# Units of area and volume

Converting units of area or volume is trickier than converting units of length. You need to remember your area and volume conversions for your exam.

These two squares have the same area.

1 cm   10 mm

1 cm   10 mm
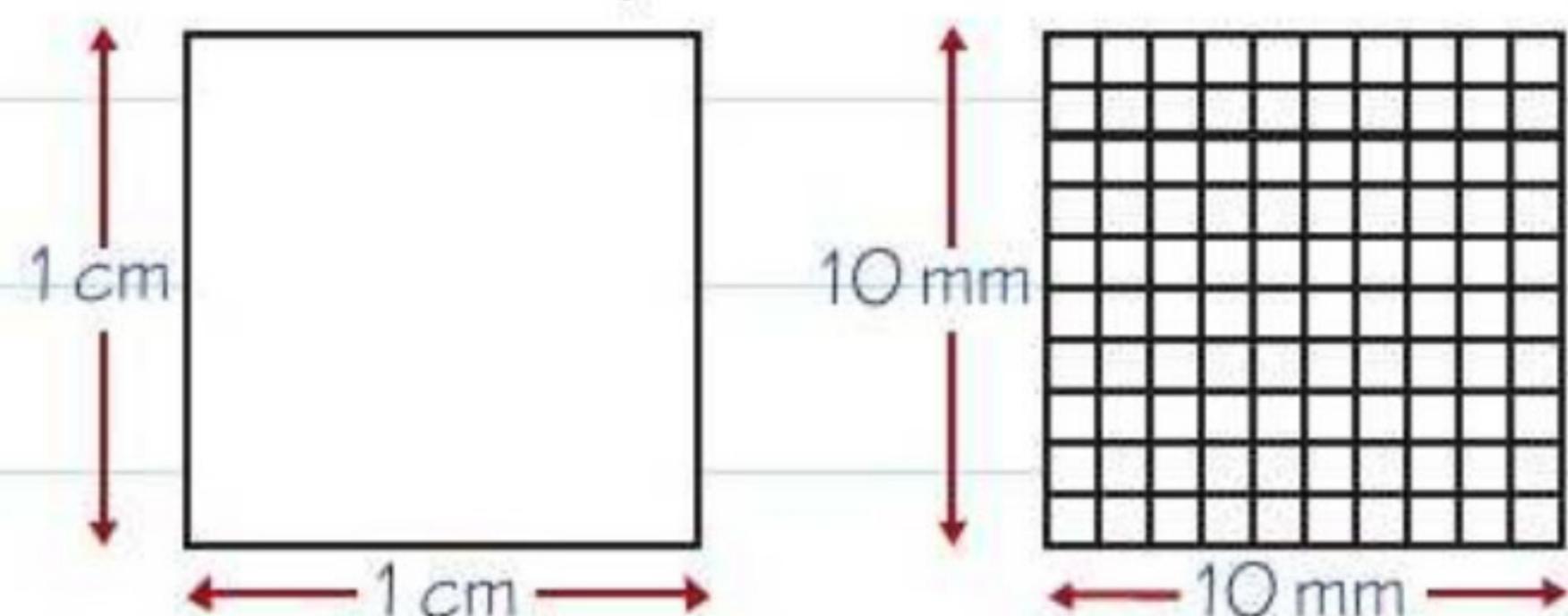
So $1 cm^2 = 100 mm^2$.

These two cubes have the same volume.

1 cm   10 mm

1 cm   1 cm   10 mm   10 mm

So $1 cm^3 = 1000 mm^3$.

Area conversions

$1 cm^2 = 10^2 mm^2 = 100 mm^2$

$1 m^2 = 100^2 cm^2 = 10\,000 cm^2$

$1 km^2 = 1000^2 m^2 = 1\,000\,000 m^2$

Volume conversions

$1 cm^3 = 10^3 mm^3 = 1000 mm^3$

$1 m^3 = 100^3 cm^3 = 1\,000\,000 cm^3$

1 litre $= 1000 cm^3$

1 ml $= 1 cm^3$

LEARN IT!
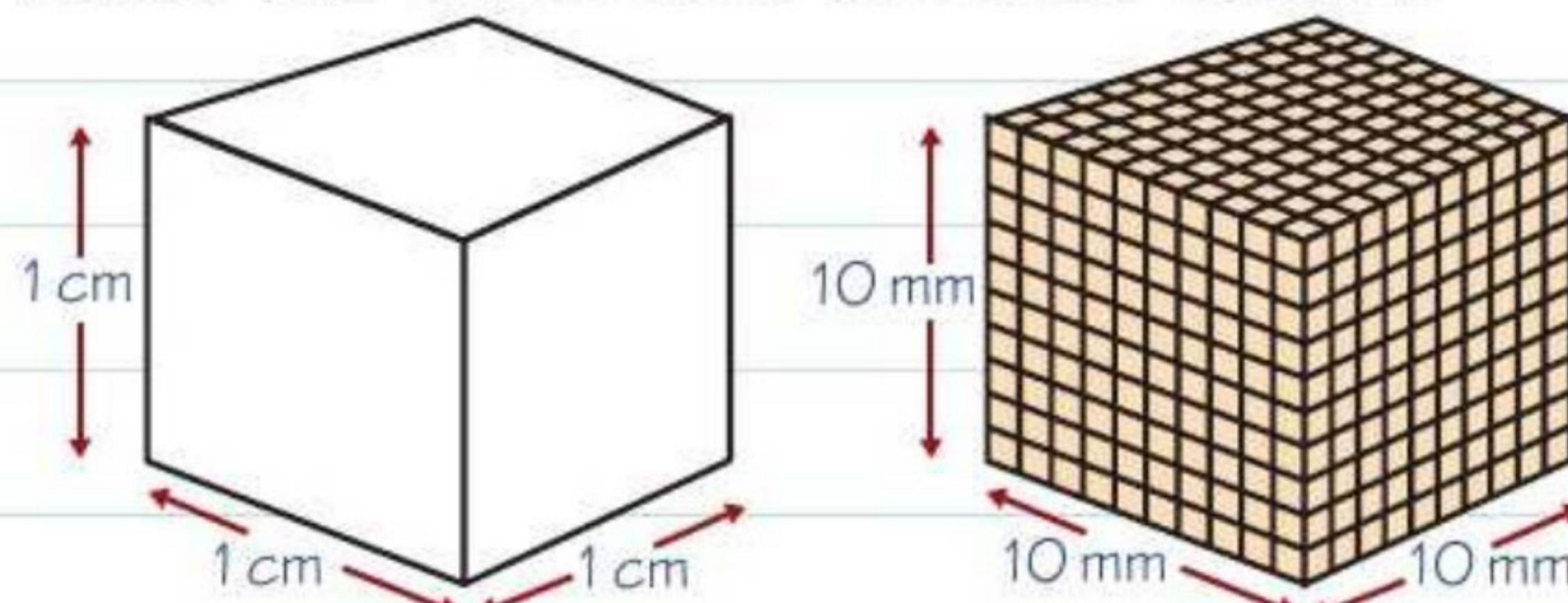
Worked example

Target grade 4

Lead has a density of $11\,350 kg/m^3$.
An antique lead model has a volume of $400 cm^3$.
Calculate the mass of the model in kg.

