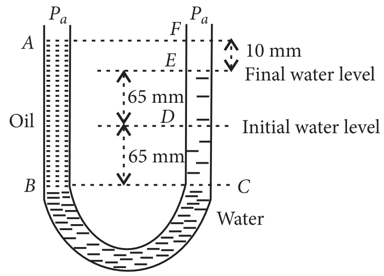
CHAPTER 10

Mechanical Properties of Fluids

10.2 Pressure

1. 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



(a) 425 kg m^{-3} (b) 800 kg m^{-3}
(c) 928 kg m^{-3} (d) 650 kg m^{-3} *(NEET 2017)*

2. Two non-mixing liquids of densities ρ and $n\rho$ ($n > 1$) are put in a container. The height of each liquid is h. A solid cylinder of length L and density d is put in this container. The cylinder floats with its axis vertical and length pL ($p < 1$) in the denser liquid. The density d is equal to
(a) $\{2 + (n - 1)p\}\rho$ (b) $\{1 + (n - 1)p\}\rho$
(c) $\{1 + (n + 1)p\}\rho$ (d) $\{2 + (n + 1)p\}\rho$
(NEET-I 2016)

10.3 Streamline Flow

3. 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

(a) $\frac{VR^2}{n^3r^2}$ (b) $\frac{V^2R}{nr}$ (c) $\frac{VR^2}{n^2r^2}$ (d) $\frac{VR^2}{nr^2}$ *(2015)*

10.4 Bernoulli's Principle

4. 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
(a) 6.4×10^{-6} m^3/s (b) 12.6×10^{-6} m^3/s
(c) 8.9×10^{-6} m^3/s (d) 2.23×10^{-6} m^3/s
(NEET 2019)

5. 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)
(a) 2.4×10^5 N, upwards
(b) 2.4×10^5 N, downwards
(c) 4.8×10^5 N, downwards
(d) 4.8×10^5 N, upwards *(2015 Cancelled)*

6. 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?
(a) The velocity is maximum at the narrowest part of the pipe and pressure is maximum at the widest part of the pipe.
(b) Velocity and pressure both are maximum at the narrowest part of the pipe.
(c) Velocity and pressure both are maximum at the widest part of the pipe.
(d) The velocity is minimum at the narrowest part of the pipe and the pressure is minimum at the widest part of the pipe.
(Karnataka NEET 2013)

10.5 Viscosity

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

(a) $\frac{79}{72}$ (b) $\frac{19}{36}$ (c) $\frac{39}{72}$ (d) $\frac{79}{36}$
(Odisha NEET 2019)

8. 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
(a) r^3 (b) r^2
(c) r^5 (d) r^4 *(NEET 2018)*

10.6 Surface Tension

9. 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 5 g. Another capillary tube of radius $2r$ is immersed in water. The mass of water that will rise in this tube is
(a) 2.5 g (b) 5.0 g
(c) 10.0 g (d) 20.0 g *(NEET 2020)*

10. 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
(a) 0.5 cm (b) 100 cm
(c) 10 cm (d) 1 cm *(NEET 2019)*

11. 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
(a) 0.250 N m^{-1} (b) 0.125 N m^{-1}
(c) 0.2 N m^{-1} (d) 8.0 N m^{-1}
(NEET-II 2016)

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 θ_1, θ_2 and θ_3 obey
(a) $\pi/2 > \theta_1 > \theta_2 > \theta_3 \geq 0$
(b) $0 \leq \theta_1 < \theta_2 < \theta_3 < \pi/2$
(c) $\pi/2 < \theta_1 < \theta_2 < \theta_3 < \pi$
(d) $\pi > \theta_1 > \theta_2 > \theta_3 > \pi/2$ *(NEET-II 2016)*

13. Water rises to a height h in capillary tube. If the length of capillary tube above the surface of water is made less than h, then
(a) water rises upto a point a little below the top and stays there
(b) water does not rise at all
(c) water rises upto the tip of capillary tube and then starts overflowing like a fountain
(d) water rises upto the top of capillary tube and stays there without overflowing. *(2015)*

