

Exercise walk-through

2.1.2

Velocity–time and acceleration–time graphs

A-Level Physics

2.1.2 Velocity–time and acceleration–time graphs

Name: _____ Class: _____ Date: _____

Total: 34 marks

- KEY WORDS**
- velocity
 - change in velocity
 - acceleration
 - gradient
 - displacement

Objective

Build the skills to answer exam questions on **velocity–time graphs** – and **acceleration–time graphs** – : an acceleration from a gradient, a displacement from an area, and one graph drawn from another. This sheet covers syllabus 2.1, learning outcomes 2, 3 and 5.

You must be able to:

- find an acceleration from the gradient of a velocity–time graph, including at one instant on a curve
- find a displacement from the area under a velocity–time graph, including area below the time axis
- tell distance from displacement on a velocity–time graph

- estimate the area under a curve by counting squares
- find a change in velocity from the area under an acceleration–time graph
- **sketch** one motion graph from another
- use **graphical methods** to represent how speed, velocity and acceleration change with time

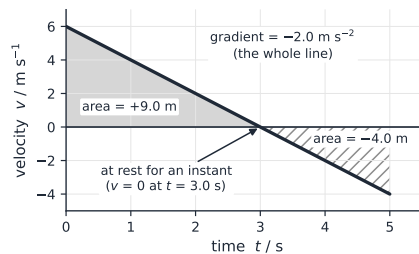
1 Key knowledge and worked examples

Study these first. Each one shows a **method** that a question later on this sheet needs.

■ Gradient and area of a velocity–time graph

On a velocity–time graph the **gradient** is the **acceleration**, and the **area** between the line and the time axis is the **displacement**. Area **below** the time axis is negative displacement: the object is moving backwards. The **distance** adds up the sizes of all the areas.

A trolley is pushed up a track at $6.0 \frac{\text{m}}{\text{s}}$. It slows down, stops for an instant at $t = 3.0 \text{ s}$, and rolls back.



- acceleration = gradient

$$a = \frac{\Delta v}{\Delta t} = \frac{-4.0 \frac{\text{m}}{\text{s}} - 6.0 \frac{\text{m}}{\text{s}}}{5.0 \text{ s}} = -2.0 \text{ m s}^{-2}$$

- the line is straight, so the acceleration is still -2.0 m s^{-2} at $t = 3.0 \text{ s}$, when the velocity is zero
- the area above the axis is a triangle of base t_1 and height v_1

$$s_1 = \frac{1}{2} t_1 v_1 = \frac{1}{2} \times 3.0 \text{ s} \times 6.0 \frac{\text{m}}{\text{s}} = +9.0 \text{ m}$$

- the area below the axis is a triangle too

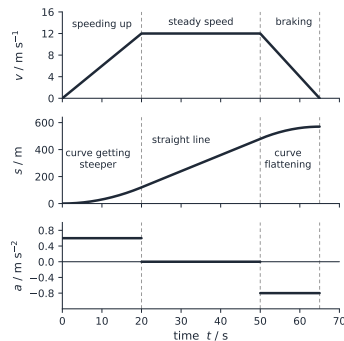
$$s_2 = \frac{1}{2} t_2 v_2 = \frac{1}{2} \times 2.0 \text{ s} \times \left(-4.0 \frac{\text{m}}{\text{s}}\right) = -4.0 \text{ m}$$

- displacement after 5.0 s: $s = s_1 + s_2 = 9.0 \text{ m} - 4.0 \text{ m} = 5.0 \text{ m}$ up the track
- distance after 5.0 s: $d = |s_1| + |s_2| = 9.0 \text{ m} + 4.0 \text{ m} = 13 \text{ m}$

A negative gradient means the acceleration points in the negative direction. On an acceleration-time graph, the area under the line is the **change in velocity**.

■ One journey, three graphs

A train starts from rest and speeds up uniformly to $12 \frac{\text{m}}{\text{s}}$ in 20 s. It keeps this speed for 30 s, then brakes uniformly to rest in 15 s.



- **acceleration–time:** each acceleration is a gradient of the velocity–time graph,

$$a = \frac{\Delta v}{\Delta t}$$

$$a_1 = \frac{12 \frac{\text{m}}{\text{s}} - 0}{20 \text{ s}} = 0.60 \text{ m s}^{-2}, \quad a_3 = \frac{0 - 12 \frac{\text{m}}{\text{s}}}{15 \text{ s}} = -0.80 \text{ m s}^{-2}$$

- while the speed is steady, $a = 0$
- **displacement–time:** its gradient is the velocity, so it gets steeper while the train speeds up, is a straight line while the speed is steady, and flattens to horizontal as the train stops
- total displacement = area under the velocity–time graph: a triangle, a rectangle and a triangle

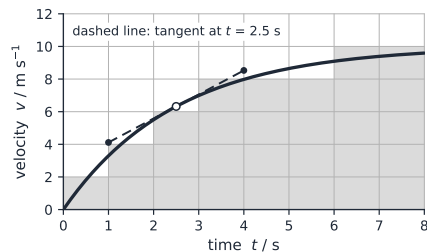
$$s = \frac{1}{2}t_1v + t_2v + \frac{1}{2}t_3v$$

$$s = \frac{1}{2}(20 \text{ s})(12 \frac{\text{m}}{\text{s}}) + (30 \text{ s})(12 \frac{\text{m}}{\text{s}}) + \frac{1}{2}(15 \text{ s})(12 \frac{\text{m}}{\text{s}}) = 570 \text{ m}$$

When you **sketch** a graph, draw and label both axes, and give each part the right shape: straight or curved, getting steeper or getting flatter.

