Answers and Solutions

Pressure and Density

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

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

According to given condition

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

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

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

where $m =$ mass of the body,

$\rho =$ density of the body

$\sigma =$ density of water

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

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

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

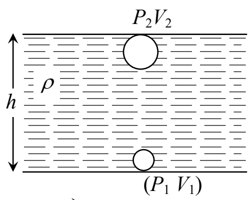
By solving we get $\rho_2 = 3$.

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

$\Rightarrow P_1V_1 = P_2V_2$

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

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



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

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

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

4. (b) Force acting on the base

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

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

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

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

and pressure difference due to *h* meter of air

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

By equating (i) and (ii) we get

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

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

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

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

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

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

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

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

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

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

= Actual weight – upthrust due to displaced air

$\Rightarrow M_0g - \left(\frac{M_0}{d_1}\right)dg = Mg - \left(\frac{M}{d_2}\right)dg \;\Rightarrow M_0 = \frac{M\left[1 - \frac{d}{d_2}\right]}{\left[1 - \frac{d}{d_1}\right]}$

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

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

Where, *h* = depth of lake

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

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

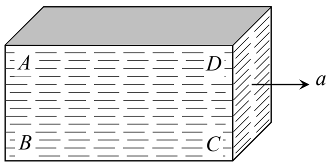
$$\Rightarrow h\rho g = 2P_0 \Rightarrow h = \frac{2 \times 75 \times 13.6 \times g}{\frac{13.6}{10} \times g} = 15\ m$$

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

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

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

15. (a)



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

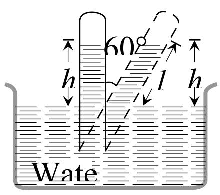
Also due to height of liquid column pressure will be more at the bottom (points B and C) in comparison with top (point A and D).

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

16. (b) Total pressure at (near) bottom of the liquid $P = P_0 + h\rho g$

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

17. (a) $\cos 60° = \frac{h}{l}$



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

$\therefore\ l = 152\ cm$

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

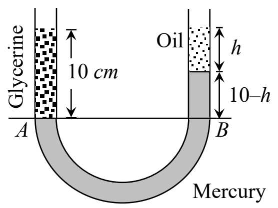
and pressure on the vertical surface = $\frac{1}{2} h\rho g$

Now, according to problem

Force at the bottom = Force on the vertical surface

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

19. (d)



At the condition of equilibrium

Pressure at point A = Pressure at point B

$P_A = P_B \Rightarrow$

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

By solving we get $h = 9.7\ cm$

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

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

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

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

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

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

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

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

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

= pressure difference between depth and surface of ocean

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

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

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

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

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

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

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

28. (a)

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

30. (c)

31. (d)

Pascal's Law and Archmidies Principle

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

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

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

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

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

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

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

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

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

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

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

3. (c) Weight of the bowl = mg

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

where D = Outer diameter ,

d = Inner diameter

ρ = Density of bowl

Weight of the liquid displaced by the bowl

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

where σ is the density of the liquid.

For the flotation

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

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

By solving we get $d = 0.98\ m$.

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

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

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

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

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

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

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

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

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

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

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

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

6. (d) Apparent weight

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

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

7. (a) Fraction of volume immersed in the liquid $V_{in} = \left(\frac{\rho}{\sigma}\right)V$ *i.e.* it depends upon the densities of the block and liquid.

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

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

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

= 1.94 *Kg-wt*

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

If *V* is the volume of sample then according to problem

$210 = V\rho g$ …(i)

$180 = V(\rho - 1)g$ …(ii)

$120 = V(\rho - \sigma)g$ …(iii)

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

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

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

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

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

12. (d)

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

$= 5 \times 5 \times 5(7 - 1)g = 6 \times 5 \times 5 \times 5\ gf$

14. (b)

15. (b) Effective weight $W = m(g - a)$ which is less than actual weight *mg*, so the length of spring decreases.

16. (d) Tension in spring *T* = upthrust – weight of sphere

$= V\sigma g - V\rho g = V\eta\rho g - V\rho g \quad (\text{As}\ \sigma = \eta\rho)$

$= (\eta - 1)V\rho g = (\eta - 1)mg$.

17. (a) When body (sphere) is half immersed, then upthrust = weight of sphere

$\Rightarrow \frac{V}{2} \times \rho_{liq} \times g = V \times \rho \times g \ \therefore\ \rho = \frac{\rho_{liq}}{2}$

When body (sphere) is fully immersed then, Upthrust = wt. of sphere + wt. of water poured in sphere

$\Rightarrow V \times \rho_{liq} \times g = V \times \rho \times g + V' \times \rho_{liq} \times g$

$\Rightarrow V \times \rho_{liq} = \frac{V \times \rho_{liq}}{2} + V' \times \rho_{liq} \Rightarrow V' = \frac{V}{2}$

18. (a) Since no change in volume of displaced water takes place, hence level of water remains same.