14. 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
(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. *(2014)*

15. The wettability of a surface by a liquid depends primarily on
(a) density
(b) angle of contact between the surface and the liquid
(c) viscosity
(d) surface tension. *(NEET 2013)*

ANSWER KEY

1. (c)	**2.** (b)	**3.** (d)	**4.** (b)	**5.** (a)	**6.** (a)	**7.** (d)	**8.** (c)	**9.** (c)	**10.** (d)
11. (b)	**12.** (b)	**13.** (d)	**14.** (c)	**15.** (b)					

Hints & Explanations

1. (c) : Pressure at point C,

$P_C = P_a + \rho_{\text{water}}\, g h_{\text{water}}$,

where $h_{\text{water}} = CE = (65 + 65)$ mm = 130 mm

Pressure at point B, $P_B = P_a + \rho_{\text{oil}}\, g h_{\text{oil}}$

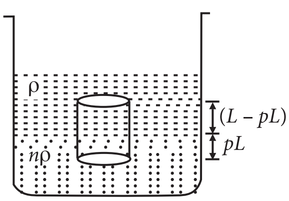
where $h_{\text{oil}} = AB = (65 + 65 + 10)$ mm = 140 mm

In liquid, pressure is same at same liquid level,

$P_B = P_C \Rightarrow \rho_{\text{oil}}\, g h_{\text{oil}} = \rho_{\text{water}}\, g\, h_{\text{water}}$

$$\rho_{\text{oil}} = \frac{130 \times 10^3}{140} = \frac{13}{14} \times 10^3 = 928.57 \text{ kg m}^{-3}$$

2. (b) :



d = density of cylinder

A = area of cross-section of cylinder

Using law of floatation,

weight of cylinder = upthrust by two liquids

$L \times A \times d \times g = n\rho \times (pL \times A)g + \rho(L - pL)Ag$

$d = np\rho + \rho(1 - p) = (np + 1 - p)\rho$

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

3. (d) : Let the speed of the ejection of the liquid through the holes be v. Then according to the equation of continuity, $\pi R^2 V = n\pi r^2 v$ or $v = \frac{\pi R^2 V}{n\pi r^2} = \frac{VR^2}{nr^2}$

4. (b) : According to Torricelli's theorem,

Velocity, $v = \sqrt{2gh} = \sqrt{2 \times 10 \times 2} = 6.32\ \text{m/s}$

From equation of continuity,

Volume of liquid flowing per second, $Q = Av$

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

5. (a)

6. (a) : According to equation of continuity,

Av = constant

Therefore, velocity is maximum at the narrowest part and minimum at the widest part of the pipe.

According to Bernoulli's theorem for a horizontal pipe,

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

Hence, when a fluid flow across a horizontal pipe of variable area of cross-section its velocity is maximum and pressure is minimum at the narrowest part and vice versa.

7. (d) : Terminal velocity, $v = \frac{2r^2(\rho - \sigma)g}{9\eta}$

Ratio of terminal velocity of spherical metal balls,

$$\frac{v_1}{v_2} = \frac{\frac{2}{9}(1)^2(8\rho_2 - 0.1\rho_2)}{\frac{2}{9}(2)^2(\rho_2 - 0.1\rho_2)}$$

$$\Rightarrow \frac{v_1}{v_2} = \frac{7.9\rho_2}{4(0.9\rho_2)} = \frac{79}{36}$$

8. (c) : The viscous drag force, $F = 6\pi\eta r v$;

where v = terminal velocity

$\therefore$ The rate of production of heat = power

= force × terminal velocity

$\Rightarrow$ Power $= 6\pi\eta r v \cdot v = 6\pi\eta r v^2$

$\because$ Terminal velocity $v = \frac{2r^2(\rho - \sigma)g}{9\eta}$;

Now, power $= 6\pi\eta r\left[\frac{4r^4(\rho - \sigma)^2}{81\eta^2}g^2\right]$

or Power $\propto r^5$

9. (c) : Force of surface tension balances the weight of water in capillary tube.

