

Speed, density, pressure and best buys

R11 · Ratio, proportion and rates of change · revision notes

Speed, density and pressure are compound measures: each one combines two other measures, such as distance and time. Questions ask you to use the three formulas (and other rates such as pay per hour), change times and units first, and often link to the area or volume of a shape. Working out the best buy is part of this subtopic too.

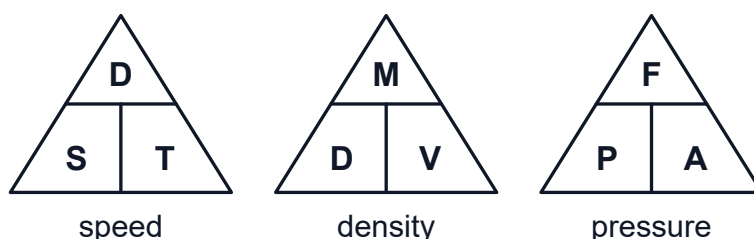
Key facts

- Speed = $\frac{\text{distance}}{\text{time}}$
- Pressure = $\frac{\text{force}}{\text{area}}$
- Minutes to hours: $\div 60$ (15 minutes = 0.25 hours, 20 minutes = $\frac{1}{3}$ hour)
- $1 \text{ m}^2 = 10\,000 \text{ cm}^2$; $1 \text{ m}^3 = 1\,000\,000 \text{ cm}^3$
- Best buy: work out the price per 100 g (or per unit) for each option; the lowest is the best buy
- Density = $\frac{\text{mass}}{\text{volume}}$
- Average speed = total distance $\div$ total time
- km/h to m/s: $\div 3.6$; m/s to km/h: $\times 3.6$
- Units: km/h, m/s, mph; g/cm³, kg/m³; N/m²

Notes

The three formulas

- Speed = distance $\div$ time, so distance = speed $\times$ time and time = distance $\div$ speed.
- Density = mass $\div$ volume, so mass = density $\times$ volume and volume = mass $\div$ density.
- Pressure = force $\div$ area, so force = pressure $\times$ area and area = force $\div$ pressure.



Cover the one you want: side by side means multiply, one above the other means divide (e.g. $S = D \div T$).

- The units come from the formula: km $\div$ h gives km/h, g $\div$ cm³ gives g/cm³, and N $\div$ m² gives N/m².
- Other rates work the same way: pay per hour, cost per kilogram, litres per minute.

Getting the units right

- Match the units before you calculate: a speed in km/h needs a time in hours.
- Minutes to hours: divide by 60. 45 minutes = 0.75 hours, but 20 minutes = $\frac{1}{3}$ hour (not 0.2 hours).
- Decimal hours to minutes: multiply the decimal part by 60. 2.3 hours = 2 hours 18 minutes.
- km/h to m/s: multiply by 1000, then divide by 3600. 72 km/h = 72 000 m per hour = 20 m/s.
- For a pressure in N/m^2 , the area must be in m^2 : $1 \text{ m}^2 = 10\,000 \text{ cm}^2$.

Average speed and multi-step problems

- Average speed = total distance $\div$ total time. Do not find the mean of the speeds.
- For a mass from a density, find the volume of the shape first (e.g. $\pi r^2 h$ for a cylinder), then mass = density $\times$ volume.
- Mixtures and alloys: density = total mass $\div$ total volume. Find the mass or volume of each part first.

Grade 6+ only

Best buys and rates of pay

- A **best buy** is the option that gives the most for the money. Work out the price of the *same amount* for each option, then compare.
- Use one unit for every option, e.g. pence per 100 g. The lower price per 100 g is the better buy.
- Example: 500 g for £2.40 is 48p per 100 g ($240 \div 5$). 800 g for £3.60 is 45p per 100 g ($360 \div 8$). The larger box is the better buy.
- With an offer such as 'buy 2, get the third half price', work out the total cost and the total amount first. Three boxes of 500 g at £2.40 with the third at half price cost £6.00 for 1500 g, which is 40p per 100 g.
- A rate of pay is money per hour: pay = rate $\times$ hours.

How to answer each type of question

M = method mark, A = answer mark, B = a mark on its own.

Work out speed, distance or time

3 marks

Grade 4

- Write down the formula you need.
- Change the time into hours (or the units the answer needs), e.g. 20 minutes = $\frac{1}{3}$ hour.
- Substitute and calculate, then give the units.

Example. A train travels 210 km in 2 hours 20 minutes.

Work out the average speed of the train in km/h.

Model answer. 2 hours 20 minutes = 140 minutes, or $2\frac{1}{3}$ hours (M1)

$210 \div 140 \times 60$, or $210 \div 2\frac{1}{3}$ (M1)

= 90 km/h (A1)

Use density with the volume of a solid

3 marks

Grade 5

1. Work out the volume of the solid (cuboid, prism or cylinder).
2. Use mass = density $\times$ volume.
3. Convert to the units asked for, e.g. grams to kilograms.

Example. A solid metal bar is a cuboid measuring 12 cm by 5 cm by 2.5 cm.

