

Hydrostatics

Matthew Williams • Physics • May 20, 2026

Hydrostatics

Hydrostatics deals with fluids (liquids and gases) at rest and the pressures they exert.

Pressure

Pressure is the force acting per unit area perpendicular to a surface:

$$P = \frac{F}{A}$$

where P is pressure in pascals (Pa), F is force in newtons (N), and A is the area in m^2 . One pascal equals one newton per square metre ($1 \text{ Pa} = 1 \text{ N m}^{-2}$).

The same force produces more pressure when applied to a smaller area. A drawing pin exerts far greater pressure than a thumb pushing with the same force, because the point has a much smaller area.

Fluid Pressure

A fluid at rest exerts pressure in all directions. The pressure at a depth h below the surface of a fluid depends on the density of the fluid and the depth:

$$\Delta P = \rho g \Delta h$$

where ρ is the fluid density (kg m^{-3}), $g = 10 \text{ N kg}^{-1}$, and Δh is the depth (m).

Key consequences:

- Pressure increases with depth. Deep-sea submarines need thick hulls to withstand it.
- Pressure does not depend on the shape of the container, only on depth and fluid density.
- At the same depth, a denser fluid exerts more pressure than a less dense one.

Fluid pressure, diver (2022 Paper 02, Q4)

Calculate the pressure that a diver experiences at 0.5 km below the surface of the sea. [Density of seawater = 1025 kg m^{-3} , $g = 10 \text{ N kg}^{-1}$]

$$\Delta P = \rho g \Delta h = 1025 \times 10 \times 500 = 5\,125\,000 \text{ Pa} \approx 5.1 \times 10^6 \text{ Pa}$$

This is about 50 times atmospheric pressure.

Archimedes' Principle

When an object is fully or partially submerged in a fluid, it experiences an **upthrust** (buoyant force) equal to the weight of fluid it displaces:

$$U = \rho_{\text{fluid}} \times g \times V_{\text{displaced}}$$

where $V_{\text{displaced}}$ is the volume of fluid pushed aside by the object.

The upthrust acts upward and opposes the object's weight.

<ArchimedesDiagram />

Floating and Sinking

- If weight > upthrust: the object sinks.
- If weight = upthrust: the object floats in equilibrium (it hovers at some depth).
- If weight < upthrust: the object accelerates upward (floats to the surface).

A floating object displaces fluid whose weight exactly equals the object's own weight. This means a floating object's density is less than or equal to the fluid's density.

Density of object < density of fluid: floats.

Density of object > density of fluid: sinks.

A steel ship floats because its hollow structure means the average density of the ship-plus-air system is less than water.

Archimedes, floating boat (2022 Paper 02, Q4)

A boat weighs 83,000 N and floats in seawater (density 1025 kg m⁻³, g = 10 N kg⁻¹). Calculate the volume of seawater displaced.

When floating, upthrust = weight:

$$U = 83\,000\text{N}$$

$$U = \rho g V \implies V = \frac{U}{\rho g} = \frac{83\,000}{1025 \times 10} = \frac{83\,000}{10\,250} \approx 8.1\text{m}^3$$

 Exam Tip

In pressure problems, convert depth to metres before substituting. A depth of 0.5 km is 500 m, not 0.5.

In Archimedes problems, the key identity is: for a floating object, upthrust = weight. State this explicitly before substituting, it earns a method mark.