# MOTION IN A STRAIGHT LINE UNDER CONSTANT ACCELERATION

*Wherever a numerical value is required, take g = 9.8ms$^{-2}$*

**1.** A particle P moves in a straight line passing through a point O with speed 8 ms$^{-1}$ and with a constant acceleration 1.5 ms$^{-2}$. Find the speed of P at time 3 seconds after leaving O and the distance it has covered.

[4]

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**2.** A particle is fired at 100 ms$^{-1}$ vertically upwards from ground level. Find

a) the greatest height attained

[2]

b) the time for which the particle is over 50 m above the ground.

[4]

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**3.** A French metro train covers 432 m in 1 minute from rest at one station to rest at the next station. It first accelerates uniformly at $\frac{1}{3}$ ms$^{-2}$ and then moves at constant speed for 12 seconds before uniformly retarding to rest. Find the time taken by the metro while it is retarding and its greatest speed during the journey.

[7]

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**4.** Galileo drops a stone from the top of the Leaning Tower of Pisa. It takes $3\frac{1}{3}$ seconds to hit the ground.

a) Find the height of the tower

[2]

He then throws another stone vertically downwards, with a speed of 12 ms$^{-1}$.

b) Find the time taken for this stone to hit the ground

[4]

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**5.** A boy stands at the top of a tower block and drops a stone. One second later he throws another stone vertically downwards with a speed of 12 ms$^{-1}$. If they both hit the ground at the same time,

a) find the time taken for the first stone to fall.

[7]

b) find the height of the tower block.

[2]

c) state one assumption that has been made in your modelling.

[1]

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## MOTION IN A STRAIGHT LINE UNDER CONSTANT ACCELERATION

**6.** An archer stands at the top of a cliff which is 30 metres high. She fires an arrow vertically upwards at a speed of 25 $ms^{-1}$. The arrow hits the sea directly below the cliff. Find

a) the time for which the arrow is in the air

[4]

b) its velocity when it hits the sea

[2]

c) State two assumptions that you have made in your modelling.

[2]

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**7.** A woman drops a ball from the top of Canary Wharf. It hits the ground with a speed of 33 $ms^{-1}$.

a) Find the time it takes to fall.

[2]

b) Find the height of Canary Wharf.

[2]

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**8.** An arrow is fired vertically upwards with a speed of 25 $ms^{-1}$. Find

a) the greatest height it can reach

[2]

b) the total time for which it is in the air.

[3]

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**9.** A fountain shoots droplets of water vertically upwards to a height of 4 metres above ground level through a nozzle.

a) Find the velocity of the water when it leaves the nozzle.

[3]

b) Find the length of time for which the droplets are more than 1 metre above ground level.

[4]

c) State one assumption you have used in your mathematical modelling

[1]

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## MOTION IN A STRAIGHT LINE UNDER CONSTANT ACCELERATION

**10.** Two trains, A and B, leave Moor Hill station simultaneously and travel in the same direction along two sets of straight horizontal tracks.
Train A accelerates uniformly from rest at 0.60 $ms^{-2}$ for 40 seconds and then continues for 3 minutes at constant speed before braking with a constant deceleration of 1.6 $ms^{-2}$, to arrive at the next station, Wylde Heath.
Train B accelerates uniformly from rest at 0.40 $ms^{-2}$ for 2 minutes and then brakes with a constant deceleration to arrive at Wylde Heath.

a) Sketch the speed-time graph for train A.

[3]

b) Hence, or otherwise find
i) The time taken for A to reach Wylde Heath

[2]

ii) The total distance between Moor Hill and Wylde Heath

[2]

c) By sketching the speed-time graph for B, or otherwise, find:
i) The time taken for B to reach Wylde Heath

[3]

ii) The deceleration of B.

