cc/s (c) 10.0 cc/s (d) 12.5 cc/s

40. A small spherical ball falling through a viscous medium of negligible density has terminal velocity v. Another ball of the same mass but of radius twice that of the earlier falling through the same viscous medium will have terminal velocity

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

41. Surface tension of a liquid is due to

(a) gravitational force between molecules

(b) electrical force between molecules

(c) adhesive force between molecules

(d) cohesive force between molecules

42. If a soap bubble formed at the end of the tube is blown very slowly, then the graph between excess pressure inside the bubble with time will be a

(a) straight line sloping up

(b) straight line sloping down

(c) parabolic curve sloping down

(d) parabolic curve sloping up

43. Surface tension may be defined as

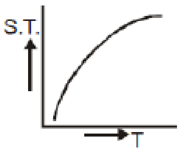
(a) the work done per unit area in increasing the surface area of a liquid under isothermal conditions

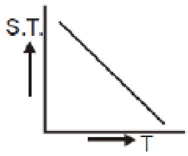
(b) the work done per unit area in increasing the surface area of a liquid under adiabatic conditions

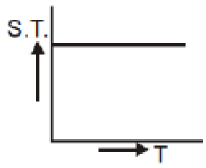
(c) the work done per unit area in increasing the surface area of a liquid under adiabatic conditions

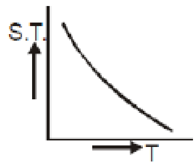
(d) free surface energy per unit volume

44. Which of the following graph represents the variation of surface tension with temperature over small temperature ranges for water?

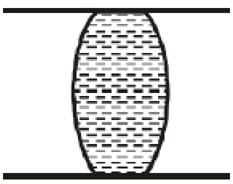
(a) 

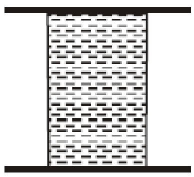
(b) 

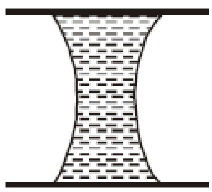
(c) 

(d) 

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

(a) 

(b) 

(c) 

(d) None of these

46. At critical temperature, the surface tension of a liquid is

(a) zero
(b) infinity
(c) the same as that at any other temperature
(d) None of these

47. If two soap bubbles of different radii are in communication with each other then

(a) air flows from the larger bubble into the smaller one until the two bubbles are of equal size

(b) the size of the bubbles remains the same

(c) air flows from the smaller bubble into the larger one and the larger one grows at the expense of the smaller one

(d) the air flows from the larger into the smaller bubble until the radius of the smaller one becomes equal to that of the larger one and of the larger one equal to that of the smaller one.

48. When a pinch of salt or any other salt which is soluble in water is added to water, its surface tension

(a) increases (b) decreases

(c) may increase or decrease depending upon salt (d) None of these

49. If more air is pushed in a soap bubble, the pressure in it

(a) decreases (b) becomes zero (c) remains same (d) increases

50. A drop of oil is placed on the surface of water. Which of the following is correct?

(a) It will remain on it as a sphere (b) It will spread as a thin layer

(c) It will partly be a spherical droplet and partly a thin film

(d) It will float as a distorted drop on the water surface

51. Kerosene oil rises up in a wick of a lantern because of

(a) diffusion of the oil through the wick (b) capillary action

(c) buoyant force of air (d) the gravitational pull of the wick

52. Due to capillary action, a liquid will rise in a tube if angle of contact is

(a) acute (b) obtuse (c) 90^o (d) zero

53. With the increase in temperature, the angle of contact

(a) decreases (b) increases

(c) remains constant (d) sometimes increases and sometimes decreases

54. **Assertion :**Smaller the droplets of water, spherical they are.

Reason : Force of surface tension is equal, and opposite to force of gravity.

(a) Assertion is correct, reason is correct; reason is a correct explanation for assertion.

(b) Assertion is correct, reason is correct; reason is not a correct explanation for assertion

(c) Assertion is correct, reason is incorrect

(d) Assertion is incorrect, reason is correct.

55. A water film is formed between two straight parallel wires of 10 cm length 0.5 cm apart. If the distance between wires is increased by 1 mm. What will be the work done?

(surface tension of water = 72 dyne/cm)

(a) 36 erg (b) 288 erg (c) 144 erg (d) 72 erg

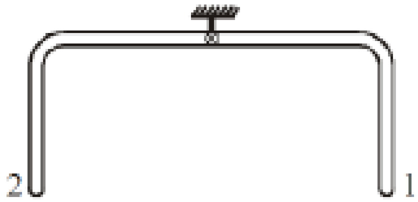
56. Two soap bubbles A and B are kept in a closed chamber where the air is maintained at pressure 8 N/m^2. The radii of bubbles A and B are 2 cm and 4 cm, respectively.Surface tension of the soap-water used to make bubbles is 0.04 N/m. Find the ratio n_B/n_A, where n_A and n_B are the number of moles of air in bubbles A and B, respectively. [Neglect the effect of gravity]

(a) 2 (b) 9 (c) 8 (d) 6

57. In a capillary tube, water rises to 3 mm. The height of water that will rise in another capillary tube having one-third radius of the first is

(a) 1 mm (b) 3 mm (c) 6 mm (d) 9 mm

58. A glass tube of uniform internal radius (r) has a valve separating the two identical ends. Initially, the valve is in a tightly closed position. End 1 has a hemispherical soap bubble of radius r. End 2 has sub-hemispherical soap bubble as shown in figure. Just after opening the valve



(a) air from end 1 flows towards end 2. No change in the volume of the soap bubbles
(b) air from end 1 flows towards end 2. Volume of the soap bubble at end 1 decreases
(c) no change occurs
(d) air from end 2 flows towards end 1. Volume of the soap bubble at end 1 increases

59. Two capillary tubes A and B of diameter 1 mm and 2 mm respectively are dipped vertically in a liquid. If the capillary rise in A is 6 cm, then the capillary rise in B is

(a) 2 cm (b) 3 cm (c) 4 cm (d) 6 cm

60. Water rises to a height of 10 cm in capillary tube and mercury falls to a depth of 3.1 cm in the same capillary tube. If the density of mercury is 13.6 and the angle of contact for mercury is 135°, the approximate ratio of surface tensions of water and mercury is

(a) 1 : 0.15 (b) 1 : 3 (c) 1 : 6 (d) 1.5 : 1

61. In a capillary rise experiment, the water level rises to a height of 5 cm. If the same capillary tube is placed in water such that only 3 cm of the tube projects outside the water level, then

(a) water will begin to overflow through the capillary (b) angle of contact decreases
(c) angle of contact increases (d) the meniscus completely vanishes

62. A thin liquid film formed between a U-shaped wire and a light slider supports a weight of 1.5 × 10^{-2} N (see figure). The length of the slider is 30 cm and its weight negligible.
The surface tension of the liquid film is

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

TOPIC WISE PRACTICE QUESTIONS

Topic 1: Pressure, Density, Pascal's Law and Archimedes' Principle

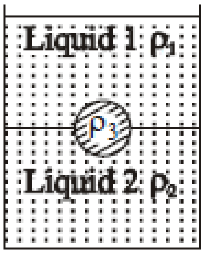
1. Pressure applied to enclosed fluid is
(1) increased and applied to every part of the fluid
(2) diminished and transmitted to wall of container
(3) increased in proportion to the mass of the fluid and then transmitted
(4) transmitted unchanged to every portion of the fluid and wall of containing vessel.

