Chapter 2. Describing motion

1.2 Motion

Core

1 Define speed as distance travelled per unit time; recall and use the equation

$v = \frac{s}{t}$

2 Define velocity as speed in a given direction

3 Recall and use the equation

$\text{average speed} = \frac{\text{total distance travelled}}{\text{total time taken}}$

4 Sketch, plot and interpret distance–time and speed–time graphs

5 Determine, qualitatively, from given data or the shape of a distance–time graph or speed–time graph when an object is:

(a) at rest

(b) moving with constant speed

(c) accelerating

(d) decelerating

6 Calculate speed from the gradient of a straight-line section of a distance–time graph

7 Calculate the area under a speed–time graph to determine the distance travelled for motion with constant speed or constant acceleration

8 State that the acceleration of free fall *g* for an object near to the surface of the Earth is approximately constant and is approximately 9.8 m/s^2

Supplement

9 Define acceleration as change in velocity per unit time; recall and use the equation

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

10 Determine from given data or the shape of a speed–time graph when an object is moving with:

(a) constant acceleration

(b) changing acceleration

11 Calculate acceleration from the gradient of a speed–time graph

12 Know that a deceleration is a negative acceleration and use this in calculations

13 Describe the motion of objects falling in a uniform gravitational field with and without air/liquid resistance (including reference to terminal velocity)

2.1 Understanding speed

1 **(a)** Complete the table below to identify the physical quantities as scalars or vectors.

physical quantity	scalar or vector
speed	
velocity	
distance	
force	
kinetic energy	

[3]

(b) Fig. 1.1 shows the path of a football as it is kicked along the ground between three players. The distances between the players are shown on Fig. 1.1.

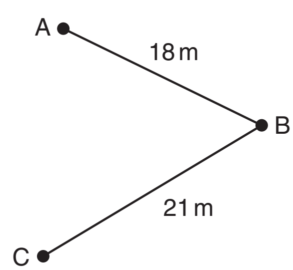


Fig. 1.1

The ball takes 1.2 s to travel from player A to player B.

(i) Calculate the average speed of the ball between A and B.

average speed = ...[2]

(ii) Player B kicks the ball to player C.
It travels with the same average speed.
Calculate the time taken for the ball to travel from B to C.

time = ...[2]

(iii) Suggest why the speed of the ball might change during its motion from A to B.

....

....[1]

(iv) Discuss whether the average velocities, from A to B and from B to C, are the same.

....

....

....[1]

[Total: 9]

