Displacement–time and velocity–time graphs

127 marks

Hints online, answers free with an account: mathswariz.uk/worksheets/a-level-mechanics-displacement-time-and-velocity-time-graphs/

Date

A Do Now

Quick questions to start.

A1 Needed today [2 marks]

Convert $54\ \text{km h}^{-1}$ to metres per second.

Answer .....

A2 Needed today [2 marks]

A trapezium has parallel sides 12 cm and 20 cm, which are 5 cm apart. Find its area.

Answer .....

A3 Common slip [2 marks]

A particle starts from rest and its velocity increases uniformly to $18\ \text{m s}^{-1}$ in 6 seconds. Find its acceleration, giving the correct units.

Answer .....

A4 Common slip [3 marks]

A runner goes 300 m due east, then 100 m due west, in a total of 80 s. Find her average speed and her average velocity.

Answer .....

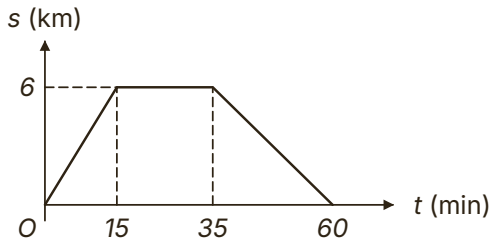
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B Example, then your turn

Your teacher works through each example with you. Then try the one beside it.

EXAMPLE 1

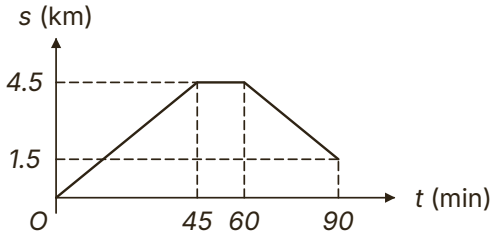
The diagram is the displacement–time graph of a cyclist who rides in a straight line from O, stops, and then rides back to O. Find her velocity in each stage of the journey in km h^{-1}, her average velocity and her average speed for the whole hour.



Hint Velocity is the gradient of a displacement–time graph. A negative gradient means she is moving back towards O. Average velocity uses the displacement; average speed uses the total distance.

B1 [5 marks]

The diagram is the displacement–time graph of a walker who moves along a straight path from O. Find her velocity in each stage in km h^{-1}, and her average velocity and her average speed for the whole 90 minutes.

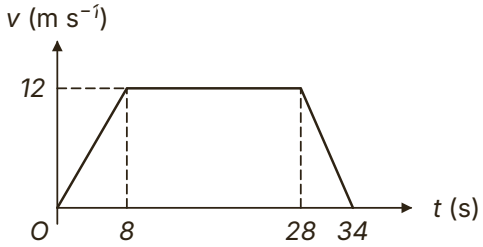


Answer .....

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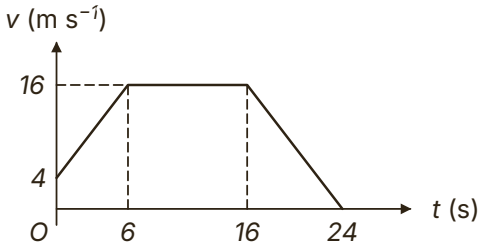
EXAMPLE 2

The diagram is the velocity–time graph of a car moving along a straight road. Find the acceleration, the deceleration, and the total distance the car travels.



Hint Acceleration is the gradient of a velocity–time graph. Distance is the area under it: a trapezium, or a triangle, a rectangle and a triangle. Keep the $\frac{1}{2}$ in every triangle and trapezium.

B2 The diagram is the velocity–time graph of a cyclist. Find her acceleration in the first stage, her deceleration in the last stage, and the total distance she travels. [5 marks]



Answer .....

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EXAMPLE 3

A train starts from rest at a station. It accelerates uniformly at $0.5\ \text{m s}^{-2}$ for 40 s, then moves at constant speed for T s, then decelerates uniformly to rest in 50 s at the next station. The stations are 3.6 km apart. Sketch a velocity–time graph of the journey and find T.

