Mechanical Properties Of Fluids **Marks: 30**

ANSWER KEY

Physics

Q.1 D	Q.2 C	Q.3 D	Q.4 B	Q.5 B	Q.6 B	Q.7 B	Q.8 C
Q.9 C	Q.10 C	Q.11 C	Q.12 D	Q.13 B	Q.14 A	Q.15 D	Q.16 B
Q.17 C	Q.18 B	Q.19 D	Q.20 C	Q.21 B	Q.22 C	Q.23 D	Q.24 C
Q.25 C	Q.26 C	Q.27 C	Q.28 D	Q.29 A	Q.30 A		

Physics

Q.1 Angle of contact depends on

Correct option: (D)

The angle of contact, which characterizes the wetting behavior of a liquid on a solid surface, is influenced by the molecular interactions at the three-phase boundary where the liquid, solid, and the surrounding medium meet. Consequently, it depends on:

- **The nature of the liquid:** Different liquids possess varying cohesive forces and exhibit different adhesive forces with the solid surface, leading to diverse contact angles.
- **The nature of the solid:** The chemical composition and surface properties (like roughness) of the solid material dictate the adhesive interactions between the liquid and the solid, thereby affecting the angle of contact.
- **The material which exists above the free surface of liquid:** This surrounding medium (e.g., air, vapor, or an immiscible fluid) interacts with both the liquid and the solid, influencing the interfacial tensions at the boundaries. The angle of contact θ is fundamentally determined by the balance of these interfacial tensions, as expressed by Young's equation: $\cos\theta = \frac{\gamma_{SV} - \gamma_{SL}}{\gamma_{LV}}$ where γ_{SV} is the solid-vapor interfacial tension, γ_{SL} is the solid-liquid interfacial tension, and γ_{LV} is the liquid-vapor interfacial tension.

Therefore, all the listed factors collectively determine the angle of contact.

Q.2 If the shape of the liquid surface is curved, then the

Correct option: (C)

Q.3 Molecular forces are

Correct option: (D)

Molecular forces are the attractive or repulsive forces that exist between molecules. These forces arise from the interactions between the electron clouds of adjacent molecules.

Cohesive forces are the attractive forces between molecules of the same substance. These forces are responsible for the properties of liquids such as surface tension and viscosity.

Adhesive forces are the attractive forces between molecules of different substances. These forces are responsible for the phenomenon of wetting.

Thus, molecular forces can be both cohesive and adhesive, depending on the nature of the molecules involved.

Q.4 Dimension of surface tension is

Correct option: (B)

Q.5 If the cohesive force is greater than the adhesive force, the liquid surface will be

Correct option: (B)

When the cohesive forces between liquid molecules are stronger than the adhesive forces between the liquid and the container, the liquid will minimize its surface area. This results in a **convex** meniscus, where the liquid surface curves upwards at the edges.

Q.6 A water drop of 0.01 cm^3 is squeezed between two glass plates and spreads in to area of 10 cm^2. If surface tension of water is 70 dyne / cm then the normal force required to separate glass plates from each other will be

Correct option: (B)

Force $F = \frac{2TA}{d}$

$= \dfrac{2TA^2}{V}$

$\left(\because d = \dfrac{V}{A} = \text{Thicknessofthelayer}\right)$

$= \dfrac{2 \times (70) \times (10)^2}{0.01} = 14 \times 10^5 \text{dyne}$

= 14 N

Q.7 The surface tension of water in C.G.S. units is 70 dyne/cm. Its value in S.I. unit is

Correct option: (B)

Surface Tension = 70 dyne/cm

$= \dfrac{70 \times 10^{-5}}{10^{-2}}$

$= 7 \times 10^{-2}$ N/m

Q.8 A metal sphere of mass 'm' and density 'σ_1' falls with terminal velocity through a container containing liquid. The density of liquid is 'σ_2'. The viscous force acting on the sphere is

Correct option: (C)

Given: Mass of sphere = m, Density of sphere = σ_1,

Density of liquid = σ_2.