2 A person is standing on the top of a cliff, throwing stones into the sea below.

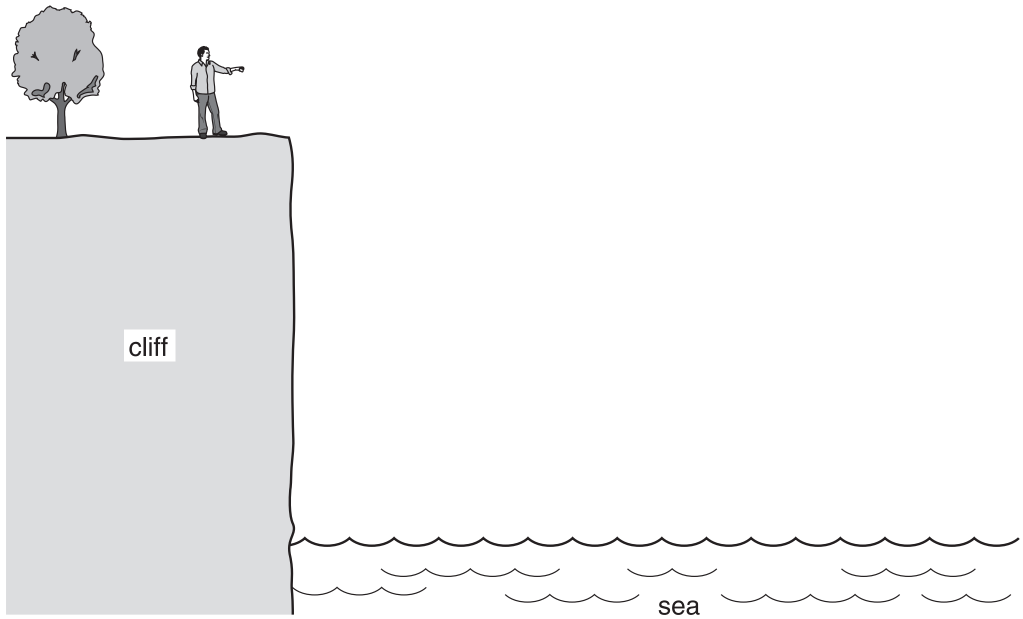


Fig. 2.1

(a) The person throws a stone horizontally.

(i) On Fig. 2.1, draw a line to show the path which the stone might take between leaving the person's hand and hitting the sea.

(ii) On the line you have drawn, at a point halfway to the sea, mark the stone and the direction of the force on the stone.

[3]

(b) Later, the person drops a small stone and a large stone vertically from the edge of the cliff.

Comment on the times taken for the two stones to hit the water.

....

....

....

....[2]

(c) 800 m from the point where the person is standing, a navy ship is having target practice.

The person finds that if a stone is dropped vertically at the same time as the spurt of smoke from the ship's gun is seen, the stone hits the water at the same time as the sound from the gun is heard.

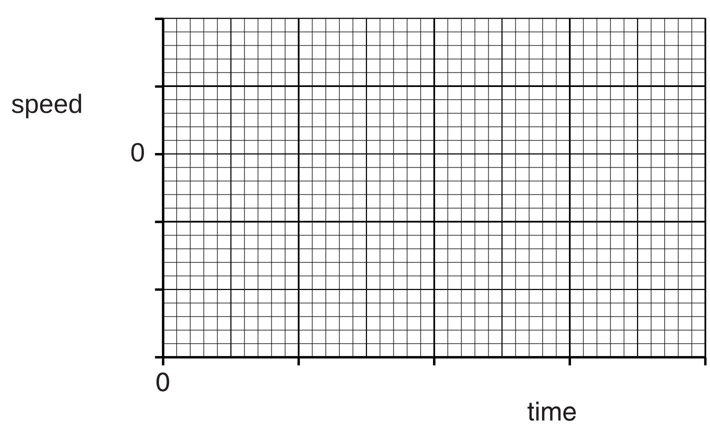
Sound travels at 320 m / s in that region.

Calculate the velocity with which the stone hits the water.

velocity = ...[4]

(d) Sketch a graph of both the horizontal and vertical components of the velocity of the small stone as a function of time starting from the time the stone is thrown.

Only the general shape and sign of the curves can be drawn. You should ignore air resistance.



[3]

[Total 12

3 Fig. 1.1 is a distance / time graph showing the motion of an object.

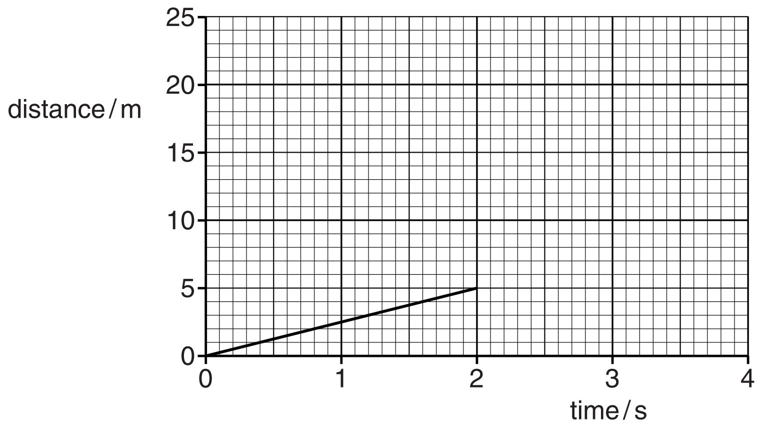


Fig. 1.1

(a) (i) Describe the motion shown for the first 2 s, calculating any relevant quantity.