19. (b) The velocity of ball before entering the water surface

$v = \sqrt{2gh} = \sqrt{2g \times 9}$

When ball enters into water, due to upthrust of water the velocity of ball decreases (or retarded)

The retardation, $a = \frac{\text{apparent weight}}{\text{mass of ball}}$

$= \frac{V(\rho - \sigma)g}{V\rho} = \left(\frac{\rho - \sigma}{\rho}\right)g = \left(\frac{0.4 - 1}{0.4}\right) \times g = -\frac{3}{2}g$

If *h* be the depth upto which ball sink, then,

$0 - v^2 = 2 \times \left(-\frac{3}{2}g\right) \times h \Rightarrow 2g \times 9 = 3gh \therefore\ h = 6$ *cm*.

20. (b) Upthrust = weight of body

For *A*, $\frac{V_A}{2} \times \rho_W \times g = V_A \times \rho_A \times g \Rightarrow \rho_A = \frac{\rho_W}{2}$

For *B*, $\frac{3}{4} V_B \times \rho_W \times g = V_B \times \rho_B \times g \Rightarrow \rho_B = \frac{3}{4}\rho_W$

(Since 1/4 of volume of *B* is above the water surface)

$\therefore \frac{\rho_A}{\rho_B} = \frac{\rho_W/2}{3/4\ \rho_W} = \frac{2}{3}$

21. (c)

22. (c) Since, up thrust (*F*) = $V\sigma g$ *i.e.* $F \propto V$

23. (b) $V\rho g = \frac{V}{2}\sigma g \therefore\ \rho = \frac{\sigma}{2}$ (σ = density of water)

24. (b)

25. (b)

26. (d)

27. (a)

Fluid Flow

1. (b) For streamline flow, Reynold's number $N_R \propto \frac{r\rho}{\eta}$ should be less. For less value of N_R, radius and density should be small and viscosity should be high.

2. (a) $d_A = 2\,cm$ and $d_B = 4\ cm$ $\therefore r_A = 1\ cm$ and $r_B = 2\ cm$

From equation of continuity, av = constant

$\therefore \frac{v_A}{v_B} = \frac{a_B}{a_A} = \frac{\pi(r_B)^2}{\pi(r_A)^2} = \left(\frac{2}{1}\right)^2 \Rightarrow v_A = 4v_B$

3. (c) If the liquid is incompressible then mass of liquid entering through left end, should be equal to mass of liquid coming out from the right end.

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

$\Rightarrow A \times 3 = A \times 1.5 + 1.5A.v \Rightarrow v = 1\ m/s$

4. (d) This happens in accordance with equation of continuity and this equation was derived on the principle of conservation of mass and it is true in every case, either tube remain horizontal or vertical.

5. (d) $a_1v_1 = a_2v_2$

$\Rightarrow 4.20 \times 5.18 = 7.60 \times v_2 \Rightarrow v_2 = 2.86\ m/s$

6. (a) Velocity head $h = \frac{v^2}{2g} = \frac{(5)^2}{2\times 10} = 1.25\,m$

7. (d) As cross-section areas of both the tubes A and C are same and tube is horizontal. Hence according to equation of continuity $v_A = v_C$ and therefore according to Bernoulli's theorem $P_A = P_C$ *i.e.* height of liquid is same in both the tubes A and C.

8. (b) Bernoulli's theorem for unit mass of liquid

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

As the liquid starts flowing, it pressure energy decreases $\frac{1}{2}v^2 = \frac{P_1 - P_2}{\rho}$

$\Rightarrow \frac{1}{2}v^2 = \frac{3.5\times 10^5 - 3\times 10^5}{10^3} \Rightarrow v^2$

$= \frac{2\times 0.5\times 10^5}{10^3} \Rightarrow v^2 = 100 \Rightarrow v = 10\ m/s$

9. (a) From the Bernoulli's theorem

$P_1 - P_2 = \frac{1}{2}\rho(v_2^2 - v_1^2) = \frac{1}{2}\times 1.3 \times [(120)^2 - (90)^2]$

$= 4095\ N/m^2$ or *Pascal*

10. (c) Time taken for the level to fall from H to H'

$t = \frac{A}{A_0}\sqrt{\frac{2}{g}}\left[\sqrt{H} - \sqrt{H'}\right]$

According to problem- the time taken for the level to fall from h to $\frac{h}{2}$