[2]

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**11.** Anyplace and Notown are connected by a straight, horizontal road. Coaches run non-stop between the two towns along the road.
Coach A leaves Anyplace and accelerates uniformly from rest at 0.40 $ms^{-2}$ for 50 seconds and then continues for 2 minutes at constant speed before braking with a constant deceleration of 1.6 $ms^{-2}$, to arrive at Notown.
Coach B leaves Anyplace 20 seconds later than A, accelerates uniformly from rest at 0.30 $ms^{-2}$ for 2 minutes and then brakes with a constant deceleration to arrive at Notown.

a) Sketch the speed-time graph for coaches A and B on the same axes.

[6]

b) Find which coach arrives first in Notown, and the difference between their arrival times, in seconds

[6]

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**12.** A train leaves a station from rest, and accelerates at a constant rate for 2 minutes, then travels at a constant speed of 20 $ms^{-1}$ for 5 minutes before it decelerates at a constant rate of 2.5 $ms^{-2}$ on approaching a red signal. The signal changes at the moment the train stops, and so it accelerates again at a constant rate to reach a speed of 25 $ms^{-1}$ in 60 seconds. Three minutes later it passes a station, travelling at the same speed.

a) Sketch a speed-time graph for the train, up to the second station, indicating clearly the time it passes the second station.

[6]

b) Hence find the distance between the stations.

[4]

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## MOTION IN A STRAIGHT LINE UNDER CONSTANT ACCELERATION

**13.** A car is travelling at a speed of 10 $ms^{-1}$, when it begins to accelerate at a constant rate of $\frac{1}{12}$ $ms^{-2}$ until it reaches its maximum speed of 60 $ms^{-1}$.

a) Sketch a speed-time graph for the car

[2]

b) Find an expression for the speed of the car after t seconds, and hence find its speed after 140 seconds.

[3]

c) Find the time taken for the car to reach its maximum speed, and the distance it has it travelled at this time.

[4]

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**14.** A parachutist jumps from a stationary helicopter and her speed increases uniformly in the first 7 seconds to 68 $ms^{-1}$. Her parachute then opens, and her speed then decreases uniformly to 9 $ms^{-1}$ in the next 20 seconds, and then remains constant until she hits the ground.

a) Describe the resultant force acting on the parachutist during her descent when she is
   i) accelerating
   ii) decelerating
   iii) moving with constant velocity

[3]

b) Sketch the speed-time graph for her jump.

[3]

c) Find the height of the helicopter when she jumped, given that the total jump takes one and a half minutes.

[5]

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## MOTION IN A STRAIGHT LINE UNDER CONSTANT ACCELERATION

**15.** A lorry skids to a halt from an initial speed of 27 $ms^{-1}$ in a distance of 40 metres. The deceleration of the lorry is uniform. Find:

a) the deceleration of the lorry.

[2]

b) the time taken for the lorry to stop.

[2]

A second lorry is travelling at a speed of U $ms^{-1}$. Assuming it decelerates at the same rate as the first lorry,

c) Find the distance (x) required for it to decelerate to rest, giving your answer in terms of U.

[2]

If the lorry driver sees a blockage on the road, it takes him T seconds to start to brake.

d) Calculate the total distance the lorry will travel between the driver seeing a blockage on the road and the lorry coming to rest

[2]

e) Deduce the minimum safe distance there should be between two lorries travelling at 22 $ms^{-1}$, assuming that T= $\frac{1}{2}$

[2]

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**16.** Towards the end of a race, Cram is 75 metres from the finish and running at a constant speed of 5 $ms^{-1}$. Nolan, who is 125 metres from the finish, and running at 4.5 $ms^{-1}$, decides to accelerate to try to win.

a) Nolan accelerates uniformly at 0.2 $ms^{-2}$. Find whether it is possible for him to win.

[4]

b) Draw the speed-time graphs for Cram and Nolan on the same axes, clearly marking the finish times on the graph.