....

.... [2]

(ii) After 2 s the object accelerates.

On Fig. 1.1, sketch a possible shape of the graph for the next 2 s. [1]

(b) Describe how a distance / time graph shows an object that is stationary.

....

.... [1]

(c) Fig. 1.2 shows the axes for a speed / time graph.

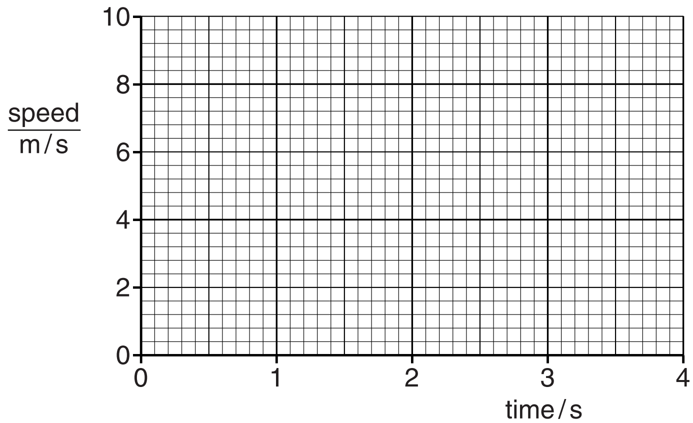


Fig. 1.2

On Fig. 1.2, draw

(i) the graph of the motion for the first 2 s as shown in Fig. 1.1,

(ii) an extension of the graph for the next 2 s, showing the object accelerating at 2 m / s^2. [3]

(d) Describe how a speed / time graph shows an object that is stationary.

....

.... [2]

[Total: 9]

2.2 Uniformly accelerated motion

1 The speed of a cyclist reduces uniformly from 2.5 m/s to 1.0 m/s in 12 s.

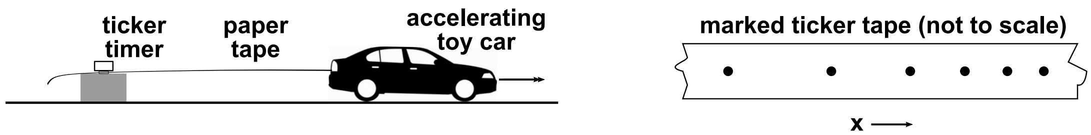
(a) Calculate the deceleration of the cyclist.

deceleration = ...[3]

(b) Calculate the distance travelled by the cyclist in this time.

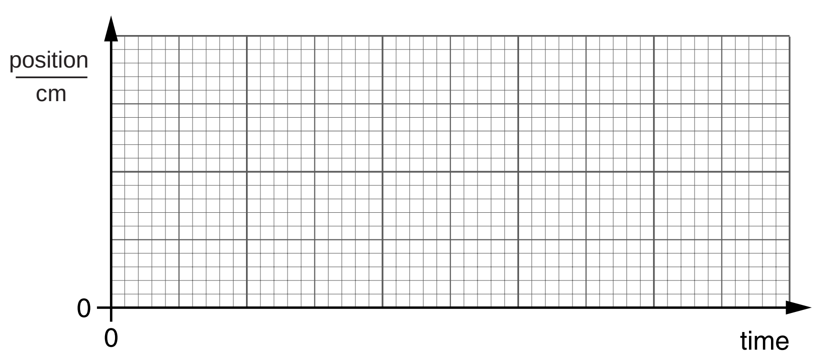
distance = ...[2]

2 A toy car accelerates uniformly from rest. Attached to the car is a paper ticker tape that is marked by a ticker timer at evenly spaced time intervals. Times and locations of the ticker marks are shown in the table below.



t / s	x / cm
0.0	0.00
0.1	1.2
0.2	5.0
0.3	11.3
0.4	19.8
0.5	32.0

(a) Plot a graph of the position of the car as a function of time.



[2]

(b) (i) Which feature of a position versus time graph gives the speed of an object?