$t_1 = \frac{A}{A_0}\sqrt{\frac{2}{g}}\left[\sqrt{h} - \sqrt{\frac{h}{2}}\right]$

and similarly time taken for the level to fall from $\frac{h}{2}$ to zero $t_2 = \frac{A}{A_0}\sqrt{\frac{2}{g}}\left[\sqrt{\frac{h}{2}} - 0\right]$

$\therefore \frac{t_1}{t_2} = \frac{1 - \frac{1}{\sqrt{2}}}{\frac{1}{\sqrt{2}} - 0} = \sqrt{2} - 1.$

11. (b) $v = \sqrt{2gh} = \sqrt{2\times 10\times 20} = 20\,m/s$

12. (a) Pressure at the bottom of tank $P = h\rho g = 3\times 10^5 \frac{N}{m^2}$ Pressure due to liquid column

$P_l = 3\times 10^5 - 1\times 10^5 = 2\times 10^5$

and velocity of water $v = \sqrt{2gh}$

$\therefore v = \sqrt{\frac{2P_l}{\rho}} = \sqrt{\frac{2\times 2\times 10^5}{10^3}} = \sqrt{400}\,m/s$

13. (c) Time required to emptied the tank $t = \frac{A}{A_0}\sqrt{\frac{2H}{g}}$

$\therefore \frac{t_2}{t_1} = \sqrt{\frac{H_2}{H_1}} = \sqrt{\frac{4h}{h}} = 2 \quad \therefore t_2 = 2t$

14. (a) The height of water in the tank becomes maximum when the volume of water flowing into the tank per second becomes equal to the volume flowing out per second.

Volume of water flowing out per second

$= Av = A\sqrt{2gh}$ ...(i)

Volume of water flowing in per second

$= 70\ cm^3/sec$ ...(ii)

From (i) and (ii) we get

$A\sqrt{2gh} = 70 \Rightarrow 1\times\sqrt{2gh} = 70$

$\Rightarrow 1\times\sqrt{2\times 980\times h} = 70$

$\therefore\ h = \frac{4900}{1960} = 2.5\ cm$

15. (d) $A = (0.1)^2 = 0.01 m^2$,

$\eta = 0.01\ Poise = 0.001\ decapoise$ (M.K.S. unit),

$dv = 0.1\ m/s$ and $F = 0.002\ N$

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

$\therefore\ dx = \frac{\eta A dv}{F} = \frac{0.001\times 0.01\times 0.1}{0.002} = 0.0005 m$.

16. (b) $F = 6\pi\eta rv$

17. (b) In the first 100 *m* body starts from rest and its velocity goes on increasing and after 100 *m* it acquire maximum velocity (terminal velocity). Further, air friction *i.e.* viscous force which is proportional to velocity is low in the beginning and maximum at $v = v_T$.

Hence work done against air friction in the first 100 *m* is less than the work done in next 100 *m*.

18. (c) If two drops of same radius *r* coalesce then radius of new drop is given by *R*

$\frac{4}{3}\pi R^3 = \frac{4}{3}\pi r^3 + \frac{4}{3}\pi r^3 \Rightarrow R^3 = 2r^3 \Rightarrow R = 2^{1/3} r$

If drop of radius *r* is falling in viscous medium then it acquire a critical velocity *v* and $v \propto r^2$

$\frac{v_2}{v_1} = \left(\frac{R}{r}\right)^2 = \left(\frac{2^{1/3} r}{r}\right)^2$

$\Rightarrow v_2 = 2^{2/3}\times v_1 = 2^{2/3}\times(5) = 5\times(4)^{1/3} m/s$

19. (c) Velocity of ball when it strikes the water surface $v = \sqrt{2gh}$ ...(i)

Terminal velocity of ball inside the water

$v = \frac{2}{9} r^2 g\frac{(\rho - 1)}{\eta}$ ...(ii)

Equating (i) and (ii) we get

$\sqrt{2gh} = \frac{2}{9}\frac{r^2 g}{\eta}(\rho - 1)$

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

20. (b) Rate of flow of liquid $V = \frac{P}{R}$

where liquid resistance $R = \frac{8\eta l}{\pi r^4}$

For another tube liquid resistance

$R = \frac{8\eta l}{\pi\left(\frac{r}{2}\right)^4} = \frac{8\eta l}{\pi r^4}.16 = 16R$

For the series combination

$V_{New} = \frac{P}{R + R} = \frac{P}{R + 16R} = \frac{P}{17R} = \frac{V}{17}$.