**(3 marks)**

$400 \div 100^3 = 0.0004$

Volume $= 0.0004 m^3$

Mass $=$ Density $\times$ Volume
$= 11\,350 \times 0.0004$
$= 4.54 kg$

[Triangle: M / D | V]

Unit conversion checklist

The multiplier for an area conversion is the length multiplier squared. ✓

The multiplier for a volume conversion is the length multiplier cubed. ✓

m m^2 m^3

×100 $\times 100^2$ $\times 100^3$

cm cm^2 cm^3

Worked solution video

[QR code]
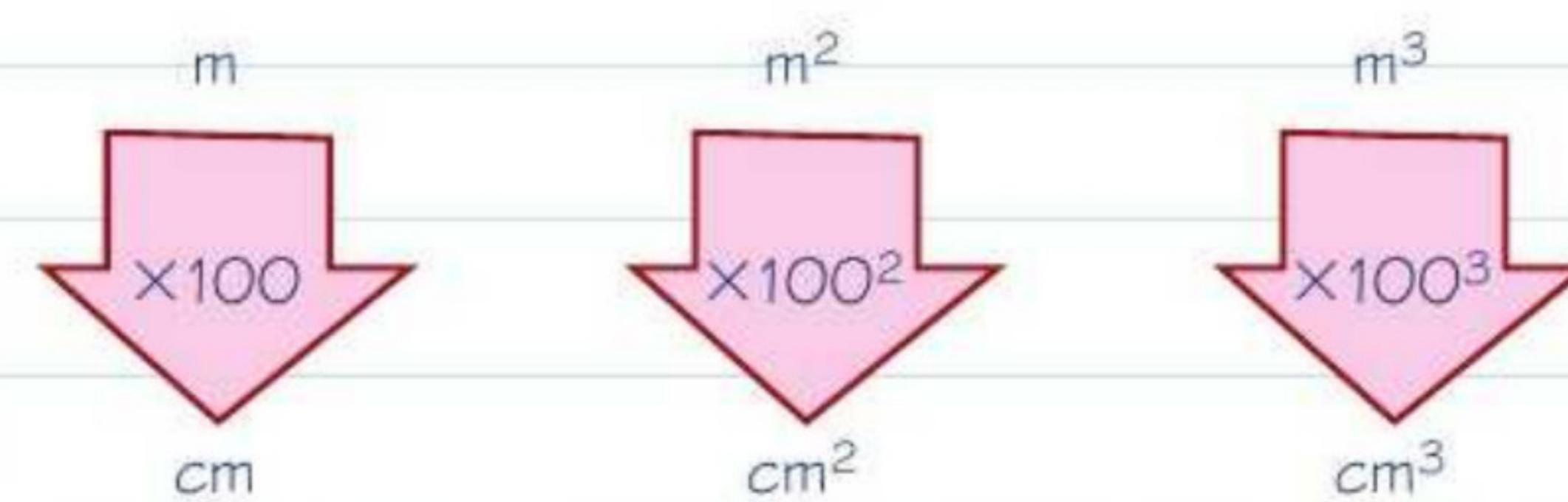
Examiners' report

You need to be really careful with the **units** when you are solving any problem involving measures. The units of density are given in kg/m^3, so you need to convert $400 cm^3$ into m^3 before you calculate. You are converting to a larger unit, so **divide** by 100^3.

For a reminder about density look at page 66.

Real students have struggled with questions like this in recent exams – **be prepared!**

Now try this

Target grade 4

1 Convert
  (a) $2.3 m^2$ into cm^2 **(1 mark)**
  (b) $400 mm^3$ into cm^3. **(1 mark)**

Target grade 5

2 Convert $0.35 m^3$ to mm^3, giving your answer in standard form.   **(2 marks)**

For a reminder about writing answers in standard form have a look at page 8.

Target grade 4

3 Jenny applies a force of 600 N to the floor. The total area of her feet is $160 cm^2$. What is the pressure, in N/m^2, between her and the floor if she stands on both of her feet?

(3 marks)

Hot Topic

Metric units

You can convert between metric units by multiplying or dividing by 10, 100 or 1000.

Length

÷1000 [km] ×1000
÷100 [m] ×100
÷10 [cm] ×10
[mm]

Weight

÷1000 [tonne] ×1000
÷1000 [kg] ×1000
÷1000 [g] ×1000
[mg]

