Excel Coaching Classes

Date: 28-Jun-2026
Time: 60min

Mechanical Properties of Fluid

Marks: 20

SECTION A

Q.1 **Select and write the correct answer for the following multiple choice type of questions:** **(3)**

i **The pressure exerted by column of liquid on the base depends only on the**

- [x] (A) height of the liquid.
- [ ] (B) shape of the vessel.
- [ ] (C) material of the vessel.
- [ ] (D) viscosity of the liquid.

Ans: ["A"]

Explanation: The pressure exerted by a column of liquid on its base is determined by the weight of the liquid column above it. The weight, in turn, depends on the **height** of the liquid column and the density of the liquid. The shape of the vessel, material of the vessel, or viscosity of the liquid doesn't affect the pressure at the base.

ii

Absorption of water by filter paper is due to _______.

- [ ] (A) cohesion
- [x] (B) capillarity
- [ ] (C) adhesion
- [ ] (D) elasticity

["B"]

iii **Two small spheres of radii r and 3r fall through a viscous liquid with the same constant speed. The viscous forces experienced by them are in the ratio**

- [ ] (A) 1 : 9
- [x] (B) 1 : 3
- [ ] (C) 9 : 1
- [ ] (D) 3 : 1

Ans: ["B"]

Explanation:

$$\frac{F_1}{F_2} = \frac{6\pi\eta r_1 v}{6\pi\eta r_2 v} = \frac{r_1}{r_2} = \frac{r}{3r} = \frac{1}{3}$$

Q.2 **Answer the following questions:** **(3)**

i **State if the relation P = hρg holds true for gases.**

Yes, the relation P = hρg holds true for gases.

ii **At what temperature the surface tension of a liquid becomes zero?**

The surface tension of a liquid becomes zero at critical temperature.

iii **Define the following term: Sphere of influence.**

Sphere of influence:

An imaginary sphere with a molecule at its centre and radius equal to the molecular range is called the sphere of influence of the molecule.

The inter-molecular force is effective only within the sphere of influence.

SECTION B

Attempt any TWO questions of the following: **(4)**

Q.3 **What is capillarity? Give any two applications of capillarity.**

Capillary action or capillarity:

The phenomenon of rise or fall of liquid level inside a capillary tube when it is dipped in the liquid is called capillary action or capillarity.

Applications of capillarity:

i. Oil rises up the wick of a lamp.

ii. Cloth rag sucks water.

iii. Water rises up the crevices in rocks.

iv. Sap and water rise up to the top most leaves in a tree.

v. Blotting paper absorbs ink. *[Any two applications]*

Q.4 **Define coefficient of viscosity. State its formula and S.I. units.**

i. **Coefficient of viscosity:** *The coefficient of viscosity is defined as the viscous force per unit area per unit velocity gradient.*

ii. Formula: $\eta = \frac{F}{\frac{dv}{dx}A}$

iii. Unit of η is Ns/m^2 or decapoise in SI system

Q.5 **How much amount of work is done in forming a soap bubble of radius r?**

i. Work done against force due to surface tension,

$W = T\,(dA)$

ii. In case of bubble of radius r, there are two surfaces in contact with air. Therefore, the total surface area of bubble is given as,

$dA = 2 \times (4\pi r^2) = 8\pi r^2$

iii. Thus, the work done in forming the bubble is given as,

$W = T\,(dA) = T\,(8\pi r^2) = 8\pi r^2 T$

Q.6 **A drop of water of radius 6 mm breaks into number of droplets, each of radius 1 mm. How many droplets will be formed?**

Given: Radius of big drop, R = 6 mm,

Radius of smaller drop, r = 1 mm

To find: Number of droplets (n)

Formula: Number of droplets = $\frac{\text{Volume of big drop}}{\text{Volume of small drop}}$

Calculation: Volume of big drop, $V_1 = \frac{4}{3}\pi R^3$

Volume of each small drop, $V_2 = \frac{4}{3}\pi r^3$

From formula,

$n = \frac{V_1}{V_2} = \frac{\frac{4}{3}\pi R^3}{\frac{4}{3}\pi r^3}$

$\therefore$ $n = \left(\frac{R}{r}\right)^3 = \left(\frac{6}{1}\right)^3 = \mathbf{216}$

SECTION C

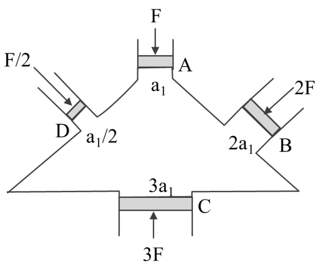
Attempt any TWO questions of the following: **(6)**

Q.7 State Pascal's law of fluid pressure. Describe the experimental proof for the same.