■ A curve: a tangent and counting squares

When a velocity–time graph is a curve, the acceleration at one instant is the gradient of the **tangent** there, and the area is estimated by counting grid squares.



- the tangent at $t = 2.5$ s passes through $(1.0 \text{ s}, 4.1 \frac{\text{m}}{\text{s}})$ and $(4.0 \text{ s}, 8.5 \frac{\text{m}}{\text{s}})$

$$a = \frac{\Delta v}{\Delta t} = \frac{8.5 \frac{\text{m}}{\text{s}} - 4.1 \frac{\text{m}}{\text{s}}}{4.0 \text{ s} - 1.0 \text{ s}} = 1.5 \text{ m s}^{-2}$$

- one square is 1 s wide and $2 \frac{\text{m}}{\text{s}}$ tall, so it is worth

$$\text{one square} = \Delta t \times \Delta v = 1 \text{ s} \times 2 \frac{\text{m}}{\text{s}} = 2 \text{ m}$$

- count every square that is **at least half** under the curve: 28 squares
- displacement $\approx \text{squares} \times \text{one square} = 28 \times 2 \text{ m} = 56 \text{ m}$

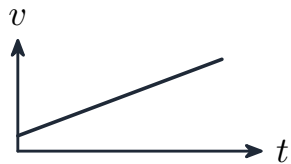
■ Key knowledge: an interval or one instant?

- Average acceleration** over t_1 to t_2 : $a_{av} = [v(t_2) - v(t_1)] / (t_2 - t_1)$, the gradient of the **chord** joining the endpoints on a velocity–time graph.
- Instantaneous acceleration**: gradient of the **tangent** at the stated time. It need not equal the chord gradient.
- Read the axis labels first. A velocity-versus-acceleration graph has neither time on its horizontal axis nor acceleration as its gradient.

Worked example. A curved graph goes from 2 to 10 m/s in 4 s . $a_{av} = \Delta v / \Delta t = (10 - 2) / 4 = 2 \text{ m s}^{-2}$. A tangent at 2 s rising 3 m/s in 2 s gives $a(2) = \Delta v / \Delta t = 3 / 2 = 1.5 \text{ m s}^{-2}$.

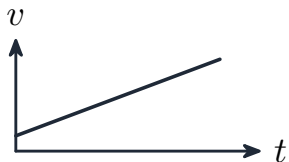
Exercise 2.1

2.1 State what is represented by (a) the gradient of a velocity–time graph; (b) the area under a velocity–time graph. [2]



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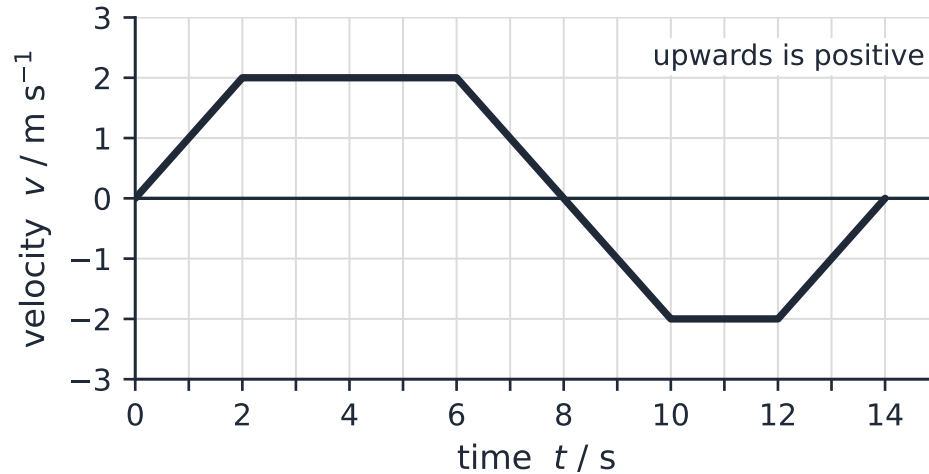
2.1

(a) the gradient is the **acceleration**

(b) the area is the **displacement**

Setup for exercise 2.2

2.2 The velocity–time graph shows a lift that goes up and then comes back down. Upwards is positive.



Exercise 2.2 (a)

(a) Calculate the acceleration of the lift between $t = 0$ and $t = 2.0$ s.

[1]

Exercise 2.2 (a)

(a) Calculate the acceleration of the lift between $t = 0$ and $t = 2.0$ s.