### Volume or capacity

÷100 [litre] ×100
÷1000 [cl] ×1000
÷10 [ml or cm³] ×10
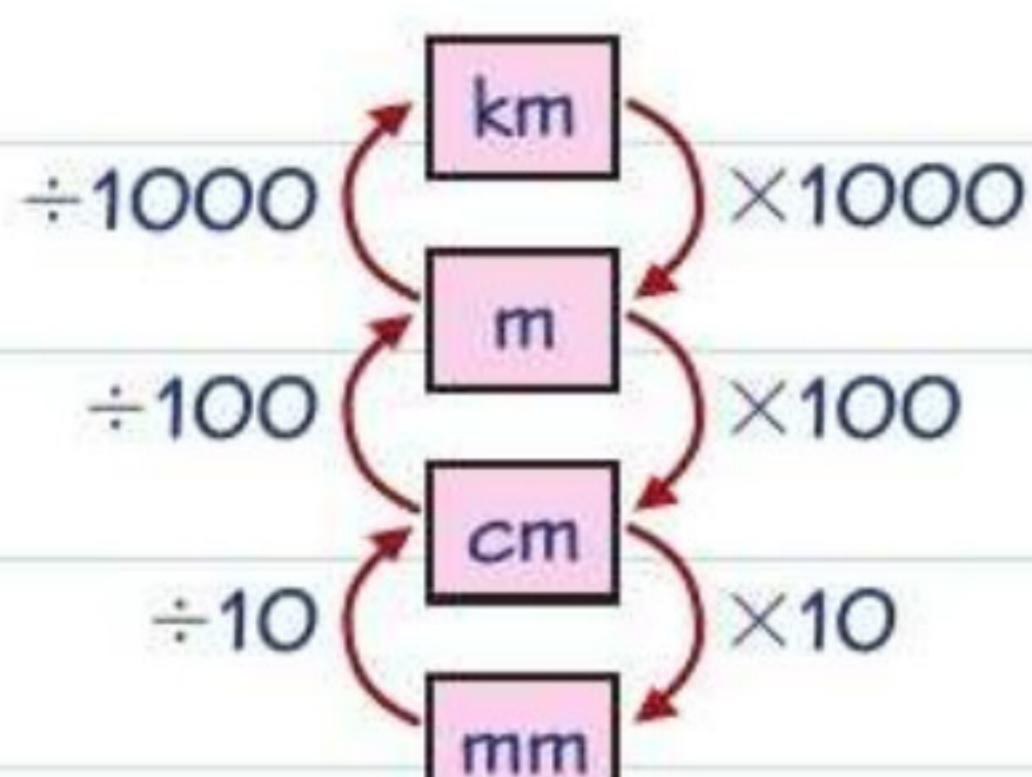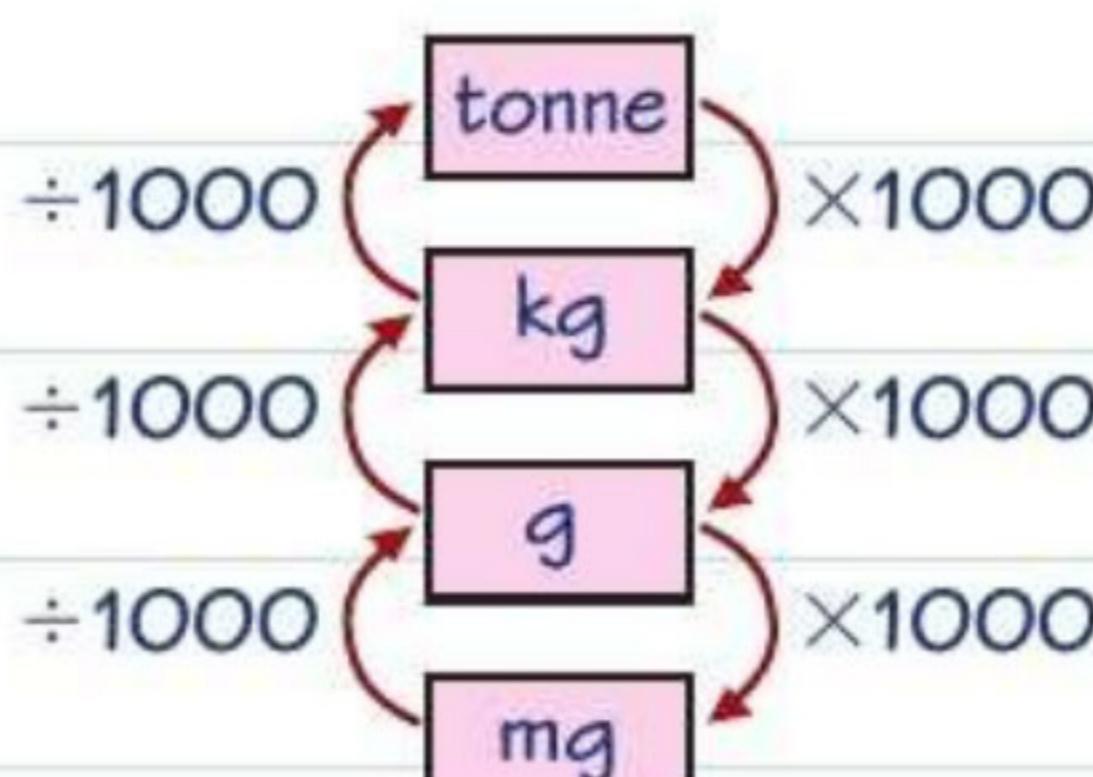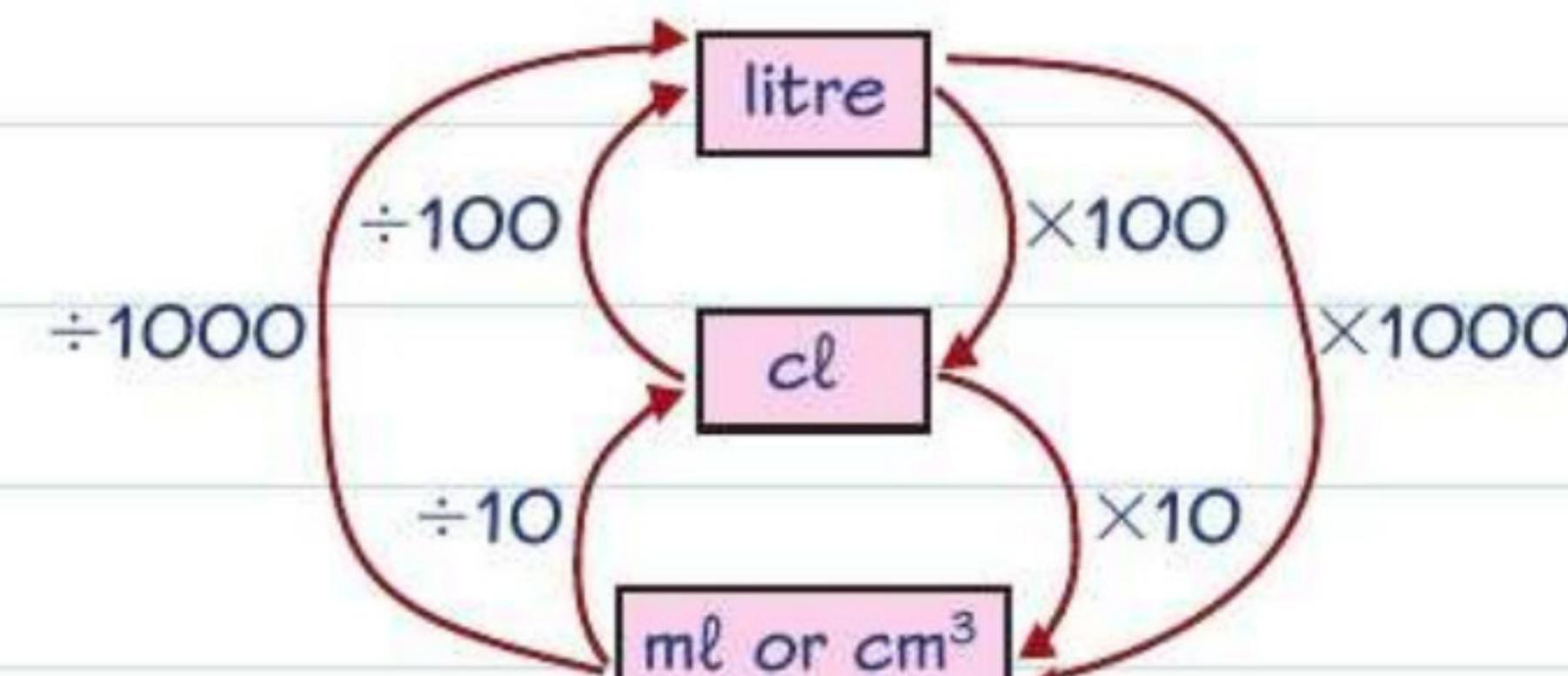
Place value diagrams

You can use a place value diagram to help you multiply and divide by 10, 100 and 1000.

For more on place value look at page 1.

Hundreds | Tens | Units | • | tenths | hundredths | thousandths

To multiply by 10, 100 or 1000 you move the digits 1, 2 or 3 places to the left.