At = v = v_t,

Weight of sphere (W) = Viscous Force (F_V) + Buoyant Force due to the medium (F_B)

$\Rightarrow W = F_V + F_B$

$Mg = F_V + (\sigma_2 V)g$ ....($\because$ m = D.V)

$\therefore F_V = mg - (\sigma_2 V)g$

$= mg\left[1 - \dfrac{\sigma_2 V}{m}\right]$

$= mg\left[1 - \dfrac{\sigma_2 V}{\sigma_1 V}\right] = mg\left[1 - \dfrac{\sigma_2}{\sigma_1}\right]$

Q.9 When a liquid flows through a tube, the Reynold's number is 900, the flow of a liquid is

Correct option: (C)

Q.10 A viscous fluid is flowing through a cylindrical tube. The velocity distribution of the fluid is best represented by the diagram

Correct option: (C)

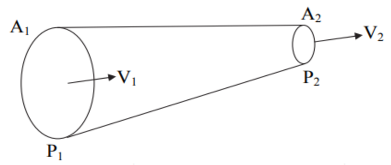
The correct option is the one with the parabolic velocity profile.

This is because viscous fluids experience friction as they move. This friction causes the fluid at the center of the tube to move faster than the fluid at the edges.

The parabolic profile represents this velocity distribution, where the velocity is highest at the center and decreases linearly to zero at the edges.

The other options represent incorrect velocity profiles. For example, the option with the uniform velocity profile assumes that the fluid is ideal with no viscosity, which is not realistic.

Q.11 Water flows through a conical tube, as illustrated in the figure. At the narrower section with area $A_2 = 20 \text{ cm}^2$, the water velocity is $40 \text{ cm}/s$. The wider section has an area of $A_2 = 10 \text{ cm}^2$. Find the pressure difference between these two cross-sections.



Correct option: (C)

$A_1 \times V_1 = A_2 \times V_2$

$20 \times V_1 = 10 \times 40$

$V_1 = 20$ cm/s

From Bernoulli's equation

$(P_A - P_B) = \dfrac{1}{2}\rho\left(V_2^2 - V_1^2\right)$

$= \dfrac{1}{2} \times 10^3 (40^2 - 20^2) \times 10^{-4}$

$= \dfrac{1}{2} \times 10^{-1} (1600 - 400)$

$= \dfrac{1}{2} \times 1200 \times 10^{-1}$

= 60 dyne/cm^2

= 6 N/m^2

Q.12 Viscosity is a transport phenomenon in which

Correct option: (D)

From kinetic theory point of view viscosity represents transport of momentum.

Q.13 A body of density ‘ρ’ and mass ‘M’ is moving downwards in a honey of density ‘σ’. The viscous force acting on the body is

Correct option: (B)

Forces acting on the body are

Weight of the body = Mg (downward)

Upthrust = weight of honey displaced

= (volume of honey) × (density of honey) × g

= (volume of body) × (density of honey) × g

$= \frac{M}{\rho} \times \sigma \times g = Mg\frac{\sigma}{\rho}$

F = viscous force (upwards)

Total upward force = Total downward force

$\therefore\ F + Mg\frac{\sigma}{\rho} = Mg$

$\therefore\ F = Mg\left(1 - \frac{\sigma}{\rho}\right)$

Q.14 Let ‘W_1’ be the work done in blowing a soap bubble of radius ‘r’ from a heated soap solution. The soap solution is now cooled down to room temperature and second soap bubble of radius ‘r/3’ is blown from it. If ‘W_2’ is the work done in forming this bubble, then

Correct option: (A)

Work done in blowing soap bubbles with radius R and R/3 is,

$W_1 = 8\pi R^2 T_1$

$W_2 = 8\pi\left(\frac{R}{3}\right)^2 T_2 = \left(\frac{8}{9}\right)\pi R^2 T_2$

$\therefore\ \frac{W_1}{W_2} = \frac{9T_1}{T_2}$

At $T_1 = T_2$, $W_1 = 9W_2$

When temperature decreases, surface tension increases.

$\therefore\ W_1 > 9W_2$

Q.15 A manometer connected to a closed tap reads 4.5×10^5 pascal. When the tap is opened the reading of the manometer falls to 4×10^5 pascal. Then the velocity of flow of water is

Correct option: (D)

$$\frac{P_1 - P_2}{\rho g} = \frac{v^2}{2g} \Rightarrow \frac{4.5 \times 10^5 - 4 \times 10^5}{10^3 \times g} = \frac{v^2}{2g}$$

∴ v = 10 m/s

Q.16 A glass capillary of radius 0.35 mm is inclined at 60° with the vertical in water. The height of the water column in the capillary is (surface tension of water = 7×10^{-2} N/m, acceleration due to gravity, g = 10 m/s^2, cos 0° = 1, cos 60° = 0.5)

Correct option: (B)

$$h = \frac{2T\cos\theta}{r\rho g} = \frac{2 \times \left(7 \times 10^{-2}\right) \times \cos 0^\circ}{\left(0.35 \times 10^{-3}\right) \times 10^3 \times 10} \ \ldots$$

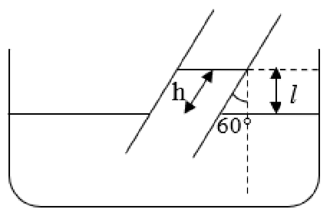
(θ = 0°,for glass-water)

h = 0.04 m

$l = \frac{h}{\cos\phi}$

where ϕ is angle of capillary with vertical as shown in figure.