[1]

(a) the acceleration is the gradient of the first line

$$a = \frac{\Delta v}{\Delta t} = \frac{2.0 \frac{\text{m}}{\text{s}} - 0}{2.0 \text{ s} - 0} = \mathbf{1.0 \text{ m s}^{-2}}$$

Exercise 2.2 (b)

(b) State the times at which the lift is at rest.

[1]

Exercise 2.2 (b)

(b) State the times at which the lift is at rest.

[1]

(b) $v = 0$ at $t = \mathbf{0}$, $\mathbf{8.0}$ s and $\mathbf{14}$ s

Exercise 2.2 (c)

(c) Calculate the total distance travelled by the lift in the 14 s. (*Hint: for distance, every area counts as positive.*) [2]

Exercise 2.2 (c)

(c) Calculate the total distance travelled by the lift in the 14 s. (*Hint: for distance, every area counts as positive.*) [2]

(c) going up, the area above the axis is a trapezium of parallel sides t_1 , t_2 and height v

$$s_{\text{up}} = \frac{1}{2}(t_1 + t_2)v = \frac{1}{2}(8.0 \text{ s} + 4.0 \text{ s})(2.0 \frac{\text{m}}{\text{s}}) = 12 \text{ m}$$

- coming down, the area below the axis is a trapezium too

$$s_{\text{down}} = \frac{1}{2}(t_1 + t_2)v = \frac{1}{2}(6.0 \text{ s} + 2.0 \text{ s})(2.0 \frac{\text{m}}{\text{s}}) = 8.0 \text{ m}$$

- total distance $d = s_{\text{up}} + s_{\text{down}} = 12 \text{ m} + 8.0 \text{ m} = \mathbf{20 \text{ m}}$

Exercise 2.2 (d)

(d) Determine the displacement of the lift from its starting point at $t = 14$ s. [1]

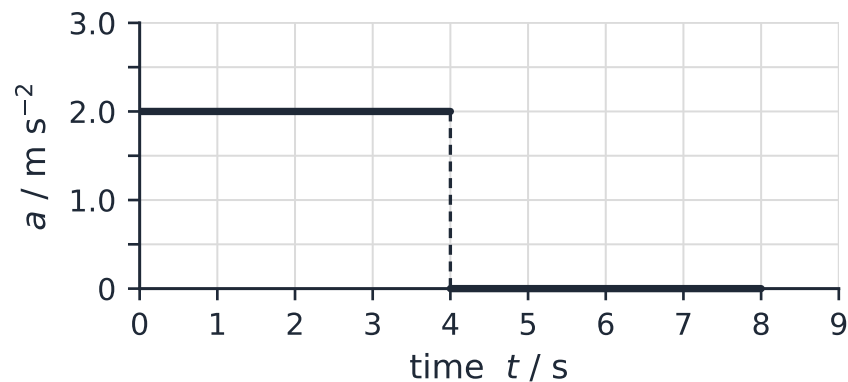
Exercise 2.2 (d)

(d) Determine the displacement of the lift from its starting point at $t = 14$ s. [1]

(d) displacement $s = s_{\text{up}} - s_{\text{down}} = 12 \text{ m} - 8.0 \text{ m} = \mathbf{4.0}$ m above the starting point

Setup for exercise 2.3

2.3 A car is moving at $5.0 \frac{\text{m}}{\text{s}}$ at time $t = 0$. The graph shows its acceleration.



Exercise 2.3 (a)

- (a) Determine the change in velocity of the car between $t = 0$ and $t = 4.0$ s. [1]

Exercise 2.3 (a)

(a) Determine the change in velocity of the car between $t = 0$ and $t = 4.0$ s. [1]

(a) change in velocity = area under the acceleration–time graph, a rectangle

$$\Delta v = a \Delta t = 2.0 \text{ m s}^{-2} \times 4.0 \text{ s} = \mathbf{8.0} \frac{\text{m}}{\text{s}}$$

Exercise 2.3 (b)

(b) State the velocity of the car at $t = 6.0$ s.

[1]

Exercise 2.3 (b)

(b) State the velocity of the car at $t = 6.0$ s. [1]

(b) $v = u + \Delta v = 5.0 \frac{\text{m}}{\text{s}} + 8.0 \frac{\text{m}}{\text{s}} = 13 \frac{\text{m}}{\text{s}}$ at 4.0 s; the acceleration is then zero, so at 6.0 s the velocity is still **13** $\frac{\text{m}}{\text{s}}$

Exercise 2.3 (c)

(c) **Sketch** the velocity–time graph of the car from $t = 0$ to $t = 8.0$ s. Label both axes and mark the values of velocity. [2]

Exercise 2.3 (c)