2. A beaker containing a liquid of density ρ moves up with an acceleration a. The pressure due to the liquid at a depth h below the free surface of the liquid is
(1) $h\rho g$ (2) $h\rho(g-a)$ (3) $h\rho(g+a)$ (4) $2h\rho g\left(\frac{g+a}{g-a}\right)$

3. In order that a floating object be in a stable equilibrium, its centre of buoyancy should be
(1) vertically above its centre of gravity (2) below its centre of gravity
(3) horizontally in a line with its centre of gravity (4) may be anywhere

4. A common hydrometer reads specific gravity of liquids. Compared to the 1.6 mark of the stem the mark 1.5 will be
(1) upwards (2) downwards (3) in the same place
(4) may be upward or downward depending upon the hydrometer

5. A jar is filled with two non-mixing liquids 1 and 2 having densities ρ_1 and ρ_2 respectively. A solid ball, made of a material of density ρ_3, is dropped in the jar. It comes to equilibrium in the position shown in the figure. Which of the following is true for ρ_1, ρ_2 and ρ_3?



(1) $\rho_3 < \rho_1 < \rho_2$ (2) $\rho_1 > \rho_3 > \rho_2$ (3) $\rho_1 < \rho_2 < \rho_3$ (4) $\rho_1 < \rho_3 < \rho_2$

6. The density of ice is x gram/litre and that of water is y gram/ litre. What is the change in volume when m gram of ice melts?
(1) mx y (x – y) (2) m/(y – x) (3) $m\left(\frac{1}{y}-\frac{1}{x}\right)$ (4) (y – x)/x

7. A small lead shot is embedded in a big lump of ice floating in a jar of water. The level of water in the jar is noted. When all the ice melts down, the level of water in the jar would
(1) be raised (2) go down (3) remain unchanged (4) None of these

8. The pressure at depth *h* below the surface of a liquid of density ρ open to the atmosphere is
(1) greater than the atmospheric pressure by ρgh
(2) less than the atmospheric pressure by ρgh
(3) equal to the atmospheric pressure (4) decreases exponentially with depth

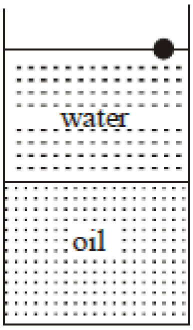
9. The force acting on a window of area 50 cm × 50 cm of a submarine at a depth of 2000 m in an ocean, interior of which is maintained at sea level atmospheric pressure is (Density of sea water = $10^3 kgm^{-3}$, g = $10\ ms^{-2}$)

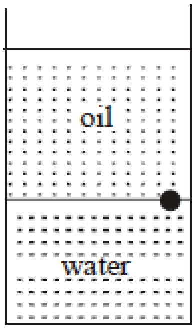
(1) 10^6 N (2) 5×10^5 N (3) 25×10^6 N (4) 5×10^6 N

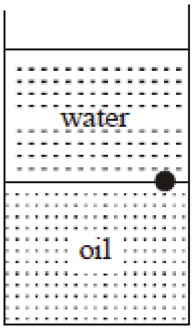
10. To what height should a cylindrical vessel be filled with a homogeneous liquid to make the sides of the vessel equal to the force exerted by the liquid on the bottom of the vessel?

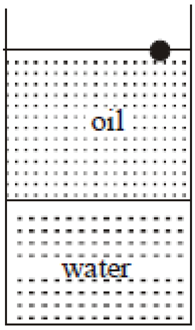
(1) Equal to the radius (2) Less than radius (3) More than radius (4) Four times of the radius

11. A ball is made of a material of density ρ where $\rho_{oil} < \rho < \rho_{water}$ with ρ_{oil} and ρ_{water} representing the densities of oil and water, respectively. The oil and water are immiscible. If the above ball is in equilibrium in a mixture of this oil and water, which of the following pictures represents its equilibrium position?

(1) 

(2) 

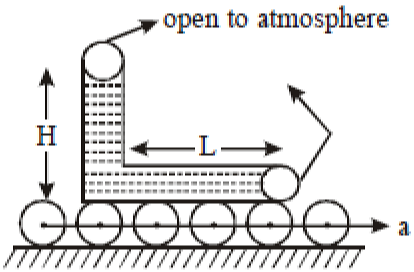
(3) 

(4) 

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

(1) $\rho = \rho_0\left[1 - \frac{\rho_0 gy}{B}\right]$ (2) $\rho = \rho_0\left[1 + \frac{\rho_0 gy}{B}\right]$ (3) $\rho = \rho_0\left[1 + \frac{B}{\rho_0 hgy}\right]$ (4) $\rho = \rho_0\left[1 - \frac{B}{\rho_0 hgy}\right]$

13. A narrow tube completely filled with a liquid is lying on a series of cylinders as shown in figure. Assuming no sliding between any surfaces, the value of acceleration of the cylinders for which liquid will not come out of the tube from anywhere is given by



(1) $\frac{gH}{2L}$ (2) $\frac{gH}{L}$ (3) $\frac{2gH}{L}$ (4) $\frac{gH}{\sqrt{2}L}$

14. The total weight of a piece of wood is 6 kg. In the floating state in water its 1/3 part remains inside the water. On this floating piece of wood what maximum weight is to be put such that the whole of the piece of wood is to be drowned in the water?

(1) 15 kg (2) 14 kg (3) 10 kg (4) 12 kg

15. A sample of metal weighs 210 g in air, 140 g in water and 120 g in an unknown liquid. Then

(1) the density of the metal is 3 g/cm3

(2) the density of the metal is 7 g/cm3

(3) density of the metal is 4 times the density of unknown liquid

(4) the metal still float in water

16. An ice-berg floating partly immersed in sea water of density 1.03 g/cm^3. The density of ice is 0.92 g/cm^3. The fraction of the total volume of the iceberg above the level of sea water is

(1) 8.1% (2) 11% (3) 34% (4) 0.8%

17. A boat having a length of 3 metres and breadth 2 metres is floating on a lake. The boat sinks by one cm when a man gets on it. The mass of the man is

(1) 60 kg (2) 62 kg (3) 72 kg (4) 128 kg

18. A body of density $\rho^{|}$ is dropped from rest at a height h into a lake of density ρ where $\rho > \rho^{|}$ neglecting all dissipative forces, calculate the maximum depth to which the body sinks before returning to float on the surface:

(1) $\frac{h}{\rho-\rho^{|}}$ (2) $\frac{h\rho^{|}}{\rho}$ (3) $\frac{h\rho^{|}}{\rho-\rho^{|}}$ (4) $\frac{h\rho}{\rho-\rho^{|}}$

19. A vessel contains oil (density = 0.8gm/cm^3) over mercury (density = 13.6gm/cm^3). A homogeneous sphere floats with half of its volume immersed in mercury and the other half in oil. The density of the material of the sphere in gm/cm^3 is

(1) 3.3 (2) 6.4 (3) 7.2 (4) 12.8

20. A sphere of solid material of relative density 9 has concentric spherical cavity and sinks in water. If the radius of the sphere be R, then the radius of the cavity (r) will be related to R as

(1) $r^3 = \frac{8}{9}R^3$ (2) $r^3 = \frac{2}{3}R^3$ (3) $r^3 = \frac{\sqrt{8}}{9}R^3$ (4) $r^3 = \sqrt{\frac{2}{3}}R^3$

21. An iceberg is floating in ocean. What fraction of its volume is above the water? (Given: density of ice = 900kg/m^3 and density of ocean water = 1030 kg/m^3)

(1) $\frac{90}{103}$ (2) $\frac{13}{103}$ (3) $\frac{10}{103}$ (4) $\frac{1}{103}$

22. In a hydraulic lift, compressed air exerts a force F_1 on a small piston having a radius of 5 cm. This pressure is transmitted to a second piston of radius 15 cm. If the mass of the load to be lifted is 1350 kg, find the value of F_1? The pressure necessary to accomplish this task is

(1) 1.4×10^5 Pa (2) 2×10^5 Pa (3) 1.9×10^5 Pa (4) 1.9 Pa

23. A cone full of water, is placed on its side on a horizontal table, the thrust on its base is x times the weight of the contained fluid, where 2α is the vertical angle of the cone. Find the value of x.

