Cambridge IGCSE · Physics 0625 · Notes

Density

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

Last checked 30 September 2026

Read first: **Physical quantities and measurement techniques**, **Mass and weight**

What you need to know

By the end of this topic you should be able to:

1. **Define density** as **mass per unit volume**, and recall and use $\rho = \frac{m}{V}$ (so $m = \rho V$ and $V = \frac{m}{\rho}$).
2. **Describe how to measure the density** of
   - a **liquid**;
   - a **regularly shaped solid** (a block, cube or cylinder you can measure with a ruler);
   - an **irregularly shaped solid that sinks** in a liquid, finding its volume **by displacement**;

   and do the calculations that go with each.
3. **Decide whether an object floats** in a liquid from density data.
4. **Extended only:** decide whether **one liquid floats on another** from density data, when the liquids do not mix.

Understand it

Mass per unit volume

Hold a 1 kg bag of feathers and a 1 kg block of iron: same mass, very different sizes. The iron packs its mass into a much smaller space. **Density** measures how tightly mass is packed: it is the **mass of each unit of volume**, for example the mass of each cubic centimetre.

$$\rho = \frac{m}{V} \qquad \text{density} = \frac{\text{mass}}{\text{volume}}$$

The symbol ρ is the Greek letter **rho**. Aluminium has a density of 2.7 g/cm^3: every cubic centimetre of aluminium has a mass of 2.7 g. Water has a density of 1.0 g/cm^3: 1 cm^3 of water has a mass of 1.0 g.

Density belongs to the **material**, not to the object. Cut a steel bar in half and each half has half the mass and half the volume, so the density is unchanged. A steel pin and a steel girder have the same density.

Units

Mass in	Volume in	Density in
g	cm^3	g/cm^3
kg	m^3	kg/m^3

$1\ \mathrm{g/cm^3} = 1000\ \mathrm{kg/m^3}$, because 1 m^3 holds $100 \times 100 \times 100 = 1\,000\,000$ cm^3, and $1\,000\,000$ g is 1000 kg. So water is 1.0 g/cm^3 or 1000 kg/m^3, and steel of 7.9 g/cm^3 is 7900 kg/m^3. Going the other way, 1200 kg/m^3 is 1.2 g/cm^3.

Always keep the units matched: grams with cm^3, kilograms with m^3. Never divide kilograms by cm^3.

What changes density and what doesn't

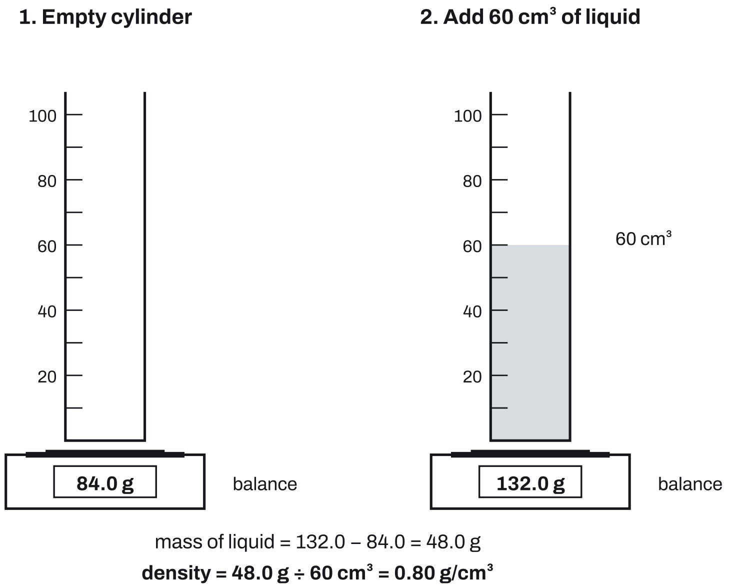
- **Moving an object** (to the Moon, to another planet) changes its weight but **not** its mass or volume, so its density stays the same.
- **Squashing** an object with air pockets (a sponge, foam) reduces its volume but **not** its mass (nothing has left it), so its density goes **up**. Its mass and weight don't change.
- **Heating** makes most materials expand: the mass is the same, the volume is bigger, so the density goes **down**. A 270 g block of 100 cm^3 has density 2.7 g/cm^3; if it expands to 101 cm^3 the density drops to about 2.67 g/cm^3. This is why hot air rises.
- **Breaking** something inside a sealed container doesn't change the total mass: no matter gets in or out.