$0.35 \times 10 = 3.5$

$0.35 \times 100 = 35$

$0.35 \times 1000 = 350$

		0	•	3	5
		3	•	5	
	3	5			
3	5	0			
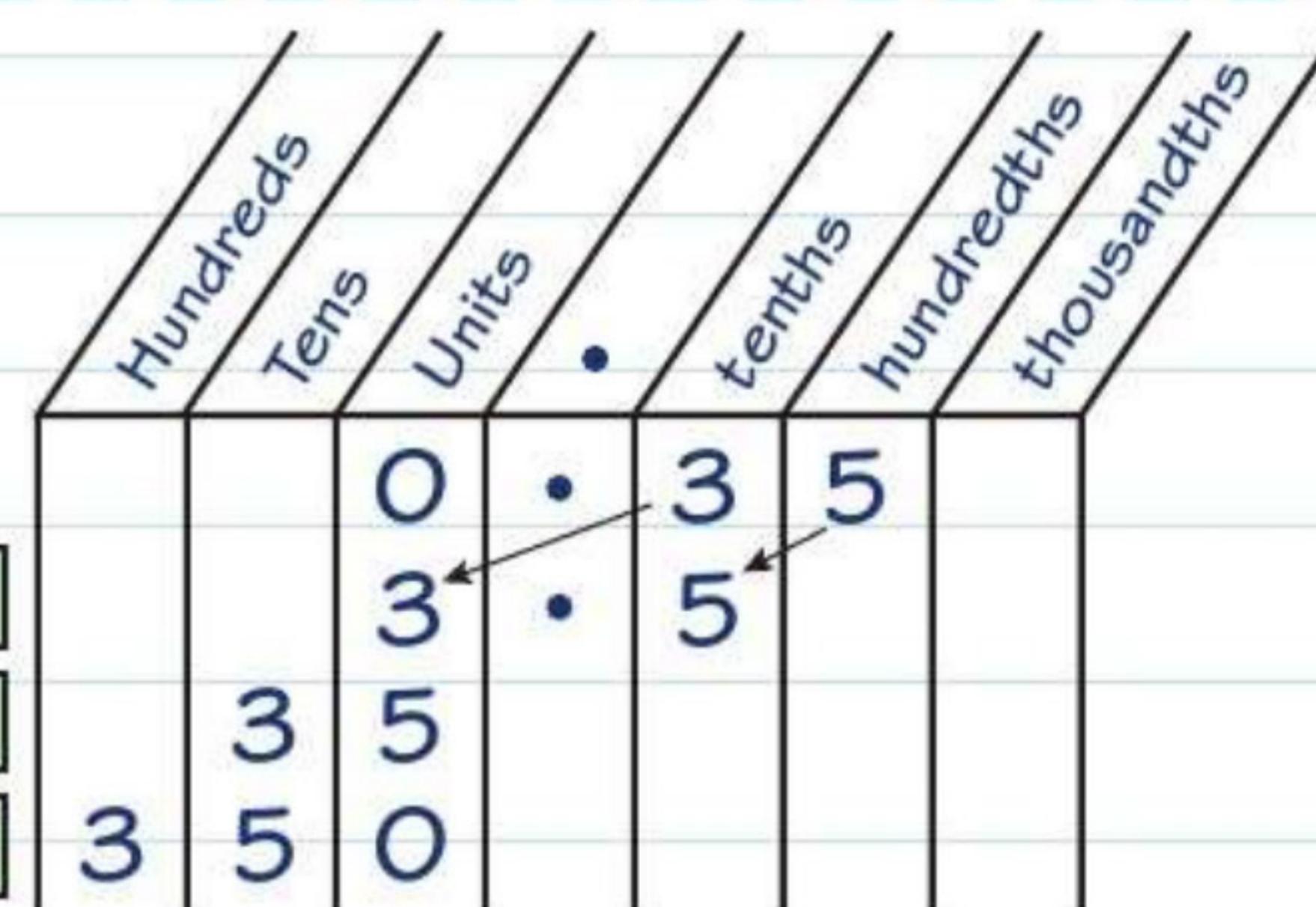
To divide by 10, 100 or 1000 you move the digits 1, 2 or 3 places to the right.

$120 \div 10 = 12$

$120 \div 100 = 1.2$

$120 \div 1000 = 0.12$

1	2	0			
	1	2			
		1	•	2	
		0	•	1	2
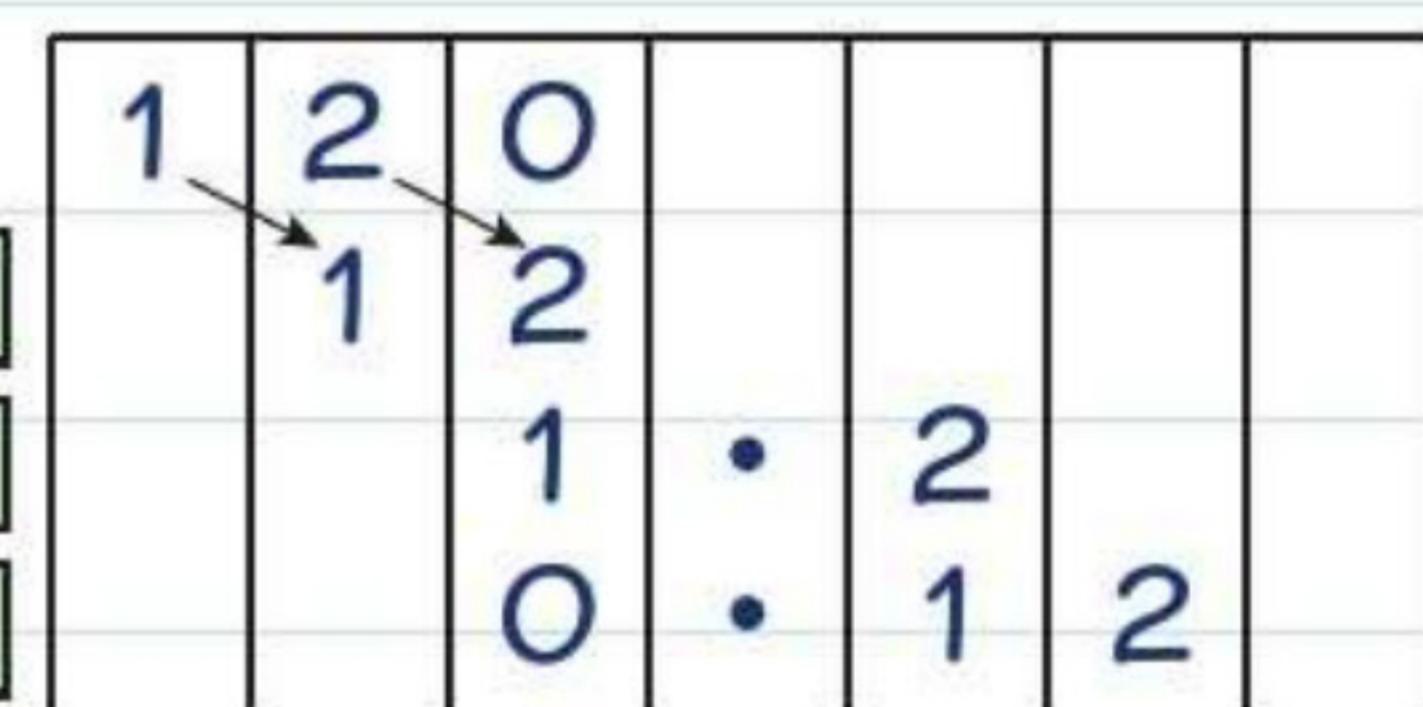
Worked example

Target grade 3

The weight of a ream of paper is 2.5 kg.
There are 500 sheets of paper in a ream.
Work out the weight, in grams, of one sheet of paper.