(1) $3 \cos\alpha$ (2) $3 \sin\alpha$ (3) $2 \sin\alpha$ (4) $2 \cos\alpha$

24. A large block of ice 5m thick has a vertical hole drilled through it and is floating in the middle of a lake. The minimum length of the rope required to scoop up a bucket of water through the hole is : (density) of ice = 0.9g/cc)

(1) 5.5m (2) 5m (3) 4.5m (4) 0.5m

25. A sphere of solid material of specific gravity 8 has a concentric spherical cavity and just sinks in water. The ratio of radius of cavity to that of outer radius of the sphere must be

(1) $\frac{7^{1/3}}{2}$ (2) $\frac{5^{1/3}}{2}$ (3) $\frac{9^{1/3}}{2}$ (4) $\frac{3^{1/3}}{2}$

Topic 2: Fluid Flow, Reynold's Number and Bernoulli's Principle

26. Water is flowing continuously from a tap having an internal diameter 8×10^{-3} m. The water velocity as it leaves the tap is 0.4ms^{-1}. The diameter of the water stream at a distance 2×10^{-1} m below the tap is close to:

(1) 7.5×10^{-3} m (2) 9.6×10^{-3} m (3) 3.6×10^{-3} m (4) 5.0×10^{-3} m

27. Air of density 1.2 kg m^{-3} is blowing across the horizontal wings of an aeroplane in such a way that its speeds above and below the wings are 150 ms^{-1} and 100 ms^{-1}, respectively. The pressure difference between the upper and lower sides of the wings, is :

(1) 60 Nm^{-2} (2) 180 Nm^{-2} (3) 7500 Nm^{-2} (4) 12500 Nm^{-2}

28. A fluid is in streamline flow across a horizontal pipe of variable area of cross section. For this which of the following statements is correct?

(1) The velocity is minimum at the narrowest part of the pipe and the pressure is minimum at the widest part of the pipe

(2) The velocity is maximum at the narrowest part of the pipe and pressure is maximum at the widest part of the pipe

(3) Velocity and pressure both are maximum at the narrowest part of the pipe

(4) Velocity and pressure both are maximum at the widest part of the pipe

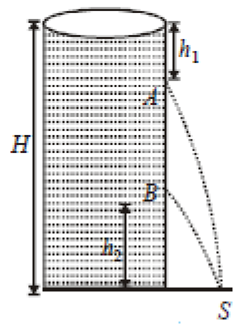
29. A cylindrical vessel contains a liquid of density ρ filled upto a height h. The upper surface of the liquid is in contact with a piston of mass m and area of cross-section A. A small hole is drilled at the bottom of the vessel. (Neglect the viscous effects) The speed with which the liquid comes out of the hoe is:

(1) $\sqrt{2}gh$ (2) $\sqrt{2g\left(h+\frac{m}{\rho A}\right)}$ (3) $\sqrt{g\left(h+\frac{m}{\rho A}\right)}$ (4) $\sqrt{g\left(h+\frac{2m}{\rho A}\right)}$

30. Oil is filled in a cylindrical container upto height 4m. A small hole of area '*p*' is punched in the wall of the container at a height 1.52m from the bottom. The cross sectional area of the container is *Q*. If *p/q* =0.1then *v* is (where *v* is the velocity of oil coming out of the hole)

(1) $5\sqrt{2}$ (2) $6\sqrt{3}$ (3) $8\sqrt{2}$ (4) $7\sqrt{5}$

31. In a cylindrical water tank, there are two small holes *A* and *B* on the wall at a depth of h_1, from the surface of water and at a height of h_2 from the bottom of water tank. Surface of water is at height of h_2 from the bottom of water tank. Surface of water is at height *H* from the bottom of water tank. Water coming out from both holes strikes the ground at the same point *S*. Find the ratio of h_1 and h_2



(1) Depends on *H* (2) 1 : 1 (3) 2 : 2 (4) 1 : 2

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

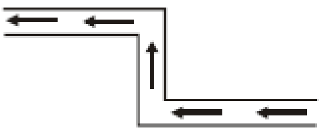
(1) 10 m/s (2) 20 m/s (3) 25.5 m/s (4) 5 m/s

33. A liquid flows through a tube of uniform cross-section with a constant speed in the direction as shown by the arrows in fig. The liquid exerts on the tube

(1) a net force to the left (2) a net force to the right

(3) an anticlockwise torque (4) a clockwise torque

34. Water is flowing through a horizontal tube having cross-sectional areas of its two ends being A and $A^{|}$ such that the ratio $A / A^{|}$ is 5. If the pressure difference of water between the two ends is 3×10^5 Nm^{-2}, the velocity of water with which it enters the tube will be (neglect gravity effects)



(1) 5 m s^{-1} (2) 10 m s^{-1} (3) 25 m s^{-1} (4) 50 10 m s^{-1}

35. In a stream line (laminar flow) the velocity of flow at any point in the liquid
(1) does not vary with time (2) may vary in direction but not in magnitude
(3) may vary in magnitude but not in direction (4) may vary both in magnitude and direction

36. A flow of liquid is streamline, if the Reynold number is
(1) between 2000 to 3000 (2) less than 1000 (3) between 4000 to 5000 (4) greater than 1000

37. Air flows horizontally with a speed v = 106 km/hr. A house has plane roof of area A = 20m^2. The magnitude of aerodynamic lift of the roof is
(1) 1.127×10^4 N (2) 5.0×10^4 N (3) 1.127×10^5 N (4) 3.127×10^4 N

38. A cylindrical vessel of cross-section A contains water to a height h. There is a hole in the bottom of radius 'a'. The time in which it will be emptied is:
(1) $\frac{2A}{\pi a^2}\sqrt{\frac{h}{g}}$ (2) $\frac{\sqrt{2}A}{\pi a^2}\sqrt{\frac{h}{g}}$ (3) $\frac{2\sqrt{2}A}{\pi a^2}\sqrt{\frac{h}{g}}$ (4) $\frac{A}{\sqrt{2}\pi a^2}\sqrt{\frac{h}{g}}$

39. There is a hole in the bottom of tank having water. If total pressure at bottom is 3 atm (1 atm = 10^5 N/m^2) then the velocity of water flowing from hole is
(1) 400m/s (2) 600m/s (3) 60m/s (4) None of these

Topic 3: Viscosity and Terminal Velocity

40. Which of the following statement(s) is/are true?
(1) For gases, in general, viscosity increases with temperature
(2) For liquids, viscosity varies directly with pressure
(3) For gases, viscosity is independent of pressure
(4) All of the above

41. If the terminal speed of a sphere of gold (density = 19.5 kg/m^3) is 0.2 m/s in a viscous liquid (density = 1.5 kg/m^3), find the terminal speed of a sphere of silver (density = 10.5 kg/m^3) of the same size in the same liquid
(1) 0.4 m/s (2) 0.133 m/s (3) 0.1 m/s (4) 0.2 m/s

