

Density of materials

6.3.1.1 · Physics · revision notes

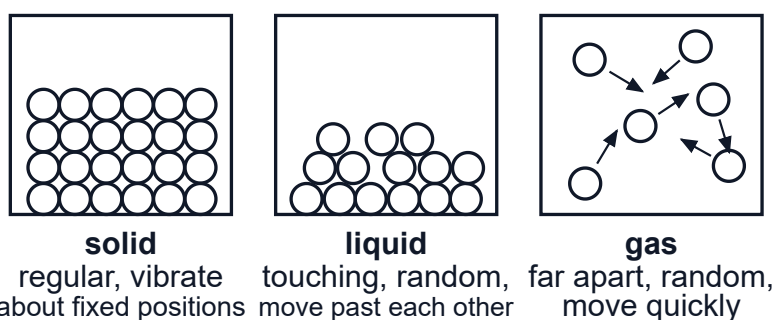
Density tells you how much mass is packed into each unit of volume of a material. You need to recall and use $\rho = m / V$, explain the different densities of solids, liquids and gases using the particle model, and describe the density required practical. Expect calculations (often with unit conversions), particle-diagram questions and 4 to 6 mark method questions.

Key facts

- density = mass $\div$ volume, $\rho = m / V$ (recall it: not on the equation sheet)
- $1 \text{ g/cm}^3 = 1000 \text{ kg/m}^3$
- Solid: regular, touching, vibrate about fixed positions
- Gas: random, far apart, move quickly in all directions
- Volume of an irregular object: displacement of water (eureka can and measuring cylinder)
- ρ in kg/m^3 , m in kg , V in m^3
- $1 \text{ m}^3 = 1\,000\,000 \text{ cm}^3$; $1 \text{ cm}^3 = 1 \text{ ml}$
- Liquid: random, close together, move past each other
- Gases have a much lower density: particles far apart, so less mass per m^3

The particle model of solids, liquids and gases

- In a **solid**, the particles are touching and packed in a regular arrangement. They vibrate about fixed positions.
- In a **liquid**, the particles are still close together (mostly touching) but in a random arrangement. They can move past each other.
- In a **gas**, the particles are far apart in a random arrangement. They move quickly in all directions.
- In particle diagrams, draw the particles the same size in all three states: only their arrangement and spacing change.



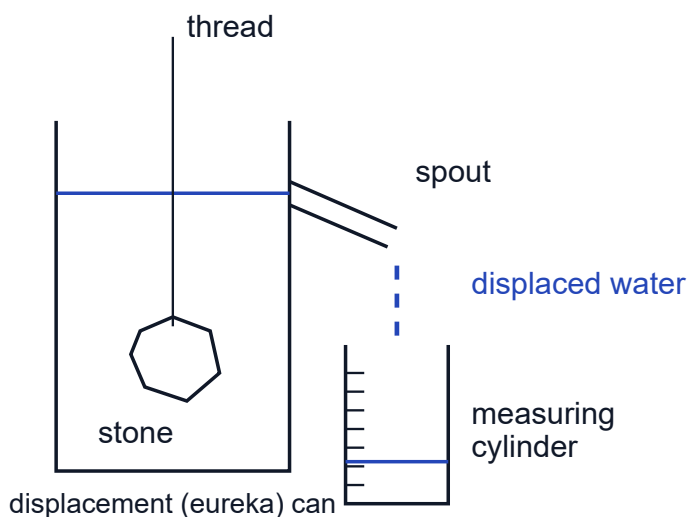
Same-sized particles in all three states: only the arrangement and spacing change.

Density

- **Density** is the mass per unit volume of a material: $\rho = m / V$.
- ρ (rho) is density in kg/m^3 , m is mass in kg and V is volume in m^3 . You must recall this equation: it is not on the equation sheet.
- Density is often given in g/cm^3 . $1 \text{ g/cm}^3 = 1000 \text{ kg/m}^3$. Water has a density of about 1000 kg/m^3 (1 g/cm^3).
- The solid and liquid forms of a substance have similar densities because in both the particles are close together.
- The gas form has a much lower density because its particles are far apart: each cubic metre contains far fewer particles, so much less mass.

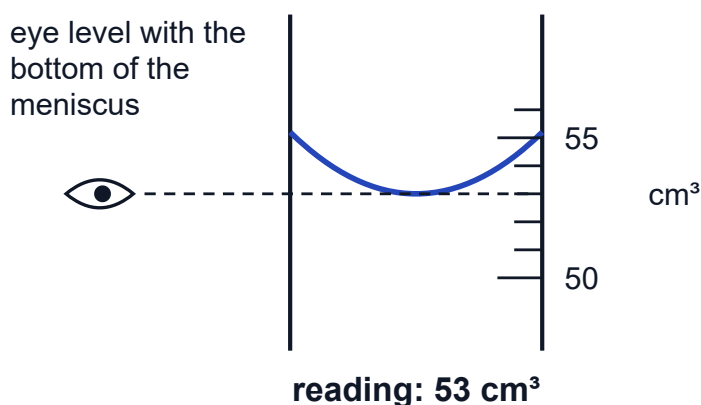
Required practical: measuring density

- Measure the mass with a top-pan balance.
- **Regular solid** (e.g. a cuboid): measure the length, width and height with a ruler (or vernier callipers for small lengths), then $\text{volume} = \text{length} \times \text{width} \times \text{height}$.
- **Irregular solid** (e.g. a stone): fill a **displacement (eureka) can** with water up to the spout, lower the object in and collect the water that overflows in a measuring cylinder. The volume of water displaced equals the volume of the object.