$2.5 \times 1000 = 2500$
$2.5\,kg = 2500\,g$
$2500 \div 500 = 5$
Each sheet of paper weighs 5 grams.

The whole ream of paper weighs 2500 g and there are 500 sheets of paper, so divide 2500 by 500 to find the weight.

Examiners' report

Students frequently lose marks by converting between different metric units incorrectly.

Start by converting 2.5 kg into grams.

[kg] ×1000 [g]
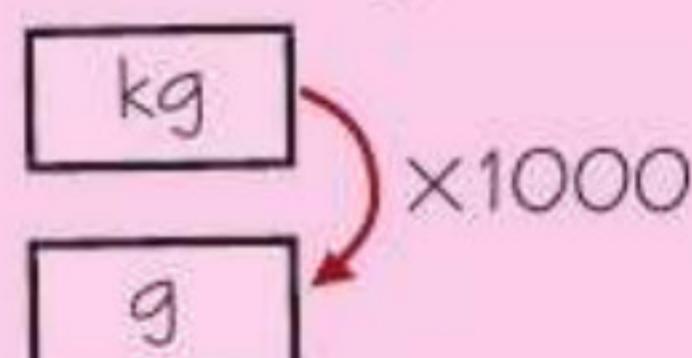
Check it!
A gram is a smaller unit than a kilogram so the number will be larger. ✓

Real students have struggled with questions like this in recent exams – **be prepared!**

Now try this

Target grade 2

1 Change
   (a) 3.2 m into cm   **(1 mark)**
   (b) 0.25 litres into ml **(1 mark)**
   (c) 960 mm into cm   **(1 mark)**
   (d) 1700 g into kg   **(1 mark)**

Target grade 3

2 A pile of fifty 20p coins is 8.5 cm high.
   Work out the thickness of one 20p coin. Give your answer in mm.

Worked solution video

(2 marks)

Speed

This is the **formula triangle** for **speed**.
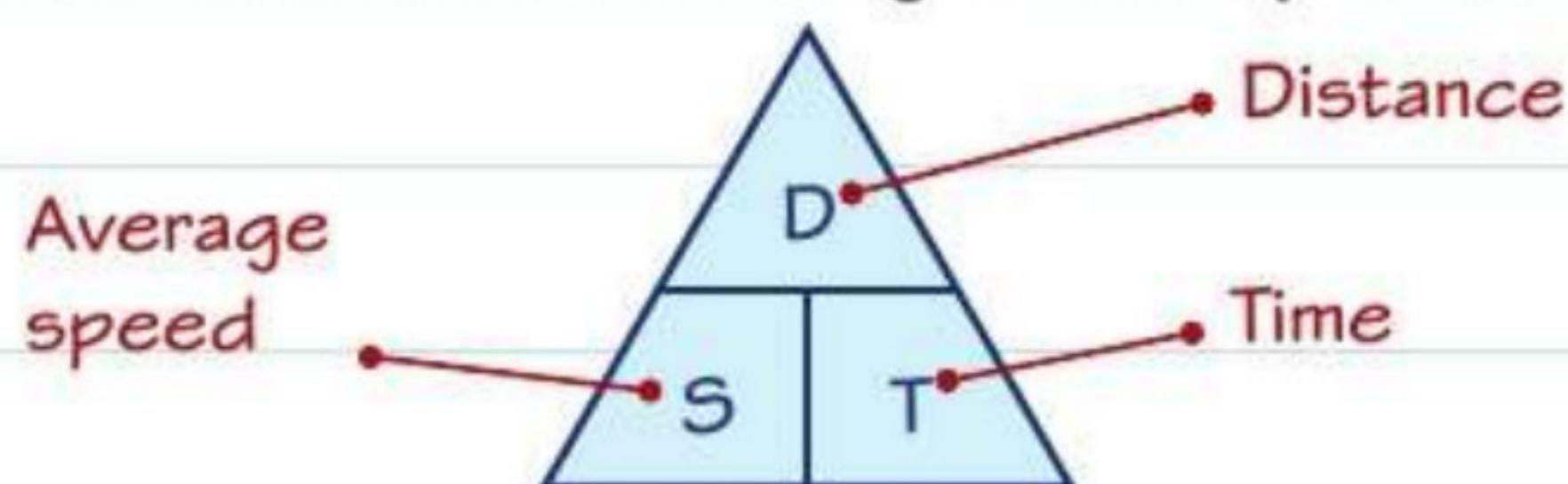
$$\text{Average speed} = \frac{\text{Total distance travelled}}{\text{Total time taken}}$$

$$\text{Time} = \frac{\text{Distance}}{\text{Average speed}}$$

LEARN IT!

$$\text{Distance} = \text{Average speed} \times \text{Time}$$

Using a formula triangle

Cover up the quantity you want to find with your finger.

The position of the other two quantities tells you the formula.

$$T = \frac{D}{S} \qquad S = \frac{D}{T} \qquad D = S \times T$$

Units

The most common units of speed are
- metres per second: m/s
- kilometres per hour: km/h
- miles per hour: mph.

The units in your answer will depend on the units you use in the formula.

When distance is measured in km and time is measured in hours, speed will be measured in km/h.

Minutes and hours

For questions on speed, you need to be able to convert between minutes and hours.

Hours	Minutes
$\frac{1}{2}$	30
$\frac{3}{4}$	45
$2\frac{1}{4}$	135

You can also write this as '2 hours and 15 minutes'.
$60 + 60 + 15 = 135$

Worked example

Target grade 3

A plane travels at a constant speed of 840 km/h for 45 minutes.
How far has it travelled? **(3 marks)**
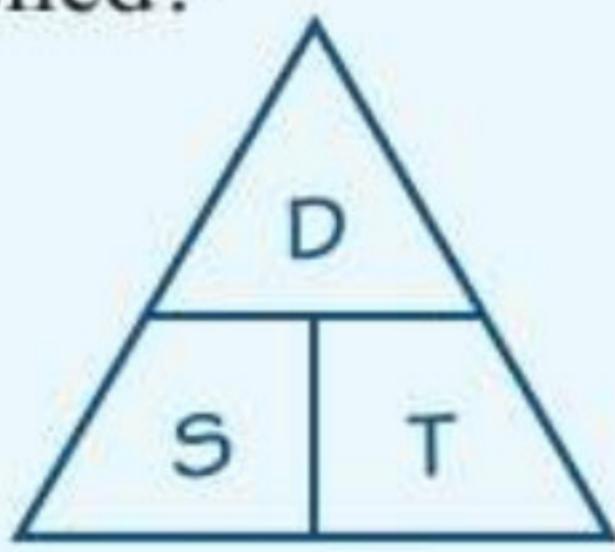
$45 \text{ minutes} = \frac{45}{60} \text{ hour} = \frac{3}{4} \text{ hour}$

$D = S \times T$

$\quad = 840 \times \frac{3}{4} = \frac{840 \times 3}{4} = \frac{2520}{4} = 630$

The plane has travelled 630 km.