$l = \frac{0.04}{\cos(60)} = 0.08m = 8cm$



Q.17 A steel coin of thickness ‘d’ and density ‘ρ’ is floating on water of surface tension ‘T’. The radius of the coin (r) is [g = acceleration due to gravity.]

Correct option: (C)

For equilibrium,

Weight of the coin = Force due to surface tension

$\Rightarrow \pi r^2 d\rho g = 2\pi r T$

$\therefore\ r = \frac{2T}{\rho g d}$

Q.18 If pressure at half the depth of a lake is equal to $\frac{2}{3}$ pressure at the bottom of the lake then what is the depth of the lake?

Correct option: (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,

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

$$\frac{1}{3}P_0 = \frac{1}{6}h\rho g$$

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

Q.19 If 'n' equal rain droplets falling through air with equal steady velocity 'v' coalesce, the new terminal velocity attained by the resultant drop is

Correct option: (D)

Radius of n rain droplets be r each.

They coalesce to form a drop of radius R.

As volume is conserved, $R^3 = nr^3$

$\therefore \quad R = n^{\frac{1}{3}}r$

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

$\therefore \quad V \propto r^2$

$$\therefore \quad V = v\frac{R^2}{r^2} = v \times \frac{n^{\frac{2}{3}}r^2}{r^2} = v.n^{\frac{2}{3}}$$

Q.20 Two solid spheres of same metal but of mass M and 64 M fall simultaneously through a viscous liquid and their terminal velocities are V and nV respectively then value of n is

Correct option: (C)

Mass = Volume × Density ⇒ $M = \frac{4}{3}\pi r^3 \times \rho$

As the density remains constant

$\therefore \quad M \propto r^3$

$$\therefore \quad \frac{r_1}{r_2} = \left(\frac{M_1}{M_2}\right)^{1/3} = \left(\frac{M}{64M}\right)^{1/3} = \frac{1}{4} \quad \text{....(i)}$$

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

$\therefore \quad v \propto r^2$

$$\therefore \quad \frac{vT_1}{vT_2} = \left(\frac{r_1}{r_2}\right)^2$$

$$\frac{v}{nv} = \left(\frac{r_1}{r_2}\right)^2 \text{ or } \frac{1}{n} = \left(\frac{1}{4}\right)^2 \quad \text{....[Using (i)]}$$

$\Rightarrow \quad n = 16$

Q.21 A capillary tube [A] is dipped in water. Another identical tube [B] is dipped in a soap‾water solution. Which of the following shows the relative nature of the liquid columns in the two tubes?

Correct option: (B)

From $h = \frac{2T\cos\theta}{r\rho g}$, the rise in capillary depends upon the surface tension of the liquid and surface tension of soap water solution is less than water. Hence, height will be less in second case. Also, as the soap solution wets the surface of capillary in contact, the shape of meniscus will be concave.

Q.22 A liquid drop of density 'ρ' is floating half immersed in a liquid of density 'd'. If 'T' is the surface tension then the diameter of the liquid drop is ($g =$ acceleration due to gravity)

Correct option: (C)

Surface Tension = T × 2πr

$$\frac{4}{3}\pi r^3\rho g = 2\pi rT + \frac{1}{2} \times \frac{4}{3}\pi r^3 dg$$

$$\therefore \quad 2\pi rT = \frac{4}{3}\pi r^3\rho g - \left(\frac{4}{3}\pi r^3 dg\right) \times \frac{1}{2}$$

$$2\pi T = \frac{4}{3}\pi r^2 dg \left(\rho - \frac{d}{2}\right)$$

$$\therefore \quad r^2 = \frac{2\pi T}{\frac{4}{3}\pi g\left(\rho - \frac{d}{2}\right)}$$

$$\therefore \quad r^2 = \frac{3T}{g(2\rho - d)} \Rightarrow r = \sqrt{\frac{3T}{g(2\rho - d)}}$$

$$\text{Diameter} = 2r = \sqrt{\frac{12T}{g(2\rho - d)}}$$

Q.23 Two small drops of mercury each of radius 'R' coalesce to form a large single

drop. The ratio of the total surface energies before and after the change is _______.

