Measurement and density

Teacher review edition. Ask your teacher if anything is unclear.

Why can a small piece of metal have more mass than a large piece of foam?

What you will learn

- Measure length, mass and liquid volume.
- Calculate the area and volume of a rectangular object.
- Find the density of a regular or irregular solid.

Measuring length and mass

Length
Distance between two points, usually measured in metres (m), centimetres (cm) or millimetres (mm).

Mass
The amount of matter in an object, measured in kilograms (kg) or grams (g).

- Measure length with a ruler or measuring tape. Use metres (m), centimetres (cm) or millimetres (mm).
- Place the object at the zero mark. Read the scale directly above its other end.
- If the object starts at another mark, subtract the starting reading from the final reading.
- Measure mass with a balance. Common units are grams (g) and kilograms (kg): 1000 g = 1 kg.

Quantity	Instrument	Common units
Length	Ruler or measuring tape	m, cm, mm
Mass	Balance	kg, g
Liquid volume	Measuring cylinder	mL or cm^3

Area is the size of a surface

Area
The size of a surface, measured in square units such as cm².

area = length × width

- For a rectangle: area = length × width.
- Use the same unit for both lengths.
- A card measuring 8 cm × 3 cm has an area of 24 cm².
- The unit cm² means square centimetres: the number of 1 cm by 1 cm squares covering the surface.

Volume is the space an object takes up

Volume
The space an object or substance takes up. It can be measured in cm³ or mL; 1 mL = 1 cm³.

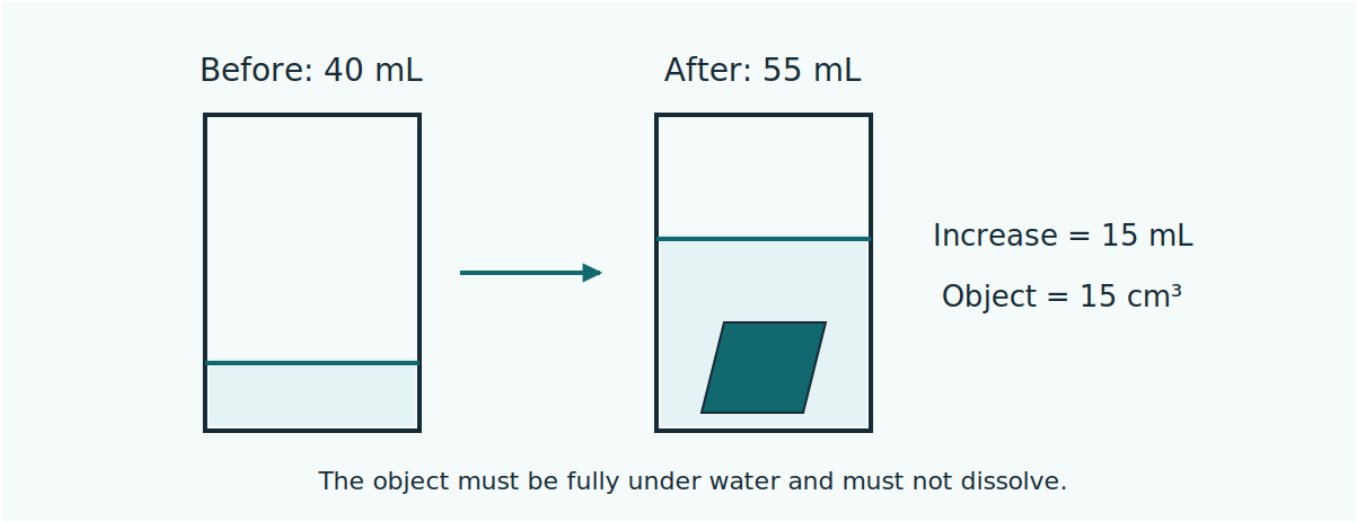
volume = length × width × height

- For a rectangular block: volume = length × width × height.
- A block measuring 4 cm × 3 cm × 2 cm has a volume of 24 cm³.
- One cm³ is the volume of a cube with sides of 1 cm. One mL = 1 cm³.
- Measure liquid volume with a measuring cylinder. For water, read the bottom of the curved surface (the meniscus) at eye level.