Make sure that the units match. Speed is given in km/h, so convert the time into hours by dividing by 60. The units of distance will be km.

Speed questions

- ✓ Draw a formula triangle.
- ✓ Make sure the units match.
- ✓ Give units with your answer.

Now try this

Target grade 3

1 Bradley cycled 170 km at an average speed of 40 kilometres per hour.
How long did it take him?
Give your answer in hours and minutes. **(3 marks)**

2 Simon drives from Newcastle to Oxford.
His average speed is 56 mph.
The journey takes 4 hours 45 minutes.
How far did he drive? **(3 marks)**

Density

The density of a material is its mass per unit volume.

This is the formula triangle for density.

LEARN IT!
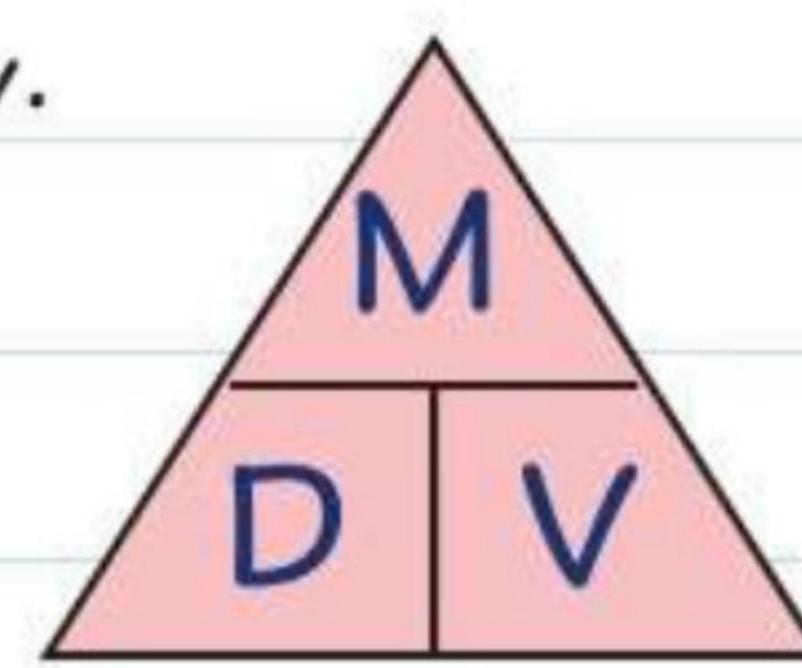
$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{Volume} = \frac{\text{Mass}}{\text{Density}}$$

$$\text{Mass} = \text{Density} \times \text{Volume}$$

Worked example

Target grade 4

$15\,cm^2$

$8\,cm$
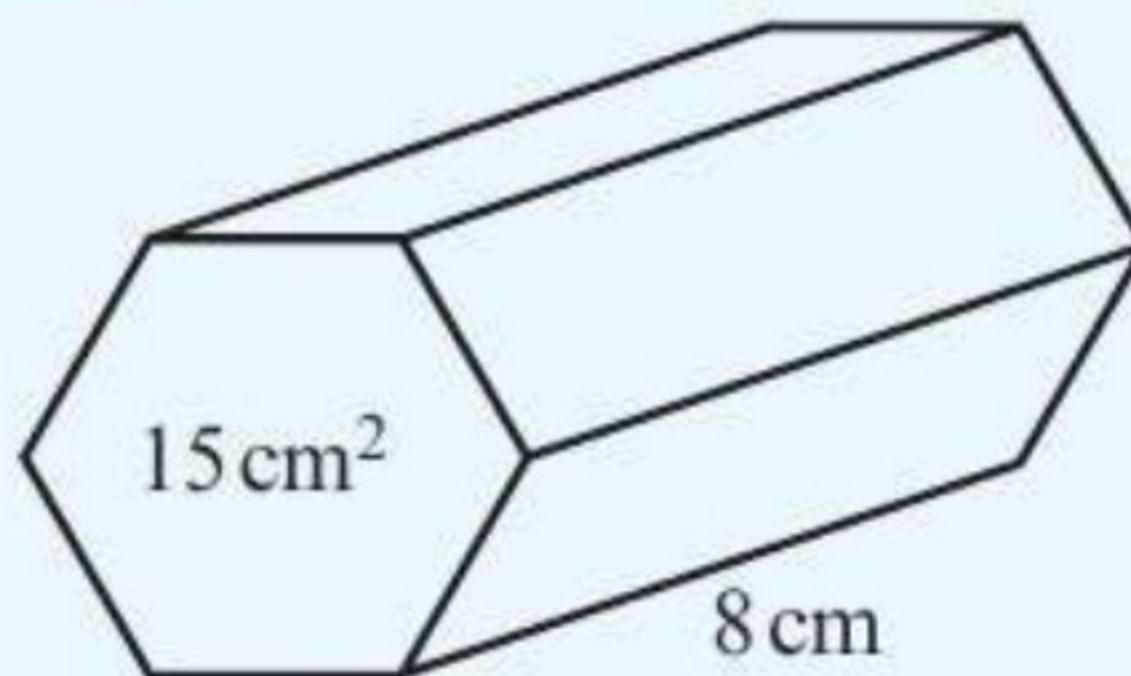
The diagram shows a solid hexagonal prism.
The area of the cross-section of the prism is $15\,cm^2$.
The length of the prism is $8\,cm$.
The prism is made from wood with a density of <u>0.8 grams per cm^3</u>.
Work out the mass of the prism.   **(4 marks)**

Volume of prism

$\quad = \text{Area of cross-section} \times \text{Length}$

$\quad = 15 \times 8$

$\quad = 120\,cm^3$

$M = D \times V$

$\quad = 0.8 \times 120$

$\quad = 96$

The mass of the prism is $96\,g$.

Revise volumes of prisms on page 84.

Units

The most common units of density are

✓ grams per cubic centimetre: g/cm^3

✓ kilograms per cubic metre: kg/m^3.

Examiners' report

Make sure you write down the formula triangle for density and that you **know how to use it**. In this question you want to find the **mass**. If you cover up M the formula triangle tells you that:

$$\text{Mass} = \text{Density} \times \text{Volume}$$

Real students have struggled with questions like this in recent exams – **be prepared!**

Worked example

Target grade 4

An iron bar has a volume of $1.2\,m^3$ and a mass of $9444\,kg$. Calculate the density of iron.

(2 marks)

$$D = \frac{M}{V} = \frac{9444}{1.2} = 7870\,kg/m^3$$

Volume is in m^3 and mass is in kg so density will be in kg/m^3.