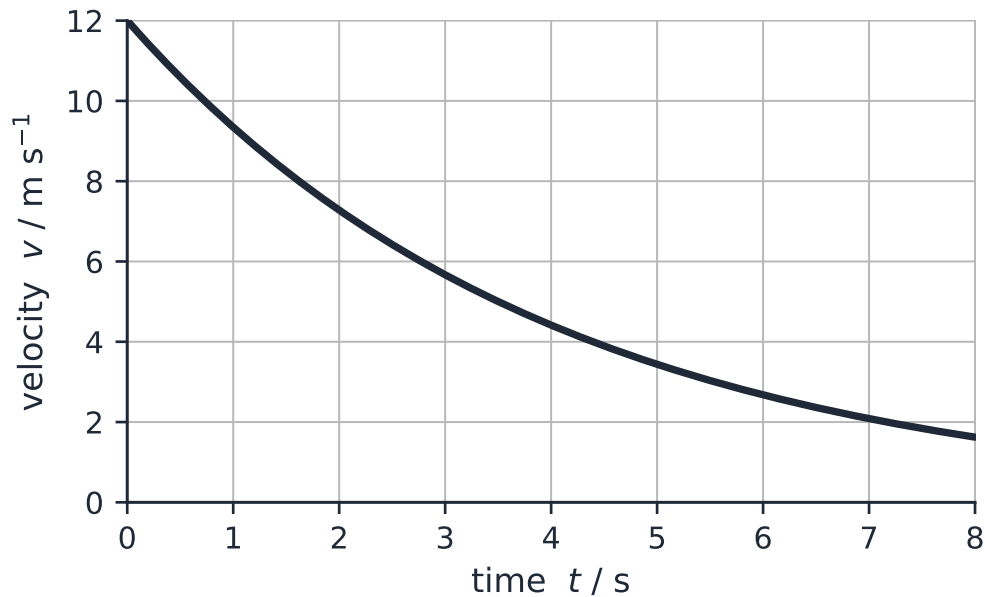
(c) **Sketch** the velocity–time graph of the car from $t = 0$ to $t = 8.0$ s. Label both axes and mark the values of velocity. [2]

(c)

- a straight line from $(0, 5.0 \frac{\text{m}}{\text{s}})$ to $(4.0 \text{ s}, 13 \frac{\text{m}}{\text{s}})$
- then a horizontal line at $13 \frac{\text{m}}{\text{s}}$ to 8.0 s, with the axes labelled $v / \frac{\text{m}}{\text{s}}$ and t / s

Setup for exercise 2.4

2.4 A cyclist stops pedalling and slows down. The graph shows the velocity of the cyclist.



Exercise 2.4 (a)

(a) By drawing a tangent, determine the acceleration of the cyclist at $t = 4.0$ s. [2]

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(a) tangent drawn at $t = 4.0$ s, for example through $(0, 8.8 \frac{\text{m}}{\text{s}})$ and $(8.0 \text{ s}, 0)$

$$a = \frac{\Delta v}{\Delta t} = \frac{0 - 8.8 \frac{\text{m}}{\text{s}}}{8.0 \text{ s} - 0} = -1.1 \text{ m s}^{-2}$$

(accept -1.0 to -1.2)

Exercise 2.4 (b)

(b) Estimate the distance travelled by the cyclist from $t = 0$ to $t = 8.0$ s by counting squares. [2]

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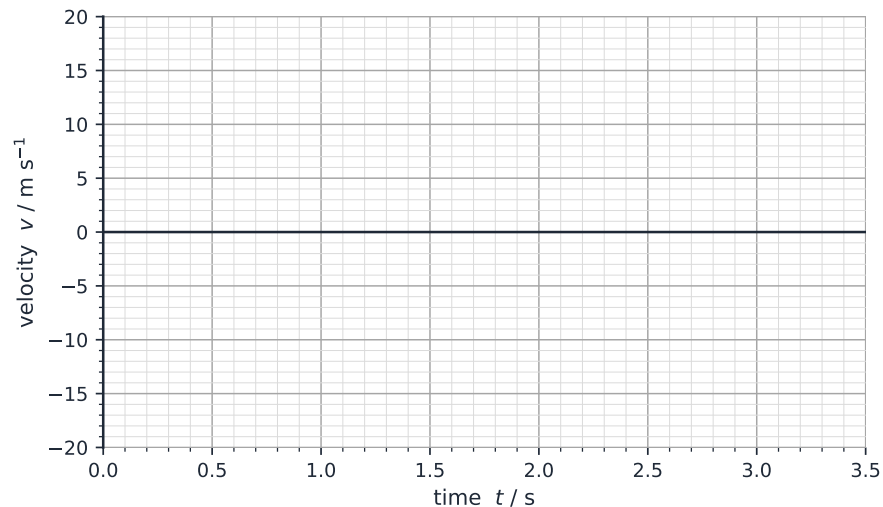
(b) about 21 squares are at least half under the curve, and one square is worth $\Delta t \times \Delta v = 1 \text{ s} \times 2 \frac{\text{m}}{\text{s}} = 2 \text{ m}$

$$\text{distance} \approx \text{squares} \times \text{one square} = 21 \times 2 \text{ m} = \mathbf{42 \text{ m}}$$

(accept 40 m to 44 m)