Hint Find the top speed first. On the sketch put the top speed on the velocity axis and 40, $40 + T$ and $90 + T$ on the time axis. The area under the graph is the distance, in metres.

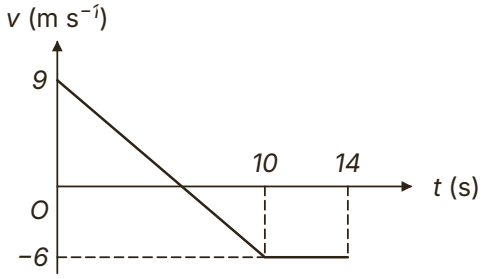
B3 A tram starts from rest. It accelerates uniformly at $0.4\ \text{m s}^{-2}$ for 30 s, then moves at constant speed for T s, then decelerates uniformly to rest in 20 s. It travels 2.1 km in all. Sketch a velocity–time graph of the motion and find T. [6 marks]

Answer .....

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EXAMPLE 4

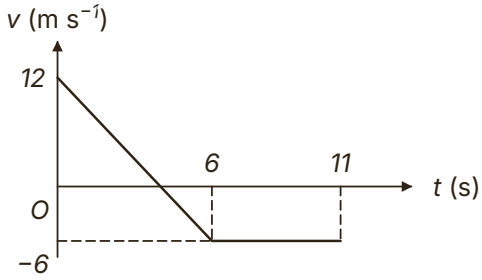
A particle moves along a straight line. The diagram is its velocity–time graph for $0 \leq t \leq 14$. Find the time at which it is at rest, the distance it travels in the 14 s, its displacement from its start at $t = 14$, and the time at which it passes its start again.



Hint The velocity falls by $15\ \text{m s}^{-1}$ in 10 s. Area above the axis is distance moved forwards; area below the axis is distance moved backwards. Distance adds the two; displacement subtracts.

B4 [6 marks]

The diagram is the velocity–time graph of a particle moving along a straight line, for $0 \leq t \leq 11$. Find the time at which it is at rest, the distance it travels in the 11 s, its displacement from its start at $t = 11$, and the time at which it passes its start again.

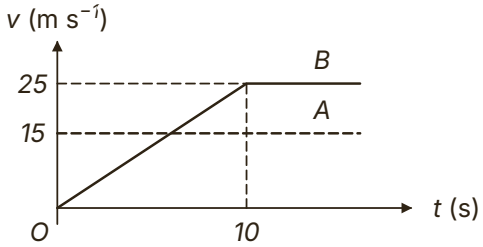


Answer .....

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EXAMPLE 5

At $t = 0$ car A passes a point P moving at a constant $15\ \text{m s}^{-1}$. At the same moment car B starts from rest at P and moves in the same direction, accelerating uniformly at $2.5\ \text{m s}^{-2}$ until it reaches $25\ \text{m s}^{-1}$, then keeping that speed. The diagram shows both velocity–time graphs. Find when the cars have the same speed, the greatest distance between them before B catches A, and the time and distance from P at which B catches A.



Hint Until the speeds are equal, A is going faster, so the gap grows. Each car's distance from P is the area under its own graph. B catches A when the two areas are equal.

B5 At $t = 0$ a motorbike passes a junction J moving at a constant $18\ \text{m s}^{-1}$. At the same moment a car starts from rest at J and moves the same way. It accelerates uniformly at $2\ \text{m s}^{-2}$ for 15 s and then keeps a constant speed. Find when they have the same speed, the greatest distance between them before the car catches the motorbike, and the time and distance from J at which the car catches it. [6 marks]

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Answer .....