.... [1]

(ii) From the above graph, approximate the speed of the car at both t = 0.2 s and t = 0.4 s. Be sure to show all your work.

v_2 = ...[2]

v_4 = ...[1]

(c) Calculate an estimate of the acceleration of the car, stating all assumptions, and showing all work.

[3]

[Total: 9]

2.3 The speed-time graph

1 A small rubber ball falls vertically, hits the ground and rebounds vertically upwards.
Fig.1 is the speed-time graph for the ball.

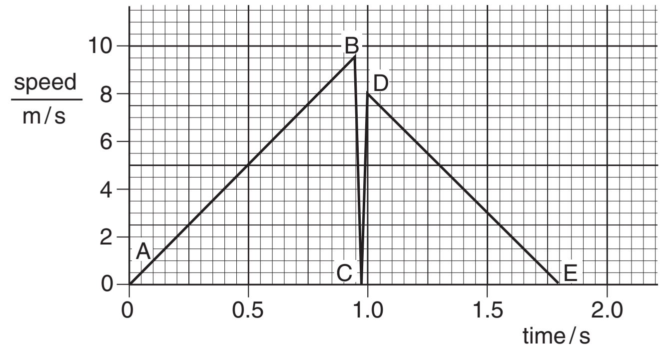


Fig. 1

(a) Using information from the graph, describe the following parts of the motion of the ball.

(i) part AB

....

....

....

(ii) part DE

....

....

....
[3]

(b) Explain what is happening to the ball along the part of the graph from B through C to D.

....

....

.... [2]

(c) Whilst the ball is in contact with the ground, what is the

(i) overall change in speed,

change in speed = ...

(ii) overall change in velocity?

change in velocity = ...
[2]

(d) Use your answer to **(c)** to explain the difference between speed and velocity.

....

....

.... [2]

(e) Use the graph to calculate the distance travelled by the ball between D and E.

distance travelled = ...[2]

(f) Use the graph to calculate the deceleration of the ball between D and E.

deceleration = ...[2]

2 Fig. 1.1 shows the speed-time graph for a bus during tests.

At time $t = 0$, the driver starts to brake.

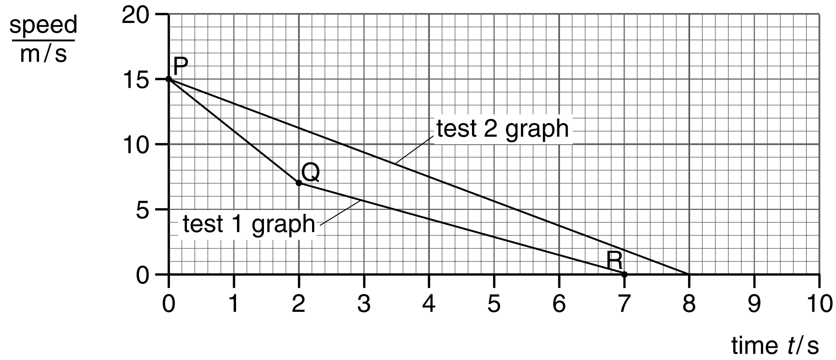


Fig. 1.1

(a) For test 1,

(i) determine how long the bus takes to stop,

....

(ii) state which part of the graph shows the greatest deceleration,

....

(iii) use the graph to determine how far the bus travels in the first 2 seconds.

distance = ...

[4]

(b) For test 2, a device was fitted to the bus. The device changed the deceleration.

(i) State two ways in which the deceleration during test 2 is different from that during test 1.

1 ....

2 ....

(ii) Calculate the value of the deceleration in test 2.

deceleration = ...

[4]

(c) Fig. 1.2 shows a sketch graph of the magnitude of the acceleration for the bus when it is travelling around a circular track at constant speed.