Measuring density

Every method measures two things, **mass with a balance** and **volume**, then divides. Only the way of finding the volume changes.

A regularly shaped solid. Find the mass on a balance. Measure the length, width and height with a ruler (or the diameter and length of a cylinder), and work out the volume: $V = \mathrm{length} \times \mathrm{width} \times \mathrm{height}$. Then $\rho = m \div V$.

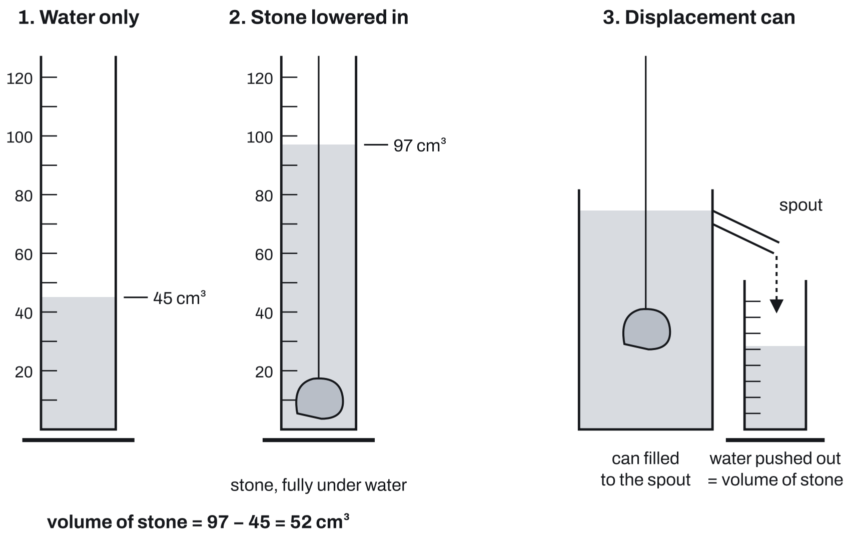
A liquid. Put an empty measuring cylinder (or beaker) on the balance and record its mass. Pour in some liquid, read the volume on the measuring cylinder (eye level with the bottom of the meniscus), and record the new mass. The liquid's mass is the **difference** between the two readings.



An irregularly shaped solid that sinks (a stone, a key, a necklace). Find its mass on a balance. You can't measure its sides with a ruler, so find its volume **by displacement**:

1. Part-fill a measuring cylinder with water and read the volume.
2. Lower the object in gently on a thread (so nothing splashes out or cracks the glass) until it is **completely under water**, and read the new volume.
3. The object's volume is the **increase** in reading: new reading – first reading.

If the object is too big for a measuring cylinder, use a **displacement (eureka) can**: fill it with water until water runs out of the spout, wait for the dripping to stop, then place an empty measuring cylinder under the spout and lower the object in. The water that runs out has the same volume as the object.



A balance measures mass, a measuring cylinder measures volume, and a ruler measures lengths for a regular shape. A stop-watch, thermometer or voltmeter plays no part.

Floating and sinking

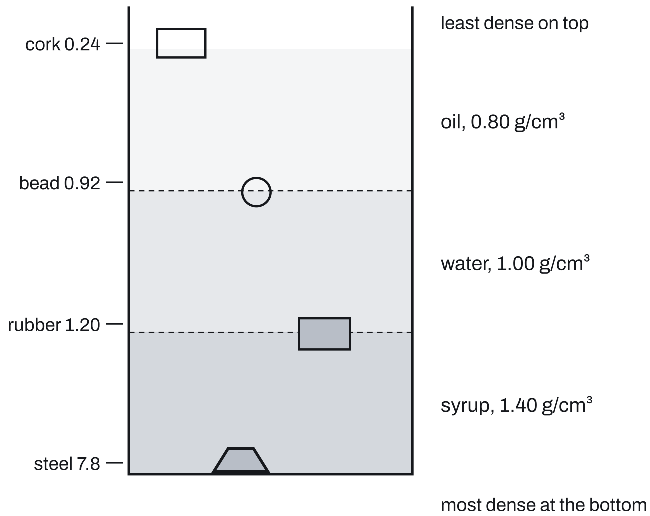
Compare the density of the object with the density of the liquid:

- **object less dense than the liquid → it floats;**
- **object denser than the liquid → it sinks.**

Ice (0.92 g/cm³) floats on water (1.0 g/cm³); a steel nut (7.8 g/cm³) sinks. Knowing only the masses, or only the volumes, is not enough: you need **both densities**.

