CHAPTER 9

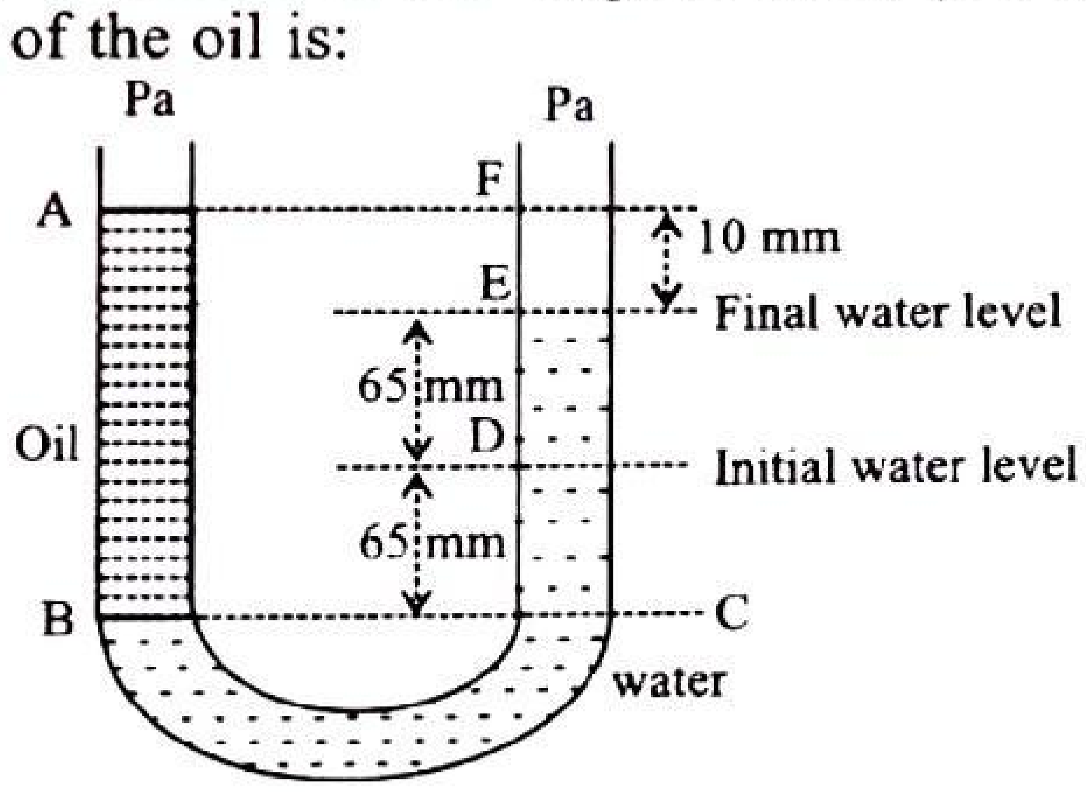
Mechanical Properties of Fluids

Variation of Pressure with Depth and Pascal's Law

1. A barometer is constructed using a liquid (density = 760 kg/m³). What would be the height of the liquid column, when a mercury barometer reads 76 cm? (density of mercury = 13600 kg/m³) *(2020-Covid)*

a. 13.6 m b. 136 m
c. 0.76 m d. 1.36 m

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-Delhi)*



a. 425 kg m⁻³ b. 800 kg m⁻³
c. 928 kg m⁻³ d. 650 kg m⁻³

3. Two non-mixing liquids of densities ρ and nρ (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 - I)*

a. {1 + (n + 1)p}ρ b. {2 + (n + 1)p}ρ
c. {2 + (n – 1)p}ρ d. {1 + (n – 1)p}ρ

Bernoulli's Theorem and its Application

4. A small hole of area of cross-section 2 mm² is present near the bottom of a fully filled open tank of height 2 m. Taking g = 10 m/s², the rate of flow of water through the open hole would be nearly *(2019)*

a. 12.6×10^{-6} m³/s
b. 8.9×10^{-6} m³/s
c. 2.23×10^{-6} m³/s
d. 6.4×10^{-6} m³/s

5. A wind with speed 40 m/s blows parallel to the roof of a house. The area of the roof is 250 m². Assuming that the pressure inside the house is atmospheric pressure, the force exerted by the wind on the roof and the direction of the force will be (P_{air} = 1.2 kg/m³): *(2015)*

a. 4.8×10^5 N, upwards
b. 2.4×10^5 N, upwards
c. 2.4×10^5 N, downwards
d. 4.8×10^5 N, downwards