42. What is the velocity v of a metallic ball of radius r falling in a tank of liquid at the instant when its acceleration is one - half that of a freely falling body? (The densities of metal and of liquid are ρ and σ respectively, and the viscosity of the liquid is η).
(1) $\frac{r^2g}{9\eta}(\rho-2\sigma)$ (2) $\frac{r^2g}{9\eta}(2\rho-\sigma)$ (3) $\frac{r^2g}{9\eta}(\rho-\sigma)$ (4) $\frac{2r^2g}{9\eta}(\rho-\sigma)$

43. A rain drop of radius 0.3 mm has a terminal velocity in air = 1 m/s. The viscosity of air is 8×10^{-5} poise. The viscous force on it is
(1) 45.2×10^{-4} dyne (2) 101.73×10^{-5} dyne (3) 16.95×10^{-4} dyne (4) 16.95×10^{-5} dyne

44. A spherical ball of iron of radius 2 mm is falling through a column of glycerine. If densities of glycerine and iron are respectively 1.3×10^3 kg/m^3 and 8×10^3 kg/m^3. η for glycerine = 0.83 Nm^{-2} sec, then the terminal velocity is
(1) 0.7 m/s (2) 0.07 m/s (3) 0.007 m/s (4) 0.0007 m/s

45. A small spherical ball falling through a viscous medium of negligible density has terminal velocity v. Another ball of the same mass but of radius twice that of the earlier falling through the same viscous medium will have terminal velocity
(1) v (2) v/4 (3) v/2 (4) 2v

46. Two drops of the same radius are falling through air with a steady velocity of 5 cm per sec. If the two drops coalesce, the terminal velocity would be
(1) 10 cm per sec (2) 2.5 cm per sec (3) $5 \times (4)^{1/3}$ cm per sec (4) $5\times\sqrt{3}$ cm per sec

47. In an experiment, a small steel ball falls through a liquid at a constant speed of 10 cm/s. If the steel ball is pulled upward with a force equal to twice its effective weight, how fast will it move upward ?

(1) 5 cm/s (2) Zero (3) 10 cm/s (4) 20 cm/s

48. When a ball is released from rest in a very long column of viscous liquid, its downward acceleration is 'a' (just after release). Its acceleration when it has acquired two third of the maximum velocity is a/X. Find the value of X.

(1) 2 (2) 3 (3) 4 (4) 5

49. Spherical balls of radius '*R*' are falling in a viscous fluid of viscosity 'h' with a velocity '*v*'. The retarding viscous force acting on the spherical ball is

(1) inversely proportional to both radius '*R*' and velocity '*v*'

(2) directly proportional to both radius '*R*' and velocity '*v*'

(3) directly proportional to '*R*' but inversely proportional to '*v*'

(4) inversely proportional to '*R*' but directly proportional to velocity '*v*'

50. A small ball (menu) falling under gravity in a viscous medium experiences a drag force proportional to the instantaneous speed u such that F_{drag} = Ku. Then the terminal speed of the ball within the viscous medium is

(1) $\frac{K}{mg}$ (2) $\frac{mg}{K}$ (3) $\sqrt{\frac{mg}{K}}$ (4) $\left(\frac{mg}{K}\right)^2$

51. An air bubble of radius 1 cm rises with terminal velocity 0.21 cm/s in liquid column. If the density of liquid is 1.47×10^3 kg/m^3. Then the value of coefficient of viscosity of liquid ignoring the density of air, will be

(1) 1.71×10^4 poise (2) 1.82×10^4 poise (3) 1.78×10^4 poise (4) 1.52×10^4 poise

Topic 4: Surface Tension, Surface Energy and Capillarity

52. Water rises in a capillary tube to a height h. It will rise to a height more than h

(1) on the surface of sun (2) in a lift moving down with an acceleration

(3) at the poles (4) in a lift moving up with an acceleration

53. With the increase in temperature, the angle of contact

(1) decreases (2) increases (3) remains constant (4) sometimes increases and sometimes decreases

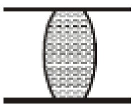
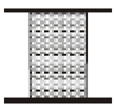
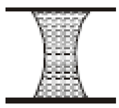
54. An isolated and charged spherical soap bubble has a radius r and the pressure inside is atmospheric. If T is the surface tension of soap solution, then charge on drop is $X\pi r\sqrt{2rT\varepsilon_0}$ then find the value of X.

(1) 8 (2) 9 (3) 7 (4) 2

55. A glass capillary tube of inner diameter 0.28 mm is lowered vertically into water in a vessel. The pressure to be applied on the water in the tube so that water level in the tube is same as that in the vessel in N/m^2 is (surface tension of water = 0.07 N/m, atmospheric pressure = 10^5 N/m^2) :

(1) 10^3 (2) 99×10^3 (3) 100×10^3 (4) 101×10^3

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

(1)  (2)  (3)  (4) None of these

57. Water rises to a height of 10 cm in capillary tube and mercury falls to a depth of 3.1 cm in the same capillary tube. If the density of mercury is 13.6 and the angle of contact for mercury is 135°, the approximate ratio of surface tensions of water and mercury is

(1) 1 : 0.15 (2) 1 : 3 (3) 1 : 6 (4) 1.5 : 1

58. Soap helps in better cleaning of clothes because

(1) it reduces the viscosity (2) it increases the viscosity

(3) it reduces the surface tension (4) it increases the surface tension

59. A film of water is formed between two straight parallel wires of length 10 cm each separated by 0.5 cm. If their separation is increased by 1 mm while still maintaining their parallelism, how much work will have to be done? (Surface tension of water = 7.2×10^{-2} N/m)

(1) 7.22×10^{-6} joule (2) 1.44×10^{-5} joule (3) 2.88×10^{-5} joule (4) 5.76×10^{-5} joule

60. The rise in the water level in a capillary tube of radius 0.07 cm when dipped vertically in a beaker containing water of surface tension 0.07 Nm^{-1} is (g = 10 ms^{-2})

(1) 2 cm (2) 4 cm (3) 1.5 cm (4) 3 cm

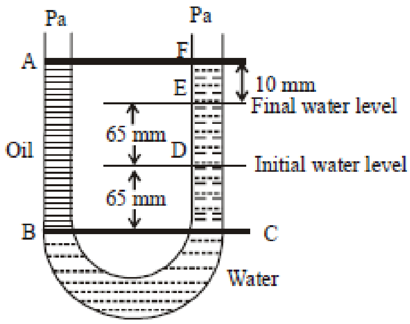
NEET PREVIOUS YEARS QUESTIONS

1. 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 **[2018]**

(1) r^3 (2) r^2 (3) r^4 (4) r^5

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

[2017]



(1) 425 kg m^{-3} (2) 800 kg m^{-3} (3) 928 kg m^{-3} (4) 650 kg m^{-3}

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

[2016]

(1) $\{1 + (n + 1)p\}\rho$ (2) $\{2 + (n + 1)p\}\rho$ (3) $\{2 + (n - 1)p\}\rho$ (4) $\{1 + (n - 1)p\}\rho$

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

(1) 4.8×10^5 N, upwards (2) 2.4×10^5 N, upwards

(3) 2.4×10^5 N, downwards (4) 4.8×10^5 N, downwards

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

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

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

(3) water does not rise at all.

