OCR A A Level Physics: Pressure, density and Archimedes' principle

35-40 minutes independent practice + 15-20 minutes review

Specification points covered

- 3.2.1(c) Understand weight of an object, W = mg.
- 3.2.1(d) Define and identify tension, normal contact force, upthrust and friction.
- 3.2.1(e) Draw and interpret free-body diagrams.
- 3.2.4(a) Define density; ρ = m / V.
- 3.2.4(b) Define pressure; p = F / A for solids, liquids and gases.
- 3.2.4(c) Use p = hρg to calculate pressure in fluids; understand upthrust and Archimedes' principle.

Main scenario

An ocean-engineering team is testing a surface marker and a suspended monitoring pod before deployment. Unless stated otherwise, take g = 9.81 m s^{-2} and the density of seawater as 1025 kg m^{-3}.

Figure 1

1. Preparing the equipment

1. Define density. **[1 mark]**

2. An aluminium pressure housing has mass 1.62 kg and volume 600 cm^3. Calculate its density in kg m^{-3}. **[2 marks]**

3. Define pressure and state its SI unit. **[2 marks]**

1. Preparing the equipment continued

Equipment-case data
Downward force = 3.60 kN. The three rectangular faces measure 0.40 m × 0.30 m, 0.60 m × 0.40 m and 0.60 m × 0.30 m.

4. An equipment case exerts a downward force of 3.60 kN on a rectangular face measuring 0.40 m by 0.30 m. Calculate the pressure exerted on the loading platform. **[2 marks]**

5. The same case is turned onto a 0.60 m by 0.40 m face. Without repeating the full calculation, state how the pressure changes and explain why. **[2 marks]**

2. Pressure beneath a liquid surface

Pod depths
Top face: 6.00 m below the seawater surface. Bottom face: 6.40 m below the surface.

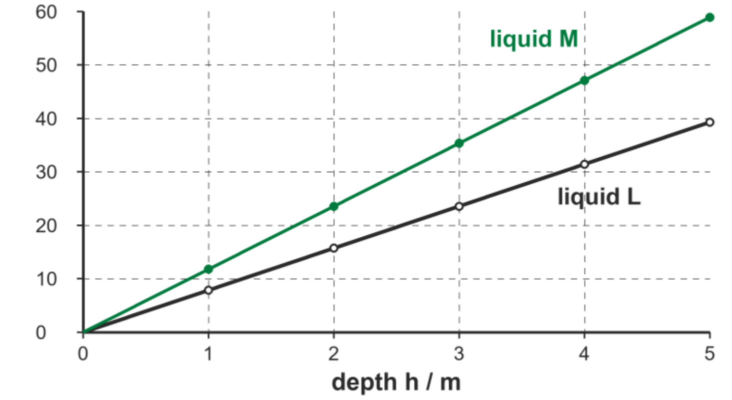
6. The top face of the monitoring pod is 6.00 m below the seawater surface. Calculate the gauge pressure due to the seawater at this depth. **[1 mark]**

7. The bottom face of the pod is 6.40 m below the surface. Calculate the gauge pressure at the bottom face. **[1 mark]**

8. Calculate the difference between the gauge pressures on the bottom and top faces of the pod. **[1 mark]**

2. Pressure beneath a liquid surface continued

Figure 2



9. Figure 2 shows calibration data for two liquids. Read the gauge pressure in liquid M at a depth of 3.50 m. [1 mark]

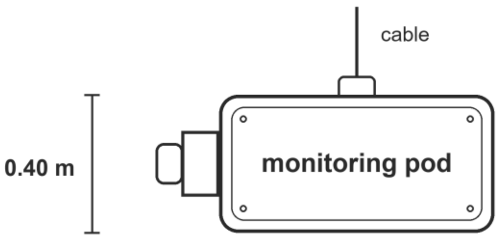
10. Use the line for liquid L in Figure 2 to determine the density of liquid L. [2 marks]

11. Explain why each line in Figure 2 is straight and passes through the origin. [2 marks]

12. State Archimedes' principle using precise wording. [1 mark]

3. Upthrust on the monitoring pod

Figure 3



mass = 12.0 kg volume = 8.00×10^{-3} m^3 face area = 0.0200 m^2

top face depth = 6.00 m bottom face depth = 6.40 m

13. The monitoring pod is stationary and fully submerged. On Figure 3 draw and label the three forces acting on the pod. [2 marks]

14. The pod has volume 8.00×10^{-3} m^3. Use Archimedes' principle to calculate the upthrust on it in seawater. [1 mark]

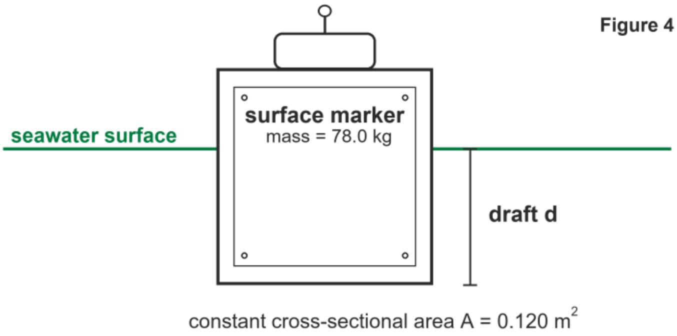
15. The mass of the pod is 12.0 kg. Calculate the tension in the cable while the pod is stationary. [2 marks]

16. Each horizontal face of the pod has area 0.0200 m^2. Use your answer to Question 8 to verify that the difference between the pressure forces on these faces equals the upthrust from Question 14. [2 marks]

17. The cable is cut. Drag is negligible at the instant the cable is cut. Calculate the initial acceleration of the pod and state its direction. [2 marks]

4. Floating equilibrium and design limits

Figure 4



18. The surface marker floats at rest. Explain how it can be in equilibrium even though two non-zero forces act on it. **[2 marks]**

19. The unloaded surface marker has mass 78.0 kg and constant horizontal cross-sectional area 0.120 m^2. Use Archimedes' principle to calculate its draft d in seawater. **[2 marks]**

20. A 24.0 kg instrument package is fitted inside the marker. Calculate the new draft. **[2 marks]**

21. The maximum safe draft is 0.900 m. Determine the greatest total payload mass that can be added to the unloaded marker. **[2 marks]**

22. A pupil says, 'In a denser liquid, the equilibrium upthrust on the same loaded marker must be larger.' Explain why this is incorrect and state how the draft changes. **[2 marks]**

Check your language

A pressure, density, force or displaced volume can increase, decrease or stay the same. Equilibrium means the resultant force is zero; it does not mean that no forces act.