

Q · Kinematics

AQA · A-Level · Mathematics

Scope and prerequisites

AQA A-level Mathematics 7357, section Q (Kinematics), version 1.3 (first assessment 2018). Original teaching notes.

Prerequisites: gradients and areas from GCSE graphs, and the quantities and units of section P.

These are original teaching examples, not official AQA material.

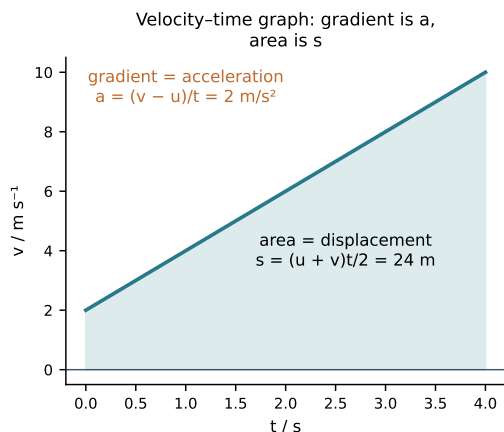
Kinematics

■ The question

- Two cars cover the same 24 metres in the same 4 seconds, yet their speed–time graphs look completely different – one is a sloping line, one is flat. How can both trips be 24 m?
 - Before reading on, say what the gradient and the area of a velocity–time graph each measure, and why a flat graph and a sloping graph can enclose the same area.
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■ The method

- **Kinematics** describes motion without asking what causes it. **Displacement** s is position change in metres; velocity v is the rate of change of displacement; **acceleration** a is the rate of change of velocity, in m/s^2 .
- On a velocity–time graph the gradient is the acceleration and the area under the graph is the displacement. When acceleration is constant, five quantities s , u , v , a , t are linked by the suvat equations, each omitting one quantity: $v = u + at$, $s = ut + at^2/2$, $s = (u + v)t/2$, $v^2 = u^2 + 2as$, $s = vt - at^2/2$.
- kinematics: The description of motion through displacement, velocity, acceleration and time, without reference to causes; displacement: Position change in a stated direction, in metres; acceleration: Rate of change of velocity, in m/s^2 .



suvat: each equation omits one quantity — choose by what is missing

$$v = u + at$$

no s

$$s = ut + at^2/2$$

no v

$$v^2 = u^2 + 2as$$

no t

valid only for constant acceleration

$$\text{Gradient } a = (10 - 2)/4 = 2 \text{ m s}^{-2}; \text{ area } s = (2 + 10)/2 \times 4 = 24 \text{ m}$$

■ Checking your work

- Choose the suvat equation by what is MISSING, not by what is given: list the four quantities involved in the question, find which of the five is absent, and pick the equation that omits it.
- Vertical motion under gravity is the same model with $a = -g \approx -9.8 \text{ m/s}^2$ when up is positive: a ball thrown up keeps the same downward acceleration on the way up, at the top, and on the way down.

■ A worked case

- Known: a cyclist starts at $u = 2 \text{ m/s}$ and accelerates at $a = 2 \text{ m/s}^2$ for $t = 4 \text{ s}$. Final velocity $v = u + at = 2 + 2 \times 4 = 10 \text{ m/s}$. Displacement $s = (u + v)t/2 = (2 + 10) \times 4/2 = 24 \text{ m}$ — the trapezium area under the graph, matching the flat-graph car at 6 m/s for 4 s .

Example:

A stone is dropped from rest and falls for 3 s . Using $g = 9.8 \text{ m/s}^2$, find its speed and the distance fallen, using the same sequence: known $\rightarrow v = u + at \rightarrow s = ut + at^2/2$. (Answer: $v = 0 + 9.8 \times 3 = 29.4 \text{ m/s}$; $s = 0 + 9.8 \times 9/2 = 44.1 \text{ m}$.)

■ Limits and traps

- Check the answer against the graph: the numerical displacement must equal the area, and the sign of the acceleration must match the slope. A negative displacement means the object finished behind its start, not that it “moved backwards in time.”

Warn:

The suvat equations apply to any motion. This claim is false: they assume CON-

STANT acceleration. On a curved velocity–time graph the gradient and area still give acceleration and displacement, but $v = u + at$ and its siblings do not apply – and real falling objects eventually reach terminal velocity, where acceleration is zero.

Key:

Kinematics: on a velocity–time graph gradient is acceleration and area is displacement; for constant acceleration pick the suvat equation that omits the missing quantity; vertical motion is the same model with $a = -g$.