C Practice

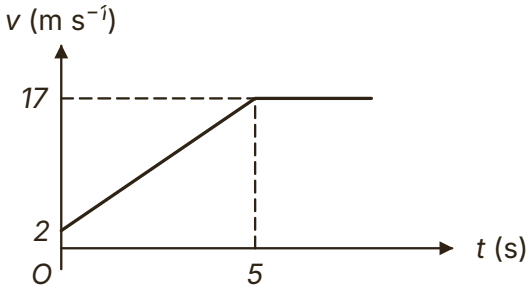
A-Level

C1 In the last 8 s of a race a runner slows down uniformly from $10\ \text{m s}^{-1}$ to $U\ \text{m s}^{-1}$ and covers 64 m. Priya writes $\frac{1}{2} \times 8 \times U = 64$, so $U = 16$. Explain why her answer cannot be right, and find U. [4 marks]

Answer .....

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C2 The diagram shows the velocity–time graph of a particle for the first 8 s of its motion. Leo says the acceleration in the first 5 s is $\frac{1}{2}(2+17)\times 5 = 47.5\ \text{m s}^{-1}$. Explain his mistake, then find the acceleration and the distance travelled in the first 5 s. [4 marks]



Answer .....

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C3 A car starts from rest and accelerates uniformly to a speed of V m s^{-1} in 12 s. It keeps this speed for 30 s, then decelerates uniformly to rest. The deceleration is twice the acceleration. The car travels 780 m in all. Find V and the acceleration. [5 marks]

Answer .....

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C4 A lift rises from rest. It accelerates uniformly at $0.8\ \text{m s}^{-2}$ for 2.5 s, then rises at a constant speed, then decelerates uniformly at $0.5\ \text{m s}^{-2}$ until it stops. It rises 30 m in all. Find the time for which it moves at constant speed and the total time of the journey. [5 marks]

Answer .....

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C5 A cyclist starts from rest, accelerates uniformly at $2\ \text{m s}^{-2}$ for 10 s, then rides at a constant $20\ \text{m s}^{-1}$. Find the time at which she has travelled 64 m. Jay says she has travelled 300 m after $\dfrac{300}{20} = 15$ s. Explain why Jay is wrong and find the correct time. [5 marks]

Answer .....

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D Exam-style questions

Edexcel exam style

D1 A train starts from rest at station A and accelerates uniformly for 50 s until its speed is $72\ \text{km h}^{-1}$. It keeps this speed for a time, then decelerates uniformly at $0.5\ \text{m s}^{-2}$, coming to rest at station B. The distance AB is 5 km.

(a) Sketch a velocity–time graph for the journey from A to B. [3 marks]

Answer .....

(b) Find the time for which the train moves at constant speed. [4 marks]

Answer .....

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(c) Find the average speed of the train between A and B. [2 marks]

Answer .....

(d) State one way in which the velocity–time graph model may not be realistic. [2 marks]

Total for D1: 11 marks

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D2

A sprinter runs 100 m in a straight line in 12 s. She is modelled as accelerating uniformly from rest for 4 s up to a speed of V m s^{-1}, then running at V m s^{-1} to the finish. Kai says her top speed is $\frac{100}{12} = 8.33$ m s^{-1}.

Kai is wrong.

(a) Find V. [3 marks]

Answer .....

(b) Explain Kai's mistake. [2 marks]

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(c) Find the time at which she has run 50 m. [3 marks]

Answer .....

(d) State one way in which the model is not realistic. [2 marks]

Total for D2: 10 marks

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D3 A van passes a point P at time $t = 0$, moving along a straight road at a constant $20\ \text{m s}^{-1}$. A car is at rest at P. At $t = 5$ s the car starts to move in the same direction as the van. It accelerates uniformly at $2.5\ \text{m s}^{-2}$ until its speed is $30\ \text{m s}^{-1}$, then keeps this speed.

(a) Sketch, on the same axes, the velocity–time graphs of the van and the car for $t \geq 0$. [3 marks]

Answer .....

(b) Find the time at which the car reaches $30\ \text{m s}^{-1}$. [2 marks]

Answer .....

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(c) Find the time at which the car overtakes the van, and the distance from P at which this happens. [5 marks]

Answer .....