Surface Tension and Surface Energy

6. If a soap bubble expands, the pressure inside the bubble : *(2022)*

a. Is equal to the atmospheric pressure
b. Decreases
c. Increases
d. Remains the same

7. 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/s², density of water = 10³ kg/m³, the value of Z_0 is : *(2019)*

a. 100 cm b. 10 cm
c. 1 cm d. 0.5 cm

8. A rectangular film of liquid is extended from (4 cm × 2 cm) to (5 cm × 4 cm). If the work done is 3×10^{-4} J, the value of the surface tension of the liquid is: *(2016 - II)*

a. 0.2 Nm⁻¹
b. 8.0 Nm⁻¹
c. 0.250 Nm⁻¹
d. 0.125 Nm⁻¹

9. 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)*

a. Energy $= 4VT\left(\frac{1}{r}-\frac{1}{R}\right)$ is released

b. Energy $= 3VT\left(\frac{1}{r}+\frac{1}{R}\right)$ is absorbed

c. Energy $= 3VT\left(\frac{1}{r}-\frac{1}{R}\right)$ is released

d. Energy is neither released nor absorbed

Angle of Contacts and Ascent/Descent Formula

10. A liquid does not wet the solid surface if angle of contact is: *(2020-Covid)*

a. Equal to 60°
b. Greater than 90°
c. Zero
d. Equal to 45°

11. 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: *(2020)*

a. 5.0 g b. 10.0 g
c. 20.0 g d. 2.5 g

12. Three liquids of densities ρ_1, ρ_2 and ρ_3 (with $\rho_1 > \rho_2 > \rho_3$) having the same value of surface tension T, rise to the same height in three identical capillaries. The angles of contact obey: *(2016 - II)*

a. $\frac{\pi}{2} < \theta_1 < \theta_2 < \theta_3 < \pi$

b. $\pi > \theta_1 > \theta_2 > \theta_3 > \frac{\pi}{2}$

c. $\frac{\pi}{2} > \theta_1 > \theta_2 > \theta_3 \geq 0$

d. $0 \leq \theta_1 < \theta_2 < \theta_3 < \frac{\pi}{2}$

13. Water rises to height 'h' in capillary tube. If the length of capillary tube above the surface of water is made less than 'h', then: *(2015 Re)*

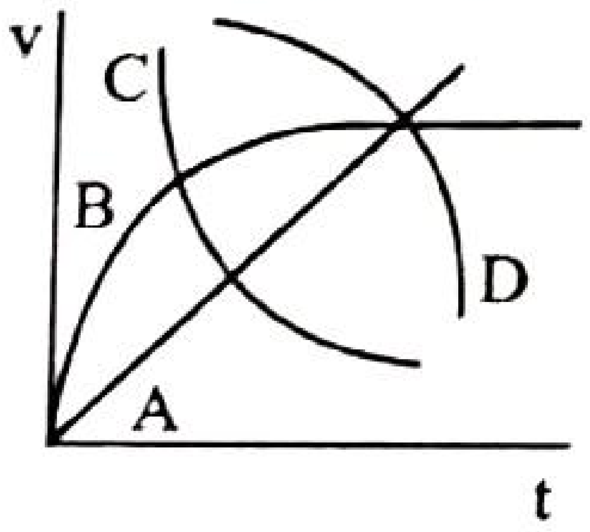
a. Water does not rise at all.
b. Water rises up to the tip of capillary tube and then starts overflowing like a fountain.
c. Water rises up to the top of capillary tube and stays there without overflowing.
d. Water rises up to a point a little below the top and stays there.

14. The wettability of a surface by a liquid depends primarily on: *(2013)*

a. Angle of contact between the surface and the liquid
b. Viscosity
c. Surface tension
d. Density

Viscosity, Stoke's Law and Terminal Velocity

15. 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 (v) as a function of time (t) is: *(2022)*



a. D b. A
c. B d. C

16. The velocity of a small ball of mass M and density d, when dropped in a container filled with glycerine becomes constant after some time. If the density of glycerine is $\frac{d}{2}$, then the viscous force acting on the ball will be: *(2021)*

a. Mg b. $\frac{3}{2}Mg$
c. 2 Mg d. $\frac{Mg}{2}$

17. 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)*

a. r^5 b. r^2
c. r^3 d. r^4

Answer Key

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
a	c	d	a	b	b	c	d	c	b	b	d	c	a	c	d	a