Worked solution video

Now try this

Target grade 5

The density of copper is $8.92\,g/cm^3$.
The density of silver is $10.49\,g/cm^3$.
$20\,cm^3$ of copper and $5\,cm^3$ of silver are mixed together to make a new kind of metal.
Work out the density of the new metal.

(4 marks)

Plan your answer:

1. Work out the masses of each metal.

2. Add the masses together.

3. You know the total mass and the total volume of the new metal, so calculate the density.

Had a look ☐ Nearly there ☐ Nailed it! ☐

Other compound measures

Compound measures are made up of two or more other measurements. **Speed** is a compound measure because it is calculated using distance **and** time.

Pressure

Pressure is a measure of the force applied over a given area. The most common units of pressure are newtons per square centimetre (N/cm^2) and newtons per square metre (N/m^2).
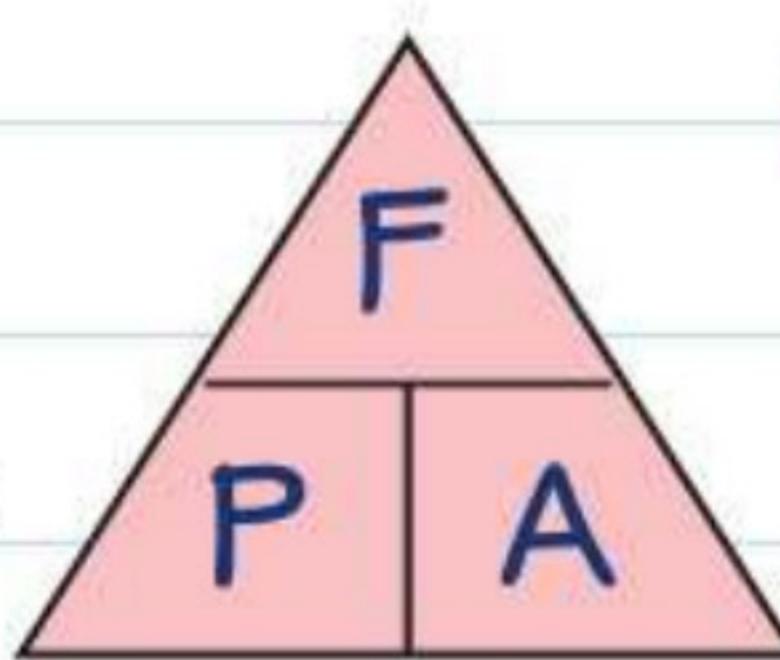
$$Pressure = \frac{Force}{Area}$$

$$Area = \frac{Force}{Pressure}$$

$$Force = Pressure \times Area$$

LEARN IT!

Worked example

Target grade 4

At a depth of 15 m, water has a pressure of $14.7\,N/cm^2$. Calculate the force applied to a diving mask with a surface area of $360\,cm^2$. **(2 marks)**

Force = Pressure × Area
$$= 14.7 \times 360 = 5292\,N$$

Rates

If the bottom unit in a compound measure is **time**, then it is a **rate**.

$$Speed = \frac{Distance}{Time}$$

$$\frac{Rate}{of\ climb} = \frac{Height}{Time}$$

$$\frac{Rate}{of\ flow} = \frac{Volume}{Time}$$

$$\frac{Rate}{of\ pay} = \frac{Salary}{Time}$$
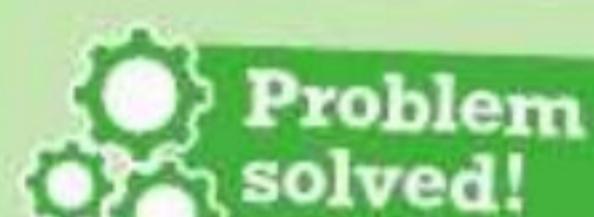
⚙ Problem solved! You need to use lots of different maths skills to solve this problem. You need to know how to calculate the volume of a cuboid (revise this on page 83) and how to convert from cm^3 to litres (for a reminder look at page 61). It's a good idea to **plan your strategy** before you start:

1. Work out the volume of the fishtank in litres.
2. Divide by 2 to get half the capacity.
3. Divide by the rate of flow to get the time taken in minutes.

Worked example

Target grade 5

This fishtank can be modelled as a cuboid.

40 cm
90 cm
120 cm
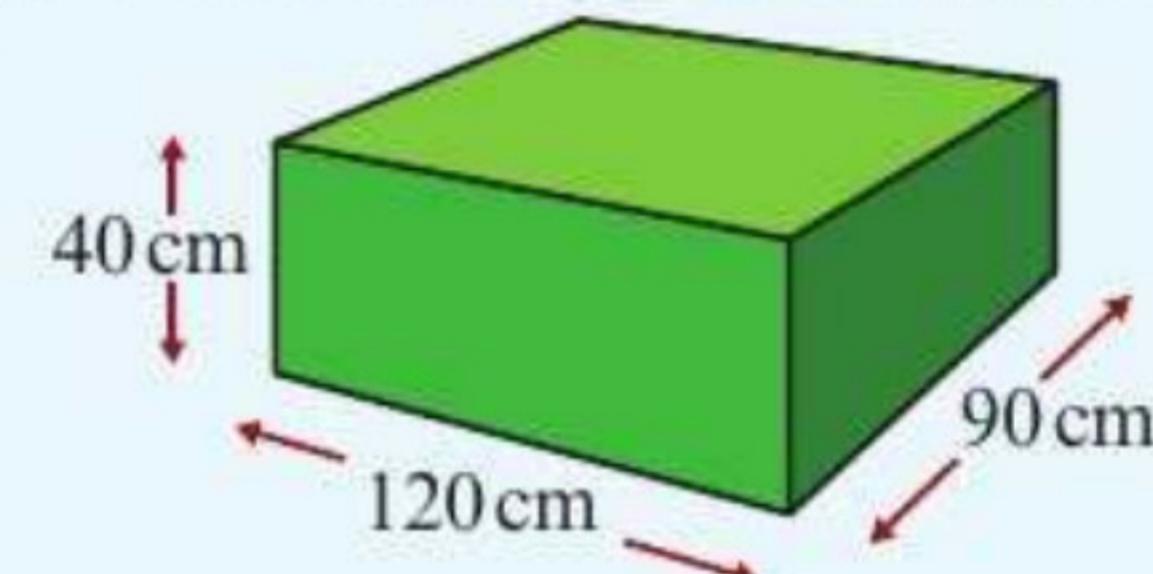
Aaron fills the fishtank with water at a rate of 12 litres per minute. How long will it take for the fishtank to be half full? **(5 marks)**

Volume = 120 × 90 × 40
$$= 432\,000\,cm^3 = 432\ litres$$

432 ÷ 2 = 216   216 ÷ 12 = 18

It will take 18 minutes to half fill the tank.

Now try this

Target grade 4

1 The average fuel consumption of a car is measured in kilometres per litre (km/litre). A car travels 249 km and uses 15 litres of petrol. What is its average fuel consumption? **(2 marks)**

Look at the units to work out what calculation to do.

