

Density calculations and required practical

AQA GCSE Physics 8463 and Combined Science Trilogy 8464 | Paper 1 | Foundation and Higher

Worked solutions and teaching prompts | 32 parts | 56 marks

Specification points covered

Density, mass and volume; unit conversions and explaining density using particle spacing: 8463 4.3.1.1; 8464 6.3.1.1

Measure density of regular solids, irregular solids and liquids: 8463 required practical 5; 8464 required practical 17

Select apparatus, calculate volumes from dimensions or displacement, and evaluate measurement methods and evidence.

A salvage workshop checks metal parts for reuse and tests a replacement cooling liquid. Use density measurements to identify suitable samples and check claims. All comparison values and acceptance limits are supplied for this exercise.

Every part is shared content for both routes and tiers. Accept equivalent wording and consistent follow-through. Suggested timing is not classroom-tested. This original PhysicsUK resource is not an official AQA paper or mark scheme.

1 Checking density calculations

Each part refers to a separate workshop sample.

1(a) A technician compares the mass per unit volume of two metal samples. Name this physical quantity. **[1 mark]**

Answer / mark points: Density. [1] It is mass per unit volume, not total mass or weight.

1(b) A sample has mass 54.0 g and volume 20.0 cm³. Calculate its density in g cm⁻³. **[1 mark]**

Answer / mark points: $\rho = m / V = 54.0 / 20.0 = 2.70 \text{ g cm}^{-3}$. [1]

1(c) A replacement insert has density 2.70 g cm⁻³ and volume 35.0 cm³. Calculate its mass. **[1 mark]**

Answer / mark points: $m = \rho V = 2.70 \times 35.0 = 94.5 \text{ g}$. [1]



1 Checking density calculations continued

1(d) A sample has mass 121.5 g and density 2.70 g cm^{-3} . Calculate its volume. [1 mark]

Answer / mark points: $V = m / \rho = 121.5 / 2.70 = 45.0 \text{ cm}^3$. [1]

1(e) A small part occupies 6.0 cm^3 . Convert its volume to m^3 . [1 mark]

Answer / mark points: $V = 6.0 \times 0.000001 = 0.0000060 \text{ m}^3$. [1]

Teacher prompt: A volume conversion cubes the length conversion: $1 \text{ cm}^3 = (0.01 \text{ m})^3$, not 0.01 m^3 .

1(f) A sample has density 2.70 g cm^{-3} . Convert this to kg m^{-3} . Show the mass and volume conversions. [2 marks]

Answer / mark points: $2.70 \text{ g} = 0.00270 \text{ kg}$ and $1 \text{ cm}^3 = 0.000001 \text{ m}^3$. [1 for both]
 $\rho = 0.00270 / 0.000001 = 2700 \text{ kg m}^{-3}$. [1]

2 Checking a regular metal part

Figure 1 shows a solid cuboid with mass 106.8 g. The drawing is not to scale.

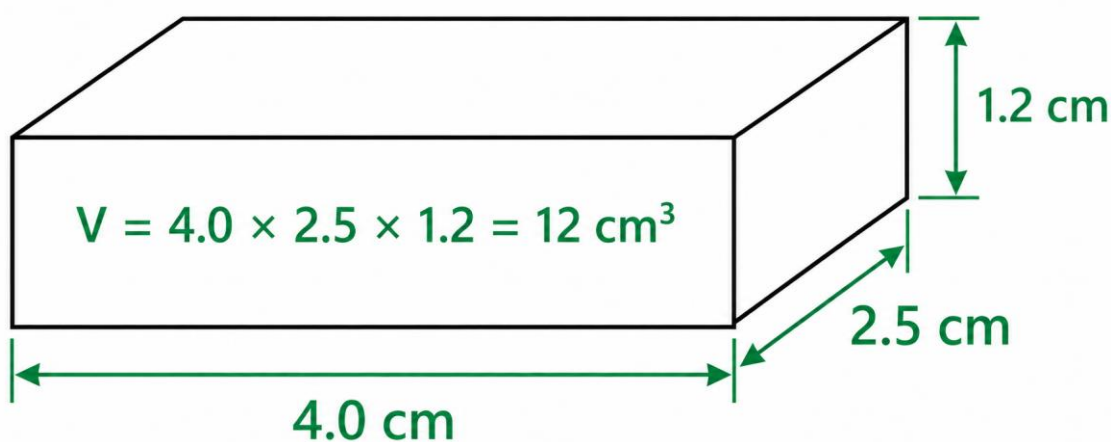


Figure 1

2(a) Use the three perpendicular dimensions in Figure 1 to calculate the cuboid's volume in cm^3 . [1 mark]