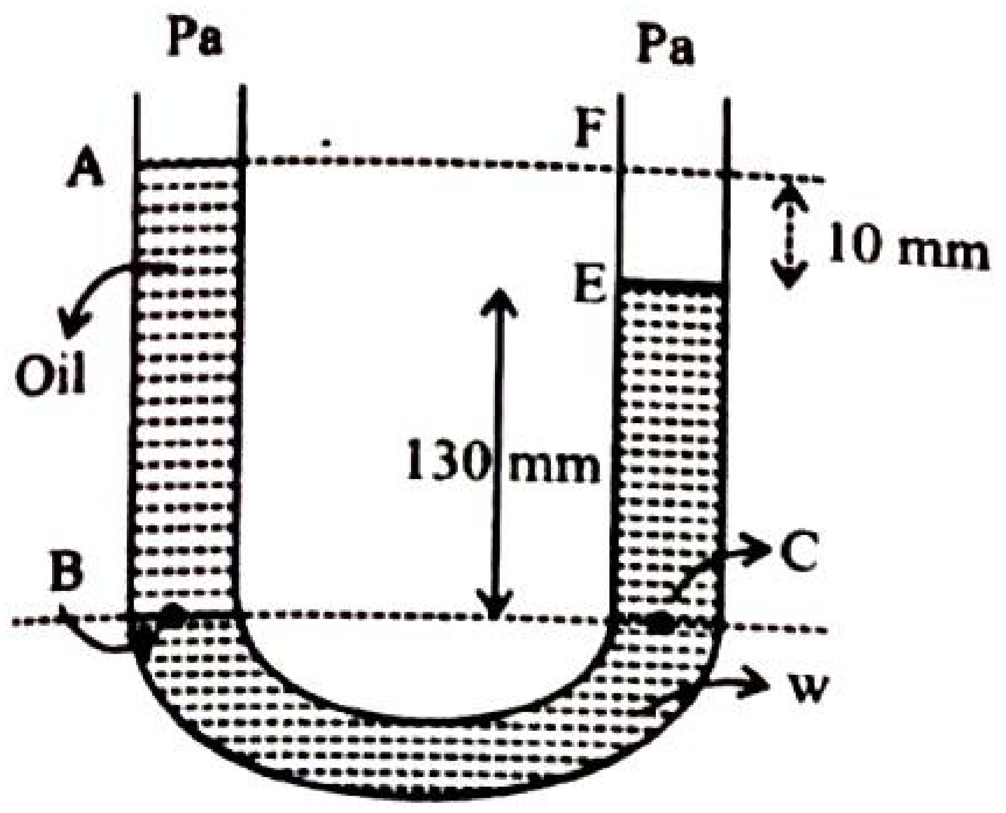
Explanations

1. (a) According to the question

$76\text{ cm} \times \rho_{Hg} \times g = h \times \rho_L \times g$

$$h = 76\text{cm} \times \frac{\rho_{Hg}}{\rho_L} = 76\text{ cm} \times \frac{13600}{760} = 13.6\text{ m}$$

2. (c)



$P_B = P_C$ (pressure at same level is same) [Pascal law]

$H\rho_{oil}\, g = h\rho_w g$

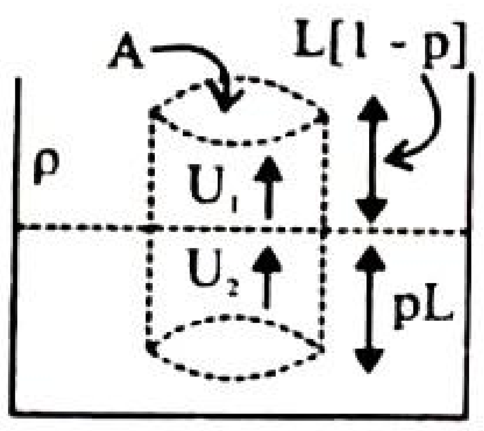
$(65 + 65 + 10) \times 10^{-3} \times \rho_0 = (65 + 65) \times 10^{-3} \times 10^3$

$140\rho_0 = 130 \times 10^3$

$$\rho_0 = \frac{130}{140} \times 10^3$$

$\rho_0 = 928\text{ kgm}^{-3}$ (approx)

3. (d)



For equilibrium.

