

Mechanical Properties of Fluids — Assignment 2

Class 11 Physics · Higher-difficulty challenge set + integrated problems · Answer key included · Narayan Gurukul Academy

Instructions: (1) Attempt all questions; start with the topic-wise challenge set, then attempt the integrated (multi-topic) problems.
(2) Give all answers with correct SI units. $g = 10 \text{ m/s}^2$ unless stated.
(3) A final answer key is provided at the end — try the full set before checking it.

Part A — Topic-wise challenge questions

Pressure and Its Variation with Depth

2 Mark Questions

1. Find the pressure at a depth of 10 m below the surface of water. ($\rho = 1000 \text{ kg m}^{-3}$, $g = 10 \text{ m/s}^2$, atmospheric pressure = 10^5 Pa .)

3 Mark Questions

1. A rectangular tank is filled with water up to a height of 2 m. Find the total force on a wall of dimensions $2 \text{ m} \times 3 \text{ m}$ due to the water. ($\rho = 1000 \text{ kg m}^{-3}$, $g = 10 \text{ m/s}^2$.)

Pascal's Law and Hydraulic Machines

2 Mark Questions

1. A hydraulic lift has pistons of areas 10 cm^2 and 200 cm^2 . What force is needed on the small piston to lift a car of weight 2000 N ?

3 Mark Questions

1. The small piston of a hydraulic press has a diameter of 2 cm and the large piston a diameter of 20 cm. If a force of 10 N is applied to the small piston, find the force on the large piston.

Archimedes' Principle and Floatation

2 Mark Questions

1. A body of volume $2 \times 10^{-3} \text{ m}^3$ is fully immersed in water. Find the buoyant force on it. ($\rho = 1000 \text{ kg m}^{-3}$, $g = 10 \text{ m/s}^2$.)
2. A body floats with one quarter of its volume above water. Find the ratio of its density to that of water.

3 Mark Questions

1. A cube of side 5 cm floats in water with 60% of its volume submerged. Find the density of the cube. ($\rho_{\text{water}} = 1000 \text{ kg m}^{-3}$.)

Equation of Continuity and Bernoulli's Principle

2 Mark Questions

1. Water flows in a pipe of area 40 cm^2 at 2 m/s. Find the speed in a section of the pipe of area 10 cm^2 .

3 Mark Questions

1. Water flows through a horizontal pipe of cross-section 30 cm^2 where its speed is 2 m/s and pressure $2 \times 10^5 \text{ Pa}$. In a narrower section of area 10 cm^2 the speed rises; find the pressure there. ($\rho = 1000 \text{ kg m}^{-3}$.)

Viscosity and Stokes' Law

2 Mark Questions

1. A sphere of radius 1 mm falls through water of viscosity 0.001 Pa s at a terminal velocity of 2 cm/s . Find the viscous force on it.

3 Mark Questions

1. A rain drop of radius 0.1 mm falls through air with viscosity $1.8 \times 10^{-5} \text{ Pa s}$. Estimate its terminal velocity. ($\rho_{\text{water}} = 1000 \text{ kg m}^{-3}$, $\rho_{\text{air}} \approx 0$, $g = 10 \text{ m/s}^2$.)

Surface Tension and Capillarity

2 Mark Questions

1. Water rises to 4 cm in a capillary tube of radius 0.5 mm . Find the surface tension of water. ($\rho = 1000 \text{ kg m}^{-3}$, $\cos\theta \approx 1$, $g = 10 \text{ m/s}^2$.)

3 Mark Questions

1. A liquid of surface tension 0.072 N m^{-1} rises to 2 cm in a capillary tube of radius 0.36 mm . Find the density of the liquid. ($\cos\theta = 1$, $g = 10 \text{ m/s}^2$.)

