Cambridge IGCSE · Physics 0625 · Notes

Pressure

Read online at **pastopic.com/cambridge/physics-0625/notes/pressure**

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Read first: **Mass and weight**

What you need to know

This is a short topic with two halves: pressure from solids pressing on a surface, and pressure inside a liquid. The part marked **Extended only** is tested on Papers 2 and 4 only. By the end of it you should be able to:

1. **Define pressure** as force per unit area, and recall and use $p = \dfrac{F}{A}$.
2. **Describe how pressure changes with force and area** in everyday examples: sharp knives and nails, wide tyres and snowshoes, lying down on thin ice.
3. **Describe, in words, how the pressure beneath the surface of a liquid changes** with the depth and with the density of the liquid.
4. **Extended only:** recall and use $\Delta p = \rho g \Delta h$ for the change in pressure beneath the surface of a liquid.

Understand it

What pressure is

Push a drawing pin into a board with your thumb. The same force presses on your thumb (through the wide, flat head) and on the board (through the tiny point). Your thumb is fine, but the point goes into the wood. The force is the same at both ends; what differs is the **area** it is spread over.

Pressure measures how concentrated a force is: the force acting on each unit of area.

$$p = \frac{F}{A} \qquad (p \text{ in Pa},\ F \text{ in N},\ A \text{ in m}^2).$$

The force is the one pressing **at right angles** to the surface. For an object resting on the ground, that force is its **weight**, $W = mg$, not its mass. The unit is the **pascal** (Pa): 1 Pa $= 1$ N/m². Papers 1 and 3 often use **N/cm²** instead. Because 1 m² $= 100 \times 100 = 10\,000$ cm², a pressure of 1 N/cm² is $10\,000$ N/m², that is $10\,000$ Pa. Kilopascals (kPa, 1000 Pa) are common for liquids and the air.

The same force on different areas

A brick of weight 24 N measures 0.20 m by 0.10 m by 0.05 m. Its weight is the same whichever way up it rests, but the area in contact with the ground changes:

Face on the ground	Area	Pressure $= 24 \div$ area
0.20 m × 0.10 m (largest)	0.020 m²	1200 Pa
0.20 m × 0.05 m	0.010 m²	2400 Pa
0.10 m × 0.05 m (smallest)	0.005 m²	4800 Pa

So for a **fixed force**, pressure is **inversely proportional** to area: halve the area and the pressure doubles. For a **fixed area**, pressure is proportional to the force. Two changes can cancel: doubling both the force and the area leaves the pressure the same.

Everyday examples come in two groups:

- **Small area, large pressure, to cut or pierce**: knives and scissors (a sharp edge has a tiny area), nails, drawing pins, needles, the studs on football boots, a stiletto heel denting a floor.
- **Large area, small pressure, to avoid sinking or damage**: wide tractor tyres and snow-tracks on soft ground, snowshoes and skis, wide straps on a heavy bag, the wide feet of a camel or elephant, lying flat or crawling across thin ice instead of walking.

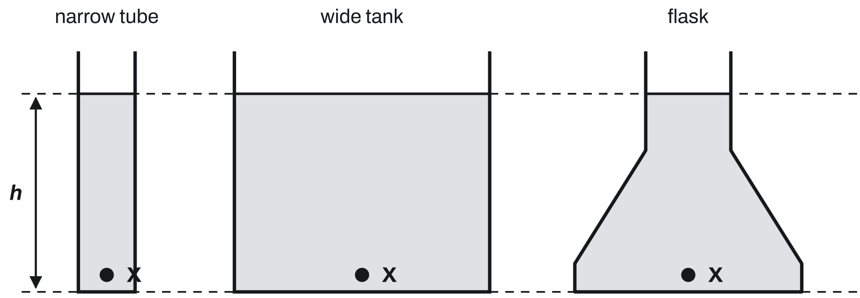
In both groups the **force** (usually the weight) stays the same. Only the area changes, and that changes the pressure. A tractor's wide tyres do not make it lighter: they spread the same weight over more ground.

Pressure in a liquid

A liquid pushes on everything it touches: the bottom and the walls of its container, and anything inside it. The deeper you go, the more liquid is above you pressing down, so the pressure increases. Divers feel it in their ears, and a dam is built thicker at the bottom than at the top.