21. (d) From $V = \frac{P\pi r^4}{8\eta l} \Rightarrow P = \frac{V 8\eta l}{\pi r^4}$

$\Rightarrow \frac{P_2}{P_1} = \frac{V_2}{V_1}\times\frac{l_2}{l_1}\times\left(\frac{r_1}{r_2}\right)^4 = 2\times 2\times\left(\frac{1}{2}\right)^4 = \frac{1}{4}$

$\Rightarrow P_2 = \frac{P_1}{4} = \frac{P}{4}$.

22. (b) $V = \frac{\pi P r^4}{8\eta l} = \frac{8 cm^3}{sec}$

For composite tube

$V_1 = \frac{P\pi r^4}{8\eta\left(l + \frac{l}{2}\right)} = \frac{2}{3}\frac{\pi P r^4}{8\eta l} = \frac{2}{3}\times 8 = \frac{16}{3}\frac{cm^3}{sec}$

$\left[\because\ l_1 = l = 2l_2 \text{ or } l_2 = \frac{l}{2}\right]$

23. (a)

24. (d)

25. (c)

26. (a) If velocities of water at entry and exit points are v_1 and v_2, then according to equation of continuity,

$A_1 v_1 = A_2 v_2 \Rightarrow \frac{v_1}{v_2} = \frac{A_2}{A_1} = \left(\frac{r_2}{r_1}\right)^2 = \left(\frac{2}{3}\right)^2 = \frac{4}{9}$

27. (a)

28. (b)

29. (a)

30. (a)

31. (a)

32. (b) According to Bernoulli's theorem.

33. (c)

34. (a) $\frac{v^2}{2g} = h \Rightarrow v = \sqrt{2gh}$

$=\sqrt{2\times 10^3\times 40}=2\sqrt{2}\times 10^2=282.8\ cm/s$

35. (b)

36. (a,d)

37. (a,c,d) According to equation of continuity the volume of liquid flowing through the tube in unit time remains constant *i.e.* $A_1v_1=A_2v_2$, hence option (a) is correct

According to Bernoulli's theorem,

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

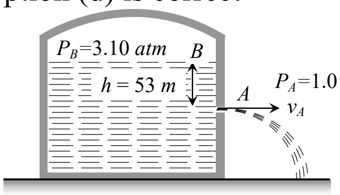
$\Rightarrow P_1-P_2=\frac{1}{2}\rho\left(v_2^2-v_1^2\right)\Rightarrow h\rho g=\frac{1}{2}\rho\left(v_2^2-v_1^2\right)$

$\therefore\ v_2^2-v_1^2=2gh$

Hence option (c) is correct.

Also, according to Bernoulli's theorem option (d) is correct

38. (b)



According to Bernoulli's theorem,

$P_B+h\rho g=P_A+\frac{1}{2}\rho v_A^2$ (As $v_A>>v_B$)

$3.10P+53\times 660\times 10=P+\frac{1}{2}\times 660v_A^2$

$\Rightarrow 2.1\times 1.01\times 10^5+3.498\times 10^5=\frac{1}{2}\times 660\times v_A^2$

$\Rightarrow 5.619\times 10^5=\frac{1}{2}\times 660\times v_A^2$

$\therefore\ v_A=\sqrt{\frac{2\times 5.619\times 10^5}{660}}=41\ m/s$

39. (b) According to Bernoulli's theorem, $h=\frac{v^2}{2g}$

$\Rightarrow h=\frac{(2.45)^2}{2\times 10}=0.314=31.4\ cm$

$\therefore$ Height of jet coming from orifice

$=31.4-10.6=20.8\ cm$

40. (a)

41. (a)

42. (c) Time taken by water to reach the bottom

$=t=\sqrt{\frac{2(H-D)}{g}}$

and velocity of water coming out of hole, $v=\sqrt{2gD}$

$\therefore$ Horizontal distance covered $x=v\times t$

$=\sqrt{2gD}\times\sqrt{\frac{2(H-D)}{g}}=2\sqrt{D(H-D)}$

43. (b) Horizontal range will be maximum when $h=\frac{H}{2}=\frac{90}{2}$

$=45\ cm$ *i.e.* hole 3.

44. (b) Time taken to be emptied for *h* height, $t=\sqrt{\frac{2h}{g}}$

and for $\frac{h}{2}$ height, $t=\sqrt{\frac{2h/2}{g}}=\sqrt{\frac{h}{g}}$

$\therefore\ \frac{t}{t}=\frac{1}{\sqrt{2}}\Rightarrow t=\frac{t}{\sqrt{2}}=\frac{10}{\sqrt{2}}=7\ minute$

45. (d) Upthrust – weight of body = apparent weight

$VDg-Vdg=Vda$,

Where a = retardation of body $\therefore$ $a=\left(\frac{D-d}{d}\right)g$

The velocity gained after fall from *h* height in air, $v=\sqrt{2gh}$

Hence, time to come in rest,

$t=\frac{v}{a}=\frac{\sqrt{2gh}\times d}{(D-d)g}=\sqrt{\frac{2h}{g}}\times\frac{d}{(D-d)}$