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

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

(1) $\frac{VR^2}{nr^2}$ (2) $\frac{VR^2}{n^3r^2}$ (3) $\frac{VR^2}{nr}$ (4) $\frac{VR^2}{n^2r^2}$

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

(1) energy $= 4VT\left(\frac{1}{r}-\frac{1}{R}\right)$ is released (2) energy $= 3VT\left(\frac{1}{r}+\frac{1}{R}\right)$ is absorbed

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

8. 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-2019]**

(1) 12.6×10^{-6} m3 /s (2) 8.9×10^{-6} m^3 /s (3) 2.23×10^{-6} m3 /s (4) 6.4×10^{-6} m^3 /s

9. 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 m/s^2 density of water = 10^3 kg/m^3, the value of $Z_0$is:- **[NEET-2019]**

(1) 100 cm (2) 10 cm (3) 1 cm (4) 0.5 cm

10. A liquid does not wet the solid surface if angle of contact is: **[NEET-2020(COVID)]**

(1) equal to 45° (2) equal to 60° (3) greater then 90° (4) zero

11. A barometer is constructed using a liquid (density = 760 kg/m^3). What would be the height of the liquid column, when a mercury barometer reads 76 cm? (Density of mercury = 13600 kg/m^3) **[NEET-2020(COVID)]**

(1) 1.36 m (2) 13.6 m (3) 136 m (4) 0.76 m

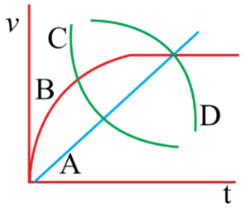
12. A capillary tube of radius r is immersed in water and water rises in it to a height h. The mass of the water in the capillary is 5g. Another capillary tube of radius 2r is immersed in water. The mass of water that will rise in this tube is **[NEET-2020]**

1) 20.0 g 2) 2.5 g 3) 5.0 g 4) 10.0g

13. The velocity of a small ball of mass M and density, when dropped in a container filled with glycerine becomes constant after some time. If the density of glycerine is d/2, then the viscous force acting on the ball will be **[NEET-2021]**

1) Mg 2) $\frac{3}{2}Mg$ 3) 2Mg 4) $\frac{Mg}{2}$

14. A spherical ball is dropped in a long column of a highly viscous liquid. The curve in the graph shown, which represents the speed of the ball (n) as a function of time (t) is:



(1) A (2) B (3) C (4) D

15. If a soap bubble expands, the pressure inside the bubble:

(1) decreases (2) increases

(3) remains the same (4) is equal to the atmospheric pressure

NCERT LINE BY LINE QUESTIONS – ANSWERS

1.	(b)	2.	(b)	3.	(c)	4.	(b)	5.	(d)
6.	(c)	7.	(d)	8.	(b)	9.	(d)	10.	(a)
11.	(a)	12.	(b)	13.	(b)	14.	(d)	15.	(d)

16.	(b)	17.	(d)	18.	(a)	19.	(d)	20.	(b)

NCERT BACED QUESTONS-ANSWERS

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

TOPIC WISE PRACTICE QUESTIONS - ANSWERS

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

NEET PREVIOUS YEARS QUESTIONS-ANSWERS

1)	4	2)	3	3)	4	4)	2	5)	1	6)	1	7)	3	8)	1	9)	3	10)	3
11)	2	12)	4	13)	4	14)	2	15)	1										

TOPIC WISE PRACTICE QUESTIONS - SOLUTIONS

1. **(4)** Pressure applied to enclosed fluid is transmitted equally in all direction according to Pascal law.

2. **(3)** When a beaker containing a liquid of density r moves up with an acceleration a, it will work as a lift moving upward with acceleration a. The effective acceleration due to gravity in lift = (a + g)

$\therefore$ Pressure of liquid of height h = h ρ (a + g)

3. (1) In order that a floating object be in a stable equilibrium its centre of buoyancy should be vertically above its centre of gravity.

4. **(1)** In hydrometer lower density mark is upwards and higher density mark is downwards.

5. **(4)** From the figure it is clear that liquid 1 floats on liquid 2.

The lighter liquid floats over heavier liquid. Therefore we can conclude that $\rho_1 < \rho_2$

Also $\rho_3 < \rho_2$ otherwise the ball would have sink to the bottom of the jar.

Also $\rho_3 > \rho_1$ otherwise the ball would have floated in liquid 1. From the above discussion we conclude that $\rho_1 < \rho_3 < \rho_2$.

6. **(3)** Volume of mg of ice = m/x and

volume of mg of water = m/y. So change in volume $= \frac{m}{y} - \frac{m}{x} = m\left(\frac{1}{y} - \frac{1}{x}\right)$

7. **(2)** When ice having lead balls melts, the volume of water formed and lead balls left will be smaller than that of ice. Due to which the level of water will go down.

8. **(1)** As we know, $P = P_a + rgh$

Thus, pressure, P at depth h below the surface of a liquid open to the atmosphere is greater than the atmospheric pressure by an amount rgh.

9. **(4)** The pressure outside the submarine is

$P = P_a + rgh$

Pressure inside the submarine is Pa.

Net pressure acting on the window is

$P_g = P - P_a = \rho gh = 10^{-3} kgm^{-3} \times 10\ ms^{-2} \times 2000\ m = 2 \times 10^7\ Pa$

Area of window is $A = 50\ cm \times 50\ cm = 2500 \times 10^{-4}\ m^2$

Force on the window is $F = P_g A = 2 \times 10^7\ Pa \times 2500 \times 10^{-4}\ m^2 = 5 \times 10^6\ N$

10. **(1)** Let h be the desired height of liquid in cylinder for which the force on the bottom and sides of the vessel is equal.

Force on bottom = $\rho g h \times \pi R^2$

Force on the walls of vessel = $\rho g (h/2) \times 2 \pi Rh$

$\therefore \rho gh \pi R^2 = \rho g h \pi R h$ or $R = h$

11. (2) $\rho_{oil} < \rho < \rho_{water}$

Oil is the least dense of them so it should settle at the top with water at the base. Now the ball is denser than oil but less denser than water. So, it will sink through oil but will not sink in water and will stay at the oil-water interface.

12. **(2)** Bulk modulus, $B = -V_0 \frac{\Delta p}{\Delta V} \Rightarrow \Delta V = -V_0 \frac{\Delta p}{B} \Rightarrow V = V_0 \left[1 - \frac{\Delta p}{B}\right]$

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

where, $\Delta p = p - p_0 = h\rho_0 g$ = pressure difference between depth and surface of ocean

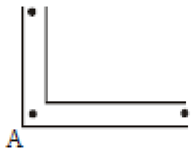
$\therefore \rho = \rho_0 \left[1 + \frac{\rho_0 gy}{B}\right]$ (As h = y)

13. **(1)** No sliding $\Rightarrow$ pure rolling

Therefore, acceleration of the tube = 2a (since COM of cylinders are moving at 'a')

$PA = P_{atm} + \rho (2a) L$

(From horizontal limb)



Also, PA = P_{atm}+ ρ gh (From vertical limb)$\Rightarrow$ a = $\dfrac{gH}{2L}$

14. **(4)** $6=\dfrac{V}{3}\rho_w$ --------(1)

$V_{\rho_w} \Rightarrow V_{\rho_B}=6$

Let body of mass m is placed on it.

