PHYSICS – CLASS XI

Chapter 9 : Mechanical Properties of Fluids

SOLUTIONS AND MARKING SCHEME (Step-by-Step)

Marks for each step are shown in brackets. Alternative correct methods carry full marks.

Quick answer key – Section A

Q	1	2	3	4	5	6	7	8
Ans	(c)	(a)	(b)	(a)	2×10^4 Pa	1.02×10^5 Pa	(b)	200 Pa

SECTION A

1. **Ans: (c) the same in A, B and C.** **(1)**

Pressure at a point depends only on the depth below the free surface, $P = P_0 + h\rho g$, not on the shape or the amount of liquid (hydrostatic paradox). All bottoms are at the same depth, so the pressure is the **same**.

2. **Ans: (a).** **(1)**

Streamlines crowd together above the wing, so the speed there is greater; by Bernoulli's principle the pressure above is **lower** than below, giving an upward lift.

3. **Ans: (b) 4*v*.** **(1)**

$v_t = 2r^2(\rho - \sigma)g/(9\eta) \propto r^2$. Doubling r gives $(2)^2 = \mathbf{4v}$.

4. **Ans: (a).** **(1)**

Both are true. A streamline gives the direction of velocity at each point; if two crossed, the particle would have two velocities at the crossing point, which is impossible, so R explains A.

5. **Ans: $\mathbf{2 \times 10^4}$ Pa.** **(1)**

$P = F/A = 4/(2 \times 10^{-4}) = \mathbf{2 \times 10^4}$ **Pa**; by Pascal's law it is transmitted equally in all directions.

6. **Ans: $\mathbf{1.02 \times 10^5}$ Pa.** **(1)**

$P_0 = h\rho g = 0.75 \times 13.6 \times 10^3 \times 10 = \mathbf{1.02 \times 10^5}$ **Pa**.

7. **Ans: surface (b).** **(1)**

The liquid wets the solid when the angle of contact is acute ($\theta < 90°$), as in (b); in (a) θ is obtuse and the liquid does not wet the surface.

8. **Ans: 200 Pa.** **(1)**

For a drop, $\Delta P = 2S/r = (2 \times 7 \times 10^{-2})/(0.7 \times 10^{-3}) = 0.14/(7 \times 10^{-4}) = \mathbf{200}$ **Pa**.

SECTION B

9. **(i)** Gauge pressure $= h\rho g = 20 \times 1000 \times 10 = \mathbf{2 \times 10^5}$ **Pa**. (1) **(2)**

(ii) Absolute pressure $= P_0 + h\rho g = 1 \times 10^5 + 2 \times 10^5 = \mathbf{3 \times 10^5}$ **Pa**. (1)

10. **(i)** Equation of continuity: $A_1v_1 = A_2v_2 \rightarrow v_2 = (40 \times 2)/10 = \mathbf{8\ m\ s^{-1}}$. (1) **(2)**

(ii) Bernoulli (horizontal pipe): $P_1 - P_2 = \tfrac{1}{2}\rho(v_2^2 - v_1^2) = \tfrac{1}{2} \times 1000 \times (64 - 4) = \mathbf{3 \times 10^4}$ **Pa**. (1)

11. The mercury levels are equal, so the pressures of the two liquid columns are equal: $h_w\rho_w g = h_o\rho_o g$. (1) **(2)**
$\rho_o = (10 \times 1000)/12.5 = 800$ kg m^{-3}, so the relative density = **0.8**. (1)

OR

(i) Drop (one free surface): $\Delta P = \mathbf{2S/r}$. **(ii)** Bubble (two surfaces): $\Delta P = \mathbf{4S/r}$. (1)
Ratio (drop : bubble) = $2S/r : 4S/r = \mathbf{1 : 2}$. (1)

12. **(i)** A soap film has two free surfaces (front and back), and each pulls the slider with a force Sl, so the total force is $2Sl$. (1) **(2)**
(ii) $W = 2Sl \rightarrow S = W/2l = (1 \times 10^{-2})/(2 \times 0.2) = \mathbf{2.5 \times 10^{-2}\ N\ m^{-1}}$. (1)

SECTION C

13. Shearing force = tension = $mg = 0.02 \times 10 = 0.2$ N. **(3)**
(i) Shearing stress = $F/A = 0.2/0.1 = \mathbf{2\ N\ m^{-2}}$. (1)
(ii) Strain rate = $v/l = 0.05/(0.5 \times 10^{-3}) = \mathbf{100\ s^{-1}}$. (1)
(iii) η = stress/strain rate = $2/100 = \mathbf{2 \times 10^{-2}\ Pa\ s}$. (1)