46. (c) $t=\frac{A}{a}\sqrt{\frac{2}{g}}\left[\sqrt{H_1}-\sqrt{H_2}\right]$

Now, $T_1=\frac{A}{a}\sqrt{\frac{2}{g}}\left[\sqrt{H}-\sqrt{\frac{H}{\eta}}\right]$

and $T_2=\frac{A}{a}\sqrt{\frac{2}{g}}\left[\sqrt{\frac{H}{\eta}}-\sqrt{0}\right]$

According to problem $T_1=T_2$

$\therefore \sqrt{H}-\sqrt{\frac{H}{\eta}}=\sqrt{\frac{H}{\eta}}-0\Rightarrow\sqrt{H}=2\sqrt{\frac{H}{\eta}}\Rightarrow\eta=4$

47. (b)

48. (b)

49. (a)

50. (a)

51. (a)

52. (d)

53. (b)

54. (d)

55. (d) $V=V_1+V_2$

$\Rightarrow \frac{\pi P r^4}{8\eta l} = \frac{\pi P r_1^4}{8\eta l} + \frac{\pi P r_2^4}{8\eta l} \Rightarrow r^4 = r_1^4 + r_2^4$

$\therefore \; r = (r_1^4 + r_2^4)^{1/4}$

56. (d) Given, $l_1 = l_2 = 1$, and $\frac{r_1}{r_2} = \frac{1}{2}$

$V = \frac{\pi P_1 r_1^4}{8\eta l} = \frac{\pi P_2 r_2^4}{8\eta l} \Rightarrow \frac{P_1}{P_2} = \left(\frac{r_2}{r_1}\right)^4 = 16$

$\Rightarrow P_1 = 16 P_2$

Since both tubes are connected in series, hence pressure difference across combination,

$P = P_1 + P_2 \Rightarrow 1 = P_1 + \frac{P_1}{16} \Rightarrow P_1 = \frac{16}{17} = 0.94 m$

57. (d) $V = \frac{\pi p r^4}{8\eta l} \; \therefore V \propto P r^4$ (η and l are constants)

$\therefore \frac{V_2}{V_1} = \left(\frac{P_2}{P_1}\right)\left(\frac{r_2}{r_1}\right)^4 = 2\times\left(\frac{1}{2}\right)^4 = \frac{1}{8} \; \therefore \; V_2 = \frac{Q}{8}$

58. (c)

59. (c) $a_1 v_1 = a_2 v_2 \Rightarrow \frac{v_2}{v_1} = \frac{a_1}{a_2} = \left(\frac{r_1}{r_2}\right)^2$

$\Rightarrow v_2 = 3\times(2)^2 = 12\ m/s$

60. (a) Fluid resistance is given by $R = \frac{8\eta l}{\pi r^4}$.

When two capillary tubes of same size are joined in parallel, then equivalent fluid resistance is

$R_e = R_1 + R_2 = \frac{8\eta L}{\pi r^4} + \frac{8\eta \times 2L}{\pi (2R)^4} = \left(\frac{8\eta L}{\pi r^4}\right)\times\frac{9}{8}$

Equivalent resistance becomes $\frac{9}{8}$ times so rate of flow will be $\frac{8}{9}X$

61. (c) A stream lined body has less resistance due to air.

62. (a)

63. (d) $\frac{P_1 - P_2}{\rho g} = \frac{v^2}{2g} \Rightarrow \frac{4.5\times10^5 - 4\times10^5}{10^3\times g} = \frac{v^2}{2g} \therefore$ $v = 10 m/s$

64. (c)

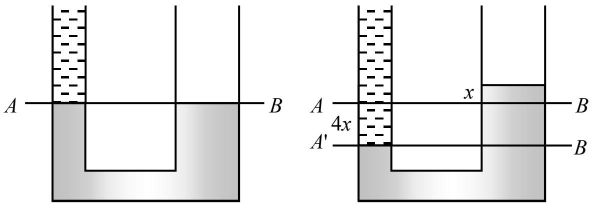
65. (c)

66. (d)

Critical Thinking Questions

1. (c) If the rise of level in the right limb be x cm. the fall of level of mercury in left limb be $4x$ cm because the area of cross section of right limb is 4 times as that of left limb.

$\therefore$ Level of water in left limb is $(36 + 4x)$ cm.



Now equating pressure at interface of Hg and water (at $A'B'$)

$(36 + 4x)\times 1\times g = 5x\times 13.6\times g$

By solving we get $x = 0.56$ cm.