Finding the volume of an irregular solid

Water displacement
A method for finding the volume of an irregular object by measuring the water it pushes aside. When the object is completely under water, the volume of water displaced equals the volume of the object.

- Record the initial water reading, then lower the object gently into the water.
- Completely submerge it and remove trapped air bubbles. Record the new reading.
- Object volume = final reading − initial reading.
- A rise from 40 mL to 55 mL gives a volume of 15 mL = 15 cm³.
- The object must not dissolve or change in water. A sugar cube is unsuitable because it dissolves.



The rise in water level gives the volume of the fully submerged object: 55 − 40 = 15 mL, equal to 15 cm³. The object must not dissolve.

What does density tell us?

Density
The mass in each unit of volume. Calculate it by dividing mass by volume.

Density compares the masses of equal volumes of material.

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

- For equal-sized cubes, the iron cube has more mass than the wooden cube. Iron is denser.
- Density = mass ÷ volume.
- Use mass in g and volume in cm³ to obtain density in g/cm³.
- A density of 3 g/cm³ means each cubic centimetre has a mass of 3 g.

A bigger object is not always denser

A larger piece of the same material has more mass and more volume, but usually the same density.

- If every side of a cube doubles, its surface area becomes four times as large.
- Its volume becomes eight times as large.
- For the same material, its mass also becomes eight times as large. Mass divided by volume stays the same.

Recording a useful measurement

Choose an instrument suited to the measurement.

- A ruler can measure a notebook's length, but not the size of a single cell.
- Record a unit with each measurement.
- Repeat measurements where possible.
- Only record the precision the instrument allows. Extra calculator digits do not improve a rough measurement.

Worked examples

A block has a mass of 72 g. It measures 4 cm long, 3 cm wide and 2 cm high. Find its volume and density.

Work through it

1. Multiply the three lengths: volume = 4 × 3 × 2 = 24 cm³.
2. Divide mass by volume: density = 72 ÷ 24 = 3 g/cm³.
3. This means each cubic centimetre of the material has a mass of 3 g.

$$\text{volume} = 4 \times 3 \times 2 = 24 \text{ cm}^3$$

$$\text{density} = \frac{72}{24} = 3 \text{ g/cm}^3$$

Find density using water displacement

A stone has a mass of 54 g. The water in a measuring cylinder rises from 35 mL to 55 mL when the stone is fully submerged. Find the density of the stone.

Working	Why?
Volume = 55 − 35 = 20 mL = 20 cm³	Subtract the starting reading. Only the rise is due to the stone. 1 mL equals 1 cm³.
Density = mass ÷ volume	Use the mass and volume of the stone, not of the water.
Density = 54 g ÷ 20 cm³ = 2.7 g/cm³	Divide the values and include the density unit.

Try it yourself

A 78 g object raises the water from 40 mL to 50 mL. Calculate its density.

Check your answer: Volume = 50 − 40 = 10 cm^3. Density = 78 ÷ 10 = 7.8 g/cm^3.

Common mistakes

Common mistake: Using the final cylinder reading as the object's volume.

Remember: Subtract the initial water reading from the final reading.

Common mistake: Assuming the object with more mass must be denser.

Remember: Compare mass divided by volume. A larger object may simply contain more material.

Answering questions

- Write the volume calculation before calculating density. Keep all lengths in the same unit.
- Match the density unit to your measurements: g with cm^3 gives g/cm^3; kg with m^3 gives kg/m^3.

Try an investigation

Use a balance to measure the mass of a solid. Find its volume from its dimensions or by water displacement, then calculate its density. Repeat with other pieces of the same material. Plot mass against volume and look for a pattern. Lower objects gently into measuring cylinders.

Plan, record and review

- Question and prediction: What are you testing, and what do you think will happen? Give a reason.
- Change, measure, keep the same: What will you deliberately change? What will you measure, and in what units? What stays the same to make it a fair test? For an observation, say what you will record consistently instead.
- Record and look for a pattern: Use a table with headings and units. Look for a pattern or a result that does not fit.
- Conclude from evidence: Answer your question using a result or observation. Say if the evidence is unclear.
- Improve the investigation: What would you repeat or change, and how would that make the evidence better?

Do practical work with your teacher and follow the laboratory safety instructions.