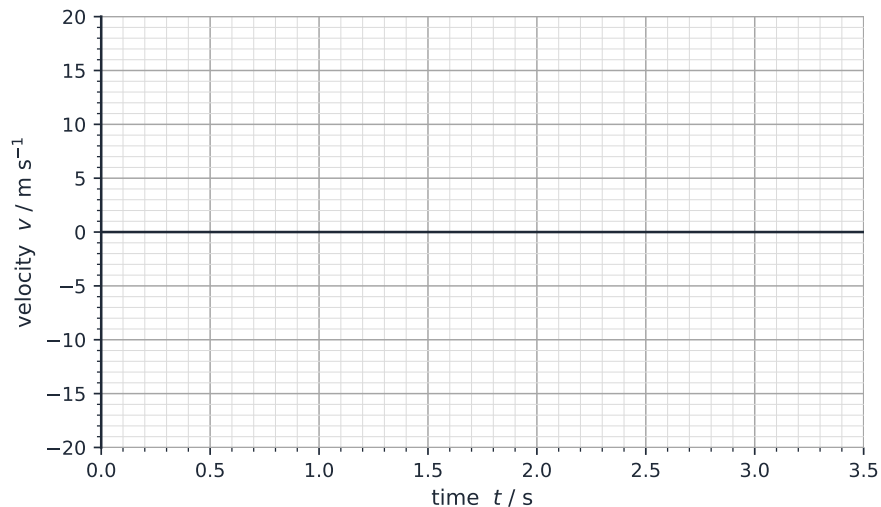
Exercise 2.5

2.5 A curved velocity–time graph goes from 3.0 m/s at 1.0 s to 15.0 m/s at 5.0 s . Its tangent at 3.0 s goes through $(2.0 \text{ s}, 6.0 \text{ m/s})$ and $(4.0 \text{ s}, 10.0 \text{ m/s})$. Find the average acceleration over the interval and the acceleration at 3.0 s . [4]



Exercise 2.5

2.5 A curved velocity–time graph goes from 3.0 m/s at 1.0 s to 15.0 m/s at 5.0 s. Its tangent at 3.0 s goes through (2.0 s, 6.0 m/s) and (4.0 s, 10.0 m/s). Find the average acceleration over the interval and the acceleration at 3.0 s. [4]



2.5

- Average: $a_{av} = \Delta v / \Delta t = (15.0 - 3.0) / (5.0 - 1.0) = 3.0 \text{ m s}^{-2}$.

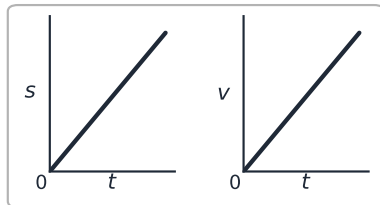
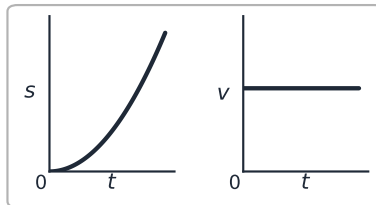
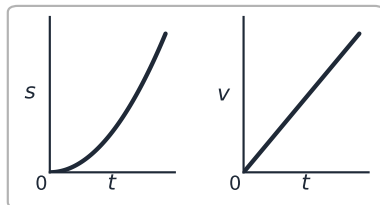
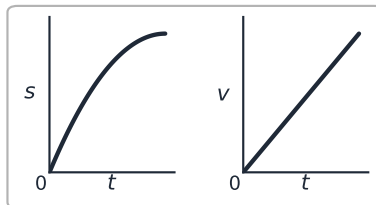
Full solution 2.5

2.5

- Average: $a_{\text{av}} = \Delta v / \Delta t = (15.0 - 3.0) / (5.0 - 1.0) = 3.0 \text{ m s}^{-2}$.
- Instantaneous: $a(3.0) = \Delta v / \Delta t = (10.0 - 6.0) / (4.0 - 2.0) = 2.0 \text{ m s}^{-2}$ using the tangent.

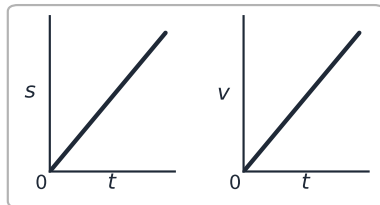
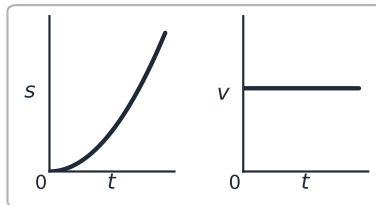
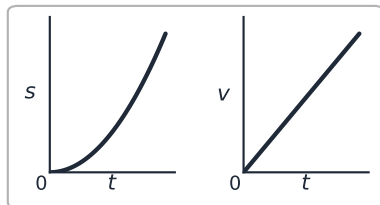
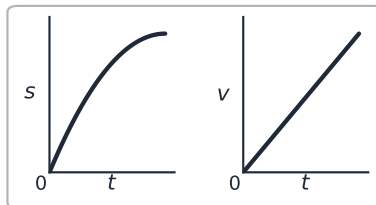
Exercise 3.1

3.1 An object starts from rest and moves in a straight line. Which pair of graphs could show how its displacement s and its velocity v change with time t ? [1]

☐**A****B****C****D**

Exercise 3.1

3.1 An object starts from rest and moves in a straight line. Which pair of graphs could show how its displacement s and its velocity v change with time t ? [1]