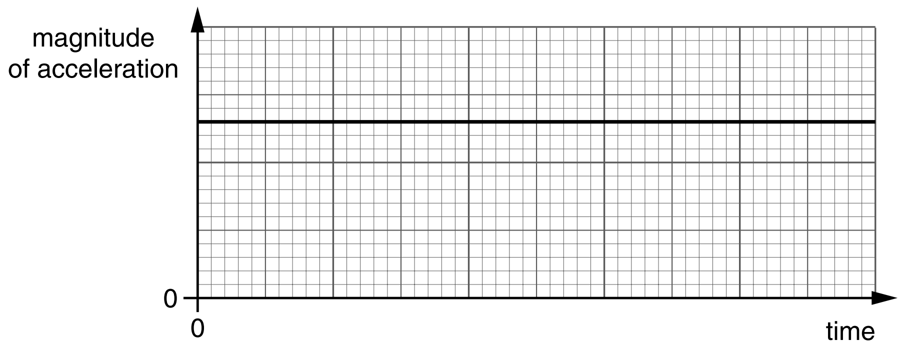


Fig. 1.2

(i) Use the graph to show that there is a force of constant magnitude acting on the bus.

....

....

(ii) State the direction of this force.

....

[3]

3 Fig. 1.1 shows a cycle track.

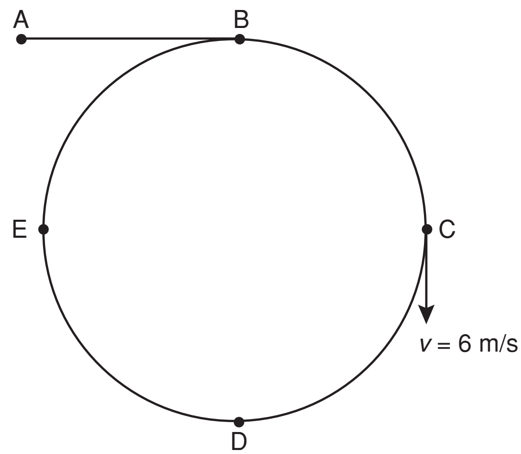


Fig. 1.1

A cyclist starts at A and follows the path ABCDEB.

The speed-time graph is shown in Fig. 1.2.

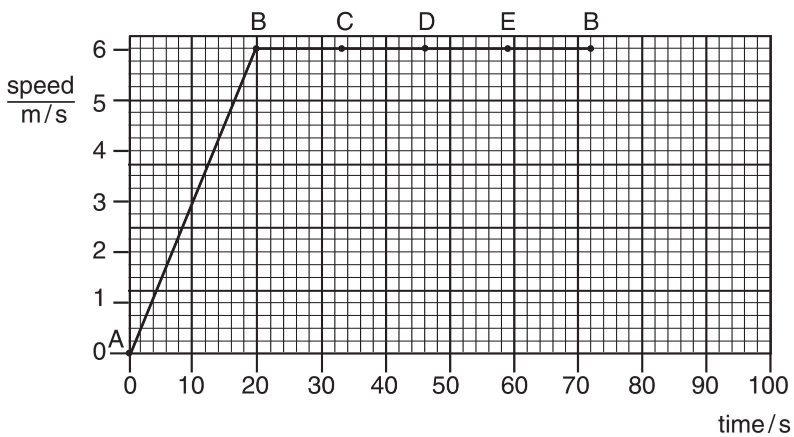


Fig. 1.2

(a) Use information from Fig. 1.1 and Fig. 1.2 to describe the motion of the cyclist

(i) along AB,

....

(ii) along BCDEB.

....

.... [4]

(b) The velocity *v* of the cyclist at C is shown in Fig. 1.1.

State one similarity and one difference between the velocity at C and the velocity at E.

similarity ....

difference ....[2]

(c) Calculate

(i) the distance along the cycle track from A to B,

distance = ...

(ii) the circumference of the circular part of the track.

circumference = ...
[4]

4 Fig. 1.1 shows the path of one drop of water in the jet from a powerful hose.

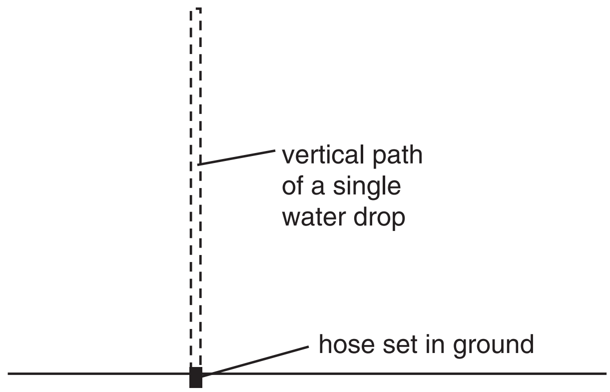


Fig. 1.1

Fig. 1.2 is a graph of speed against time for the water drop shown in Fig. 1.1.

