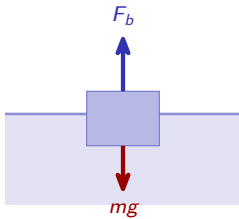


Fluids

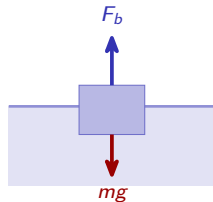
AP Physics 1 ■ Unit 8

AP Physics 1



What we will cover

- 1 Density
- 2 Pressure
- 3 Buoyancy and Archimedes
- 4 Continuity and Bernoulli





Density

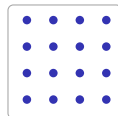
Density is how tightly matter is packed – mass per unit volume:

Mass per volume

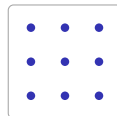
$$\rho = \frac{m}{V}$$

Solids and liquids are dense (particles almost touching); gases are far less dense.

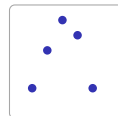
600 g in 200 cm³: $\rho = 3 \text{ g/cm}^3$ – three times water.



solid



liquid



gas

What makes something a fluid

a fluid

liquid or gas – it has **no fixed shape** and takes the shape of its container

why they differ

solids, liquids and gases differ in **how strongly their particles interact**

density

$\rho = m/V$ – a **scalar**, and a property of the material rather than of the object

incompressible

a liquid's density barely changes with pressure, which is what lets the fluid equations be so simple

an ideal fluid

incompressible, with no **viscosity** – the model AP uses throughout

real fluids

have viscosity, so some energy is always lost to internal friction

Every fluid result on this paper assumes the ideal model. Saying which assumption you are using is often itself a marked step.



Pressure

Pressure is force spread over an area:

Two key formulas

$$P = \frac{F}{A}, \quad P = \rho gh$$

- smaller area $\Rightarrow$ bigger pressure (a sharp knife)
- fluid pressure grows with **depth**, and pushes equally in **all directions**



Pressure is force per unit area

Gauge pressure and absolute pressure

Gauge pressure

The extra pressure the fluid column adds: $P_{\text{gauge}} = \rho gh$. It reads zero at the surface.

Absolute pressure

The total: $P = P_0 + P_{\text{gauge}}$, with P_0 usually atmospheric. Never negative.

The tyre

A gauge reading 200 kPa is *gauge* pressure – the air inside is really about 300 kPa absolute.

Gas-law and buoyancy problems need **absolute** pressure; a pressure *difference* across a wall is the gauge value.

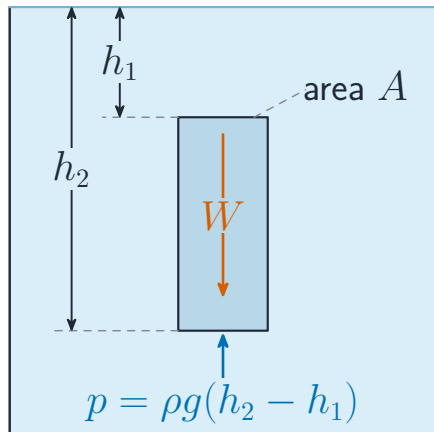
Worked example – pressure on a diver

Find the total pressure on a diver 10 m below the surface. ($\rho = 1000 \text{ kg/m}^3$, surface pressure $1.0 \times 10^5 \text{ Pa}$)

- **gauge pressure** : $P_{\text{gauge}} = \rho gh = (1000)(9.8)(10) = 9.8 \times 10^4 \text{ Pa}$
- **absolute pressure** : $P = P_0 + \rho gh$
- $= 1.0 \times 10^5 + 9.8 \times 10^4 = 2.0 \times 10^5 \text{ Pa}$

Gauge pressure is what the *column* adds; absolute pressure includes the atmosphere on top. Read the question for which it wants – the two differ by a whole atmosphere.

The weight of a liquid column sets



The weight of a liquid column sets the extra pressure at a depth



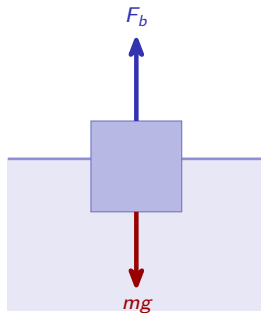
Buoyancy and Archimedes' principle

A fluid pushes up with a **buoyant force** .

