

E1.12 Rates

Name: _____ Class: _____ Date: _____ **Total: 32 marks**

KEY WORDS average speed 平均速度 • density 密度 • mass 质量 • volume 体积 • pressure 压强

Objective

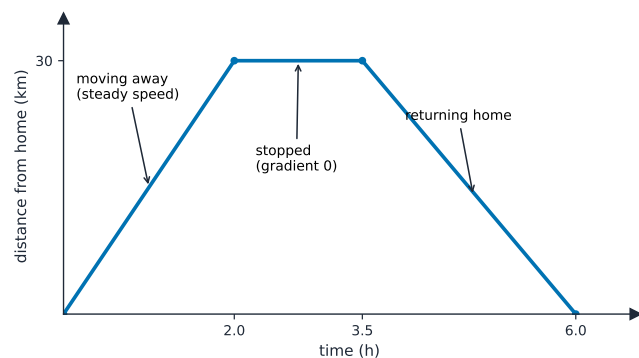
Build the skills to answer Extended exam questions on **rates** 比率 — **average speed** 平均速度, **density** 密度, and other rates that combine two quantities.

You must be able to:

- use average speed = $\frac{\text{distance}}{\text{time}}$
- use density = $\frac{\text{mass}}{\text{volume}}$
- convert times correctly and rearrange a rate formula

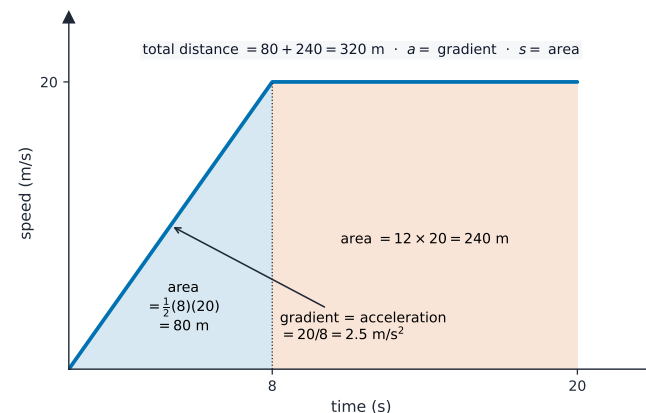
1 Worked examples

■ Speed, distance, time



speed = gradient of distance-time graph · flat $\Rightarrow$ speed = 0

A rate compares two quantities in different units



A rate also reads off a speed-time graph

$$\text{average speed} = \frac{\text{total distance}}{\text{total time}} \quad \text{density} = \frac{\text{mass}}{\text{volume}}$$

- **Worked:** 45 km in 3 h 45 min = 3.75 h $\rightarrow$ speed = $\frac{45}{3.75} = 12$ km/h.
- Change minutes to a decimal of an hour (45 min = 0.75 h) — **not** 3.45.

Answer shapes: M1 a correct method, A1 the correct answer.

■ Three formulas with the same shape

$$\text{speed} = \frac{\text{distance}}{\text{time}} \quad \text{density} = \frac{\text{mass}}{\text{volume}} \quad \text{pressure} = \frac{\text{force}}{\text{area}}$$

Each rearranges the same way, and each is checked the same way — by the **units**. If a speed comes out in km/h but the question wanted m/s, the conversion is part of the answer.

The unit conversions worth memorising:

- 1 km/h = $\frac{1000}{3600}$ m/s, so **divide by 3.6** to go from km/h to m/s and multiply by 3.6 to come back.
- 1 m³ = 1 000 000 cm³, and 1 g/cm³ = 1000 kg/m³.
- Time given as 2 h 30 min must become 2.5 h — **not** 2.30.

△ **Average speed is total distance $\div$ total time**, never the average of the speeds. A journey of 60 km at 60 km/h then 60 km at 30 km/h takes 1 + 2 = 3 hours for 120 km, so the average speed is 40 km/h — not the 45 you get by averaging the two speeds. That difference is a favourite exam question, and averaging the speeds is the trap it is set to catch.