The pressure beneath the surface of a liquid:

- **increases with depth**: twice as deep, twice the pressure due to the liquid;
- **increases with the density of the liquid**: at the same depth, sea water gives more pressure than fresh water, and water more than oil;
- **acts in all directions** at a point, not just downwards;
- does **not** depend on the **shape** or **width** of the container, or on how much liquid there is. Only the **vertical depth** below the surface matters.



same liquid, same depth h

so the pressure at X is the same in all three: Δp = ρgh

The wide tank holds far more water than the tube, but its weight is spread over a bigger base, so the pressure at the bottom is the same. Point X in the flask is below the same depth of liquid as the others, so it has the same pressure too.

The equation for liquid pressure

Extended only. Picture a column of liquid of density ρ, height h and cross-sectional area A standing on the bottom of the container. Its volume is Ah, so its mass is ρAh and its weight is ρAhg. The pressure it makes on the area A beneath it is

$$p = \frac{\text{weight}}{\text{area}} = \frac{\rho Ahg}{A} = \rho gh.$$

The area cancels, which is why the width of the container does not matter. The syllabus writes this for a **change** in depth:

$$\Delta p = \rho g \Delta h \qquad (\rho \text{ in kg/m}^3,\ g = 9.8\ \text{N/kg},\ \Delta h \text{ in m},\ \Delta p \text{ in Pa}).$$

- At 2.0 m below the surface of water (1000 kg/m³): $\Delta p = 1000 \times 9.8 \times 2.0 = 19\,600$ Pa.
- At the same depth in oil (800 kg/m³): $800 \times 9.8 \times 2.0 = 15\,680 \approx 15\,700$ Pa, less, because oil is less dense.
- Moving **between** two depths, use the difference in depth: going from 10 m down to 30 m changes the pressure by $\rho g \times 20$.

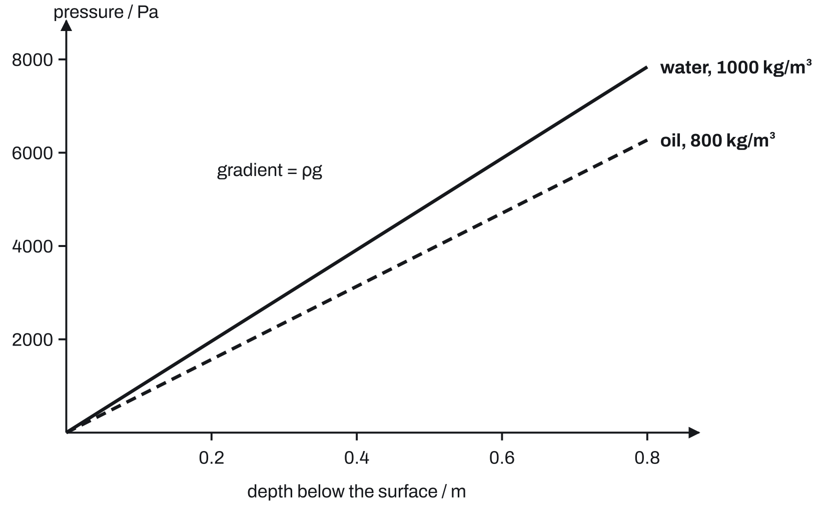
ρgh is the pressure **due to the liquid** only. The air above the surface presses on it too, so the **total pressure** at a depth is