$(6+m)=V\rho_w$; $6+m=18\Rightarrow m=12\text{kg}$

15. **(1)** Specific gravity $=\dfrac{\text{weight of body in air}}{\text{weight of water displaced}}=\dfrac{210}{210-140}=\dfrac{210}{70}=3$

Density of body = sp. gravity × density of water= 3 ×1 g/cm^3 = 3 g/cm^3

16. **(2)** Let v be the volume of the ice-berg outside the sea water and V be the total volume of ice-berg. Then as per question

0.92 V = 1.03 (V – v) or v/V = 1 – 0.92/1.03 = 11/103

$\therefore$ (v/V) × 100 = 11 × 100 / 103 $\cong$ 11%

17. **(1)** Weight of a man = wt. of water displaced= volume × density $=3\times2\times\dfrac{1}{100}\times10^3=60\,\text{kg}$

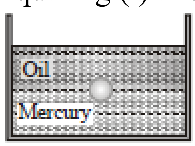
18. **(3)** $v^2=\dfrac{2\left(\rho-\rho^{|}\right)gd}{\rho^{|}}=2gh\Rightarrow d=\dfrac{h\rho^{|}}{\rho-\rho^{|}}$

19. **(3)** As the sphere floats in the liquid. Therefore its weight will be equal to the upthrust force on it

Weight of sphere $=\dfrac{4}{3}\pi R^3\rho g$

Upthrust due to oil and mercury $=\dfrac{2}{3}\pi R^3\times\sigma_{oil}g+\dfrac{2}{3}\pi R^3\sigma_{Hg}g$

Equating (i) and (ii)



$\dfrac{4}{3}\pi R^3\rho g=\dfrac{2}{3}\pi R^3 0.8g+\dfrac{2}{3}\pi R^3+13.6g\Rightarrow 2\rho=0.8+13.6=14.4\Rightarrow\rho=7.2$

20. (1) According to law of floatation, a body floats if weight of the body is equal to the weight of water displaced

$\Rightarrow W_s=W_w$

$\Rightarrow V_s\times\rho_s\times g=V_w\times\rho_w\times g$

$\Rightarrow \frac{4}{3}\pi\left(R^3-r^3\right)\times9\rho_w=\frac{4}{3}\pi R^3\times\rho_w$

$\Rightarrow 9\left(R^3-r^3\right)=R^3$

$\Rightarrow r^3=\dfrac{8}{9}R^3$

21. **(2)** Let V be the volume of iceberg and let x be the fraction of volume above water.

Using law of floatation, weight of floating body = weight of liquid displaced by part of the floating body inside the liquid.

Therefore, $V\rho_{ice}g = (1-x)V\rho_{water}g$.

Using the value of ρ_{ice} and ρ_{water} , we get $x = (13/103)$.

22. **(3)** Since pressure is transmitted undiminished throughout the fluid (Pascal's law)

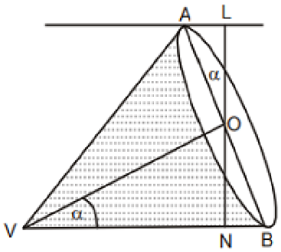
$$F_1 = \frac{A_1}{A_2}F_2 = \frac{\pi(5\times5)}{\pi(15\times5)}(1350\times9.81) \approx 1.5\times10^3\,\text{N}$$

The air pressure that will produce this force is

$$P = \frac{F_1}{A_1} = \frac{1.5\times10^3}{\pi(5\times10^{-2}\,\text{m})^2} = 1.9\times10^5\,\text{Pa}$$

23. **(2)**V is the vertex of the cone and VB is the generator in contact with the horizontal

A is the highest point of the cone and the horizontal plane passing through A is the level of the free surface . Let α be the semi-vertical angle of the cone, then ∠AOL = α. Let h be the height of the cone, then the radius of the base of the cone = h tan α . Also the depth of O, the C. G. of the base of the cone below the free surface.



$OL = AO\cos\alpha = h\tan\alpha\ \cos\alpha = h\sin\alpha$

Thrust on the base of the

$$= \rho g.OL.\pi(h\tan\alpha)^2$$

$$= \pi\rho gh\sin\alpha\, h^2\tan^2\alpha$$

$$= 3\sin\alpha\left[\frac{1}{3}\pi h^3\tan^2\alpha.\rho g\right]$$

3 sin α [weight of the liquid contained in the cone]

24. **(4)** Weight of ice black = weight liquid displaced

$A \times 5 \times 0.9 \times g = (5-h) \times A \times 1 \times g$ $h = 0.5\text{m}$

25. **(1)** Let r be the density of the material. ρ_0 be the density of water when the sphere has just started sinking, the weight of the sphere = weight of water displaced\(approx).

$$\Rightarrow \frac{4}{3}\pi(R^3-r^3)\rho g = \frac{4}{3}\pi R^3\rho_0 g \Rightarrow (R^3-r^3)\rho = R^3\rho_0 \Rightarrow \frac{(R^3-r^3)}{R^3} = \frac{\rho_0}{\rho} \Rightarrow \frac{r}{R} = \frac{(7)^{1/3}}{2}$$

26. **(3)** From Bernoulli's theorem,

$$P_0 + \frac{1}{2}\rho v_1^2 \rho gh = P_0 + \frac{1}{2}\rho v_2^2 + 0$$

$$v_2 = \sqrt{v_1^2 + 2gh} = \sqrt{0.16 + 2\times10\times0.2} = 2.03\,\text{m/s}$$

From equation of continuity, $A_2v_2 = A_1v_1$

$$\pi\frac{D_2^2}{4}\times v_2 = \pi\frac{D_1^2}{4}v_1 \Rightarrow D_2 = D_1\sqrt{\frac{v_1}{v_2}} = 3.55\times10^{-3}\,\text{m}$$

27. **(3)** Pressure difference

$$P_2 - P_1 = \frac{1}{2}\rho(v_2^2 - v_1^2) = \frac{1}{2}\times1.2\left[(150)^2 - (100)^2\right] = \frac{1}{2}\times1.2[22500 - 10000] = 7500\,\text{Nm}^{-2}$$

28. **(2)** According to Bernoulli's theorem,

$P+\frac{1}{2}\rho v^2=$ constant and Av= constant

If Ais minimum, vis maximum, Pis minimum.

29. **(2)** $h\rho g+\frac{mg}{A}=\frac{1}{2}\rho v^2$

30. **(1)** $\rho.A.v=\text{constants}$

$A_1V_1=A_2V_2\,;VQ=VP$

$V=V\times 0.1\Rightarrow V=1V$

$\rho+\rho gh+\frac{1}{2}\rho V^2=\text{constant}\ \ ;\rho+\rho gh_1+\frac{1}{2}\rho V^2=\frac{1}{2}\rho\left(100V^2\right)+\rho gh_2+\rho$

$\rho g\left(h_1-h_2\right)=\frac{1}{2}\rho\left(99V^2\right)\ ;\ \ V^2=\frac{2\times 9.8\times\left(4-1.52\right)}{99}\Rightarrow V=0.7=7$

31. **(1)** Range is same for both holes $\therefore 2\sqrt{\left(H-h_1\right)h_1}=2\sqrt{\left(H-h_2\right)h_2}$

Squaring both sides, $4\left(H-h_1\right)h_1=4\left(H-h_2\right)h_2$

$Hh_1-h_1^2=Hh_2-h_2^2$

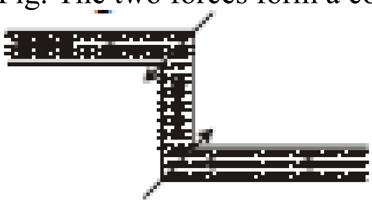
On solving we get, $H=h_1+h_2$

Hence, the ratio of $\frac{h_1}{h_2}$ depends on *H*.