[4]

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**17.** An object is dropped from the top of a large multi-storey car park and accelerates freely under gravity. The distance between the levels of the car park is H. The levels are numbered from 1 upwards. The ball takes 1.2 seconds to fall the length of the $11^{th}$ level, and 0.5 seconds to fall the length of the $10^{th}$ level. Find

a) the average speed of the ball as it falls the length of the $11^{th}$ level and as it falls the length of the $10^{th}$ level, giving your answer in terms of H.

[2]

b) the value of H

[5]

c) State two assumptions made in the mathematical modelling used in this question

[2]

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## MOTION IN A STRAIGHT LINE UNDER CONSTANT ACCELERATION

**18.** Andrea and Dominic stand at opposite ends of a straight, horizontal, 100m running track. Dominic accelerates from rest at 1.1 $ms^{-2}$ for 6 seconds, runs at a constant rate for 2 seconds and then decelerates at a constant rate to stop at the end of the track.
Andrea sets off running simultaneously at a constant speed of 6 $ms^{-1}$. and maintains this speed throughout the race.

a) Calculate Dominic's maximum speed.

[2]

b) By sketching a speed-time graph, or otherwise, find Dominic's deceleration

[3]

c) Calculate the time at which Dominic and Andrea pass each other.

[11]

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**19.** Kerry is standing at the top of a cliff of height 20m, and Liam is standing directly below her.
Simultaneously, Liam drops a ball and Kerry throws a ball vertically upward with speed 30 $ms^{-1}$.

a) Find the time taken for the balls to achieve the same height

[5]

b) Find the height at which this occurs

[3]

c) State two assumptions you have made in your mathematical modelling

[2]

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**20.** A car accelerates at a constant rate a $ms^{-2}$ from rest. It passes point A with speed $\sqrt{32}$ $ms^{-1}$ and point B with speed $\sqrt{80}$ $ms^{-1}$. The distance between point A and point B is D.

a) Show that aD = 24.

[3]

Point C is 2m from point B, and the car passes through point C with speed $\sqrt{82}$ $ms^{-1}$

b) Find the acceleration of the car

[2]

c) Find the time for which the car had been travelling before reaching point A.

[2]

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## MOTION IN A STRAIGHT LINE UNDER CONSTANT ACCELERATION

**21**. Glenn and Kevin are planning to run a 800m race. Kevin initially runs at a steady speed of 5 $ms^{-1}$ for 70 seconds. He then accelerates at 0.5 $ms^{-2}$ for 3 seconds, and runs at this new steady speed until he has run 600m all together. He then decelerates to 4 $ms^{-1}$ over 10 seconds, and then runs at this steady speed until the end of the race.

Glenn accelerates at a constant rate for 70 seconds to achieve a maximum speed of 7 $ms^{-1}$. He then decelerates at a constant rate until the end of the race.

a) Find the distance travelled by Glenn while he is accelerating.

[2]

b) Find the time for which Glenn is decelerating

[2]

c) Find the time Kevin takes to run his first 600m

[6]

d) Find the distance Kevin runs while he is travelling at a steady speed of 4 $ms^{-1}$

[3]

e) Establish who won the race, and by how many seconds.

[4]

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**22**. A particle accelerates from rest at a constant rate of A $ms^{-2}$ for T seconds. It then travels at a constant speed for 3T seconds, before decelerating to rest in 4T seconds.

a) Sketch a speed-time graph for the particle.

[3]

The particle's average speed for the total journey was 2.5$ms^{-1}$.

b) Show that 11AT = 40

[6]

c) The total distance travelled was 200m . Find the value of T

[3]

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**23.** Particle A has an initial speed of U $ms^{-1}$. It accelerates for T seconds to reach a speed of 3U $ms^{-1}$, then decelerates at a constant rate for t seconds until it is stationary.
Simultaneously, Particle B starts from rest, accelerates at a constant rate until it reaches a speed of $\frac{11}{3}$ U, then decelerates at the same constant rate to rest.
The journeys of A and B take the same time and cover the same distance.

a) Sketch, on the same axes, speed time graphs for particles A and B

[5]

b) Show that T = 2t

[8]

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