$$\text{total pressure} = \text{atmospheric pressure} + \rho gh.$$

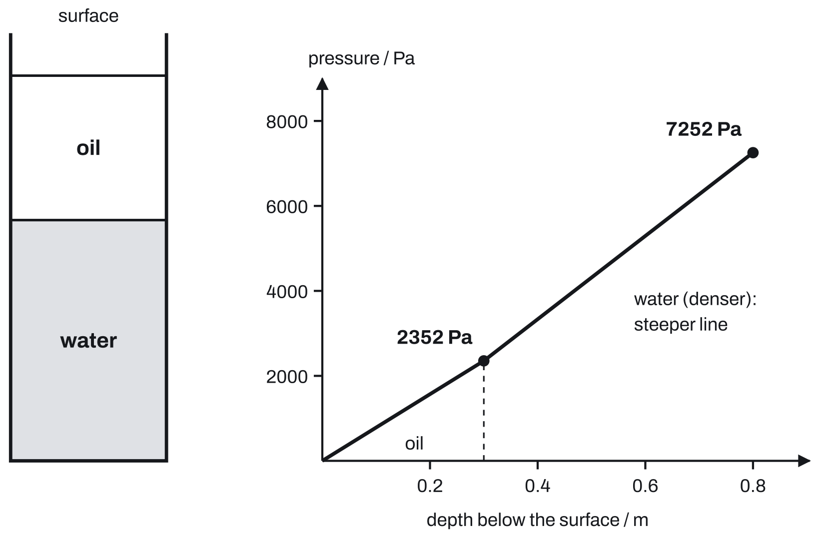
At 10 m below the surface of water, with atmospheric pressure 1.0×10^5 Pa, the total is $1.0 \times 10^5 + 1000 \times 9.8 \times 10 = 1.98 \times 10^5$ Pa, nearly double the pressure at the surface. The same equation works for air if its density is taken as constant: climbing a hill of height Δh lowers the air pressure by $\rho_{\text{air}} g \Delta h$.

Graphs of pressure against depth

Because $p = \rho g h$, a graph of the pressure due to a liquid against depth is a **straight line through the origin**. Its gradient is ρg, so a denser liquid gives a **steeper** line.



If two liquids that do not mix are poured into one container, the less dense one floats on top. Going down, the pressure rises along a gentle line through the top liquid, then along a **steeper** line through the denser liquid below. The line bends at the boundary but never jumps, and it never goes down. You can read the density of a liquid from its line: $\rho = \dfrac{\Delta p}{g\,\Delta h}$.



Here the pressure at the boundary is $800 \times 9.8 \times 0.30 = 2352$ Pa, and at the bottom it is $2352 + 1000 \times 9.8 \times 0.50 = 7252$ Pa.

Key facts and formulas

The 0625 papers have no formula sheet, so learn every equation. The value of g is printed on the front of the paper.

Formula	Status
Pressure $p = \frac{F}{A}$ (force per unit area); so $F = pA$ and $A = \frac{F}{p}$	Learn it
Force from a mass: weight $W = mg$	Learn it
Extended only: change in pressure in a liquid $\Delta p = \rho g \Delta h$; so $\rho = \frac{\Delta p}{g\Delta h}$ and $\Delta h = \frac{\Delta p}{\rho g}$	Learn it
Extended only: total pressure $=$ atmospheric pressure $+\rho g h$	Learn it
Density $\rho = \frac{m}{V}$ (for the mass of liquid in a tank)	Learn it
$g = 9.8$ N/kg	Given
Units: 1 Pa $= 1$ N/m²; 1 kPa $= 1000$ Pa; 1 N/cm² $= 10\,000$ Pa; 1 m² $= 10\,000$ cm²	Learn it

How to do it

We have tagged 92 questions for this topic across Papers 1–4, 2021–2025; 13 are repeats on other papers, leaving 79 different questions. 5 of the 79 mix two or more types, so the counts add up to more than 79.

Question type	Questions
Calculating pressure, force or area with $p = \frac{F}{A}$	25
Extended only: calculations with $\Delta p = \rho g \Delta h$	18
How liquid pressure depends on depth and density	18
Force and area in everyday examples	16
Definition, unit and choosing the equation	9

1. Calculating pressure, force or area with p = F/A (25 questions)

1. **Find the force.** If you are given a mass, find the weight first: $W = mg$ (with m in kg). If the object stands on several wheels or feet, decide whether you want the pressure under one of them (share the weight) or under all of them (add the areas).
2. **Find the area in contact** with the surface: length × width of the face that is **touching**, in the units the answer line wants.
3. **Write** $p = \frac{F}{A}$, substitute and give the unit: Pa (N/m²) if you used m², N/cm² if you used cm².

For example, a 900 N load on 0.030 m² gives $p = 900 \div 0.030 = 30\,000$ Pa, which is 3.0 N/cm².

