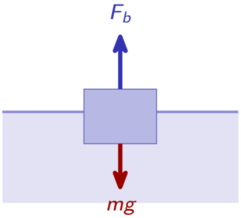
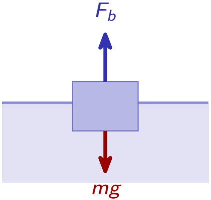
Fluids

AP Physics 1 ▪ Unit 8

AP Physics 1



What we will cover



1 Density

Density

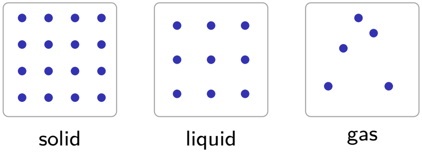
Density 密度 is how tightly matter is packed – mass per unit volume:

Mass per volume

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

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

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



What makes something a fluid

a fluid 流体	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** 标量, and a property of the material rather than of the object
incompressible 不可压缩	a liquid's density barely changes with pressure, which is what lets the fluid equations be so simple
an ideal fluid 理想流体	incompressible, with no **viscosity** 黏度 – 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.

2

Pressure

Pressure

Pressure 压强 is force spread over an area:

Two key formulas

$$P = \frac{F}{A}, \qquad P = \rho g h$$

- smaller area ⇒ 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: $P_{\text{gauge}} = \rho g h$. 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.

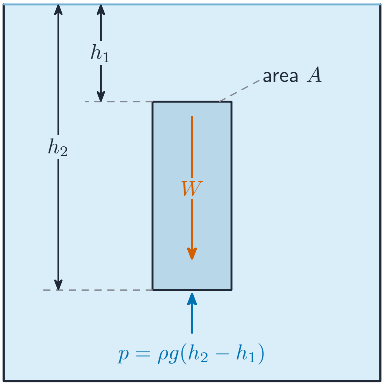
Worked example – pressure on a diver

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

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

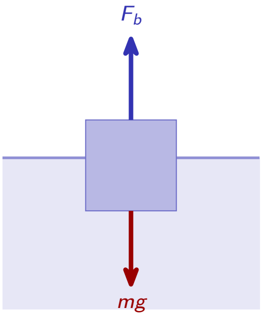
3 Buoyancy

Buoyancy and Archimedes' principle

A fluid pushes up with a **buoyant force** 浮力. **Archimedes' principle** 阿基米德原理: it equals the weight of the fluid displaced.

$F_b >$ weight $\Rightarrow$ **floats**

$F_b <$ weight $\Rightarrow$ **sinks**



Floats when less dense than the fluid.

4 Flow

Continuity and Bernoulli

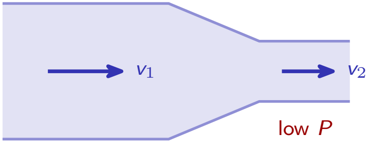
Two conservation laws for flowing fluids:

Continuity (mass)

$$A_1 v_1 = A_2 v_2$$

A narrower pipe forces a faster flow.

Bernoulli's principle 伯努利原理 (energy): where a fluid flows faster, its pressure is lower.



$A : 4 \to 1\,\mathrm{cm}^2$ raises $v : 2 \to 8\,\mathrm{m/s}$.

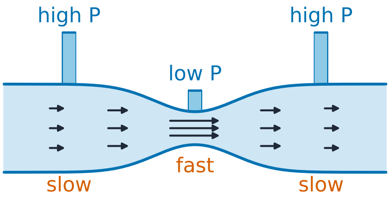
Worked example – continuity in a narrowing pipe

Water flows at 2.0 m/s through a pipe of area 0.010 m^2, then enters a section of area 0.0050 m^2. Find the new speed.

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

Halve the area and the speed doubles. **Bernoulli's equation** 伯努利方程 then says the faster section is at lower pressure – which is the counter-intuitive half of every fluid question.

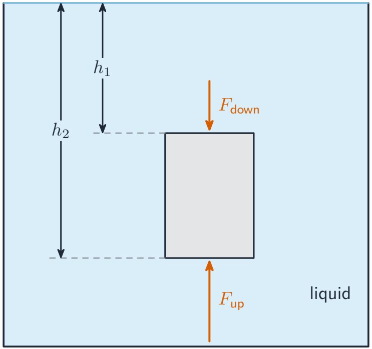
Fluids and Conservation Laws



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

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

Upthrust arises because the pressure on the



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

Exam tips

- Pressure with depth is $P = P_0 + \rho g h$ – 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).

5 Recap

Unit 8 – key takeaways

1 **Density**

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

2 **Pressure**

$P = F/A$; in a fluid $P = \rho g h$, 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

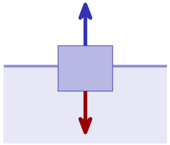
Check yourself

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