For a hollow object, or one with more than one material in it, use its **average density**: total mass ÷ total volume (including the air inside). A steel ship floats even though steel is 7.8 times as dense as water, because the ship is mostly air: its total mass divided by the total volume of its hull is less than 1.0 g/cm³. A balloon floats in air if its average density (balloon, gas and instruments) is less than the air's, and stays still at the height where the two are equal.

Extended only: liquids that don't mix behave in the same way. They settle in layers with the **least dense on top** and the **densest at the bottom**, and a solid comes to rest on top of the first liquid that is denser than it.



An object floats on any liquid denser than itself and sinks through any liquid less dense.

Key facts and formulas

The 0625 papers have no formula sheet, so learn the equation.

Formula	Status
Density: $\rho = \dfrac{m}{V}$ (mass per unit volume)	Learn it
Rearranged: $m = \rho V, V = \dfrac{m}{\rho}$	Learn it
Volume of a cuboid $=$ length $\times$ width $\times$ height	Learn it

Formula	Status
Volume by displacement $=$ reading with object $-$ reading without	Learn it
Units: g/cm³ or kg/m³; 1 g/cm³ $= 1000$ kg/m³	Learn it
Density of water $= 1.0$ g/cm³ $= 1000$ kg/m³ (given in the question when needed)	Learn it
Floats if $\rho_{\text{object}} < \rho_{\text{liquid}}$; sinks if $\rho_{\text{object}} > \rho_{\text{liquid}}$	Learn it

How to do it

In the Paper 1 to 4 questions we have tagged for this topic (74 different questions about density, 2021–2025; 21 more appear on two or more papers; two more tagged questions never ask about density and are left out: one asks for the area, weight and pressure of a metal block, the other for the instruments that measure a block's mass and sides (a balance and a ruler), then its weight, area and pressure), the types came up this often. 21 of the 74 questions mix two or three types, so the counts add up to more than 74.

Question type	Questions
Calculating density, mass or volume	45
Measuring density: method and apparatus	20
Floating, sinking and layers	20
What density means: definition, symbol, what changes it	12

1. Calculating density, mass or volume (45 questions)

1. **Write the equation in symbols**: $\rho = \dfrac{m}{V}$.
2. **Get the mass and the volume.** You may have to work them out first: a volume from dimensions, a volume by displacement, or a mass by subtracting two balance readings.
3. **Match the units**: g with cm³, kg with m³.
4. **Rearrange if needed**: for mass, **multiply** $\rho \times V$; for volume, **divide** $m \div \rho$.
5. **Substitute, calculate, add the unit.**

For example, a 5.0 cm × 4.0 cm × 2.0 cm block has $V = 40$ cm³; if it has a mass of 316 g, $\rho = 316 \div 40 = 7.9$ g/cm³.

Variations you will meet:

- **Mixed units.** A 1.8 kg object of volume 600 cm³: change 1.8 kg to 1800 g, so $\rho = 1800 \div 600 = 3.0$ g/cm³. Or change cm to m **before** multiplying: a 10 cm × 8 cm × 5 cm block is $0.10 \times 0.08 \times 0.05 = 0.0004$ m³ (400 cm³ is 0.0004 m³, not 0.4).
- **Large volumes in metres.** A tank 40 m × 10 m filled to 1.5 m holds 600 m³; with water of 1000 kg/m³ its mass is $600 \times 1000 = 600\,000$ kg.