Variations you will meet:

- **Rearranging.** Force from pressure: $F = pA$ (a $15\,000$ Pa pressure on 2.2 m² means a force of $33\,000$ N). Area from pressure: $A = \frac{F}{p}$. An animal of weight $45\,000$ N standing on four feet at an average pressure of $30\,000$ Pa has a total foot area of 1.5 m², so 0.375 m² per foot.

- **Several wheels or legs.** A 600 N trolley on four wheels, each touching the floor over 12 cm², presses on $4 \times 12 = 48$ cm² in total: $p = 600 \div 48 = 12.5$ N/cm². Forgetting the number of wheels is a common slip.
- **Change in pressure** when a block is turned onto another face: work out both pressures and subtract.
- **Which block exerts the greatest pressure?** Work out $F \div A$ for every row of the table; the biggest force does not always win.
- **A liquid in a tank** (Core): the force on the base is the weight of the liquid, mg, so $p = \dfrac{mg}{A}$. The mass alone is not a force.
- **Converting units.** Keep the area and the answer in matching units. Change cm² to m² by dividing by $10\,000$, and mm² by dividing by $1\,000\,000$.

2. Calculations with Δp = ρgΔh (18 questions)

Extended only.

1. **Pick out** the density ρ (kg/m³), the **vertical** depth below the surface Δh (m) and $g = 9.8$ N/kg. Convert cm to m and g/cm³ to kg/m³ (× 1000).
2. **Write** $\Delta p = \rho g \Delta h$ and substitute.
3. **Decide whether atmospheric pressure is needed.** "Pressure due to the water" or "relative to atmospheric pressure": ρgh only. "Total pressure": add atmospheric pressure.
4. **Give the unit**, Pa.

For example, the pressure due to sea water (1030 kg/m³) at 50 m is $1030 \times 9.8 \times 50 = 504\,700 \approx 5.0 \times 10^5$ Pa.

Variations you will meet:

- **Depth from pressure.** Subtract atmospheric pressure first if you are given the total, then $\Delta h = \dfrac{\Delta p}{\rho g}$. A total of 2.0×10^5 Pa in water with 1.0×10^5 Pa of air above gives $\Delta h = \dfrac{1.0 \times 10^5}{1000 \times 9.8} = 10$ m.
- **Density from pressure or from a graph.** $\rho = \dfrac{\Delta p}{g\,\Delta h}$. Read one point off the line (or the change between two points): 4000 Pa at 0.50 m gives $\rho = \dfrac{4000}{9.8 \times 0.50} = 820$ kg/m³. If you are given a volume of liquid in a cylinder, the depth is volume ÷ cross-sectional area.
- **Force on a surface in a liquid**, such as the base of a tank, a plate on a lake bed or the top of a block under water: find ρgh, then $F = pA$. This equals the weight of the liquid sitting on that area.
- **Air instead of water.** The drop in air pressure going up a hill is $\rho_{\text{air}} g \Delta h$; subtract it from the pressure at the bottom.
- **Two pressures added.** The pressure at a point under floating ice, or under a piston, is the pressure from the object on top ($\frac{F}{A}$) plus ρgh of the liquid (plus the air, if the question includes it).
- **Manometers and barometers** were removed from the syllabus from 2023, so skip **0625/21/O/N/22 Q11** and part (a) of **0625/32/M/J/21 Q5**.
- **"Show that"**: write the equation, the numbers and an answer with one more significant figure than printed, for example $14\,700$ Pa for "about $15\,000$ Pa".

- **The pressure then goes into another topic**, such as the volume of a gas bubble rising through water (pV constant, from the gas topic): use the **total** pressure at each depth.

3. How liquid pressure depends on depth and density (18 questions)

1. **Find the vertical depth** of each point below the liquid surface. Ignore the shape and width of the container and the amount of liquid.
2. **Deeper means greater pressure.** At the same depth, the **denser** liquid gives the greater pressure.
3. **Explain** in terms of the liquid above: the deeper the point, the greater the weight of liquid above it.