Archimedes' principle : it equals the weight of the fluid displaced.

$$F_b > \text{weight} \Rightarrow \text{floats}$$

$$F_b < \text{weight} \Rightarrow \text{sinks}$$



Floats when **less**
dense than the fluid.



Continuity and Bernoulli

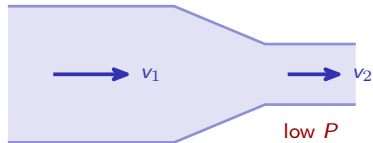
Two conservation laws for flowing fluids:

Continuity (mass)

$$A_1 v_1 = A_2 v_2$$

A narrower pipe forces a **faster** flow.

Bernoulli's principle (energy):
where a fluid flows **faster**, its pressure is **lower**.



$A : 4 \rightarrow 1 \text{ cm}^2$ raises $v : 2 \rightarrow 8 \text{ m/s}$.

Worked example – continuity in a narrowing pipe

Water flows at 2.0 m/s through a pipe of area 0.010 m², then enters a section of area 0.0050 m². Find the new speed.

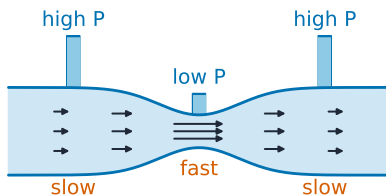
- continuity: $A_1 v_1 = A_2 v_2$ – the same volume passes every second
- $v_2 = \frac{(0.010)(2.0)}{0.0050}$
- = 4.0 m/s

Halve the area and the speed doubles.

Bernoulli's equation

then says the faster section is at **lower** pressure – which is the counter-intuitive half of every fluid question.

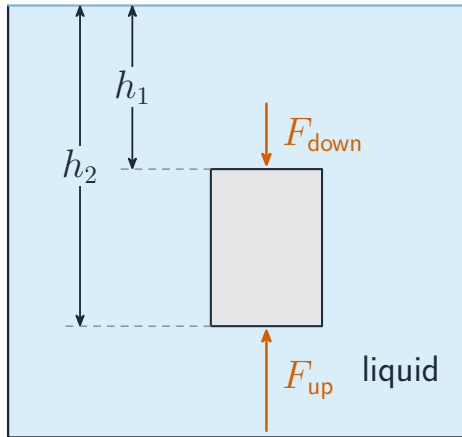
Fluids and Conservation Laws



$$A_1 v_1 = A_2 v_2 \quad \cdot \quad P + \frac{1}{2} \rho v^2 = \text{const (horizontal)}$$

Where the pipe narrows the fluid speeds up (continuity) and its pressure drops (Bernoulli)

Upthrust arises because the pressure below is greater



Upthrust arises because the pressure on the bottom of an object exceeds that on the top

Exam tips

- Pressure with depth is $P = P_0 + \rho gh$ – it depends on **depth only**, not the container's shape or width.
- **Buoyant force** = weight of fluid displaced ($\rho_{\text{fluid}} g V_{\text{disp}}$); a floating object displaces its own weight, so the fraction submerged is $\rho_{\text{object}} / \rho_{\text{fluid}}$.
- Compare densities to predict floating vs sinking; a floating object is in equilibrium (buoyancy = weight), not weightless.
- Use **continuity** $A_1 v_1 = A_2 v_2$: a narrower pipe means faster flow.
- **Bernoulli**: where a fluid flows faster its pressure is lower (wing lift, spray).



Unit 8 – key takeaways

1

Density

$\rho = m/V$; how tightly matter is packed

2

Pressure

$P = F/A$; in a fluid $P = \rho gh$, grows with depth

3

Buoyancy

F_b = weight of displaced fluid;
float if less dense

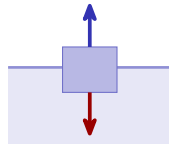
4

Flow

$A_1 v_1 = A_2 v_2$; faster flow means lower pressure

Check yourself

- 1 Dive twice as deep – what happens to the fluid pressure?
- 2 What does the buoyant force equal?
- 3 A pipe narrows. Does the fluid speed up or slow down?
- 4 Where the flow is faster, is the pressure higher or lower?



Answers 1. it doubles 2. the weight of displaced fluid 3. speeds up 4. lower