$U_1 + U_2 = mg$

$AL[1-p]g \times \rho + ApL\, n\rho g = d\, ALg$

$ALg\rho\, [1 - p + np] = d\, ALg$

$d = \rho[1 + (n-1)p]$

4. (a) Rate of flow liquid

$Q = Au = A\sqrt{2gh}$

$= 2\times10^{-6}\text{m}^2 \times \sqrt{2\times10\times2}\text{m/s}$

$= 2 \times 2 \times 3.16 \times 10^{-6}\text{ m}^3/\text{s}$

$= 12.6 \times 10^{-6}\text{ m}^3/\text{s}$

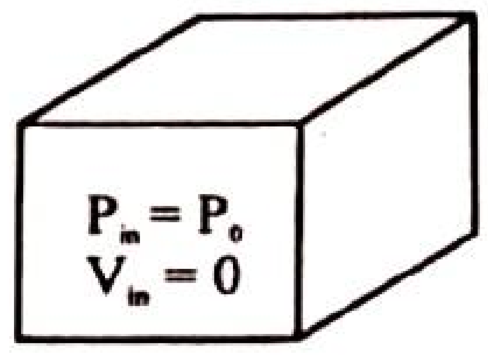
5 (b) Applying Bernoulli's theorem between two points just inside the house and on the roof,

$$P + \frac{\rho v^2}{2} = P_0$$

$$P_0 - P = \frac{\rho v^2}{2}$$

$F = (P_0 - P)A$

$$F = \frac{\rho v^2 A}{2} = \frac{1}{2} \times 1.2 \times (40)^2 \times 250 = 2.4\times10^5$$



Force is in upward direction pressure goes from higher to lower pressure area.

6. (b) Total pressure inside a soap bubble is given by

$$P = P_0 + \frac{4T}{R}$$

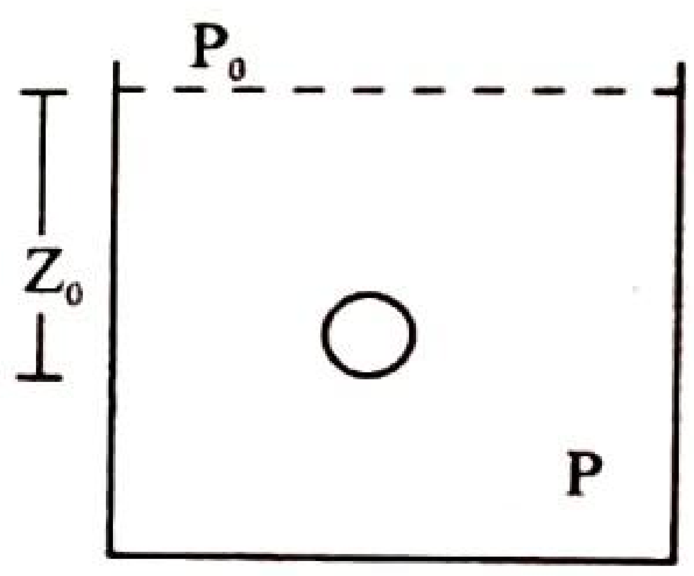
$\Rightarrow$ As the bubble expands R increases and P decreases

7. (c) Excess pressure $= \frac{4T}{R}$,

Gauge pressure $= \rho g Z_0$

Pressure at depth Z_0 = pressure inside soap bubble

$$P_0 + \frac{4T}{R} = P_0 + \rho g Z_0$$



$$Z_0 = \frac{4T}{R \times \rho g}$$

$$Z_0 = \frac{4 \times 2.5 \times 10^{-2}}{10^{-3} \times 1000 \times 10}\text{ m}$$

$Z_0 = 1\text{ cm}$

8. (d) Initial area $(A_1) = 4\text{ cm} \times 2\text{ cm} = 8\text{ cm}^2$

Final area $(A_2) = 5\text{ cm} \times 4\text{ cm} = 20\text{ cm}^2$

Change in area $(\Delta A) = 20\text{ cm}^2 \times 8\text{ cm}^2 = 12\text{ cm}^2$

The required work done, $W = T \times 2 \times \Delta A$

Where, T is the surface tension,

$$\Rightarrow T = \frac{W}{2\Delta A} = \frac{3\times10^{-4}}{2\times12\times10^{-4}} = 0.125\text{ N/m}$$