Variations you will meet:

- **Containers of different shapes or widths**, same liquid, same depth: the pressure at the bottom is the **same** in all of them. A container on a block or a stand makes no difference: only the depth of liquid counts. Containers filled to the top: the **tallest** one has the greatest pressure at its base.
- **Two liquids, same depth**: the denser one (water rather than oil, sea water rather than fresh water) gives more pressure at the bottom.
- **Graphs.** Pressure against depth is a straight line through the origin (for a constant density). Two layers of liquid give two straight lines, the lower (denser) one steeper.
- **"What does the pressure at the bottom of a pond depend on?"** Depth and density (and g), **not** surface area, length or width.
- **Why does the pressure on a diver or a gauge increase as it goes down?** The depth increases, so the weight of water above increases. The density of water and g do not change noticeably with depth.
- **Changing depth**: the change in pressure depends on the change in depth, so a submarine moving from 10 m to 30 m has the same change as one moving from 50 m to 70 m.
- **Liquids that don't mix**: the less dense one floats on top.

4. Force and area in everyday examples (16 questions)

1. **Say what stays the same**: the force (usually the weight).
2. **Say what changes**: the area in contact.
3. **Link them with $p = \frac{F}{A}$**: a larger area gives a smaller pressure (or a smaller area gives a larger pressure).
4. **Say what happens**: it sinks less, it cuts more easily, the ice is less likely to break.

For example: "The tractor and the car have the same weight. The tractor's wide tyres have a larger area in contact with the ground, so the pressure on the ground is smaller ($p = F/A$) and the tractor does not sink."

Variations you will meet:

- **Which position gives the least pressure?** The one with the biggest contact area: lying flat, rather than sitting, kneeling or standing (standing on tiptoe gives the most).
- **Which face gives the greatest or least pressure?** Same weight, so the **smallest** face gives the **greatest** pressure and the largest face the least. Work out each area if the options are numbers.

- **Which sculpture or block is least likely to sink?** The one with the widest base.
- **Which pair of changes always increases the pressure?** Increase the force **and** decrease the area. Increasing both, or decreasing both, could go either way.
- **Which changes keep the pressure the same?** Multiply the force and the area by the same number.
- **Distractors from other topics.** A long spanner is easier to turn because of its **moment** (turning effect), not pressure. A sharp edge cutting is about pressure, not the density of the metal or the force being bigger.

5. Definition, unit and choosing the equation (9 questions)

1. **Definition**: pressure is **force per unit area** (not area per unit force, mass per unit area or mass per unit volume).
2. **Unit**: the pascal, Pa, which is N/m². kg/m³ is a unit of density and N m is a unit of moment.
3. **Equation**: $p = \dfrac{\text{weight}}{\text{area of contact}}$ for an object on a surface. **Extended only:** $\Delta p = \rho g \Delta h$ for a liquid, where ρ is the **density of the liquid** (not of an object in it). Rearranged: $h = \dfrac{p}{\rho g}$ and $\rho = \dfrac{p}{hg}$.

When asked to **describe** how liquid pressure varies, give both parts: pressure increases with depth, and pressure increases with density.

Worked examples

The bold codes show where marks are earned, as in Cambridge mark schemes. The number is how many marks.

- **A1** accuracy mark: for a correct answer; it needs the M mark before it.
- **B1** mark for a correct result on its own, with no method needed.

Example 1

A crate of mass 45 kg rests on a floor. Its base measures 0.60 m by 0.50 m.

(a) Calculate the weight of the crate. **[2]**

(b) Calculate the pressure the crate exerts on the floor. **[4]**

(c) The crate is lifted onto four legs. Each leg touches the floor over an area of 4.0 cm². Calculate the pressure on the floor in N/cm², and explain why the legs may dent the floor. **[4]**

(a) $W = mg$ **C1** $= 45 \times 9.8 = 441$ N **A1**.

(b) Area $= 0.60 \times 0.50 = 0.30$ m² **C1**. $p = \dfrac{F}{A}$ **C1** $= \dfrac{441}{0.30}$ **C1** $= 1470$ Pa **A1**.

(c) Total area of the four legs $= 4 \times 4.0 = 16$ cm² **C1**. $p = \dfrac{441}{16} = 27.6 \approx 28$ N/cm² **A1**. The weight is the same, but the area in contact is much smaller **B1**, so the pressure is much greater, and it may be large enough to push into the floor **B1**.