- **Mass by difference.** Container full minus container empty. A bottle of 40 g that has a mass of 88 g when holding 60 cm³ of liquid: $\rho = (88 - 40) \div 60 = 0.80$ g/cm³.
- **Adding more liquid to a cylinder already on a balance.** Use the **increase** in mass with the **increase** in volume. If the reading goes from 120 g to 150 g as the level goes from 50 cm³ to 80 cm³, $\rho = 30 \div 30 = 1.0$ g/cm³, not $30 \div 80$.
- **Displacement readings.** Volume = rise in level; mass from the balance. Don't use the final water level as the volume.
- **Which is least (or most) dense?** Work out mass ÷ volume for every row: 12 g in 10 cm³ is 1.2 g/cm³, 18 g in 20 cm³ is 0.9 g/cm³. The biggest mass is not always the densest.
- **Equal masses, different volumes** (**Extended only**). The **smallest volume is the densest**. In a cylinder of layers it sits at the bottom, so the first boundary is at its volume. With volumes of 120, 160 and 250 cm³, the boundaries are at 120 cm³ and 120 + 160 = 280 cm³.
- **A given density, find a mass or volume in a bigger question**: the mass of air in a room for a heating calculation, the mass of liquid above a block for a pressure question, the volume of a planet. Use $m = \rho V$ or $V = m \div \rho$, then carry the answer on.
- **An expression, not numbers.** A block of mass m with sides p, q, r has density $\dfrac{m}{pqr}$.

2. Measuring density: method and apparatus (20 questions)

1. **Say what you measure and with what**: mass with a **balance**; volume with a **measuring cylinder** (liquid, or an irregular solid by displacement) or a **ruler** (regular solid).
2. **Give the steps in order**, including any subtraction.
3. **Finish with the equation**: density = mass ÷ volume.

Variations you will meet:

- **Liquid.** Mass of the empty cylinder; pour in liquid and read its volume; mass of cylinder + liquid; subtract to get the liquid's mass; divide by the volume.
- **Irregular solid.** Mass on a balance; water in a measuring cylinder, read the level; lower the solid in so it is fully covered; read again; volume = difference. Or use a displacement can and collect the overflow.
- **Regular solid** (a copper block): a balance and a ruler. No measuring cylinder needed.
- **"Which apparatus?" tables.** Tick the balance and the measuring cylinder (or ruler for a regular block); cross the stop-watch and thermometer. For a necklace or a stone you need **both** a balance and a measuring cylinder: the cylinder alone can't give mass.
- **Which two readings?** For a rock in a cylinder on a balance: the **increase in mass** and the **increase in volume** of the liquid (not the increase in depth, and not the final reading).
- **Reading a measuring cylinder.** Work out what one small division is worth before reading, and read at the bottom of the meniscus with your eye level with it.

3. Floating, sinking and layers (20 questions)

1. **Get both densities** in the same units. Work them out from mass ÷ volume if you're given masses and volumes.
2. **Compare**: less dense than the liquid floats; denser sinks.
3. **Extended only, liquids:** order them from the least dense (top) to the densest (bottom).

Variations you will meet:

- **Several objects, one liquid.** Three hollow spheres of 40 cm³ with masses 18, 34 and 46 g in a liquid of 0.90 g/cm³: their densities are 0.45, 0.85 and 1.15 g/cm³, so only the first two float.
- **One object, several liquids.** Tick "floats" for each liquid that is denser than the object. Wood of 0.65 g/cm³ floats on a liquid of 0.78 g/cm³ and on one of 1.05 g/cm³; plastic of 0.88 g/cm³ floats only on the second.
- **"Which liquids rise to the surface of water?"** (**Extended only**) Those less dense than 1000 kg/m³.
- **"What information is needed to predict floating?"** The density of the object and the density of the liquid.
- **Explain why it floats.** Name both densities and compare them: "the ice is less dense than the water". For a steel ship or a hollow ball, say that it contains **air**, so its **average** density is less than the water's; saying "steel is denser, so it floats" or talking about the area of the base earns nothing.
- **A block resting between layers** (**Extended only**): it is denser than the liquid above and less dense than the liquid below.
- **A balloon stationary in air**: its average density equals the air's. If its gas cools and shrinks, its volume falls, its average density rises, and it sinks.
- **A leaking hollow ball** sinks once its average density reaches the liquid's. A 12 g ball of volume 30 cm³ reaches 1.0 g/cm³ when its total mass is 30 g, so after 18 g of water has leaked in.
- **Two liquids, one poured on the other** (**Extended only**): the one with the smaller density ends up on top. Explain it in terms of density, not mass: 1 cm³ of the lower liquid has more mass than 1 cm³ of the upper one.