Answer / mark points: $V = \text{length} \times \text{width} \times \text{height} = 4.0 \times 2.5 \times 1.2 = 12 \text{ cm}^3$. [1]

2(b) Calculate the density of the cuboid in g cm^{-3} . [1 mark]

Answer / mark points: $\rho = 106.8 / 12 = 8.9 \text{ g cm}^{-3}$. [1]



2 Checking a regular metal part continued

Table 1

Material	Supplied density / g cm^{-3}
Steel	7.8
Aluminium	2.7
Copper	8.9

2(c) Use Table 1 to identify the material most consistent with the cuboid's density. Explain why density alone does not prove its identity. **[2 marks]**

Answer / mark points: Copper is most consistent: 8.9 g cm^{-3} matches the supplied copper value. [1] Another material/alloy may have a similar density, so a density match is evidence rather than proof of identity. [1]

2(d) A smaller piece cut from the same cuboid has mass 26.7 g and volume 3.0 cm^3 . Calculate its density. **[1 mark]**

Answer / mark points: $\rho = 26.7 / 3.0 = 8.9 \text{ g cm}^{-3}$. [1]

2(e) The solid cuboid is cut into two equal-volume pieces without losing material. Explain why each piece has the original density. **[2 marks]**

Answer / mark points: Each piece has half the original mass and half its volume. [1] Their ratio m / V is unchanged, so density is unchanged. [1]

Teacher prompt: A smaller sample is not less dense simply because its total mass is smaller.

2(f) Describe how to determine the density of another solid cuboid using a balance and a ruler or callipers. Include measurements and a calculation. **[3 marks]**

Answer / mark points: Check/zero the balance and measure the dry cuboid's mass. [1] Measure its three perpendicular dimensions with a ruler/callipers and calculate $V = \text{length} \times \text{width} \times \text{height}$. [1] Calculate $\rho = m / V$ using consistent units. [1] Repeat dimension readings at suitable positions to check consistency; account for any zero error.



3 Measuring an irregular metal part

Figure 2 shows water before and after a solid part is fully immersed. Its mass is 67.5 g. It does not absorb water or dissolve; ignore the volume of the thin thread. The apparatus drawing is not to scale; use the marked volume scales.

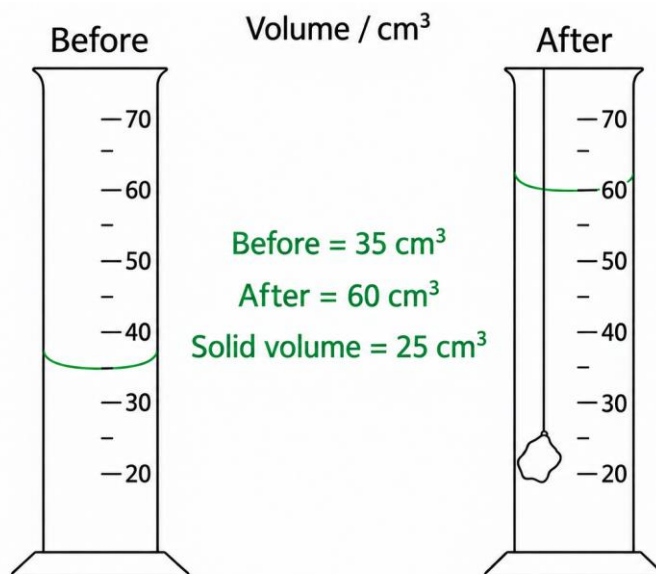


Figure 2

3(a) Read the water volumes before and after immersion from Figure 2. **[2 marks]**

Answer / mark points: Before = 35 cm³. [1] After = 60 cm³. [1] Read the bottom of each concave meniscus.