Correct option: (D)

Due to volume conservation,

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

Surface energy ∝ Area

$$\therefore \frac{(Surface\ energy)_{before}}{(Surface\ energy)_{after}} = \frac{2A_1}{A_2} = \frac{2R^2}{r^2} =$$

$$\frac{2R^2}{2^{2/3} \times R^2} = 2^{1/3}$$

Q.24 The surface tension of a liquid is 5 N m^{-1}. If a thin film is formed on a loop of area 0.02 m^2, then its surface energy will be

Correct option: (C)

Effective area = 2 ´ 0.02 m^2 = 0.04 m^2

Surface energy, T ΔA = 5 N m^{-1} ´ 0.04 m^2

= 2 ´ 10^{-1} J

Q.25 According to Newton's law of viscosity, for a streamline flow, viscous force for any layer is (A = area of layer)

Correct option: (C)

According to Newton's law of viscosity, for a stream line flow, viscous force for any layer is F ∝ $A\left(\frac{dV}{dx}\right)$ where, $\frac{dV}{dx}$ is called the velocity gradient.

Q.26 To increase the size of soap film from 10 cm × 7 cm to 10 cm × 12 cm, the work of 2.7 × 10^{-4}J is required to be done. The surface tension of the soap film is

Correct option: (C)

$$\Delta A = 2((10 \times 12) - (10 \times 7)) = 100 cm^2$$

Surface tension is:

$$T = \frac{W}{\Delta A} = \frac{2.7 \times 10^{-4}}{100}$$

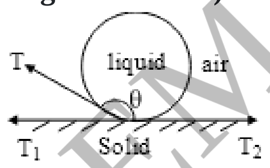
$$T = 2.7 \times 10^{-2}\ N/m$$

Q.27 Two glass plates are separated by water. If surface tension of water is 75 dyne per cm and the area of each plate wetted by water is 8 cm^2 and the distance between the plates is 0.12 mm, then the force applied to separate the two plates is

Correct option: (C)

$$F = \frac{2AT}{t} = \frac{2 \times 8 \times 75}{0.12 \times 10^{-1}} = 10^5 \text{ dyne}$$

Q.28 Let T_1 be surface tension between solid and air, T_2 be the surface tension between solid and liquid and T be the surface tension between liquid and air. Then in equilibrium, for a drop of liquid on a clean glass plate, the relation is (θ is angle of contact)



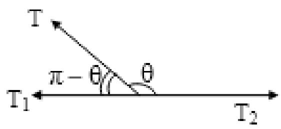
Correct option: (D)

$T_1 + T\cos(\pi - \theta) = T_2$

$$\therefore \cos(\pi - \theta) = \frac{T_2 - T_1}{T}$$

$$\therefore -\cos\theta = \frac{T_2 - T_1}{T}$$

$$\therefore \cos\theta = \frac{T_1 - T_2}{T}$$



Q.29 The surface of water in a water tank of cross section area $750 cm^2$ on the top of a house is 'h' m above the tap level. The speed of water coming out through the tap of cross section area $500 mm^2$ is $30 cm/s$. At that instant $\frac{dh}{dt}$ is $x \times 10^{-3}$ m/s. The value of 'x' will be

Correct option: (A)

From equation of continuity, $A_1v_1 = A_2v_2$

$(750 \times 10^{-4})\, v_1 = (500 \times 10^{-6}) \times (30 \times 10^{-2})$

$$v_1 = \frac{500 \times 10^{-6} \times 30 \times 10^{-2}}{750 \times 10^{-4}} = 2 \times 10^{-3} \text{ m/s}$$

$$\text{But, } v_1 = \frac{dh}{dt} = x \times 10^{-3} \text{ m/s}$$

∴ x = 2

Q.30 The work done in blowing a soap bubble of radius 'R' is 'W_1' at room temperature. Now the soap solution is heated. From the heated solution another soap bubble of radius '2R' is blown and the work done is 'W_2'. Then

Correct option: (A)

$W_1 = 8\pi R^2 T_1$

$W_2 = 8\pi (2R)^2 T_2 = 32\pi R^2 T_2$

$\therefore \frac{W_1}{W_2} = \frac{T_1}{4T_2}$

When $T_1 = T_2$, $W_2 = 4W_1$

When temperature increases, surface tension decreases.

$\therefore W_2 < 4W_1$