32. **(2)** P.E. = K.E.

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

33. **(3)** As the liquid undergoes change in momentum only at the bends of tube, hence the liquid and tube exert forces on each other at these locations. The forces exerted by the liquid at the bends are shown in Fig. The two forces form a couple causing an anticlockwise torque.



34. **(1)** According to Bernoulli's theorem

$P_1+\frac{1}{2}\rho v_1^2=P_2+\frac{1}{2}\rho v_2^2$----------------(i)

From question, $P_1-P_2=3\times 10^5,\frac{A_1}{A_2}=5$

According to equation of continuity $\quad A_1v_1=A_2v_2$ or $\frac{A_1}{A_2}=\frac{v_2}{v_1}=5\Rightarrow v_2=5v_1$

From equation (i) $P_1-P_2=\frac{1}{2}\rho\left(v_2^2-v_1^2\right)$ or $3\times 10^5=\frac{1}{2}\times 1000\left(5v_1^2-v_1^2\right)$

$\Rightarrow 600=6v_1\times 4v_1\Rightarrow v_1^2=25;\therefore v_1=5\,m/s$

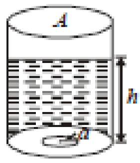
35. **(1)** In stream line flow velocity of flow at any point in the liquid does not vary with time.

36. **(2)** If Reynolds number is less than 1000, the flow is streamline. If Reynolds number is greater than 2000, the flow is turbulent. If Reynolds number lies between 1000 and 2000 , the flow becomes unsteady.

37. **(1)** Conceptual

38. **(2)** Let the rate of falling water level be $-\dfrac{dh}{dt}$

Initially at $t=0\,;\,h=h$
$t=t\,;\,h=0$



Then, $A\left(-\dfrac{dh}{dt}\right)=\pi a^2 .v$

$dt=-\dfrac{A}{\pi a^2\sqrt{2gh}}dh$

[$\because$ velocity of efflux of liquid $v=\sqrt{2gh}$]

Integrating both sides

$$\int_0^t dt=-\frac{A}{\sqrt{2g}\pi a^2}\int_h^0 h^{-1/2}dh$$

$$[t]_0^t=-\frac{A}{\sqrt{2g}\pi a^2}\left[\frac{h^{1/2}}{1/2}\right]_h^0 \Rightarrow t=\frac{\sqrt{2}A}{\pi a^2}\sqrt{\frac{h}{g}}$$

39. **(1)** Pressure at the bottom of tank $P=h\rho g=3\times10^5\dfrac{N}{m^2}$

Pressure due to liquid column ; $P_1=3\times10^5-1\times10^5=2\times10^5$

and velocity of water $v=\sqrt{2gh}$; $\quad\therefore v=\sqrt{\dfrac{2P_1}{\rho}}=\sqrt{\dfrac{2\times2\times10^5}{10^3}}=\sqrt{400}\,m/s$

40. **(4)** For gases, $\eta\propto\sqrt{T}$; for liquids, h increases with increase in pressure, whereas for gases, η is independent of pressure.

41. **(3)** Terminal velocity, $v_T=\dfrac{2r^2(d_1-d_2)g}{9\eta}$

$$\frac{v_{T_2}}{0.2}=\frac{(10.5-1.5)}{(19.5-1.5)}\Rightarrow v_{T_2}=0.2\times\frac{9}{18}\;;\;\therefore v_{T_2}=0.1\,m/s$$

42. **(3)**Net force on the ball= downward force- upward force $=$ mg / 2

$$\frac{4}{3}\pi r^3(\rho-\sigma)g-6\pi\eta rv=\frac{mg}{2}$$
$$\frac{4}{3}\pi r^3(\rho-\sigma)g-6\pi\eta rv=\frac{1}{2}\left(\frac{4}{3}\pi r^3\rho\right)g$$
$$r^2(\rho-\sigma)g-\frac{9}{2}\eta v=\frac{1}{2}r^2\rho g$$
$$\frac{9}{2}v\eta=r^2(\rho-\sigma)g-\frac{1}{2}r^2\rho g$$
$$=\frac{1}{2}r^2\rho g-r^2\sigma g$$
$$\frac{9}{2}v\eta=\frac{1}{2}r^2g(\rho-2\sigma)$$
$$v=\frac{r^2g}{9\eta}(\rho-2\sigma)$$

43. **(1)** F $=6\pi\eta rv=6\times3.14\times(8\times10^{-5})\times0.03\times100=4.52\times10^{-3}$ dyne

44. **(2)** Terminal velocity, $v_0=\dfrac{2r^2(\rho-\rho_0)g}{9\eta}=\dfrac{2\times\left(2\times10^{-3}\right)^2\times(8-1.3)\times10^3\times9.8}{9\times0.83}=0.07\,ms^{-1}$

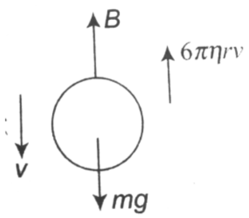
45. **(3)** If r is the density of the ball and r¢ that of the another ball, m for the balls are the same, but $r^{|}=2r$

$\therefore mg = 6\pi r\eta v$ (by Stoke's law) or, $= 6\pi r\eta v = 6\pi 2r\eta v^{|}$ So, $v^{|} = \frac{v}{2}$

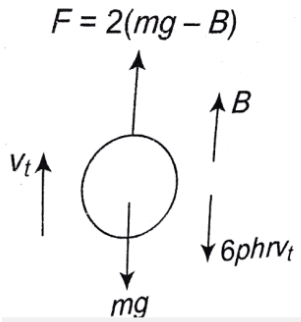
46. **(3)** If R is radius of bigger drop formed, then $\frac{4}{3}\pi R^3 = 2\times\frac{4}{3}\pi r^3$ or $R = 2^{1/3} r$

As $v_0 \propto r^2 \therefore \frac{v_{01}}{v_0} = \frac{R^2}{r^2} = \frac{(2^{1/3} r)^2}{r^2} = 2^{2/3}$ or $v_{01} = v_0 \times 2^{2/3} = 5\times(4)^{1/3}$

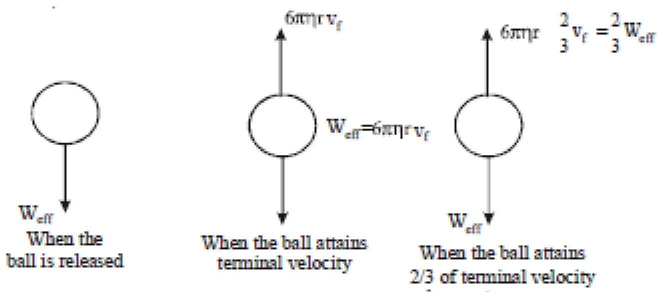
47. **(3)**



First case:
$B + 6\pi\eta r v = mg$ ..(i)
For second case:
$F = 2(mg - B)$
$F + B = mg + 6\pi\eta r v_i$
$\Rightarrow 2mg - 2B + B = mg + 6\pi\eta r v_i$
$mg - B = 6\pi\eta r v_i$.(ii)
From (i) and (ii) $v_t = v = 10\frac{cm}{s}$



48. **(2)**



When the ball is just released, the net force on ball is W_{eff} (= mg - buoyant force)
The terminal velocity v_f of the ball is attained when net force on the ball is zero.
$\therefore$ Viscous force $6\pi\eta r\, v_f = W_{eff}$

When the ball acquires $\frac{2}{3}$ rd of its maximum velocity

v_f the viscous force is $= = \frac{2}{3}W_{eff}$; Hence net force is $W_{eff} - \frac{2}{3}W_{eff} = \frac{1}{3}W_{eff}$

$\therefore$ required acceleration is a/3

49. **(4)** Due to acceleration down the plane, both body B and liquid will received the same component of acceleration down the plane.