**A****B****C****D**

3.1 C

- the curve in **C** gets steeper, so the velocity increases from zero, which matches a velocity line rising from the origin

Full solution on next slide

Full solution 3.1

3.1 C

- the curve in **C** gets steeper, so the velocity increases from zero, which matches a velocity line rising from the origin
- **A**: a straight displacement line means a constant velocity, not an increasing one
- **B**: a curve that gets steeper cannot have a constant velocity
- **D**: a curve that gets flatter means the velocity is decreasing

Exercise 3.2

3.2 The velocity–time graph of an object is a straight line from $8.0 \frac{\text{m}}{\text{s}}$ at $t = 0$ to $-4.0 \frac{\text{m}}{\text{s}}$ at $t = 6.0 \text{ s}$. What is the displacement of the object after 6.0 s ? [1]

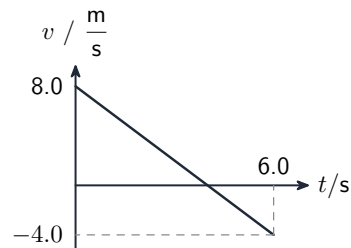
☐

A 12 m

B 20 m

C 24 m

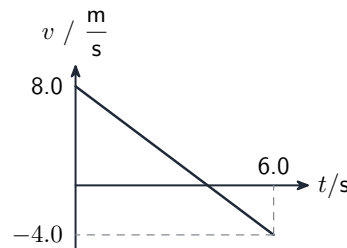
D 36 m



Exercise 3.2

3.2 The velocity–time graph of an object is a straight line from $8.0 \frac{\text{m}}{\text{s}}$ at $t = 0$ to $-4.0 \frac{\text{m}}{\text{s}}$ at $t = 6.0 \text{ s}$. What is the displacement of the object after 6.0 s ? [1]

- ☐ **A** 12 m
☐ **B** 20 m
☐ **C** 24 m
☐ **D** 36 m



3.2 A

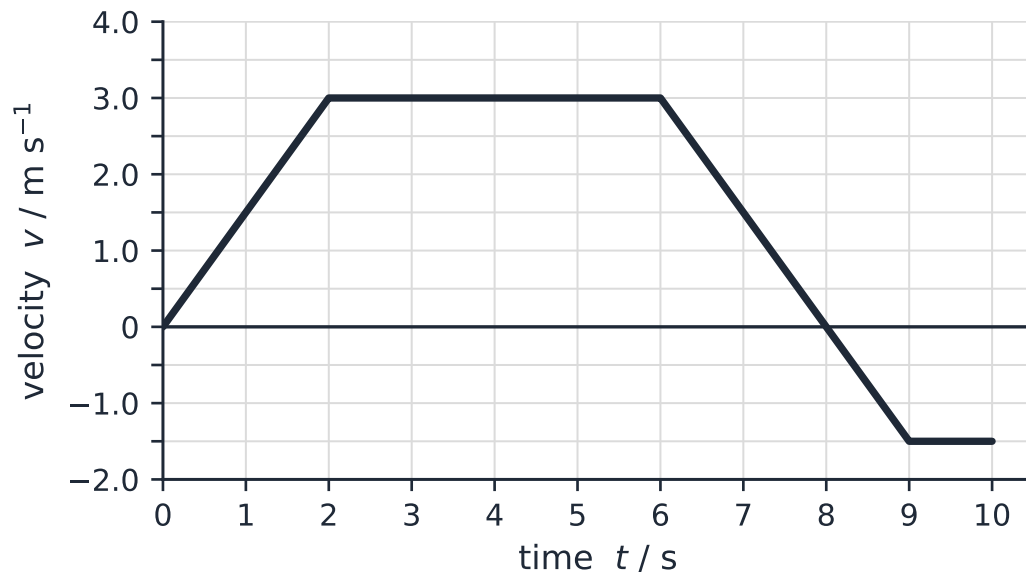
- the gradient is $a = \frac{\Delta v}{\Delta t} = \frac{-4.0 \frac{\text{m}}{\text{s}} - 8.0 \frac{\text{m}}{\text{s}}}{6.0 \text{ s}} = -2.0 \text{ m s}^{-2}$, so $v = 0$ at $t = 4.0 \text{ s}$
- each area is a triangle, $s = \frac{1}{2} t v$

$$s_1 = \frac{1}{2}(4.0 \text{ s})(8.0 \frac{\text{m}}{\text{s}}) = 16 \text{ m}, \quad s_2 = \frac{1}{2}(2.0 \text{ s})(-4.0 \frac{\text{m}}{\text{s}}) = -4.0 \text{ m}$$

- displacement $s = s_1 + s_2 = 16 \text{ m} - 4.0 \text{ m} = \mathbf{12 \text{ m}}$
- B** is the distance; **C** treats the whole graph as one triangle; **D** ignores the minus sign

Setup for exercise 3.3

3.3 A remote-controlled toy car moves along a straight track. A **motion sensor** records its velocity v . The graph shows how v varies with time t .



Exercise 3.3 (a)

(a) **Define** acceleration.