Total for D3: 10 marks

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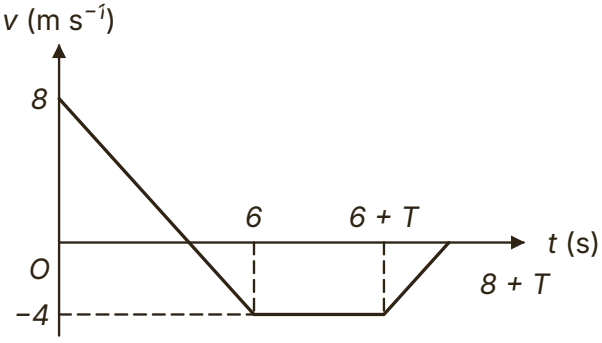
D4 A train travels between two stations 6.3 km apart, starting and finishing at rest. Its greatest speed is $30\ \text{m s}^{-1}$, its acceleration is $0.5\ \text{m s}^{-2}$ and its deceleration is $0.75\ \text{m s}^{-2}$. Find the shortest possible time for the journey. [7 marks]

Answer .....

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D5 A particle moves along a straight line. The diagram, which is not drawn to scale, is its velocity–time graph. The velocity falls uniformly from $8\ \text{m s}^{-1}$ to $-4\ \text{m s}^{-1}$ in the first 6 s, stays at $-4\ \text{m s}^{-1}$ for T s, then rises uniformly to 0 in 2 s. At the end of the motion the particle is back at its starting point.

(a) Find the deceleration in the first 6 s. [2 marks]



Answer .....

(b) Find the time at which the particle is instantaneously at rest. [2 marks]

Answer .....

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(c) Find T. [3 marks]

Answer .....

(d) Find the total distance travelled by the particle. [2 marks]

Answer .....

Total for D5: 9 marks

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D6 A car moves along a straight road from rest at A to rest at B. It accelerates uniformly for T seconds up to a speed of $V\ \text{m s}^{-1}$, moves at $V\ \text{m s}^{-1}$ for $4T$ seconds, then decelerates uniformly to rest in $2T$ seconds. The journey takes 84 s and $AB = 1320$ m.

(a) Sketch a velocity–time graph for the journey. [3 marks]

Answer .....

(b) Show that $T = 12$. [2 marks]

Answer .....

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(c) Find V. [3 marks]

Answer .....

(d) Find the acceleration and the deceleration of the car. [2 marks]

Answer .....

Total for D6: 10 marks

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No route is given. The hints are at the end of the sheet. Use one at a time.

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E1 A car travels along a straight road from rest at A to rest at B. Its acceleration and its deceleration each have the same constant size $a\ \mathrm{m\ s^{-2}}$. On one day it accelerates and then at once decelerates, with no constant-speed stage, and the journey takes 40 s. On another day it keeps to a speed limit of $15\ \mathrm{m\ s^{-1}}$: it accelerates at $a\ \mathrm{m\ s^{-2}}$ to $15\ \mathrm{m\ s^{-1}}$, keeps this speed, then decelerates at $a\ \mathrm{m\ s^{-2}}$ to rest at B. This journey takes 50 s. Find a and the distance AB. [10 marks]

Answer .....

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Extension hints

Cover these with paper. Uncover one at a time.

E1

Hint 1 Sketch both velocity–time graphs. The first is a triangle; by symmetry its peak is at $t = 20$.

Hint 2 From the first journey, $AB = 400a$. In the second, speeding up and slowing down each take $\dfrac{15}{a}$ s.

Hint 3 You get a quadratic in a. For each root, check whether the first journey's top speed is more than $15\ \text{m s}^{-1}$.

How did it go?

Colour one circle on each line: not yet, nearly, yes.

I can find velocities, average velocity and average speed from a displacement–time graph.	○ ○ ○
I can find accelerations as gradients and distances as areas on a velocity–time graph.	○ ○ ○
I can sketch a velocity–time graph from a description and use the area to find an unknown time or speed.	○ ○ ○
I can tell distance from displacement when the velocity changes sign, and compare two vehicles on one graph.	○ ○ ○

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