

Solutions

Each answer shows the steps, then the **result**.

2.1

- the pressure in a fluid increases with depth, so the pressure on the bottom of the object is greater than on its top

- the upward force on the bottom is greater than the downward force on the top, and the resultant is upwards

2.2

- Archimedes' principle, $F = \rho g V$

$$F = \rho g V = 1000 \text{ kg m}^{-3} \times 9.81 \text{ m s}^{-2} \times 2.0 \times 10^{-3} \text{ m}^3 = \mathbf{20 \text{ N}}$$

2.3

(a) equilibrium, $F_T + F_U = F_W$: $F_U = F_W - F_T = 3.6 - 2.2 = \mathbf{1.4 \text{ N}}$

(b) Archimedes, $V = \frac{F_U}{\rho g} = \frac{1.4}{1000 \times 9.81} = 1.43 \times 10^{-4} \text{ m}^3$

- mass from $F_W = mg$: $m = \frac{F_W}{g} = \frac{3.6}{9.81} = 0.367 \text{ kg}$

$$\rho = \frac{m}{V} = \frac{0.367 \text{ kg}}{1.43 \times 10^{-4} \text{ m}^3} = \mathbf{2.6 \times 10^3 \text{ kg m}^{-3}}$$

2.4

- floating, $F_U = F_W$: $\rho_{\text{water}} V_{\text{below}} g = \rho_{\text{wood}} V g$
- fraction below $= \frac{\rho_{\text{wood}}}{\rho_{\text{water}}} = \frac{650}{1000} = \mathbf{0.65}$

2.5

- same pressure at the boundary level: $\rho_{\text{oil}} g h_{\text{oil}} = \rho_{\text{water}} g h_{\text{water}}$

$$\rho_{\text{oil}} = \frac{\rho_{\text{water}} h_{\text{water}}}{h_{\text{oil}}} = \frac{1000 \times 8.0}{10.0} = \mathbf{800 \text{ kg m}^{-3}}$$

2.6

- resultant force $F_U - F_W$, with $F_U = \rho_{\text{water}} V g$ and $m = \rho_{\text{ball}} V$

$$a = g \left(\frac{\rho_{\text{water}}}{\rho_{\text{ball}}} - 1 \right) = 9.81 \times \left(\frac{1000}{300} - 1 \right) = \mathbf{23 \text{ m s}^{-2} \text{ upwards}}$$

3.1 B

- floating: fraction below $= \rho_{\text{object}} / \rho_{\text{water}}$, so $\rho_{\text{object}} = (\text{fraction below}) \times \rho_{\text{water}} = 0.75 \times 1000 = 750 \text{ kg m}^{-3}$
- D** inverts the fraction; **A** uses the fraction above the surface **D** **A**

3.2 C

- the pressure at the top and at the bottom both increase by the same amount, so their difference, and the upthrust $\rho g V$, is unchanged

- A** confuses the pressure with the pressure difference **A**

3.3

(a) the pressure in the oil increases with depth, so it is greater on the bottom of the sphere than on the top

- the resultant force of the oil on the sphere is therefore upwards: the upthrust

(b) weight, vertically **downwards**

- upthrust, vertically **upwards**
- drag (viscous force), vertically **upwards** ()

(c) $V = \frac{4}{3} \pi r^3 = \frac{4}{3} \pi (3.0 \times 10^{-3})^3 = 1.13 \times 10^{-7} \text{ m}^3$

$$F_U = \rho_{\text{oil}} g V = 900 \times 9.81 \times 1.13 \times 10^{-7} = \mathbf{1.0 \times 10^{-3} \text{ N}}$$

(d) weight $F_W = \rho_{\text{steel}} V g = 7800 \times 1.13 \times 10^{-7} \times 9.81 = 8.7 \times 10^{-3} \text{ N}$

- terminal velocity, $F_W = F_U + F_D$: $F_D = F_W - F_U = 8.7 \times 10^{-3} - 1.0 \times 10^{-3} = 7.7 \times 10^{-3} \text{ N}$

$$v = \frac{F_D}{6\pi\eta r} = \frac{7.7 \times 10^{-3}}{6\pi \times 0.20 \times 3.0 \times 10^{-3}} = \mathbf{0.68 \text{ m s}^{-1}}$$

3.4

(a) the upthrust on an object in a fluid equals the **weight of the fluid it displaces**

(b) the reading falls by the upthrust, $F_U = F_W - F_T = 6.3 - 5.5 = 0.80 \text{ N}$; Archimedes, $F_U = \rho g V$

$$V = \frac{F_U}{\rho g} = \frac{0.80}{1000 \times 9.81} = \mathbf{8.2 \times 10^{-5} \text{ m}^3}$$

(c) $m = \frac{F_W}{g} = \frac{6.3}{9.81} = 0.642 \text{ kg}$, then $\rho = \frac{m}{V}$

$$\rho = \frac{m}{V} = \frac{0.642}{8.15 \times 10^{-5}} = \mathbf{7.9 \times 10^3 \text{ kg m}^{-3}}$$

(d) new upthrust $F_U = \rho g V = 1150 \times 9.81 \times 8.15 \times 10^{-5} = 0.92 \text{ N}$

- reading $F_T = F_W - F_U = 6.3 - 0.92 = \mathbf{5.4 \text{ N}}$