Statement: The pressure applied at any point of an enclosed fluid at rest is transmitted equally and undiminished to every point of the fluid and also on the walls of the container, provided the effect of gravity is neglected.

Explanation:

i. Consider a vessel with four arms A, B, C and D having different cross-sectional areas a_1, $2a_1$, $3a_1$ and $a_1/2$ respectively filled with incompressible fluid and fitted with frictionless, water tight pistons as shown in figure.



Demonstration of Pascal's law

ii. Initially, the enclosed water is at rest. Now suppose that the piston A is pushed down with a force F_1 so that the pressure exerted by it on the fluid is, $P_A = \frac{F_1}{a_1}$.

iii. It is found that the pistons B, C and D can be prevented from moving backwards only if forces $2F_1$, $3F_1$ and $F_1/2$ are exerted on them respectively.

iv. The pressure on the pistons B, C and D are,

piston B: $P_B = \frac{2F_1}{2a_1} = \frac{F_1}{a_1}$

piston C: $P_C = \frac{3F_1}{3a_1} = \frac{F_1}{a_1}$

piston D: $P_D = \frac{F_1/2}{a_1/2} = \frac{F_1}{a_1}$

i.e., $P_A = P_B = P_C = P_D$

v. This shows that the applied pressure on A is transmitted undiminished on pistons B, C and D as required by Pascal's law.

Q.8 (A) Two soap bubbles have radii in the ratio 2 : 3. Compare the excess of pressure inside these bubbles.

Excess of pressure inside two bubbles,

$P_1 = \frac{4T}{r_1}$ and $P_2 = \frac{4T}{r_2}$

$\therefore \frac{P_1}{P_2} = \frac{r_2}{r_1} = \frac{3}{2}$

(B) State the properties of an ideal fluid.

An ideal fluid has the following properties:

i. It is incompressible i.e., its density is constant.

ii. Its flow is irrotational i.e., its flow is smooth with no turbulences in the flow.

iii. It is non-viscous i.e., there is no internal friction in the flow and hence the fluid has no viscosity.

iv. Its flow is steady i.e., its velocity at each point is constant in time.

Q.9 A spherical drop of oil falls at a constant speed of 4 cm/s in steady air. Calculate the radius of the drop. The density of the oil is 0.9 g/cm^3, density of air is 0.0013 g/cm^3 and the coefficient of viscosity of air is 1.8 × 10^{-4} poise. (g = 980 cm/s^2)

Given: $v = 4$ cm/s, $\eta = 1.8 \times 10^{-4}$ poise,

$\sigma = 0.0013$ g/cm^3, $\rho = 0.9$ g/cm^3,

$g = 980$ cm/s^2

To find: Radius of the drop (r)

Formula: $\eta = \frac{2}{9}\frac{r^2(\rho-\sigma)g}{v}$

Calculation: From formula,

$$r = \sqrt{\frac{9\eta v}{2(\rho-\sigma)g}}$$

$$\therefore \quad r = \sqrt{\frac{9 \times 1.8 \times 10^{-4} \times 4}{2 \times (0.9 - 0.0013) \times 980}}$$

$$= \sqrt{\frac{9 \times 1.8 \times 10^{-4} \times 4}{2 \times 0.8987 \times 980}}$$

$$= \sqrt{\frac{18 \times 18 \times 10^{-6}}{0.8987 \times 98}} = \frac{18 \times 10^{-3}}{7\sqrt{0.8987 \times 2}}$$

$\therefore$ **r = 1.918 × 10^{-3}cm**

SECTION D

Attempt any ONE question of the following: (4)

Q.10 (A) The pressure of water inside the closed pipe is 3 × 10^5 N/m^2. This pressure reduces to 2 × 10^5 N/m^2 on opening the valve of the pipe. Calculate the speed of water flowing through the pipe. (Density of water = 1000 kg/m^3).

Given: $P_1 = 3 \times 10^5$ N/m^2, $P_2 = 2 \times 10^5$ N/m^2,

ρ_W = 1000 kg/m^3, v_1 = 0

To find: Speed of water (v_2)

Formula: $P_1 - P_2 = \frac{1}{2}\rho\left(v_2^2 - v_1^2\right)$

Calculation: From formula,

$$3 \times 10^5 - 2 \times 10^5 = \frac{1}{2} \times 10^3 \times \left(v_2^2 - 0\right)$$

$\therefore$ $v_2^2 = \frac{2 \times 10^5}{10^3}$

$\therefore$ $v_2 = \sqrt{2} \times 10$

= **14.14 m/s**

(B) Calculate the rise of water inside a clean glass capillary tube of radius 0.1 mm, when immersed in water of surface tension 7 × 10^{-2} N/m. The angle of contact between water and glass is zero, density of water = 1000 kg/m^3, g = 9.8 m/s^2.