Part B — Integrated problems (multi-topic)

- Find the pressure at a depth of 10 m below the surface of water. ($\rho = 1000 \text{ kg m}^{-3}$, $g = 10 \text{ m/s}^2$, atmospheric pressure $= 10^5 \text{ Pa}$.) Explain why a dam wall is thicker at the bottom than at the top.
- A hydraulic lift has pistons of areas 10 cm^2 and 200 cm^2 . What force is needed on the small piston to lift a car of weight 2000 N ? If the small piston moves down 20 cm , how far does the car rise?
- A body of volume $2 \times 10^{-3} \text{ m}^3$ is fully immersed in water. Find the buoyant force on it. ($\rho = 1000 \text{ kg m}^{-3}$, $g = 10 \text{ m/s}^2$.) If this body floats with one quarter of its volume above water, find the ratio of its density to that of water.
- Water flows in a pipe of area 40 cm^2 at 2 m/s . Find the speed in a section of the pipe of area 10 cm^2 , and the change in pressure if this is a horizontal constriction. ($\rho = 1000 \text{ kg m}^{-3}$.)
- Water rises to 4 cm in a capillary tube of radius 0.5 mm . Find the surface tension of water. ($\rho = 1000 \text{ kg m}^{-3}$, $\cos\theta \approx 1$, $g = 10 \text{ m/s}^2$.) Explain why small liquid drops are spherical.

Answer Key

Pressure and Its Variation with Depth

2M(0): $P = P_0 + \rho gh = 10^5 + 1000 \times 10 \times 10 = 2 \times 10^5 \text{ Pa}$. 3M(1): Mean pressure $= \frac{1}{2}\rho gh = \frac{1}{2} \times 1000 \times 10 \times 2 = 10^4 \text{ Pa}$; $F = \text{mean pressure} \times \text{area} = 10^4 \times (2 \times 3) = 6 \times 10^4 \text{ N}$.

Pascal's Law and Hydraulic Machines

2M(0): $F_1 = (A_1/A_2) W = 2000 \times 10/200 = 100 \text{ N}$. 3M(1): Area ratio $= (D_2/D_1)^2 = (20/2)^2 = 100$, so $F_2 = 10 \times 100 = 1000 \text{ N}$.

Archimedes' Principle and Floatation

2M(0): $F_b = \rho g V = 1000 \times 10 \times 2 \times 10^{-3} = 20 \text{ N}$. 2M(2): Fraction submerged $= 1 - 1/4 = 3/4$, so $\rho_{\text{body}}/\rho_{\text{water}} = 3/4 = 0.75$. 3M(1): $\rho_{\text{cube}} = 0.6 \rho_{\text{water}} = 600 \text{ kg m}^{-3}$.

Equation of Continuity and Bernoulli's Principle

2M(0): $v_2 = v_1 A_1/A_2 = 2 \times 40/10 = 8 \text{ m/s}$. 3M(1): $v_2 = 3v_1 = 6 \text{ m/s}$; $P_2 = P_1 + \frac{1}{2}\rho(v_1^2 - v_2^2) = 2 \times 10^5 - 1.6 \times 10^4 = 1.84 \times 10^5 \text{ Pa}$.

Viscosity and Stokes' Law

2M(0): $F = 6\pi\eta r v = 6\pi \times 0.001 \times 10^{-3} \times 0.02 \approx 3.8 \times 10^{-7} \text{ N}$. 3M(1): $v_t = 2r^2(\rho - \sigma)g/(9\eta) = [2 \times (10^{-4})^2 \times 1000 \times 10]/(9 \times 1.8 \times 10^{-5}) \approx 1.2 \text{ m/s}$.

Surface Tension and Capillarity

2M(0): $T = h\rho g r/2 = 0.04 \times 1000 \times 10 \times 5 \times 10^{-4}/2 = 0.1 \text{ N m}^{-1}$. 3M(1): $\rho = 2T/(h r g) = 0.144/(0.02 \times 3.6 \times 10^{-4} \times 10) = 2000 \text{ kg m}^{-3}$.

Integrated problems

1: $P = 2 \times 10^5 \text{ Pa}$; the wall must withstand $P = P_0 + \rho g h$, which grows with depth. 2: $F = 100 \text{ N}$; $A_1 x_1 = A_2 x_2$ $x_2 = (10/200) \times 20 = 1 \text{ cm}$. 3: $F_b = 20 \text{ N}$; ratio $= 3/4 = 0.75$. 4: $v_2 = 8 \text{ m/s}$; $P_2 - P_1 = \frac{1}{2}\rho(v_1^2 - v_2^2) = -3 \times 10^4 \text{ Pa}$ (pressure drops $3 \times 10^4 \text{ Pa}$). 5: $T = 0.1 \text{ N m}^{-1}$; a sphere has the minimum surface area — and hence minimum surface energy — for a given volume.