14. **(i)** Weight W (downwards), upthrust U (buoyant force, upwards) and viscous drag $F = 6\pi\eta av$ (upwards). At terminal velocity $W = U + F$. (1) **(3)**
(ii) $v_t = 2a^2(\rho - \sigma)g/(9\eta) = 2 \times (3 \times 10^{-3})^2 \times (3000 - 1000) \times 10/(9 \times 0.2) = 0.36/1.8 = \mathbf{0.2\ m\ s^{-1}}$. (1)
(iii) $v_t \propto a^2$, so doubling the radius makes it 4 times: **0.8 m s^{-1}**. (1)

OR

(i) Torricelli's law: $v = \sqrt{(2gh)} = \sqrt{(2 \times 10 \times 5)} = \mathbf{10\ m\ s^{-1}}$. (1)
(ii) Vertical fall of 1.25 m from rest: $t = \sqrt{(2y/g)} = \sqrt{(2 \times 1.25/10)} = \mathbf{0.5\ s}$. (1)
(iii) Range $R = vt = 10 \times 0.5 = \mathbf{5\ m}$. (1)

15. **(i)** Pressure balance at the meniscus gives $h = 2S\cos\theta/(a\rho g)$ (a = tube radius); for $\theta = 0$, $h = 2S/(a\rho g)$. (1) **(3)**
(ii) $h = (2 \times 7 \times 10^{-2})/(0.7 \times 10^{-3} \times 1000 \times 10) = 0.14/7 = \mathbf{2 \times 10^{-2}\ m} = 2$ cm. (1)
(iii) $h \propto 1/a$, so for half the radius the rise doubles: **4 × 10^{-2} m** = 4 cm. (1)

SECTION D

16. **(a)** Pascal's law: a pressure applied to an enclosed fluid is transmitted undiminished to every point of the fluid and to the walls of the container. (1) **(5)**
(b) Mechanical advantage = $A_2/A_1 = 2000/40 = \mathbf{50}$. (1)
(c) $F_2 = mg = 1000 \times 10 = 10^4$ N; $F_1 = F_2/50 = \mathbf{200\ N}$. (1)
(d) $P = F_1/A_1 = 200/(40 \times 10^{-4}) = \mathbf{5 \times 10^4\ Pa}$. (1)
(e) The liquid volume is conserved: $d_1 = 50 \times 4$ cm = 200 cm = **2 m**. Work on small piston = $200 \times 2 = 400$ J; gain in PE = $mgh = 10^4 \times 0.04 = 400$ J. They are **equal**. (1)

OR

(a) $P_A = h\rho g = 2 \times 800 \times 10 = \mathbf{1.6 \times 10^4\ Pa}$. (1)
(b) $P_B = 1.6 \times 10^4 + 3 \times 1000 \times 10 = \mathbf{4.6 \times 10^4\ Pa}$. (1)
(c) Absolute pressure = $1 \times 10^5 + 4.6 \times 10^4 = \mathbf{1.46 \times 10^5\ Pa}$. (1)
(d) Force due to the liquids = $4.6 \times 10^4 \times 2 = \mathbf{9.2 \times 10^4\ N}$ (gauge pressure used; atmospheric push is also on the outside of the base). (1)
(e) No. The pressure depends only on depth and density, not on the shape of the vessel; this is the **hydrostatic paradox**. (1)

17. **(a)** Bernoulli's principle: along a streamline of a steady, non-viscous, incompressible flow, $P + \tfrac{1}{2}\rho v^2 + \rho g h$ remains constant. (1) **(5)**

(b) $A_1 v_1 = A_2 v_2 \rightarrow v_2 = (4 \times 10^{-3} \times 1)/(1 \times 10^{-3}) =$ **4 m s⁻¹**. (1)

(c) Volume flow rate $= Av = 4 \times 10^{-3} \times 1 =$ **4 × 10⁻³ m³ s⁻¹**. (1)

(d) ΔKE per unit volume $= \tfrac{1}{2}\rho(v_2^2 - v_1^2) = \tfrac{1}{2} \times 1000 \times (16 - 1) =$ **7500 J m⁻³**. (1)

(e) $P_2 = P_1 - \tfrac{1}{2}\rho(v_2^2 - v_1^2) - \rho g h = 1.8 \times 10^5 - 7500 - 1000 \times 10 \times 2 =$ **1.525 × 10⁵ Pa**. (1)

OR

(a) The streamlines crowd above the wing, so the air speed there is greater; by Bernoulli's principle the pressure is lower above than below. (1)

(b) $\Delta P = \tfrac{1}{2}\rho(v_u^2 - v_l^2) = \tfrac{1}{2} \times 1.25 \times (8100 - 4900) = 0.625 \times 3200 =$ **2000 Pa**. (1)

(c) Lift $= \Delta P \times A = 2000 \times 30 =$ **6 × 10⁴ N**. (1)

(d) Lift $= mg \rightarrow m = 6 \times 10^4/10 =$ **6000 kg**. (1)

(e) The **Magnus effect**: the spinning ball drags air with it, so the air speed (and hence the pressure) differs on the two sides, giving a sideways force. (1)

— END OF SOLUTIONS —