Worked example. A car travels 150 km in 1 h 15 min. Find its average speed in km/h and in m/s.

- 1 h 15 min = 1.25 h.
- Speed = $\frac{150}{1.25} = 120$ km/h.
- In m/s: $120 \div 3.6 = 33.3$ m/s (3 s.f.).

2 Practice

2.1 A car travels 120 km in 2 hours. Calculate its average speed. [1]

2.2 A metal block has mass 240 g and volume 30 cm³. Calculate its density. [2]

2.3 A runner's average speed is 5 m/s. How far does she run in 40 seconds? [2]

2.4 Convert 72 km/h to m/s. [2]

2.5 A block has mass 480 g and volume 60 cm³. Find its density. [2]

2.6 A force of 250 N acts on an area of 0.5 m². Find the pressure. [2]

3 Exam-style questions

3.1 A train travels 150 km in 1 hour 30 minutes. Calculate its average speed in km/h. [2]

3.2 Gold has a density of 19.3 g/cm³. Calculate the mass of a gold bar of volume 50 cm³. [2]

3.3 A cyclist travels 36 km at an average speed of 24 km/h. Calculate the time taken, in minutes. [3]

3.4 A lorry travels from town A to town B, a distance of 135 km, in 1 h 48 min.

- (a) Calculate the average speed of the lorry in km/h. [3]

- (b) Convert this speed to m/s, giving your answer to 3 significant figures. [2]

- (c) The lorry returns from B to A at an average speed of 90 km/h. Calculate the average speed for the whole journey there and back. [4]

- (d) Explain why the answer to (c) is not the mean of the two speeds. [2]

- (e) The lorry carries a steel block of volume 0.4 m^3 . Steel has a density of 7.8 g/cm^3 . Calculate the mass of the block in tonnes. [3]

Solutions

Marking: **M1** a correct method, **A1** the correct answer.

2.1 $\frac{120}{2} = 60 \text{ km/h}$.

2.2 $\text{density} = \frac{240}{30} = 8 \text{ g/cm}^3$.

2.3 $\text{distance} = 5 \times 40 = 200 \text{ m}$.

2.4 $72 \div 3.6 = 20 \text{ m/s}$.

2.5 $\frac{480}{60} = 8 \text{ g/cm}^3$.

2.6 $\frac{250}{0.5} = 500 \text{ N/m}^2$, or 500 Pa .

3.1 $1 \text{ h } 30 \text{ min} = 1.5 \text{ h} \rightarrow \text{speed} = \frac{150}{1.5} = 100 \text{ km/h}$.

3.2 $\text{mass} = \text{density} \times \text{volume} = 19.3 \times 50 = 965 \text{ g}$.

3.3 $\text{time} = \frac{36}{24} = 1.5 \text{ h} = 1.5 \times 60 = 90 \text{ minutes}$.

3.4 (a) $1 \text{ h } 48 \text{ min} = 1.8 \text{ h}$; $\frac{135}{1.8} = 75 \text{ km/h}$.

(b) $75 \div 3.6 = 20.8 \text{ m/s}$.

(c) $\text{Return time} = \frac{135}{90} = 1.5 \text{ h}$; $\text{total distance} = 270 \text{ km}$, $\text{total time} = 1.8 + 1.5 = 3.3 \text{ h}$;
 $\text{average speed} = \frac{270}{3.3} = 81.8 \text{ km/h}$.

(d) Average speed is total distance divided by total time; the lorry spends longer travelling at the slower speed, so that speed carries more weight and the mean of 75 and 90 is not correct.

(e) $0.4 \text{ m}^3 = 0.4 \times 10^6 = 400\,000 \text{ cm}^3$; $\text{mass} = 400\,000 \times 7.8 = 3\,120\,000 \text{ g} = 3.12 \text{ tonnes}$.