4. What density means: definition, symbol, what changes it (12 questions)

1. **Definition**: mass per unit volume; symbol ρ; unit g/cm³ or kg/m³.
2. **Equation**: $\rho = m \div V$, so $m = \rho \times V$. Weight, area and force don't belong in it.
3. **What changes**: squashing or heating changes the volume and so the density; the mass stays the same unless matter is added or removed.

Variations you will meet:

- **"Which equation is correct?"** mass = density × volume. Density × volume is not weight, and density is not mass × volume.
- **"Which quantity is ρ?"** Density (not pressure, which uses p).
- **"Which two quantities are needed?"** Mass and volume.

- **Two blocks of the same size but different weights on force meters**: equal volumes, different masses, so different densities.
- **Foam squeezed smaller**: mass and weight unchanged, density up.
- **A liquid heated**: it expands, mass unchanged, density decreases.
- **A sealed bottle shaken until something inside breaks**: the total mass is the same each time.

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.
- **C1** compensatory mark: earned for working even though the final answer is wrong.

Example 1

A metal block measures 5.0 cm × 4.0 cm × 2.0 cm. Its mass is 316 g.

(a) Calculate the volume of the block. **[1]**

(b) Calculate the density of the metal. **[2]**

(c) Give this density in kg/m³. **[1]**

(d) Mercury has a density of 13.6 g/cm³. State whether the block floats or sinks in mercury, and give a reason. **[1]**

(a) $V = 5.0 \times 4.0 \times 2.0 = 40$ cm³ **B1**

(b) $\rho = \frac{m}{V}$ **C1** $= \frac{316}{40} = 7.9$ g/cm³ **A1**

(c) $7.9 \times 1000 = 7900$ kg/m³ **B1**

(d) It floats, because the metal (7.9 g/cm³) is less dense than mercury (13.6 g/cm³). **B1**

Example 2

A student wants to find the density of a small irregularly shaped stone. She has a balance, a measuring cylinder, water and some thread.

(a) Describe how she can find the volume of the stone. **[3]**

(b) The mass of the stone is 156 g. The water level rises from 45.0 cm³ to 97.0 cm³. Calculate the density of the stone. **[3]**

(a) Pour water into the measuring cylinder and read the volume. **B1** Tie the thread to the stone and lower it in until it is completely under the water; read the new volume. **B1** The volume of the stone is the new reading minus the first reading. **B1**

(b) Volume $= 97.0 - 45.0 = 52.0$ cm³ **C1**

$\rho = \frac{m}{V}$ **C1** $= \frac{156}{52.0} = 3.0$ g/cm³ **A1**

Example 3

A student places an empty measuring cylinder on a balance, which reads 84.0 g. She pours liquid X into the cylinder until it reads 60 cm³, and the balance then reads 132.0 g.

(a) Calculate the density of liquid X. **[3]**

(b) **Extended only.** Liquid X, water (1.00 g/cm³) and liquid Y (1.26 g/cm³) are poured gently into a tall beaker. They do not mix. A plastic bead of density 0.92 g/cm³ is then dropped in. State the order of the liquids from top to bottom, and state where the bead comes to rest. **[2]**

(a) Mass of liquid $= 132.0 - 84.0 = 48.0$ g **C1**

$\rho = \frac{m}{V} = \frac{48.0}{60}$ **C1** $= 0.80$ g/cm³ **A1**

(b) From the top: X (0.80), water (1.00), Y (1.26), least dense on top. **B1** The bead sinks through X, because it is denser than X, and floats on the water, because it is less dense than water: it rests at the boundary between X and the water. **B1**

Example 4

(a) A tank measures 2.0 m × 1.5 m × 0.80 m. It is full of sea water of density 1030 kg/m³. Calculate the mass of the sea water. **[3]**

(b) A hollow plastic ball has a mass of 12 g and a volume of 30 cm³. It floats on water of density 1.0 g/cm³.

