

Mechanical Properties of Fluids

ANSWERS

Module 1 Pressure

A.10.1.1 (A)

We have $P = hdg$

As g is maximum on the surface of the earth.

Hence the correct option is (A).

A.10.1.2 (C)

We have $P = hdg$

As the density of glycerine is more than that of water, $P_a < P_b$ which is option (C).

A.10.1.3 (C) Total number of marbles on the pan at time $t = n.t$ Mass of the marbles $= nt.m$

Weight of the marbles $= n tm.g$

Loss of momentum of the marbles in time $t = (ntm).u$

The pan must gain an equal amount of momentum.

Rate of change of momentum $= n mu$

By the second law of motion, the rate of change of momentum is the force.

$$\therefore F = n mu$$

Reading in the scale $= F + \text{Weight of the marbles} = nmu + n. mtg.$

So option (C) is correct.

A.10.1.4 (D)

By definition of pressure, all the units given in (A), (B) and (C) are the same.

So option (D) is correct.

A.10.1.5 (B)

We have, $P_A - P_B = P_B - P_C = P_C - P_D.$

The pressure difference is given by $(\Delta h)\rho g$ provided the density of air remains constant.

We know that the density of air in the atmosphere decreases as height increases.

Hence the pressure difference will be the same in the three cases only if $h_1 < h_2 < h_3$ which is option (B).

A.10.1.6 (C)

Given that $P_A - P_B = P_B - P_C = P_C - P_D$.

The pressure difference is given by $(\Delta h) \rho g$

As the density of air is assumed to be constant and the given points are near the earth (so g is constant), the pressure differences will be equal only if $h_1 = h_2 = h_3$ which is option (C).

A.10.1.7 (A)

The atmospheric pressure at a point is the weight of the air above a surface measured per unit area of the surface. The weight will be the maximum when the point is inside the well.

Hence option (A) is correct.

A.10.1.8 (D)

The pressure exerted by a liquid column depends only on the height of the column and not on the shape of the container. $\therefore P_A = P_B$.

But Force = Pressure $\times$ area

$\therefore F_B > F_A$ as the vessel B has a larger base area.

Hence $P_A = P_B$; $F_A < F_B$ which is option (D).

A.10.1.9 (A) (Fig. A.10.1.1)

Pressure from left side of the door = $h \rho_1 g$

Pressure from right side of the door = $h \rho_2 g$

As $\rho_1 > \rho_2$; we have $P_{\text{left}} > P_{\text{right}}$.

$\therefore$ Force from the left side exceeds the force from right side of the door.

Hence the door experiences a net force directed towards the right which is option (A).

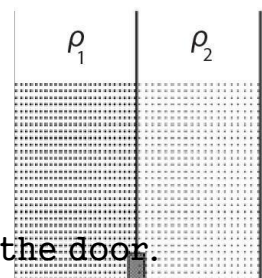


Fig. A.10.1.1

A.10.1.10 (B)

In Fig.A.10.1.2 (a), the pressure of the gas in the enclosure exceeds the atmospheric pressure by 20 cm of the liquid column.

In Fig.A.10.1.2 Fig. (b), the pressure of the gas in the enclosure is

less than the atmospheric pressure by 18 cm of the liquid column.

∴ Change in pressure in terms of length of the liquid column is 38 cm which is option (B).

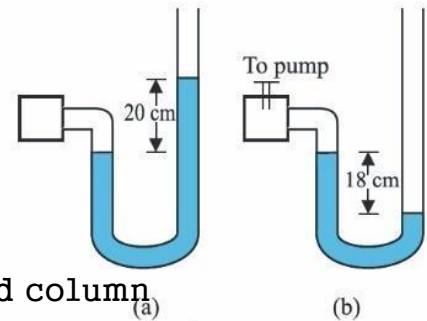


Fig.A.10.1.2

Module 2 Bernoulli's Principle

A.10.2.1 (A)

For an ideal fluid, the density remains constant. This rules out options (C) and (D).

A closer packing of streamlines indicates an increase in velocity. Hence, option (A) is correct.

A.10.2.2 (C)

According to the equation of continuity, $A \cdot v = \text{constant}$.

When the radius is doubled, the area of the cross section becomes four times and the speed of flow is reduced to one-fourth. Hence option (C) is correct.

A.10.2.3 (B)

The flow of an ideal fluid tends to be turbulent if the density is low and speed of flow is high.

Hence option (B) is correct.

A.10.2.4 (C)

The mass of liquid crossing any section of liquid in one second is

i.e. (volume/sec). density = constant.

or $Av\rho = \text{constant}$, v is the speed of flow of the liquid.

As liquid is assumed to be incompressible, so ρ is constant $\Rightarrow A.v = \text{constant}$ which is the equation of continuity.

Hence the correct option is (C).

A.10.2.5 (C)

Let v be the speed with which the liquid emerges out of each small hole.

According to the equation of continuity, $A.v = A'v'$.

$$R^2.v = N.r^2.v'$$

$$\text{Therefore } v' = R^2v / Nr^2$$

Option (C) is correct.