[1]

Exercise 3.3 (a)

(a) **Define** acceleration.

[1]

(a) acceleration is the **rate of change of velocity**

Exercise 3.3 (b)

(b) **Compare** the acceleration of the car at $t = 1.0$ s with its acceleration at $t = 7.0$ s, in terms of magnitude and direction. [2]

Exercise 3.3 (b)

(b) **Compare** the acceleration of the car at $t = 1.0$ s with its acceleration at $t = 7.0$ s, in terms of magnitude and direction. [2]

(b) each acceleration is the gradient of the line through that instant, $a = \frac{\Delta v}{\Delta t}$

$$\text{at } 1.0 \text{ s : } \frac{3.0 \frac{\text{m}}{\text{s}} - 0}{2.0 \text{ s} - 0} = 1.5 \text{ m s}^{-2} \quad \text{at } 7.0 \text{ s : } \frac{-1.5 \frac{\text{m}}{\text{s}} - 3.0 \frac{\text{m}}{\text{s}}}{9.0 \text{ s} - 6.0 \text{ s}} = -1.5 \text{ m s}^{-2}$$

- magnitude: **the same**
- direction: **opposite**

Exercise 3.3 (c)

(c) The car is at rest for an instant at $t = 8.0$ s. Determine the acceleration of the car at this instant. [2]

Exercise 3.3 (c)

(c) The car is at rest for an instant at $t = 8.0$ s. Determine the acceleration of the car at this instant. [2]

(c) the acceleration is the gradient of the straight line from 6.0 s to 9.0 s, which includes 8.0 s

$$a = \frac{\Delta v}{\Delta t} = \frac{-1.5 \frac{\text{m}}{\text{s}} - 3.0 \frac{\text{m}}{\text{s}}}{9.0 \text{ s} - 6.0 \text{ s}} = -\mathbf{1.5} \text{ m s}^{-2}$$

- it is not zero: the velocity is zero for an instant, but it is still changing

Exercise 3.3 (d)

(d) Determine the greatest displacement of the car from its starting point, and the time at which it happens. [3]

Exercise 3.3 (d)

(d) Determine the greatest displacement of the car from its starting point, and the time at which it happens. [3]

(d) the car moves forwards until $v = 0$, so the greatest displacement is at $t = \mathbf{8.0\ s}$

- displacement = area under the line from 0 to 8.0 s: a triangle, a rectangle and a triangle

$$s = \frac{1}{2}t_1v + t_2v + \frac{1}{2}t_3v$$

$$s = \frac{1}{2}(2.0\ \text{s})(3.0\ \frac{\text{m}}{\text{s}}) + (4.0\ \text{s})(3.0\ \frac{\text{m}}{\text{s}}) + \frac{1}{2}(2.0\ \text{s})(3.0\ \frac{\text{m}}{\text{s}}) = \mathbf{18\ m}$$

Exercise 3.3 (e)

(e) Determine the displacement of the car from its starting point at $t = 10.0$ s. [2]

Exercise 3.3 (e)

(e) Determine the displacement of the car from its starting point at $t = 10.0$ s. [2]

(e) area below the axis from 8.0 s to 10.0 s: a triangle and a rectangle

$$\Delta s = \frac{1}{2}t_1v + t_2v$$

$$\Delta s = \frac{1}{2}(1.0 \text{ s})(-1.5 \frac{\text{m}}{\text{s}}) + (1.0 \text{ s})(-1.5 \frac{\text{m}}{\text{s}}) = -2.25 \text{ m}$$

- displacement $s = 18 \text{ m} + \Delta s = 18 \text{ m} - 2.25 \text{ m} = \mathbf{15.75 \text{ m}}$, i.e. about 16 m

Exercise 3.3 (f)

(f) **Sketch** the variation with time of the displacement of the car from $t = 0$ to $t = 10.0$ s. Label both axes and mark the greatest displacement. [3]

Exercise 3.3 (f)

(f) **Sketch** the variation with time of the displacement of the car from $t = 0$ to $t = 10.0$ s. Label both axes and mark the greatest displacement. [3]

(f) the gradient of a displacement–time graph **is** the velocity, so every stage of the v – t graph fixes a shape: a **constant** v gives a straight line of that gradient, a **uniform** a gives a parabola. Take the stages in turn with

$$s = ut + \frac{1}{2}at^2$$

and add each result to the displacement already reached. Each Δs is one of the areas counted in (d) and (e).

- $0 \rightarrow 2.0$ s: $u = 0$, $a = +1.5 \text{ m s}^{-2}$, $t = 2.0$ s – a curve getting **steeper**, reaching $s = 3.0$ m

$$\Delta s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2}(1.5 \text{ m s}^{-2})(2.0 \text{ s})^2 = 3.0 \text{ m}$$

Full solution 3.3 (f) (1/4)

(f) the gradient of a displacement–time graph **is** the velocity, so every stage of the v – t graph fixes a shape: a **constant** v gives a straight line of that gradient, a **uniform** a gives a parabola. Take the stages in turn with

$$s = ut + \frac{1}{2}at^2$$

and add each result to the displacement already reached. Each Δs is one of the areas counted in (d) and (e).

