Class 11 Physics · Chapter 9: Mechanical Properties of Fluids

Answer key and marking scheme · 20 marks · about 40 minutes · based on NCERT

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1. A small flat disc is held at one fixed point under still water, first horizontal, then vertical, then tilted at 45°. The force of the water on one face of the disc is [1]

(a) zero when the disc is vertical

(b) greatest when the disc is horizontal, since water presses downward

(c) the same in size in every orientation, but always directed vertically downward

(d) the same in size in every orientation, and always normal to the face

Answer: (d) At a point in a fluid at rest the pressure is the same in all directions, so the force on the small face has the same size whatever its orientation. A fluid at rest can push only normal to a surface, never along it.

2. The dimensions of the coefficient of viscosity are [1]

(a) $[ML^{-1}T^{-2}]$

(b) $[MLT^{-1}]$

(c) $[MT^{-2}]$

(d) $[ML^{-1}T^{-1}]$

Answer: (d) $\eta = Fl/(vA)$: $[MLT^{-2}][L]/([LT^{-1}][L^2]) = [ML^{-1}T^{-1}]$. $[ML^{-1}T^{-2}]$ is pressure, $[MT^{-2}]$ is surface tension and $[MLT^{-1}]$ is momentum.

3. In a steady flow, two streamlines can never cross because [1]

(a) a fluid particle at the crossing point would have two velocities at once

(b) the fluid would have to be compressed at that point

(c) the pressure at that point would become zero

(d) the flow at that point would have to be turbulent

Answer: (a) The tangent to a streamline gives the velocity of the fluid at that point. At a crossing there would be two tangents, that is two velocities for the particle there, which is impossible in steady flow.

4. At a place where a barometer reads 76 cm of mercury, the long barometer tube is tilted so that it makes an angle of 60° with the vertical. The length of the mercury column along the tube is now [1]

(a) 152 cm

(b) 76 cm

(c) 87.8 cm

(d) 38 cm

Answer: (a) $P_a = \rho gh$ fixes the vertical height of the column at 76 cm. Along a tube at 60° to the vertical, length = 76/cos 60° = 152 cm.

5. In an ideal hydraulic lift, which quantity has the same value at the small piston and at the large piston? [1]

(a) the force on the piston

(b) the distance moved by the piston

(c) the pressure of the liquid on the piston

(d) the speed of the piston

Answer: (c) By Pascal's law the pressure applied at the small piston is transmitted undiminished through the liquid, so the pressure is the same at both pistons; the forces differ in the ratio of the areas.

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6. Water flows through a horizontal pipe at 4.0 m s^{-1} under a pressure of 150 kPa. Taking ρ = 1000 kg m^{-3} and g = 10 m s^{-2}, find its velocity head and its pressure head. [2]

Velocity head = $v^2/2g = 16/(2 \times 10) = 0.80$ m. Pressure head = $P/\rho g = 150\,000/(1000 \times 10) = 15$ m. (Dividing Bernoulli's equation by ρg gives $P/\rho g + v^2/2g + h$ = constant.)

- velocity head $v^2/2g = 0.80$ m (1)
- pressure head $P/\rho g = 15$ m (1)

7. State the condition, in terms of surface energies, for a liquid to stick to (wet) a solid surface, and give one example each of a liquid that wets glass and one that does not. [2]

A liquid sticks to a solid if the solid–liquid surface energy is smaller than the sum of the solid–air and liquid–air surface energies; the liquid is then attracted to the solid. Water wets glass (acute angle of contact); mercury does not (obtuse angle of contact).

- S_{sl} smaller than $S_{sa} + S_{la}$ (1)
- water wets glass; mercury does not (1)

8. A small air bubble released at the bottom of a tall jar of glycerine soon rises at a steady speed. Explain why it stops speeding up. [2]

The bubble is lighter than the liquid it displaces, so the upward buoyant force exceeds its weight and it accelerates upward. The viscous drag of the liquid opposes its motion and grows with its speed. When drag plus weight equals the buoyant force, the net force is zero and the bubble moves at a constant (terminal) velocity.

- buoyant force exceeds weight at first; viscous drag grows with speed (1)
- forces balance, net force zero, so constant terminal velocity (1)

9. An open-tube manometer containing water is connected to a domestic gas pipeline. The water in the open arm stands 20 cm above the water in the arm joined to the pipe. (a) Find the gauge pressure of the gas (g = 10 m s^{-2}). (b) What height difference would a mercury manometer (density 13.6×10^3 kg m^{-3}) show for the same gas? (c) Which liquid is the better choice here, and why? [3]

(a) $P - P_a = \rho g h = 1000 \times 10 \times 0.20 = 2000$ Pa. (b) $h = 2000/(13\,600 \times 10) = 0.0147$ m = 1.47 cm. (c)

Water: for a small pressure difference a low-density liquid gives a large, easily read height difference; mercury suits large pressure differences.

- gauge pressure 2.0 kPa (1)
- mercury height about 1.5 cm (1)
- water, as a low-density liquid suits small pressure differences (1)

10. Water flows steadily down a sloping pipe. At point 1, 5.0 m above the ground, the area of cross-section is 10 cm^2, the speed 2.0 m s^{-1} and the pressure 1.50×10^5 Pa. At point 2, at ground level, the area is 5.0 cm^2. Taking ρ = 1000 kg m^{-3} and g = 10 m s^{-2}, find the speed and the pressure at point 2. [3]

Continuity: $v_2 = A_1 v_1 / A_2 = 10 \times 2.0/5.0 = 4.0$ m s^{-1}. Bernoulli: $P_2 = P_1 + \tfrac{1}{2}\rho(v_1^2 - v_2^2) + \rho g(h_1 - h_2) = 150\,000 + \tfrac{1}{2} \times 1000 \times (4 - 16) + 1000 \times 10 \times 5.0 = 150\,000 - 6000 + 50\,000 = 194\,000$ Pa $= 1.94 \times 10^5$ Pa.

- $v_2 = 4.0$ m s^{-1} from continuity (1)
- Bernoulli's equation with both height and speed terms (1)
- $P_2 = 1.94 \times 10^5$ Pa (1)

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11. A steel ball of radius 1.0 mm is dropped into a tall jar of glycerine. Name the forces on the ball when it falls at its terminal velocity, and find that velocity. (Density of steel 7.8×10^3 kg m^{-3}, of glycerine 1.26×10^3 kg m^{-3}; viscosity of glycerine 0.83 Pa s; g = 10 m s^{-2}.) [3]

Forces: weight downward; buoyant force and viscous drag $6\pi\eta a v$ upward. At terminal velocity they balance: $6\pi\eta a v_t = (4\pi/3)a^3(\rho - \sigma)g$, so $v_t = 2a^2(\rho - \sigma)g/(9\eta) = 2 \times (1.0 \times 10^{-3})^2 \times 6540 \times 10/(9 \times 0.83) = 0.0175$ m s^{-1} = 1.75 cm s^{-1}.

- weight, buoyant force and viscous drag (1)
- balance gives $v_t = 2a^2(\rho - \sigma)g/(9\eta)$ (1)
- $v_t \approx 1.75$ cm s^{-1} (1)

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