Example 2

A student of weight 600 N sinks into deep snow when wearing boots. The total area of her boots in contact with the snow is 0.040 m². She then puts on snowshoes; each has an area of 0.075 m² in contact with the snow.

(a) Calculate the pressure on the snow when she stands in her boots. **[2]**

(b) Calculate the pressure on the snow when she stands on both snowshoes. **[2]**

(c) Explain why she sinks less when wearing snowshoes. **[2]**

(a) $p = \dfrac{F}{A} = \dfrac{600}{0.040}$ **C1** $= 15\,000$ Pa **A1**.

(b) Area $= 2 \times 0.075 = 0.15$ m², so $p = \dfrac{600}{0.15}$ **C1** $= 4000$ Pa **A1**.

(c) Her weight (the force on the snow) is the same, but the snowshoes have a larger area **B1**, so the pressure on the snow is smaller ($p = F/A$), less than a third as much **B1**.

Example 3

Extended only. A swimming pool is filled with water of density 1000 kg/m³ to a depth of 2.5 m. Atmospheric pressure is 1.0×10^5 Pa.

(a) Calculate the pressure due to the water at the bottom of the pool. **[2]**

(b) Calculate the total pressure at the bottom of the pool. **[1]**

(c) A drain cover of area 0.040 m² lies on the bottom of the pool. Calculate the force on it due to the water. **[2]**

(d) The pool is emptied and filled to the same depth with sea water. State and explain the effect on the pressure at the bottom. **[2]**

(a) $\Delta p = \rho g \Delta h$ **C1** $= 1000 \times 9.8 \times 2.5 = 24\,500$ Pa **A1**.

(b) $1.0 \times 10^5 + 24\,500 = 124\,500 \approx 1.2 \times 10^5$ Pa **A1**.

(c) $F = pA$ **C1** $= 24\,500 \times 0.040 = 980$ N **A1**.

(d) The pressure increases **B1**, because sea water is denser and the pressure at a given depth is proportional to the density **B1**.

Example 4

Extended only. A diver is in the sea, where the density of the water is 1030 kg/m³. The total pressure on the diver is 3.5×10^5 Pa. Atmospheric pressure is 1.0×10^5 Pa.

(a) Calculate the depth of the diver below the surface. **[3]**

(b) The diver swims up through a vertical distance of 12 m. Calculate the total pressure on the diver now. **[3]**

(a) Pressure due to the water $= 3.5 \times 10^5 - 1.0 \times 10^5 = 2.5 \times 10^5$ Pa **C1**.

$\Delta h = \dfrac{\Delta p}{\rho g} = \dfrac{2.5 \times 10^5}{1030 \times 9.8}$ **C1** $= 24.77 \approx 25$ m **A1**.

(b) Change in pressure $= \rho g \Delta h = 1030 \times 9.8 \times 12$ **C1** $= 121\,128$ Pa, about 1.2×10^5 Pa **C1**. The diver is shallower, so the pressure falls: $3.5 \times 10^5 - 121\,128 = 228\,872 \approx 2.3 \times 10^5$ Pa **A1**.

Common mistakes

- **Using mass instead of weight.** The force in $p = \frac{F}{A}$ is a force in newtons: a 120 kg cube pushes down with 120×9.8 N, not 120. Examiners report this every year, for solid blocks, liquids in tanks and ice on a pond.
- **Multiplying instead of dividing**, or turning the equation upside down. Pressure is force ÷ area. If your "pressure" is a huge number like 1536 from 48×32, you multiplied.
- **Mixing units.** N ÷ cm² gives N/cm², N ÷ m² gives Pa. Don't put a cm² area into the equation and write Pa, and don't forget the unit when the question asks for it.
- **Forgetting the number of wheels, legs or feet.** Decide whether the question wants the pressure under one of them or under all of them together.
- **Rounding to one significant figure.** Give 0.89, not 0.9; two or three significant figures are expected.
- **Saying the force changes.** In "why do wide tyres help" answers, the weight is the same; only the area changes. And say pressure, not force: "wide tyres exert a smaller force" is wrong.
- **Explanations with no link to pressure.** "Snow-tracks stop it sinking" is not enough; say the area is larger, so the pressure is smaller. Talk of friction or balance earns nothing in a question about pressure.
- **Thinking the shape or width of the container matters.** Only the vertical depth and the density decide the liquid pressure; $\rho g h$ has no area in it.
- **Forgetting** g in $\rho g h$ (giving $15\,000$ Pa instead of $147\,000$ Pa for a 15 m dam), or using the atmospheric pressure in place of ρ.
- **Atmospheric pressure the wrong way round.** For a **total** pressure, **add** it; to find a depth from a total pressure, **subtract** it first. Leaving it out, or adding when you should subtract, is the most common error in the harder questions.
- **Only one part of a two-part pressure.** Under floating ice, add the pressure from the ice to the pressure from the water, and don't subtract them.