$F_s = T\cos\theta\,(2\pi r) = mg$

$m \propto r$

Hence, $\frac{m'}{m} = \frac{r'}{r} \Rightarrow \frac{m'}{5\text{ g}} = \frac{2r}{r} \Rightarrow m' = 10\text{ g}$

10. (d) : The pressure at a point Z_0 below the surface of water, $P_{Z_0} = P_0 + \rho g Z_0$

Also, pressure inside a soap bubble, $P = P_0 + \frac{4T}{R}$

As per question, $P_{Z_0} = P$

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

$$Z_0 = \frac{4T}{R\rho g} = \frac{4 \times 2.5 \times 10^{-2}}{1 \times 10^{-3} \times 10^3 \times 10} = 1 \times 10^{-2}\ \text{m} = 1\ \text{cm}$$

11. (b) : Work done = Surface tension of film × Change in area of the film

or, $W = T \times \Delta A$

Here, $A_1 = 4\ \text{cm} \times 2\ \text{cm} = 8\ \text{cm}^2$, $A_2 = 5\ \text{cm} \times 4\ \text{cm} = 20\ \text{cm}^2$

$\Delta A = 2(A_2 - A_1) = 24\ \text{cm}^2 = 24 \times 10^{-4}\ \text{m}^2$

$W = 3 \times 10^{-4}$ J, $T = ?$

$$\therefore\ T = \frac{W}{\Delta A} = \frac{3 \times 10^{-4}}{24 \times 10^{-4}} = \frac{1}{8} = 0.125\ \text{N m}^{-1}$$

12. (b) : Capillary rise, $h = \frac{2T\cos\theta}{r\rho g}$

For given value of T and r, $h \propto \frac{\cos\theta}{\rho}$

Also, $h_1 = h_2 = h_3$ or $\frac{\cos\theta_1}{\rho_1} = \frac{\cos\theta_2}{\rho_2} = \frac{\cos\theta_3}{\rho_3}$

Since, $\rho_1 > \rho_2 > \rho_3$, so $\cos\theta_1 > \cos\theta_2 > \cos\theta_3$

For $0 \le \theta < \pi/2$, $\theta_1 < \theta_2 < \theta_3$

Hence, $0 \le \theta_1 < \theta_2 < \theta_3 < \pi/2$

13. (d) : Water will not overflow but will change its radius of curvature.

14. (c) : Let n droplets each of radius r coalesce to form a big drop of radius R.

$\therefore$ Volume of n droplets = Volume of big drop

$$n \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3 \Rightarrow n = \frac{R^3}{r^3} \quad \text{... (i)}$$

Volume of big drop, $V = \frac{4}{3}\pi R^3$ ...(ii)

Initial surface area of n droplets,

$$A_i = n \times 4\pi r^2 = \frac{R^3}{r^3} \times 4\pi r^2 \quad \text{(Using (i))}$$

$$= 4\pi\frac{R^3}{r} = \left(\frac{4}{3}\pi R^3\right)\frac{3}{r} = \frac{3V}{r} \quad \text{(Using (ii))}$$

Final surface area of big drop

$$A_f = 4\pi R^2 = \left(\frac{4}{3}\pi R^3\right)\frac{3}{R} = \frac{3V}{R} \quad \text{(Using (ii))}$$

Decrease in surface area

$$\Delta A = A_i - A_f = \frac{3V}{r} - \frac{3V}{R} = 3V\left(\frac{1}{r} - \frac{1}{R}\right)$$

$\therefore$ Energy released = Surface tension × Decrease in surface area

$$= T \times \Delta A = 3VT\left(\frac{1}{r} - \frac{1}{R}\right)$$

15. (b) : The wettability of a surface by a liquid depends primarily on angle of contact between the surface and the liquid.

❖❖❖