2. (a) Weight of cylinder = upthrust due to both liquids

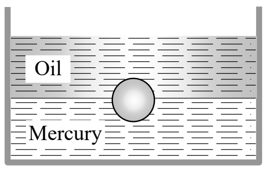
$V\times D\times g = \left(\frac{A}{5}\times\frac{3}{4}L\right)\times d\times g + \left(\frac{A}{5}\times\frac{L}{4}\right)\times 2d\times g$

$\Rightarrow \left(\frac{A}{5}\times L\right)\times D\times g = \frac{A\times L\times d\times g}{4} \Rightarrow \frac{D}{5} = \frac{d}{4}$

$\therefore D = \frac{5}{4}d$

3. (d) As the block moves up with the fall of coin, l decreases, similarly h will also decrease because when the coin is in water, it displaces water equal to its own volume only.

4. (c)



As the sphere floats in the liquid. Therefore its weight will be equal to the upthrust force on it

Weight of sphere

$= \frac{4}{3}\pi R^3 \rho g$ …(i)

Upthrust due to oil and mercury

$= \frac{2}{3}\pi R^3 \times \sigma_{oil} g + \frac{2}{3}\pi R^3 \sigma_{Hg} g$ …(ii)

Equating (i) and (ii)

$\frac{4}{3}\pi R^3 \rho g = \frac{2}{3}\pi R^3 0.8 g + \frac{2}{3}\pi R^3 \times 13.6 g$

$\Rightarrow 2\rho = 0.8 + 13.6 = 14.4 \Rightarrow \rho = 7.2$

5. (a) Upthrust $= V\rho_{\text{liquid}}(g - a)$

where, a = downward acceleration,

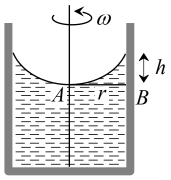
V = volume of liquid displaced

But for free fall $a = g$ $\therefore$ Upthrust = 0

6. (b) From Bernoulli's theorem,

$$P_A + \frac{1}{2}dv_A^2 + dgh_A = P_B + \frac{1}{2}dv_B^2 + dgh_B$$

Here, $h_A = h_B$



$$\therefore P_A + \frac{1}{2}dv_A^2 = P_B + \frac{1}{2}dv_B^2$$

$$\Rightarrow P_A - P_B = \frac{1}{2}d[v_B^2 - v_A^2]$$

Now, $v_A = 0, v_B = r\omega$ and $P_A - P_B = hdg$

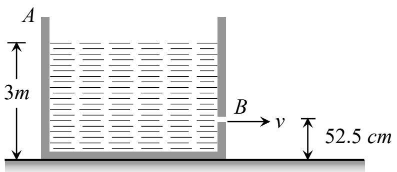
$$\therefore hdg = \frac{1}{2}dr^2\omega^2 \text{ or } h = \frac{r^2\omega^2}{2g}$$

7. (a) Let A = cross-section of tank

a = cross-section hole

V = velocity with which level decreases

v = velocity of efflux



From equation of continuity $av = AV \Rightarrow V = \frac{av}{A}$

By using Bernoulli's theorem for energy per unit volume

Energy per unit volume at point A

= Energy per unit volume at point B

$$P + \rho gh + \frac{1}{2}\rho V^2 = P + 0 + \frac{1}{2}\rho v^2$$

$$\Rightarrow v^2 = \frac{2gh}{1 - \left(\frac{a}{A}\right)^2} = \frac{2 \times 10 \times (3 - 0.525)}{1 - (0.1)^2} = 50(m/\sec)^2$$

8. (b) Velocity of efflux when the hole is at depth h, $v = \sqrt{2gh}$

Rate of flow of water from square hole

$$Q_1 = a_1v_1 = L^2\sqrt{2gy}$$

Rate of flow of water from circular hole

$$Q_2 = a_2v_2 = \pi R^2\sqrt{2g(4y)}$$

According to problem $Q_1 = Q_2$

$$\Rightarrow L^2\sqrt{2gy} = \pi R^2\sqrt{2g(4y)} \Rightarrow R = \frac{L}{\sqrt{2\pi}}$$

9. (c) Let A = The area of cross section of the hole

v = Initial velocity of efflux

d = Density of water,

Initial volume of water flowing out per second = Av

Initial mass of water flowing out per second = Avd

Rate of change of momentum = Adv^2

Initial downward force on the flowing out water = Adv^2

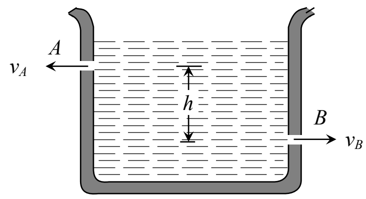
So equal amount of reaction acts upwards on the cylinder.