How to get the marks

- **Write the equation first**, in symbols or words: $p = \frac{F}{A}$ or $\Delta p = \rho g \Delta h$. The first mark is usually for the equation, the second for the numbers, then the answer. Answers without working can't get part marks.
- **"Include the unit"**: Pa or N/m² for pressure (N/cm² if the areas are in cm²). The answer line often gives the unit; use the same one.
- **"Explain, using ideas about pressure"**: three links in a chain: the force (weight) is the same; the area is larger (or smaller); so the pressure is smaller (or larger), because $p = F/A$ or pressure is inversely proportional to area.
- **"Describe how pressure varies with depth and density"**: two separate statements: it increases as depth increases; it increases as density increases.
- **"Define pressure"**: force per unit area (or force ÷ area). A formula is accepted only if its letters are clearly force and area.
- **"Show that"**: equation, substitution, and an answer to one more significant figure than the printed value.
- **"Pressure due to the water" vs "total pressure"**: read which one is asked. Atmospheric pressure is only added for a total.
- **Use $g = 9.8$ N/kg** (as printed on the paper) and give answers to 2 or 3 significant figures.
- **Multiple choice**: work it out first, then look at the options. The wrong options are usually the slips above: mass for weight, multiplying, no g, atmospheric pressure forgotten or added.

Quick check

1. Define pressure and state its SI unit.
2. A block of weight 36 N rests on a face measuring 3.0 cm by 4.0 cm. Calculate the pressure on the ground in N/cm² and in Pa.
3. A drawing pin has a sharp point and a wide, flat head. Explain why each end is shaped like this.
4. **Extended only.** The pressure due to a liquid at 0.60 m below its surface is 5292 Pa. Calculate the density of the liquid.
5. **Extended only.** A tank with a base of area 0.80 m² contains water (1000 kg/m³) to a depth of 1.5 m. Calculate the pressure due to the water at the base, and the force it exerts on the base.

Answers

1. Pressure is the force per unit area (force ÷ area, acting at right angles to the surface). Its unit is the pascal, Pa, which is 1 N/m².
2. Area $= 3.0 \times 4.0 = 12$ cm². $p = \frac{36}{12} = 3.0$ N/cm². In Pa: $3.0 \times 10\,000 = 30\,000$ Pa.
3. The same force acts at both ends. The point has a tiny area, so the pressure on the board is very large and the pin goes in. The head has a large area, so the pressure on your thumb is small and it doesn't hurt.
4. $\rho = \frac{\Delta p}{g\,\Delta h} = \frac{5292}{9.8 \times 0.60} = 900$ kg/m³.
5. $\Delta p = 1000 \times 9.8 \times 1.5 = 14\,700$ Pa. $F = pA = 14\,700 \times 0.80 = 11\,760 \approx 12\,000$ N.

Past questions to try

- **0625/33/O/N/24 Q3**: the mass of a boy from his weight, then the pressure of a block on the ground (Core).
- **0625/42/M/J/23 Q3**: why crawling across ice is safer, then the pressure under floating ice (Extended).
- **0625/43/M/J/21 Q2**: explaining the pressure of books on a shelf, then a diver's depth from the total pressure (Extended).
- **0625/41/O/N/23 Q3**: "show that" for the pressure under a floating block, then the force and the block's mass (Extended).