Given: r = 0.1 mm = 10^{-4} m,

T = 7 × 10^{-2} N/m, θ = 0^0,

ρ = 1000 kg/m^3, g = 9.8 m/s^2

To find: Height of capillary rise (h)

Formula: $h = \frac{2T\cos\theta}{r\rho g}$

Calculation: From formula,

$$h = \frac{2 \times \left(7 \times 10^{-2}\right) \times \cos 0^\circ}{10^{-4} \times 10^3 \times 9.8}$$

$= \frac{14 \times 10^{-1}}{9.8} = \frac{1}{7}$ = **0.143 m**

Q.11 Derive Bernoulli's equation.

Consider an ideal fluid flowing through a tube of varying cross section and height. Consider an element of fluid lying between cross sections P and R.

i. Let,

a. v_1, v_2 = speeds of the fluid at the lower end P and the upper end R respectively.

b. A_1, A_2 = cross section areas of the fluid at the lower end P and upper end R respectively.

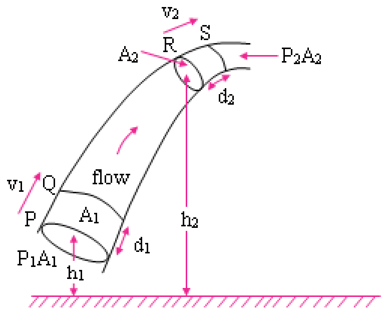
c. P_1, P_2 = pressures of the fluid at the lower end P and upper end R respectively.

d. d_1, d_2 = distances travelled by the fluid at the lower end P and the upper end R during the time interval dt with velocities v_1 and v_2 respectively.

e. ρ = density of the fluid flowing through the tube

f. h_1, h_2 = mean heights of section P and R from ground or reference level.

g. P_1A_1, P_2A_2 = forces acting on the fluid at section P and R respectively.



Flow of fluid through a tube of varying cross section and height

ii. The volume dV of the fluid passing through any cross section during time interval dt is the same i.e.,$dV = A_1 d_1 = A_2 d_2$ ….(1)

iii. Since, the fluid is ideal there is no internal friction in the fluid. The only non gravitational force working on the fluid element is due to the pressure of the surrounding fluid.

iv. Therefore, the net work W done on the element by the surrounding fluid during the flow from P to R is,

$W = P_1 A_1 d_1 - P_2 A_2 d_2$ ….(2)

The negative sign indicates that the force at R opposes the displacement of the fluid.

v. Substituting equation (1) in equation (2), we get,

$W = P_1 dV - P_2 dV$

$\therefore W = (P_1 - P_2)\, dV$ ….(3)

vi. At the beginning of the time interval dt,

a. mass of the fluid between P and Q = $\rho A_1 d_1$,

b. Kinetic energy of the fluid between P and Q = $\frac{1}{2}\rho(A_1 d_1)v_1^2$

c. Potential energy of the fluid between P and Q = $mgh_1 = \rho dVgh_1$

vii. At the end of the time interval dt,

a. mass of the fluid between R and S = $\rho A_2 d_2$

b. Kinetic energy of the fluid between R and S = $\frac{1}{2}\rho(A_2 d_2)v_2^2$

c. Potential energy of the fluid between R and S = $mgh_2 = \rho dVgh_2$

viii. The net change in the kinetic energy ΔK.E, during time interval dt is,

$\Delta K.E = \frac{1}{2}\rho\,(A_2 d_2)v_2^2 - \frac{1}{2}\rho\,(A_1 d_1)v_1^2$

$\Delta K.E. = \frac{1}{2}\rho\,(dV)v_2^2 - \frac{1}{2}\rho\,(dV)v_1^2$

$\therefore \quad \Delta K.E. = \frac{1}{2}\rho dV\left(v_2^2 - v_1^2\right)$ ….(4)

ix. The net change in the gravitational potential energy during time interval dt is,

$\Delta P.E. = \rho dVgh_2 - \rho dVgh_1$

$\therefore \quad \Delta P.E. = \rho dVg(h_2 - h_1)$ ….(5)

x. As the work done W is due to forces other than the conservative force of gravity, it equals the change in the total mechanical energy

a. W = ΔK.E. + ΔP.E.

Substituting equation (3), (4) and (5) in the above equation,

$(P_1 - P_2)\ dV = \frac{1}{2}\rho dV\left(v_2^2 - v_1^2\right) + \rho dVg(h_2 - h_1)$

$(P_1 - P_2) = \frac{1}{2}\rho\left(v_2^2 - v_1^2\right) + \rho g(h_2 - h_1)$…(6)

This is known as Bernoulli's equation.

xi. Bernoulli's equation can be written as,

$P_1 + \frac{1}{2}\rho v_1^2 + \rho gh_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho gh_2$

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