50. (2)Drag force + upthrust = weight ; $\therefore ku + F = mg$; $u = \frac{mg - F}{k}$

51. **(4)** Using the formula of the terminal velocity of a body falling through a viscous medium,

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

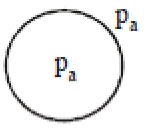
Where ρ is the density of material of body and σ is the density of medium.
In case of the air bubble $\rho = 1$ and $\sigma = 1.47 \times 10^3$ kg/ms and the air bubble rises up.

$$\eta = \frac{2r^2\sigma g}{9V} = \frac{2\times(10^{-2})^2\times1.47\times10^3\times9.8}{9\times0.21\times10^{-2}} = \frac{2\times1.47\times9.8\times10}{9\times0.21} = 1.52\times10^3 \text{decapoise} = 1.52\times10^4 \text{ Poise}$$

52. **(2)** When lift is accelerated downwards, the observed weight of body in a lift decreases. Hence to counter balance the upward pull due to S.T. on the liquid meniscus, the height through which the liquid rises must increase.

53. **(1)** With the increase in temperature, the surface tension of liquid decreases and angle of contact also decreases.

54. **(1)** Inside pressure must be $\frac{4T}{r}$ greater than outside pressure in bubble.



This excess pressure is provided by charge on bubble

$$\frac{4T}{r}=\frac{\sigma^2}{2\varepsilon_0};\frac{4T}{r}=\frac{Q^2}{16\pi^2r^4\times2\varepsilon_0}\left[\sigma=\frac{Q}{4\pi r^2}\right];\ Q=8\pi r\sqrt{2rT\varepsilon_0}$$

55. **(2)** $\frac{2T}{r}=\frac{2\times0.07}{0.14\times10^{-3}}=10^3\,N/m^2$; Pressure applied $=P_a-\frac{2T}{r}=10^5-10^3=99\times10^3\,N/m^2$

56. (3)when water is in contact with glass plate first they are in adhesive bonding with each other due to which they try to repeal each other due to which we found a concave outward shape.

57. **(3)** $h=\frac{2\sigma\cos\theta}{r\rho g}\Rightarrow\sigma\propto\frac{h\rho}{\cos\theta}\Rightarrow\frac{\sigma_w}{\sigma_m}=\frac{h_w\rho_w}{\cos\theta_w}\times\frac{\cos\theta_m}{h_m\rho_m}=\frac{10\times1}{\cos0^0}\times\frac{\cos135^0}{-3.1\times13.6}=\frac{10\times(-0.707)}{-3.1\times13.6}\approx\frac{1}{6}$

58. (3) Soaps decreases the surface tension of water so as to increase wetting ability of water which helps in cleaning clothes.

59. **(2)** Increment in area of soap film = $A_2-A_1=2\times[(10\times0.6)-(10\times0.5)]\times10^{-4}=2\times10^{-4}\,m^2$
Work done = $T\times\Delta A=7.2\times10^{-2}\times2\times10^{-4}=1.44\times10^{-5}J$

60. **(1)** Rise of a liquid in a capillary tube is given by $h=\frac{2S\cos\theta}{r\rho g}$

For water, $S=0.07\,Nm^{-1},\ \rho=10^3kgm^{-3}$

Angle of contact q = 0° ; $\therefore h=\frac{2\times(0.07Nm^{-1})\times1}{(0.07\times10^{-2}m)(10^3kgm^{-3})(10ms^{-2})}=2\times10^{-2}m=2cm$

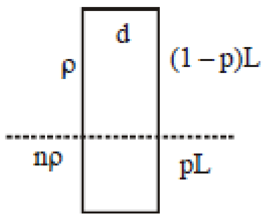
NEET PREVIOUS YEARS QUESTIONS-EXPLANATIONS

1. **(4)**Power = rate of production of heat = $F.V=6\pi\eta rV_T.V_T=6\pi\eta rV_T^2$ ($\because F=6\pi\eta V_Tr$ stoke's formula)

$$V_T\propto r^2\ ;\ \because V_T=\frac{2}{9}\frac{r^2(\rho-\sigma)}{\eta}g\ ;\qquad\therefore \text{Power}\propto r^5$$

2. **(3)**Here, $h_{oil}\times\rho_{oil}\times g=h_{water}\times\rho_{water}\times g$; $\rho_0g\times140\times10^{-3}=\rho_wg\times130\times10^{-3}$

3. **(4)**As we know,;Pressure P = Vdg

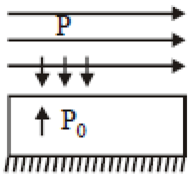


Here, L A d g = (pL) A (n ρ)g + (1 – p)L A ρ g ⇒ d = (1 – p) ρ + pn ρ = [1 + (n – 1)p] ρ

4. **(2)**According to Bernoulli's theorem

$P + \frac{1}{2}\rho v^2 = P_0 + 0$

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



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

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

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

5. **(1)**Water rises upto the top of capillary tube and stays there without overflowing.

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

6. **(1)**Inflow rate of volume of the liquid = Outflow rate of volume of the liquid

7. **(3)**As surface area decreases so energy is released.

$$\text{Energy released} = 4\pi R^2 T\left[n^{1/3} - 1\right]$$

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

8.

velocity of efflux $v = \sqrt{2gh}$

volume flow rate $= Av = A\sqrt{2gh}$

$= (2 \times 10^{-6})(2 \times 10 \times 2)^{1/2}$

$= 4\sqrt{10} \times 10^{-6} \text{ m}^3/\text{s}$

$\cong 12.6 \times 10^{-6} \text{ m}^3/\text{s}$

9. $P = P_0 + rgZ_0$ ....(i) ;Also, $P = P_0 + 4T/R$.........(ii)

From (i) & (ii)

$$\rho g Z_0 = \frac{4T}{R}$$

$$Z_0 = \frac{4T}{\rho g R} = \frac{4 \times 2.5 \times 10^{-2}}{10^3 \times 10 \times 10^{-3}}$$

$= 10^{-2} \text{ m} = 1 \text{ cm}$

10. We know that the liquids make the solid substances wet when they get into physical contact with each other. This depends on the contact angle between the liquid and solid surfaces. When the liquid does not wet the sides of a solid object, it means that the angle of contact is more than 90° but less than 180°.
A liquid does not wet the solid surface if the angle of contact is obtuse (i.e. $\theta > 90^0$).

11. $76\,\text{cm} \times \rho_{Hg} \times g = h \times \rho_L \times g$; $h = 76\,\text{cm} \times \frac{\rho_{Hg}}{\rho_L} = 76\,\text{cm} \times \frac{13600}{760} = 13.6\text{m}$

12. For equilibrium of water column in capillary tube

$$mg = T.2\pi r \;;\; m \propto r \Rightarrow \frac{m_2}{m_1} = \frac{r_2}{r_1} \;; \quad \Rightarrow m_2 = 2m_1 = 10gm$$

13. $W = F_B + F_V$; $mg = \frac{mg}{2} + F_V \Rightarrow F_V = \frac{mg}{2}$

14. Velocity initially increases and then constant

15. $P = \frac{4T}{R}$

$R \uparrow P \downarrow$