$\therefore$ Initial upward reaction = Adv^2 [As $v = \sqrt{2gh}$]

$\therefore$ Initial decrease in weight $= Ad(2gh)$

$$= 2Adgh = 2 \times \left(\frac{1}{4}\right) \times 1 \times 980 \times 25 = 12.5 \; gm\text{-}wt.$$

10. (c)



Net force (reaction) = $F = F_B - F_A = \frac{dp_B}{dt} - \frac{dp_A}{dt}$

$$= av_B\rho \times v_B - av_A\rho \times v_A$$

$\therefore$ $F = a\rho(v_B^2 - v_A^2)$ ...(i)

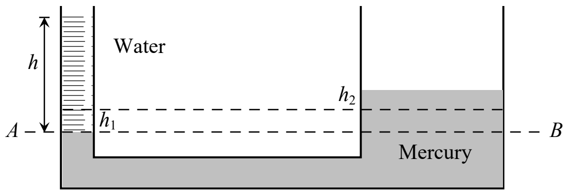
According to Bernoulli's theorem

$$p_A + \frac{1}{2}\rho v_A^2 + \rho gh = p_B + \frac{1}{2}\rho v_B^2 + 0$$

$$\Rightarrow \frac{1}{2}\rho(v_B^2 - v_A^2) = \rho gh \Rightarrow v_B^2 - v_A^2 = 2gh$$

From equation (i), $F = 2a\rho gh$

11. (b)



If the level in narrow tube goes down by h_1 then in wider tube goes up to h_2,

Now, $\pi r^2 h_1 = \pi(nr)^2 h_2 \Rightarrow h_1 = n^2 h_2$

Now, pressure at point A = pressure at point B

$$h\rho g = (h_1 + h_2)\rho' g$$

$\Rightarrow h = (n^2h_2 + h_2)sg \left(\text{As } s = \frac{\rho'}{\rho}\right) \Rightarrow h_2 = \frac{h}{(n^2+1)s}$

12. (a) Let $L = PQ$ = length of rod

$\therefore\ SP = SQ = \frac{L}{2}$

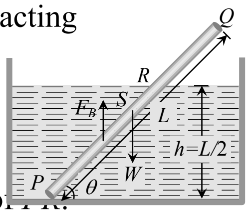
Weight of rod, $W = Al\rho g$, acting

At point S

And force of buoyancy,

$F_B = Al\rho_0 g$, $[l = PR]$

which acts at mid-point of PR.



For rotational equilibrium,

$Al\rho_0 g \times \frac{l}{2}\cos\theta = AL\rho g \times \frac{L}{2}\cos\theta$

$\Rightarrow \frac{l^2}{L^2} = \frac{\rho}{\rho_0} \Rightarrow \frac{l}{L} = \sqrt{\frac{\rho}{\rho_0}}$

From figure, $\sin\theta = \frac{h}{l} = \frac{L}{2l} = \frac{1}{2}\sqrt{\frac{\rho_0}{\rho}}$

13. (b) The volume of liquid displaced by floating ice $V_D = \frac{M}{\sigma_L}$

Volume of water formed by melting ice, $V_F = \frac{M}{\sigma_W}$

If $\sigma_1 > \sigma_W$, then, $\frac{M}{\sigma_L} < \frac{M}{\sigma_W}$ *i.e.* $V_D < V_F$

i.e. volume of liquid displaced by floating ice will be lesser than water formed and so the level if liquid will rise.

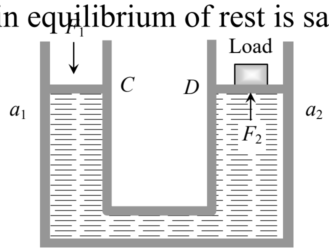
14. (a)

Graphical Questions

1. (a)
2. (b)
3. (d) When we move from centre to circumference, the velocity of liquid goes on decreasing and finally becomes zero.
4. (a) When cross-section of duct is decreased, the velocity of water increased and in accordance with Bernoulli's theorem, the pressure P decreased at that place.
5. (d)

Assertion and Reason

1 (b) According to Pascal's law, if gravity effect is neglected, the pressure at every point of liquid in equilibrium of rest is same.



$P_1 = P_2$ *i.e.* $\frac{F_1}{a_1} = \frac{F_2}{a_2}$ or $F_2 = \frac{a_2}{a_1}F_1$

As $a_2 >> a_1\ \therefore F_2 >> F_1$

This shows that small force (F_1) applied on the smaller piston (of area a_1) will be appearing as a very large force on the larger piston.