Volume of water collected = volume of the stone.

- Or lower the object into a measuring cylinder part-filled with water: $\text{volume of object} = \text{new reading} - \text{starting reading}$.
- **Liquid**: put an empty measuring cylinder on the balance and zero it, pour in some liquid, then read the mass and the volume.
- Read a measuring cylinder at eye level, from the bottom of the meniscus. $1 \text{ ml} = 1 \text{ cm}^3$. Then calculate $\rho = m / V$.



Read from the bottom of the meniscus, with your eye level with it.

How to answer each type of question

Calculate density (with a unit conversion)

2 to 3 marks

Grade 5

1. Write $\rho = m / V$.
2. Check the unit the question wants. For kg/m^3 , either convert g to kg and cm^3 to m^3 first, or work in g/cm^3 and multiply by 1000 at the end.
3. Substitute, calculate and give the unit.

Example. A metal block measures $2.0 \text{ cm} \times 3.0 \text{ cm} \times 5.0 \text{ cm}$. Its mass is 243 g.
Calculate the density of the metal in kg/m^3 .

Model answer. Volume = $2.0 \times 3.0 \times 5.0 = 30 \text{ cm}^3$ (1)

$$\rho = 243 \div 30 = 8.1 \text{ g/cm}^3 \text{ (1)}$$

$$8.1 \times 1000 = 8100 \text{ kg/m}^3 \text{ (1)}$$

(Or: $V = 3.0 \times 10^{-5} \text{ m}^3$ and $m = 0.243 \text{ kg}$, so $\rho = 0.243 \div (3.0 \times 10^{-5}) = 8100 \text{ kg/m}^3$.)

Describe how to measure the density of an object (required practical)

4 to 6 marks

Grade 5

1. Say how you measure the mass: a top-pan balance.
2. Say how you find the volume: measure the dimensions (regular shape) or use displacement of water (irregular shape).
3. Say how you calculate the density: mass $\div$ volume.
4. Add a detail that improves accuracy, e.g. read the meniscus at eye level.

Example. Describe a method a student could use to determine the density of a small, irregularly shaped stone. (4 marks)

Model answer. Measure the mass of the stone with a top-pan balance (1). Fill a displacement (eureka) can with water up to the spout and, when it stops dripping, put an empty measuring cylinder under the spout (1). Lower the stone gently into the can and collect the water that overflows in the measuring cylinder (1). The volume of water collected equals the volume of the stone, so density = mass $\div$ volume (1).

Don't lose marks

- ✗ Mixing units, e.g. grams with m^3 or kg with cm^3 , which makes the answer wrong by a factor of 1000 or 1 000 000.
- ✗ Converting cm^3 to m^3 by dividing by 100 or 1000 instead of 1 000 000.
- ✗ Writing that gas particles are bigger, smaller or lighter. The particles are the same; they are just further apart.
- ✗ Drawing liquid particles spread out like a gas. Liquid particles should mostly be touching.

- ✗ Taking the final measuring cylinder reading as the object's volume instead of the change in reading.

More tips

Memory tricks

- Density triangle: m on top, ρ and V on the bottom. Cover the one you want: $\rho = m \div V$, $V = m \div \rho$, $m = \rho \times V$.
- Sense check: water is 1000 kg/m^3 . Most solids and liquids are between a few hundred and about $20\,000 \text{ kg/m}^3$; gases at room temperature are only a few kg/m^3 or less.
- g/cm^3 to kg/m^3 : multiply by 1000. kg/m^3 to g/cm^3 : divide by 1000.
- cm^3 to m^3 : divide by 1 000 000 ($100 \times 100 \times 100$).

Exam technique

- Write $\rho = m / V$ down before you substitute: it is a recall equation, and the correct equation or substitution often earns the first mark.
- Look at the unit the question asks for before you start, and convert consistently.
- In particle explanations, use comparisons: 'further apart', 'closer together', 'less mass per unit volume'.
- In practical questions, name the equipment (top-pan balance, ruler, eureka can, measuring cylinder) and say what you do with each measurement.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3

Draw particle diagrams for the three states

Solid: particles touching in regular rows; liquid: particles touching but jumbled; gas: particles far apart and random.

Grade 4

Recall and use density = mass $\div$ volume

Substitute into $\rho = m / V$ with mass in kg and volume in m^3 to get a density in kg/m^3 .

Grade 5

Rearrange the density equation

Use $m = \rho \times V$ to find a mass and $V = m \div \rho$ to find a volume.

Grade 5

Describe the density required practical

Measure mass on a balance and find volume from measured dimensions or by displacement of water.

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