The metal has a density of 8.4 g/cm^3 .

Work out the mass of the bar in kilograms.

Model answer. Volume = $12 \times 5 \times 2.5 = 150 \text{ cm}^3$ (M1)

Mass = $8.4 \times 150 = 1260 \text{ g}$ (M1)

= 1.26 kg (A1)

Work out pressure with a change of units

3 marks

Grade 5

1. Change the lengths to metres before finding the area (or change cm^2 to m^2 by dividing by 10 000).
2. Use pressure = force $\div$ area, rearranged if you need the force or the area.
3. Give the units, N/m^2 .

Example. A box rests on a floor. The base of the box is a rectangle measuring 40 cm by 30 cm.

The box exerts a force of 180 newtons on the floor.

pressure = $\frac{\text{force}}{\text{area}}$

Work out the pressure on the floor in N/m^2 .

Model answer. Area = $0.4 \times 0.3 = 0.12 \text{ m}^2$ (M1)

$180 \div 0.12$ (M1)

= 1500 N/m^2 (A1)

Convert a compound unit

2 marks

Grade 5

1. Deal with one unit at a time: first the time, then the distance (or the other way round).
2. Per second to per hour: multiply by 3600. Metres to kilometres: divide by 1000.
3. Sense check: the same speed is a bigger number in km/h than in m/s.

Example. A cheetah can run at 30 m/s.

Change 30 m/s into km/h.

Model answer. $30 \times 3600 = 108\,000$ metres per hour (M1)

$108\,000 \div 1000 = 108 \text{ km/h}$ (A1)

Find the density of a mixture or alloy

3 marks

Grade 6

1. Find the mass and the volume of each part separately, using $\text{mass} = \text{density} \times \text{volume}$ or $\text{volume} = \text{mass} \div \text{density}$.
2. Add to get the total mass and the total volume.
3. Density of the mixture = total mass $\div$ total volume (never the mean of the two densities).

Example. Metal A has a density of 6 g/cm^3 . Metal B has a density of 9 g/cm^3 .
240 g of metal A and 540 g of metal B are mixed to make an alloy.
Assume that the volume of the alloy is the total volume of the two metals.
Work out the density of the alloy.

Model answer. Volume of A = $240 \div 6 = 40 \text{ cm}^3$ or volume of B = $540 \div 9 = 60 \text{ cm}^3$ (M1)
Total mass = 780 g and total volume = 100 cm^3 , so density = $780 \div 100$ (M1)
= 7.8 g/cm^3 (A1)

Don't lose marks

- ✗ Writing 2 hours 20 minutes as 2.2 hours: it is $2\frac{1}{3}$ hours, about 2.33 hours.
- ✗ Finding the mean of two speeds instead of total distance $\div$ total time.
- ✗ Mixing units, e.g. an area in cm^2 with a pressure in N/m^2 , or grams with kg/m^3 .
- ✗ Turning a formula upside down, e.g. $\text{volume} \div \text{mass}$ for density.
- ✗ Leaving a time as a decimal (3.6 hours) when the question asks for hours and minutes (3 hours 36 minutes).

More tips

Memory tricks

- Formula triangles: D over $S \times T$, M over $D \times V$, F over $P \times A$. Cover the one you want to find.
- The units tell you the formula: g/cm^3 means $\text{grams} \div \text{cm}^3$, so density = mass $\div$ volume.
- m/s to km/h: multiply by 3.6; km/h to m/s: divide by 3.6.
- Sense check: walking is about 5 km/h, a car on a motorway about 110 km/h, and water has a density of 1 g/cm^3 .

Exam technique

- Write the formula before you substitute: it shows your method.
- Check the units the answer needs (km/h or m/s, g or kg) and convert at the start or the end.
- If the question gives a formula, such as $\text{pressure} = \text{force} \div \text{area}$, use it; learn all three formulas anyway.
- Give time answers in the form the question asks for.

What each grade needs

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

Grade 3**Use speed = distance ÷ time**

For example, 150 km in 2.5 hours is an average speed of 60 km/h.

Grade 4**Convert between minutes and decimal hours**

Divide the minutes by 60, e.g. 1 hour 45 minutes = 1.75 hours.

Grade 4**Calculate density, mass or volume**

Use density = mass ÷ volume and its rearrangements, with matching units.

Grade 5**Calculate pressure, force or area**

Use pressure = force ÷ area, with the area in m^2 for a pressure in N/m^2 .

Grade 5**Convert compound units such as km/h to m/s**

Convert one unit at a time, e.g. $72 \text{ km/h} = 72\,000 \text{ m per hour} = 72\,000 \div 3600 = 20 \text{ m/s}$.

Grade 5**Find the average speed for a whole journey**

Divide the total distance by the total time, including any stops.

Grade 5**Use density with volumes of 3D shapes**

Find the volume of the solid first, then multiply by the density to get the mass.

Grade 6**Find the density of a mixture**

Divide the total mass by the total volume, working out each part separately first.

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