(i) Calculate the average density of the ball. **[1]**

(ii) The ball has a small crack, and water slowly leaks in without changing the ball's volume. Calculate the mass of water that has entered when the ball just starts to sink. **[2]**

(a) $V = 2.0 \times 1.5 \times 0.80 = 2.4$ m³ **C1**

$m = \rho V$ **C1** $= 1030 \times 2.4 = 2472 \approx 2470$ kg **A1**

(b)(i) $\rho = \frac{12}{30} = 0.40$ g/cm³ **B1**

(b)(ii) It sinks when its average density reaches that of water, 1.0 g/cm³, so its total mass is $1.0 \times 30 = 30$ g. **C1** Mass of water $= 30 - 12 = 18$ g. **A1**

Common mistakes

- **Turning the equation upside down**: dividing volume by mass, or multiplying mass and volume. Examiners see this every year. Write $\rho = m \div V$ first, then rearrange: $m = \rho \times V$, not $V \div \rho$.
- **Using the total volume instead of the change.** When liquid is added to a cylinder, or a stone lowered in, the volume you want is the **increase** in reading, used with the **increase** in mass.
- **Adding lengths instead of multiplying them.** The volume of a 3 cm × 4 cm × 5 cm block is 60 cm³, not 12 cm³.
- **Mixing units**: kg with cm³, or cm lengths in a density given in kg/m³. Convert first. For big objects in km or m, convert to m before cubing.
- **Wrong or missing units.** Density is g/cm³ or kg/m³; examiners report "cm/g", "Pa" or "M/V" as units. Give a unit whenever the answer line doesn't print one.
- **Vague methods.** "Put it in water and measure" is not enough. Say that the **balance** measures **mass**, the **measuring cylinder** measures **volume**, that you subtract the empty mass, and that density = mass ÷ volume. A measuring cylinder cannot find a mass.
- **Picking a ruler for an irregular stone**, or leaving out the balance. A ruler is only for regular shapes.
- **Explaining floating without comparing densities.** "Steel is denser than water so the ship floats" and "it floats because of its large base" are wrong. Say that the ship's **average** density (with the air inside) is less than the water's.
- **Thinking mass changes** when an object is heated, squashed or broken. The mass is the same; the volume (and so the density) changes.
- **Rounding too far or not far enough.** Give 2 or 3 significant figures, as the data does.

How to get the marks

- **Calculations** earn a mark for the equation (in symbols, words or a correct substitution) and one for the answer; longer ones have a mark for the volume or the mass difference too. Write the equation, then the numbers, then the answer with its unit, so the method marks are safe even if you slip.
- **"Include the unit"** means a separate mark for g/cm³ or kg/m³.
- **"Describe an experiment to determine the density"** is usually marked out of 3 or 4: name the instruments and what each measures, give the subtraction, and write density = mass ÷ volume. A labelled diagram can help.
- **"Explain why it floats"** needs a comparison of two densities, naming both materials: "the wood is less dense than the sea water".
- **"Show that"** answers need the equation written, the substitution, and an answer to one more figure than the one printed.

- **Multiple choice.** Work the answer out before looking at the options. Wrong options are built from the usual slips: $V \div m$, $m \times V$, the total volume instead of the change, or the final balance reading instead of the increase.

Quick check

1. Define density and give two units for it.
2. A cube of side 3.0 cm has a mass of 72.9 g. Calculate its density.
3. Olive oil has a density of 0.92 g/cm³. Calculate the mass of 250 cm³ of it.
4. A stone of mass 30 g is lowered into a measuring cylinder, and the water level rises from 35 cm³ to 47 cm³. Calculate the density of the stone, and state whether it would float in water.
5. **Extended only.** Three liquids that don't mix, A (1.3 g/cm³), B (0.70 g/cm³) and C (1.0 g/cm³), are poured into a beaker. State their order from top to bottom.

Answers

1. Density is mass per unit volume. Units: g/cm³ and kg/m³ (1 g/cm³ = 1000 kg/m³).
2. $V = 3.0^3 = 27$ cm³. $\rho = 72.9 \div 27 = 2.7$ g/cm³ (that is 2700 kg/m³).
3. $m = \rho V = 0.92 \times 250 = 230$ g.
4. $V = 47 - 35 = 12$ cm³. $\rho = 30 \div 12 = 2.5$ g/cm³. It sinks, because 2.5 g/cm³ is more than water's 1.0 g/cm³.
5. B (0.70) on top, then C (1.0), then A (1.3) at the bottom.

Past questions to try

- **0625/31/O/N/24 Q3**: volume of a metal piece by displacement, then its density.
- **0625/22/M/J/22 Q5**: density from the increase in mass and the increase in volume.
- **0625/33/O/N/23 Q3**: volume from mass and density, then where two spoons settle in oil and water.
- **0625/42/F/M/23 Q2**: why a steel ship floats (Extended).