3(b) Calculate the volume of the solid part from the two readings. **[1 mark]**

Answer / mark points: $V = 60 - 35 = 25 \text{ cm}^3$. [1]

3(c) Calculate the density of the 67.5 g part in g cm⁻³. **[1 mark]**

Answer / mark points: $\rho = 67.5 / 25 = 2.70 \text{ g cm}^{-3}$. [1]

3(d) A different part has mass 117 g. A cylinder reading rises from 28 cm³ to 43 cm³ when it is fully immersed. Calculate its density. **[2 marks]**

Answer / mark points: $V = 43 - 28 = 15 \text{ cm}^3$. [1] $\rho = 117 / 15 = 7.8 \text{ g cm}^{-3}$. [1]



3 Measuring an irregular metal part continued

3(e) An air bubble remains attached to the submerged part. The mass measurement is correct. Explain how this affects the calculated density. **[2 marks]**

Answer / mark points: The bubble also displaces water, so the measured volume is too large. [1]
Dividing the correct mass by this larger volume makes the calculated density too low. [1]

3(f) Only part of the solid is submerged, but the technician uses the mass of the whole part. Explain how this affects the calculated density. **[2 marks]**

Answer / mark points: The displaced volume is smaller than the whole solid's volume. [1] Using the whole mass with this underestimated volume gives a density that is too high. [1]

3(g) Describe how to read a water-filled measuring cylinder and explain why the viewing position matters. **[2 marks]**

Answer / mark points: Keep the cylinder upright on a level surface and read the bottom of the meniscus with the eye at that level. [1] Viewing from above or below can cause parallax, giving an incorrect volume reading. [1]

4 Improving the measurements

The workshop repeats displacement tests before accepting its results.

4(a) The final water volume is about 60 cm^3 and the part fits both cylinders. Choose a 100 cm^3 cylinder with 1 cm^3 divisions or a 250 cm^3 cylinder with 5 cm^3 divisions. Justify your choice. **[2 marks]**

Answer / mark points: Choose the 100 cm^3 cylinder: it holds the final volume. [1] Its smaller divisions give better resolution/a smaller reading uncertainty. [1]

4(b) Three repeated displacement measurements give volumes 25, 26 and 24 cm^3 . Calculate their mean. **[1 mark]**

Answer / mark points: Mean $V = (25 + 26 + 24) / 3 = 25 \text{ cm}^3$. [1]

4(c) Explain why repeating the measurements and using a mean can improve the density estimate. State one type of error this does not remove. **[2 marks]**

Answer / mark points: A mean can reduce the effect of random variations in the measurements. [1]
It does not remove a systematic error, such as a balance zero error or a consistently incorrect volume scale. [1]



4 Improving the measurements continued

4(d) Write a method to determine the density of another irregular metal part using a balance and the displacement technique in Figure 2. The part sinks, does not dissolve or absorb water, and fits fully inside the cylinder. Include a reliable volume measurement and safe handling. Use this order: mass → initial volume → immersion → final volume → density → checks. **[6 marks]**

Answer / mark points: Model method: Check/zero the balance and measure the dry part's mass. Choose a cylinder with fine divisions that is wide enough for the part and has room for the final water level. Put it upright on a level surface and partly fill it with water. Read the initial volume at the bottom of the meniscus with the eye at that level.

Lower the part gently on a thin thread until completely submerged. Remove trapped bubbles and avoid losing water by splashing. Read the final volume in the same way. The part's volume is final reading minus initial reading; ignore the negligible thread volume.

Calculate density = mass / volume using consistent units. Repeat the displacement measurement, record both readings each time and find a mean of consistent volumes. Use a stable surface, lower the part slowly to protect the glass, and wipe up spills. Dry the part before repeating any mass measurement.

Holistic marking: 5–6 for a logically ordered usable method obtaining the part's mass and valid volume, then density, with useful checks; 3–4 for a mostly workable method with an omission; 1–2 for isolated relevant steps. 0 for no relevant physics. Choose the level then the mark for completeness and clarity, not six automatic ticks.