9. (c) Volume of n smaller drops = volume of single bigger drop

$$\Rightarrow n \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3 = V$$

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

We know that surface energy = surface tension × change in surface area

$$\Rightarrow E = T[A_{final} - A_{intial}]$$

$\Rightarrow E = T[A_{final} - A_{initial}]$

$= T[4\pi R^2 - n4\pi r^2]$

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

$= 4\pi R^3 T\left[\frac{1}{R} - \frac{1}{r}\right] = 3VT\left[\frac{1}{R} - \frac{1}{r}\right]$

As $R > r \Rightarrow \frac{1}{R} < \frac{1}{r}$

$\therefore$ E is negative

Hence, $3VT\left[\frac{1}{r} - \frac{1}{R}\right]$ energy will be released

10. **(b)** When angle of contact $\geq 90°$ then liquid doesn't wet solid.

11. **(b)** In a capillary tube force of surface tension balances the weight of water in capillary tube

$F_s = 2\pi r T\cos\theta = mg$

Here, T and θ are constant

So, $m \propto r$

Hence, $\frac{m_2}{5.0} = \frac{2r}{r} \Rightarrow m_2 = 10.0g$

12. **(d)** $h = \frac{2T\cos\theta}{\rho g r}$

As r, h, T are same, $\frac{\cos\theta}{\rho}$ = constant

$\Rightarrow \frac{\cos\theta_1}{\rho_1} = \frac{\cos\theta_2}{\rho_2} = \frac{\cos\theta_3}{\rho_3}$

As $\rho_1 > \rho_2 > \rho_3$

$\Rightarrow \cos\theta_1 > \cos\theta_2 > \cos\theta_3 \Rightarrow \theta_1 < \theta_2 < \theta_3$

As water rises so θ must be acute

So, $0 \leq \theta_1 < \theta_2 < \theta_3 < \pi/2$

13. **(c)** At normal condition water height h is given as $h = \frac{2s}{\rho g R}$

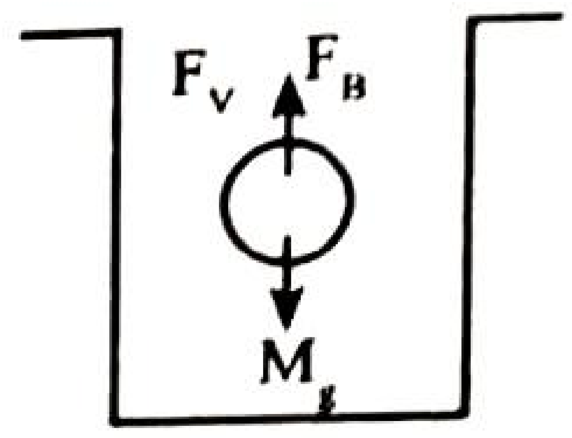
It is clear that, $h \propto \frac{1}{R}$ So, when height above the surface is decreased, there won't be any motion as the water rises till height h and stays there. Overflowing of water is not possible because there is no external force on molecules that causes it to overflow from the capillary tube.

14. **(a)** The wettability of a surface by a liquid depends primarily on angle of contact between the surface and the liquid.

15. **(c)** When a ball is dropped in a liquid that is highly viscous in nature then initially gravitational force acts in it. As it goes inside the liquid dragging force will start to work and when its value becomes equal to gravity force mg, net acceleration will be zero. And velocity will remain constant.

It is best represented by curve B.

16. **(d)**



$F_B = V_s\rho_l g = V \times \frac{d}{2} \times g = \frac{Vdg}{2}$

$F_g = M_g = Vdg$ [$\because$ M = Vd, V is the volume of ball]

When velocity of moving body becomes constant, then $F_{net} = 0$.

$\Rightarrow F_B + F_V = Mg$

$\Rightarrow \frac{Vdg}{2} + F_V = Vdg \Rightarrow F_V = Vdg - \frac{Vdg}{2} = \frac{(2-1)Vdg}{2}$

$\Rightarrow F_V = \frac{Vdg}{2} = V\left(\frac{d}{2}\right)g \Rightarrow F_V = \frac{Mg}{2}$

17. **(a)** Rate of heat produced = $F_v \cdot v_{terminal}$

$\frac{dQ}{dT} = F_V.v_T$

$= 6\pi\eta r v_T.v_T$

$\therefore \frac{dQ}{dt} \propto r.v_T^2$

$\propto r.r^4$ $[\because v_T \propto r^2]$

$\propto r^5$