2 (a) Height of the blood column in the human body is more at feet than at the brain. As $P = h\rho g$, therefore the blood exerts more pressure at the feet than at the brain.

3 (e) Since due to applied force on liquid, the pressure is transmitted equally in all directions inside the liquid. That is why there is no fixed direction for the pressure due to liquid. Hence hydrostatic pressure is a scalar quantity.

4 (c) Net force = actual weight – upthrust force

= Actual weight – Weight of liquid displaced.

The body will rise above the surface of liquid to such an extent that the weight of the liquid displaced by the immersed part of the body (*i.e.* upward thrust) becomes equal to the weight of the body. Thus the body will float when upward thrust is more than its actual weight. In this special case the density of solid body is less than the density of liquid.

5 (e) The level of water does not change. The reason is that on drinking the water (say *m gm*), the weight of man increases by *m gm* and hence water displaced by man increases by *m gm*, tending to raise the level. However, this much amount of water has already been consumed by the man. Therefore the level of pond remain same.

6 (a)

7 (a) In a stream line flow of a liquid, according to equation of continuity $av =$ constant.
Where a is the area of cross section and v is the velocity of liquid flow. When water flowing in a broader pipe enters a narrow pipe, the area of cross-section of water decreases therefore the velocity of water increases.

8 (b) As a man jumps-out from a height in air with a parachute, its velocity increases first, because the gravity pull dominates the viscous drag and buoyancy of air which opposes the motion. As the velocity increases, the viscous drag of air also increases and soon a stage is reached where viscous drag and buoyancy of air balances the gravity pull. Then the man with a parachute falls with a constant velocity, called terminal velocity.

9 (a) According to Bernoulli's theorem, $P + \frac{1}{2}\rho v^2 =$ a constant
i.e. when velocity is large, the pressure is less in a stream line flow of an ideal liquid through a horizontal tube.

10 (c) When a body moves through a fluid, its motion is opposed by the force of fluid friction, which increases with the speed of the body. When cars and planes move through air, their motion is opposed by the air friction, which in turn, depend upon the shape of the body. It is due to this reason that the cars or planes are given such shape (known as stream lined shaped) so that air friction is minimum. Rather the movement of air layers on the upper and lower side of stream line shape provides a lift which helps in increasing the speed of the car.

11 (c) According to Bernoulli's equation,
$\frac{P}{\rho} + hg + \frac{1}{2}v^2 =$ constant
Thus, total energy of the injectable medicine depends upon second power of the velocity and first power of the pressure. It implies that total energy of the injectable medicine has greater dependence on its velocity. Therefore, a doctor adjust the flow of the medicine with the help of the size of the needle of the syringe $(a_1v_1 = a_2v_2)$ rather than the thumb pressure.

12 (a) Due to small area of cross-section of the hole, fluid flows out of the vessel with a large speed and thus the fluid possesses a large linear momentum. As no external forces acts on the system, in order to conserve linear momentum, the vessel acquires a velocity in backward direction or in other words a backward thrust results on the vessel.

13 (a) The stability of a floating body depends on the relative position of centre of gravity of a body, through which its weight acts and centre of gravity of the displaced water called centre of buoyancy through which the upthrust act.

14 (a)

15 (e) The viscosity of liquid decreases rapidly with rise of temperature. The variation of viscosity of liquid with temperature is given by $\eta_t = \eta_0(1 + \alpha t + \beta t^2)$
Where η_t and η_0 are the coefficient of viscosities at $t°C$ and $0°C$ respectively and α and β are constant.

16 (a) According to Bernoulli's theorem, when wind velocity over the wings is larger than the wind velocity under the wings, pressure of wind over the wings becomes less than the pressure of wind under the wing's. This provides the necessary lift to the aeroplane.

17 (a)

18 (a) Viscosities of fluids are markedly dependent on temperature, increasing for gases and decreasing for liquids as the temperature is increased. Thus important consideration in the design of oils for engine lubrication is to reduce the temperature variation of viscosity as much as possible.

19 (a)

20 (a) When a body falls through a viscous medium, finally, it attains terminal velocity. At this velocity, viscous force on rain drop balances the weight of the body.

21 (a) Smaller the area, larger the pressure exerted by a force

22 (d) Railways tracks are laided on large sized wooden sleepers. Due to large sized

sleepers the weight of rail act on the large area. Hence, the pressure exerted is reduced appreciably.

23 (a)

24 (c) When two holes are made in the tin, air keeps on entering through the other hole. Due to this the pressure inside the tin does not become less than atmospheric pressure which happen only one hole is made.

25 (e) Terminal velocity and critical velocity are not same. Critical velocity is the velocity below which the flow of liquid is streamline.

26 (b)

27 (a)

28 (b)