Teacher prompt: The final cylinder reading is water PLUS the part's displaced volume, not the part's volume alone. For an oversized part, a correctly prepared displacement can is a valid alternative apparatus.

5 Checking the cooling liquid

Table 2 gives readings for two liquid batches at the same temperature. The density acceptance range is 1030–1090 kg m⁻³, inclusive. This is a density check only.

Table 2

Batch	Empty cylinder / g	Cylinder plus liquid / g	Liquid volume / cm ³
A	64.0	140.0	80.0
B	64.0	149.6	80.0

5(a) Use Table 2 to calculate the mass of liquid in batch A, excluding the cylinder. **[1 mark]**

Answer / mark points: $m = 140.0 - 64.0 = 76.0$ g. [1]

5(b) Calculate the density of batch A in g cm⁻³. **[1 mark]**

Answer / mark points: $\rho = 76.0 / 80.0 = 0.950$ g cm⁻³. [1]

5(c) Convert the density of batch A to kg m⁻³. **[1 mark]**

Answer / mark points: 0.950 g cm⁻³ = 950 kg m⁻³. [1]



5 Checking the cooling liquid continued

5(d) Use Table 2 to calculate the density of batch B in g cm^{-3} . [2 marks]

Answer / mark points: $m = 149.6 - 64.0 = 85.6 \text{ g}$. [1] $\rho = 85.6 / 80.0 = 1.07 \text{ g cm}^{-3}$. [1]

5(e) Which batch passes the density check? Compare BOTH batches with the 1030–1090 kg m^{-3} acceptance range. [2 marks]

Answer / mark points: B passes: $1.07 \text{ g cm}^{-3} = 1070 \text{ kg m}^{-3}$, within the range. [1] A fails: 950 kg m^{-3} is below 1030 kg m^{-3} . [1] This does not establish chemical compatibility or real-system safety.

5(f) The workshop needs 1.50 L of batch B. Use its density of 1070 kg m^{-3} to calculate the mass needed in kg. [2 marks]

Answer / mark points: $V = 1.50 \times 1000 \times 0.000001 = 0.00150 \text{ m}^3$. [1] $m = \rho V = 1070 \times 0.00150 = 1.605 \text{ kg}$ (1.61 kg to three significant figures). [1]

5(g) A trainee divides the cylinder-plus-liquid mass by the liquid volume without subtracting the empty-cylinder mass. Explain the effect on the calculated density. [2 marks]

Answer / mark points: The mass used includes the cylinder, so it is too large for the liquid sample. [1] At the correct liquid volume, the calculated density is too high. [1]

5(h) Describe a method to determine an unknown liquid's density using a balance and a measuring cylinder. Include how to find the liquid's mass. [3 marks]

Answer / mark points: Measure the mass of the dry, empty cylinder with a checked/zeroed balance. Add liquid and read its volume at the bottom of the meniscus at eye level. [1] Measure cylinder plus liquid and subtract empty-cylinder mass. [1] Calculate $\rho = \text{liquid mass} / \text{liquid volume}$ with consistent units. [1] Use an appropriate fine-scale cylinder, keep its outside dry and repeat readings at the same temperature. Alternatively tare the empty cylinder before adding liquid.

6 Connecting density to particles

A liquid sample and a vapour sample of the SAME substance have equal mass. The vapour occupies a much larger volume.

6(a) Explain why the vapour has a lower density than the liquid in terms of particle spacing and mass per unit volume. Do not say the particles themselves expand. [2 marks]

Answer / mark points: The vapour particles are much farther apart than the closely spaced liquid particles. [1] The same mass occupies a larger volume, so mass per unit volume/density is lower. [1]

Teacher prompt: Gas particles are not larger particles. Both solids and liquids have closely spaced particles; do not claim every solid is denser than its liquid.

Review and improve

Use the volume of the sample, not the final water reading. Subtract container mass for liquids. For fixed mass, an overestimated volume gives an underestimated density. Repeats do not remove a systematic error.

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