Target grade 5

2 A large tank holds 1680 litres of water. The tank can be filled from a hot tap or from a cold tap. The cold tap on its own takes 4 minutes to fill the tank. The hot tap on its own takes 6 minutes to fill the tank. Evie turns both taps on at the same time. How long does the tank take to fill? **(3 marks)**
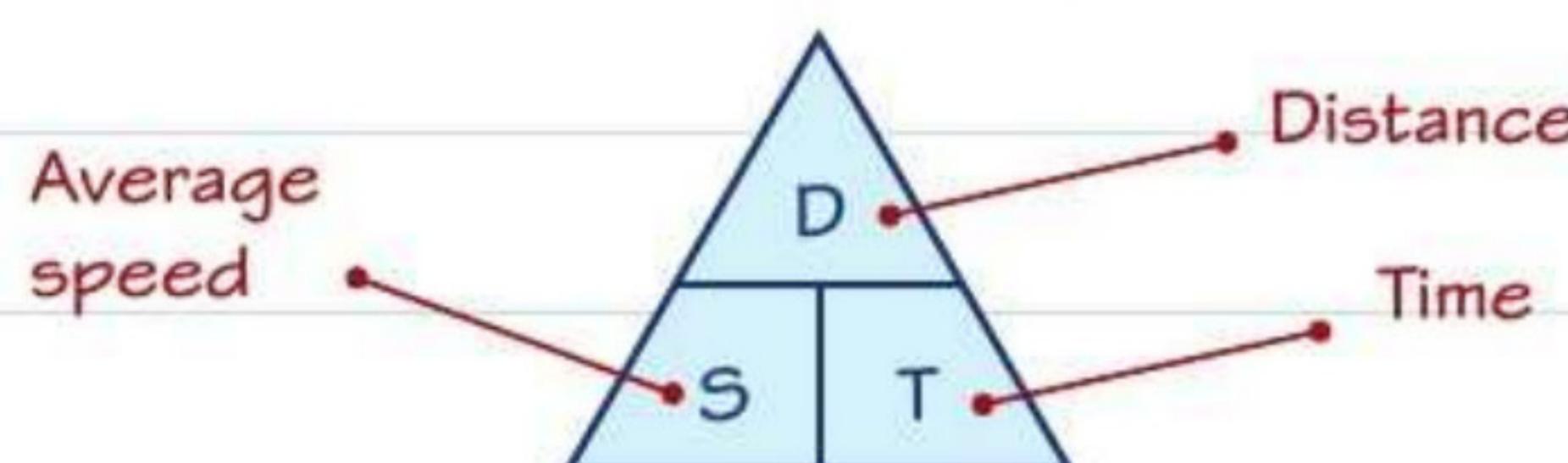
Hot Topic

Speed

This is the formula triangle for speed.

Average speed · · Distance
D
· Time
S | T

$$\text{Average speed} = \frac{\text{Total distance travelled}}{\text{Total time taken}}$$

$$\text{Time} = \frac{\text{Distance}}{\text{Average speed}}$$

LEARN IT!

$$\text{Distance} = \text{Average speed} \times \text{Time}$$

Using a formula triangle

Cover up the quantity you want to find with your finger.

D
S
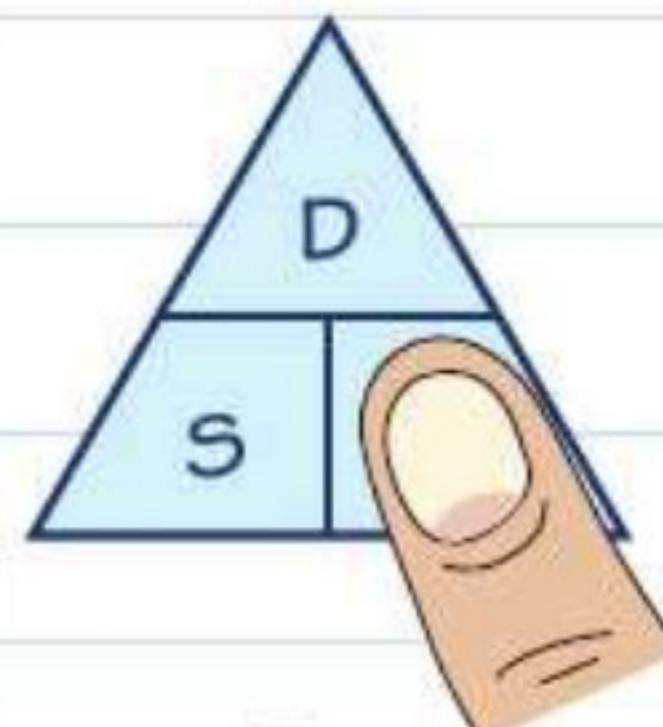
The position of the other two quantities tells you the formula.

$$T = \frac{D}{S} \qquad S = \frac{D}{T} \qquad D = S \times T$$

Units

The most common units of speed are:

- metres per second: m/s
- kilometres per hour: km/h
- miles per hour: mph.

To convert between measures of speed you need to convert one unit first then the other. Write the new units at each step of your working. To convert 72 km/h into m/s:

72 km/h → 72 × 1000 = 72 000 m/h

72 000 m/h → 72 000 ÷ 3600 = 20 m/s

1 hour = 60 × 60 = 3600 seconds

Minutes and hours

For questions on speed, you need to be able to convert between minutes and hours.

Remember there are 60 minutes in 1 hour.

To convert from minutes to hours you divide by 60.

24 minutes = 0.4 hours $\frac{24}{60} = \frac{2}{5} = 0.4$

To convert from hours to minutes you multiply by 60.

0.2 hours = 12 minutes   3.2 × 60 = 192
3.2 hours = 3 hours 12 minutes

Worked example

Target grade 5

The speed of light in a vacuum is approximately 1.08×10^9 km/h.

Light from the Sun takes approximately 8 minutes and 15 seconds to travel to Earth.

Estimate the distance from the Earth to the Sun.   **(3 marks)**

D
S | T

$$8 \text{ mins } 15 \text{ secs} = 8.25 \text{ mins} = \frac{8.25}{60}$$
$$= 0.1375 \text{ hours}$$

$$D = S \times T$$
$$= 1.08 \times 10^9 \times 0.1375$$
$$= 1.485 \times 10^8 \text{ km}$$

Be careful with the units. You need to convert 12 minutes and 15 minutes into hours before doing your calculations.

Speed checklist

Draw formula triangle. ✓

Make sure units match. ✓

Give units with answer. ✓

If you're answering questions involving speed, distance and time you must always make sure that the units match. Speed is given in km/h here, so convert the time into hours before calculating.

Now try this

Target grade 4

Rosa lives in Durham and works in Newcastle. She takes the train to work every day.

Last Tuesday her train journey to work took 12 minutes, at an average speed of 108 km/h.

Her journey home from work took 15 minutes.

Calculate Rosa's average speed on her journey home.   **(3 marks)**