A.10.2.6 (B) (Fig.A.10.2.1)

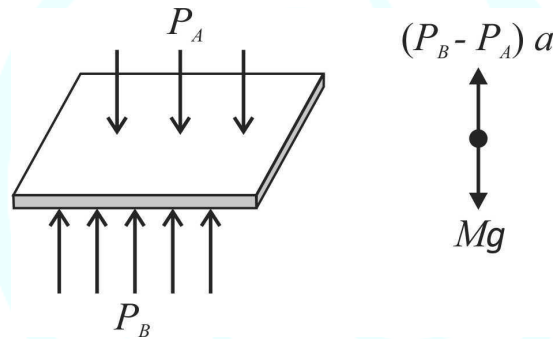


Fig.A.10.2.1

Using Bernoulli's principle, we get $\frac{P_B}{d} + \frac{v^2}{2} = \frac{P_A}{d} + \frac{(nv)^2}{2}$

$$\text{Therefore, Pressure difference} = P_B - P_A = \frac{(n^2-1)v^2d}{2}.$$

For equilibrium of the plate

$$a(P_B - P_A) = \frac{(n^2-1)av^2d}{2} = Mg$$

$$\therefore M = \frac{(n^2-1)av^2d}{2g}$$

Hence option (B) is correct.

A.10.2.7 (B) According to Bernoulli's principle, the region in which the fluid speed is high, the pressure is low. As the wind speed above the roof is high, the pressure is lower than the pressure below the roof. So, the roof is lifted up and blown away by the storm. Hence option (B) is correct.

A.10.2.8 (D)

In Fig. (b), the speed of the liquid will be high in the narrower part of the tube resulting in reduced pressure. So the Fig. (b) is correct.

In Fig. (c), the area of cross-section is uniform resulting in equal speeds and hence equal pressures at the two points. Hence option (D) is correct.

A.10.2.9 (B)

According to the equation of continuity, we get $A_1 v_1 = A_2 v_2$.

$$(\text{no. of holes}) \left(\frac{1}{100}\right) \times 60 = 8 \times 15.$$

$$\therefore \text{no. of holes} = \frac{8 \times 15 \times 100}{60} = 200.$$

Hence option (B) is correct.

A.10.2.10 (C)

According to the equation of continuity, the speed increases as the area decreases.

The speed increases as we move towards the right end of the pipe.

$$\therefore v_1 < v_2.$$

According to Bernoulli's principle, the region in which the fluid speed is high, the pressure is low so $P_1 > P_2$.

Hence option (C) is correct.



Module 3 Surface Tension

A.10.3.1 (D)

For the liquid surface to be convex, the angle of contact must be obtuse ($>90^\circ$). This is true for mercury in glass. Hence option (D) is correct.

A.10.3.2 (B)

The liquid surface is concave if the adhesive forces exceed the cohesive forces and the angle of contact is acute. $\therefore$ Option (B) is correct.

A.10.3.3 (B) and (C)

By definition, Surface tension = Force/length = Energy/area.

So options (B) and (C) are correct.

A.10.3.4 (B)

Let r_1 and r_2 be the radii of the smaller drops and R the radius of the coalesced drop.

When the drops coalesce, the volume remains constant.

$$\therefore (4/3)\pi R^3 = (4/3)\pi r_1^3 + (4/3)\pi r_2^3$$
$$\text{or } R^3 = (0.1)^3 + (0.2)^3 \Rightarrow R = (0.009)^{\frac{1}{3}} \text{ cm.}$$

$$\text{Decrease in area} = 4\pi r_1^2 + 4\pi r_2^2 - 4\pi R^2 = 4\pi(r_1^2 + r_2^2 - R^2).$$

$$= 4\pi(.0067) = 0.084 \text{ cm}^2$$

$$\text{Energy released} = (\text{surface tension}) \cdot (\text{decrease in area}) = 3.7 \times 10^{-6} \text{ J.}$$

So option (B) is correct.

A.10.3.5 (C)

When the frame is taken out, the liquid membrane formed has two free surfaces.

$\therefore$ The force on the frame is $8SL$ ($=2 \times 4L \times S$) which is option (C).

A.10.3.6 (A)

Given, work done = 2×10^{-4} J.

The soap film has two free surfaces.

$$\therefore \text{Increase in area} = 2 \times [(10 \times 11) - (10 \times 6)] \text{ cm}^2 = 100 \text{ cm}^2 = 10^{-2} \text{ m}^2$$

Surface tension = Work/Increase in area = 2×10^{-2} N/m.

Hence option (A) is correct.

A.10.3.7 (B)

We have $h = \frac{2 T \cos \theta}{r \rho g}$.

Given, $r_1/r_2 = 1/2$;

$$\therefore h_1/h_2 = 2/1$$

Volume of liquid in the capillary = $\pi r^2 h$

$$\therefore \frac{V_1}{V_2} = \frac{r_1^2 h_1}{r_2^2 h_2} = \frac{1}{2}.$$

$$\therefore \frac{m_1}{m_2} = \frac{V_1 \cdot \rho}{V_2 \cdot \rho} = \frac{1}{2} \Rightarrow m_2 = 2m_1 = 2M.$$

So option (B) is correct.

A.10.3.8 (B)

We have $h_1 = \frac{2 T_1 \cos \theta}{r_1 \rho g}$

and $h_2 = \frac{2 T_2 \cos \theta}{r_2 \rho g}$.

$$\therefore h_1/h_2 = (T_1/T_2) \cdot (r_2/r_1) = 6/5.$$

Hence option (B) is correct.

A.10.3.9 (C)

We have, $h = \frac{2 T \cos \theta}{r \rho g}$.

∴ The graph of h versus r will be hyperbolic, which is option (C).

A.10.3.10 (A)

On the earth, $h_E = \frac{2T \cos \theta}{r \rho g}$.

On the moon, $h_M = \frac{2T \cos \theta}{(3r) \rho \frac{g}{6}}$.

$$\therefore \frac{h_M}{h_E} = \frac{2}{1}.$$

Hence option (A) is correct.



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