- $0 \rightarrow 2.0$ s: $u = 0$, $a = +1.5 \text{ m s}^{-2}$, $t = 2.0$ s – a curve getting **steeper**, reaching $s = 3.0$ m

$$\Delta s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2}(1.5 \text{ m s}^{-2})(2.0 \text{ s})^2 = 3.0 \text{ m}$$

- $2.0 \rightarrow 6.0$ s: $v = 3.0 \frac{\text{m}}{\text{s}}$, $a = 0$, $t = 4.0$ s – a **straight line** of gradient $3.0 \frac{\text{m}}{\text{s}}$, reaching $s = 15$ m

$$\Delta s = vt = (3.0 \frac{\text{m}}{\text{s}})(4.0 \text{ s}) = 12 \text{ m}$$

- $6.0 \rightarrow 8.0$ s: $u = 3.0 \frac{\text{m}}{\text{s}}$, $a = -1.5 \text{ m s}^{-2}$, $t = 2.0$ s – a curve getting **flatter**, reaching $s = 18$ m

Full solution 3.3 (f) (2/4)

$$\Delta s = ut + \frac{1}{2}at^2 = (3.0 \frac{\text{m}}{\text{s}})(2.0 \text{ s}) + \frac{1}{2}(-1.5 \text{ m s}^{-2})(2.0 \text{ s})^2 = 3.0 \text{ m}$$

- 8.0 $\rightarrow$ 9.0 s: $u = 0$, $a = -1.5 \text{ m s}^{-2}$, $t = 1.0 \text{ s}$ – the graph **turns over** and comes back down to $s = 17.25 \text{ m}$

$$\Delta s = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2}(-1.5 \text{ m s}^{-2})(1.0 \text{ s})^2 = -0.75 \text{ m}$$

- 9.0 $\rightarrow$ 10.0 s: $v = -1.5 \frac{\text{m}}{\text{s}}$, $a = 0$, $t = 1.0 \text{ s}$ – a **straight line** of gradient $-1.5 \frac{\text{m}}{\text{s}}$, reaching $s = 15.75 \text{ m}$

$$\Delta s = vt = (-1.5 \frac{\text{m}}{\text{s}})(1.0 \text{ s}) = -1.5 \text{ m}$$

- the six points to plot are (0, 0), (2.0 s, 3.0 m), (6.0 s, 15 m), (8.0 s, 18 m), (9.0 s, 17.25 m) and (10.0 s, 15.75 m)

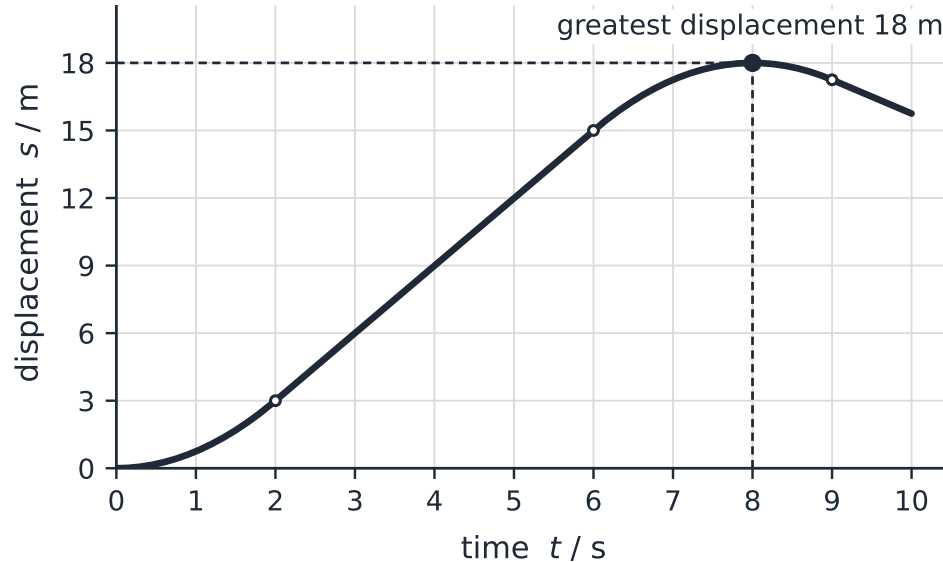
Full solution 3.3 (f) (3/4)

- axes labelled s / m and t / s ; a curve getting steeper to 3.0 m at 2.0 s, then a straight line to 15 m at 6.0 s
- a curve getting flatter to a maximum of 18 m at 8.0 s, flat at the top, and that maximum marked
- s then falling to 15.75 m at 10.0 s, staying **above** the axis – the car is still 15.75 m in front of where it started

Sketch the graph by joining those six points with the shapes named above, and mark the greatest displacement.



Full solution 3.3 (f) (4/4)



- the open circles on the graph are the three places where the shape changes, at 2.0 s, 6.0 s and 9.0 s
- common error: drawing the $s-t$ graph as a copy of the $v-t$ graph. The car going backwards after 8.0 s makes s **decrease**; it does not make s negative