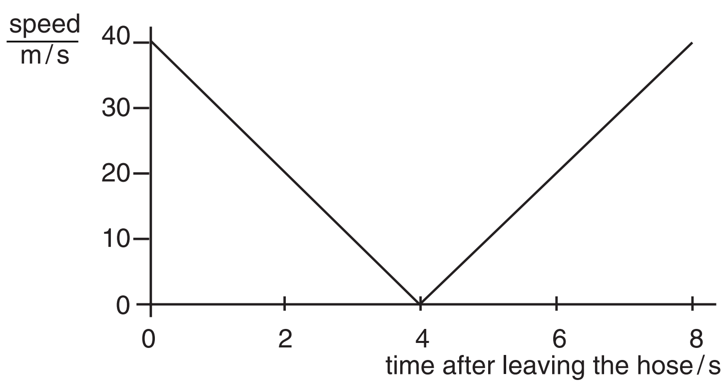


Fig. 1.2

(a) Describe the movement of the water drop in the first 4 s after leaving the hose.

....

....

....[2]

(b) Use Fig. 1.2 to find

(i) the speed of the water leaving the hose,

speed = …………………...

(ii) the time when the speed of the water is least.

time = ……………………..

[2]

(c) Use values from Fig. 1.2 to calculate the acceleration of the drop as it falls back towards the ground. Show your working.

acceleration = ……………………...[3]

(d) Calculate the greatest distance above the ground reached by the drop.

distance = ……………………...[3]

5 **(a)** A stone falls from the top of a building and hits the ground at a speed of 32 m/s.
The air resistance-force on the stone is very small and may be neglected.

(i) Calculate the time of fall.

time = ...

(ii) On Fig. 1.1, draw the speed-time graph for the falling stone.

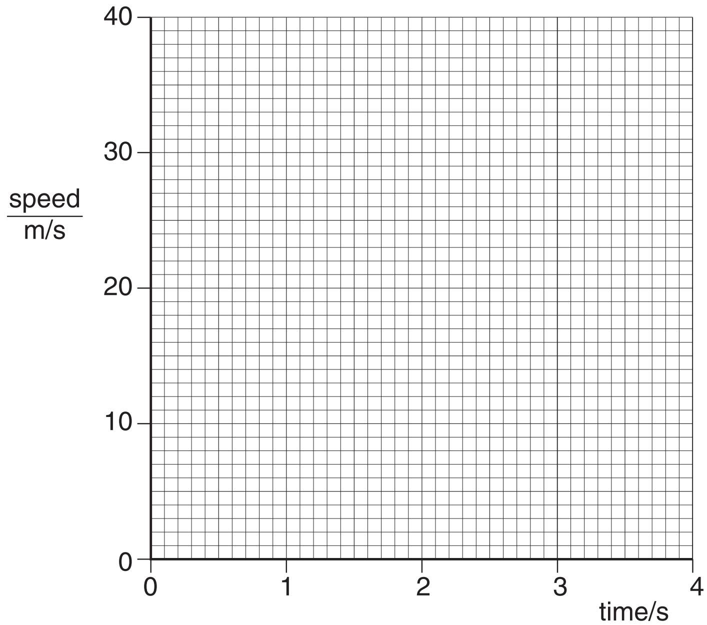


Fig. 1.1

(iii) The weight of the stone is 24 N.
Calculate the mass of the stone.

mass = ...

[5]

(b) A student used a suitable measuring cylinder and a spring balance to find the density of a sample of the stone.

(i) Describe how the measuring cylinder is used, and state the readings that are taken.

....

....

....

....

(ii) Describe how the spring balance is used, and state the reading that is taken.

....

....

(iii) Write down an equation from which the density of the stone is calculated.

....

(iv) The student then wishes to find the density of cork. Suggest how the apparatus and the method would need to be changed.

....

....

....

[6]

6 Fig. 1.1 shows a model car moving clockwise around a horizontal circular track.

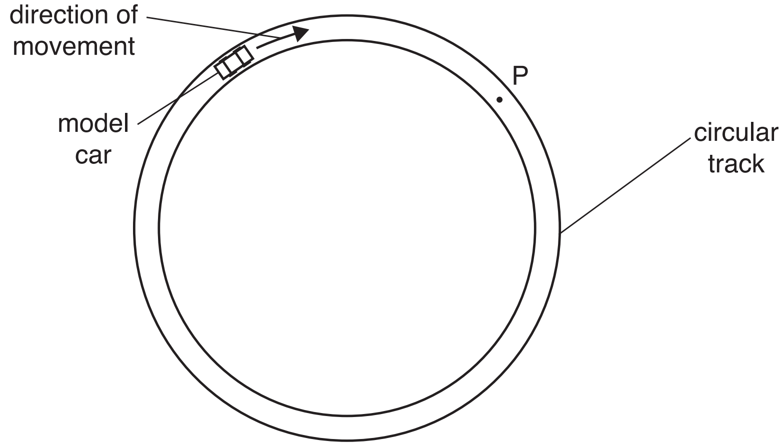


Fig. 1.1

(a) A force acts on the car to keep it moving in a circle.

(i) Draw an arrow on Fig. 1.1 to show the direction of this force. [1]

(ii) The speed of the car increases. State what happens to the magnitude of this force.

.... [1]

(b) (i) The car travels too quickly and leaves the track at P. On Fig. 1.1, draw an arrow to show the direction of travel after it has left the track. [1]

(ii) In terms of the forces acting on the car, suggest why it left the track at P.

....

....

.... [2]

(c) The car, starting from rest, completes one lap of the track in 10 s. Its motion is shown graphically in Fig. 1.2.

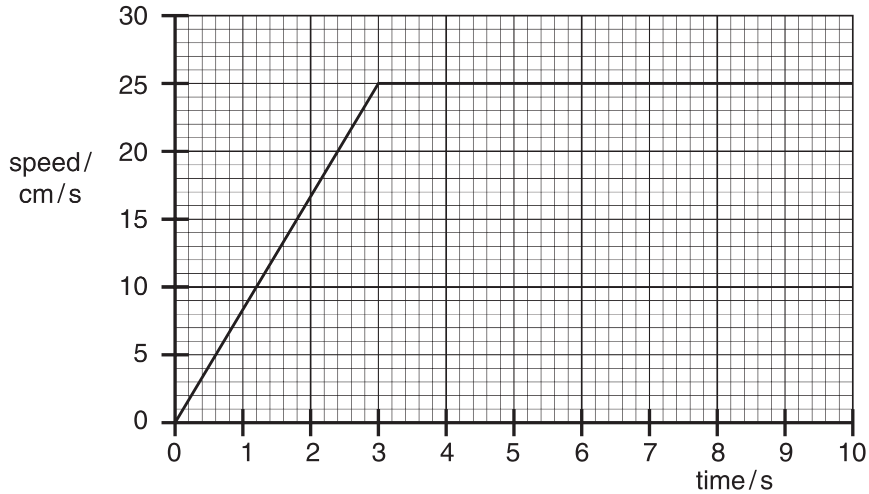


Fig. 1.2

(i) Describe the motion between 3.0 s and 10.0 s after the car has started.

.... [1]

(ii) Use Fig. 1.2 to calculate the circumference of the track.

circumference = ... [2]

(iii) Calculate the increase in speed per second during the time 0 to 3.0 s.

increase in speed per second = ... [2]

[Total: 10]

7 Fig. 1.1 shows the speed/time graph for a car travelling along a straight road.

The graph shows how the speed of the car changes as the car passes through a small town.

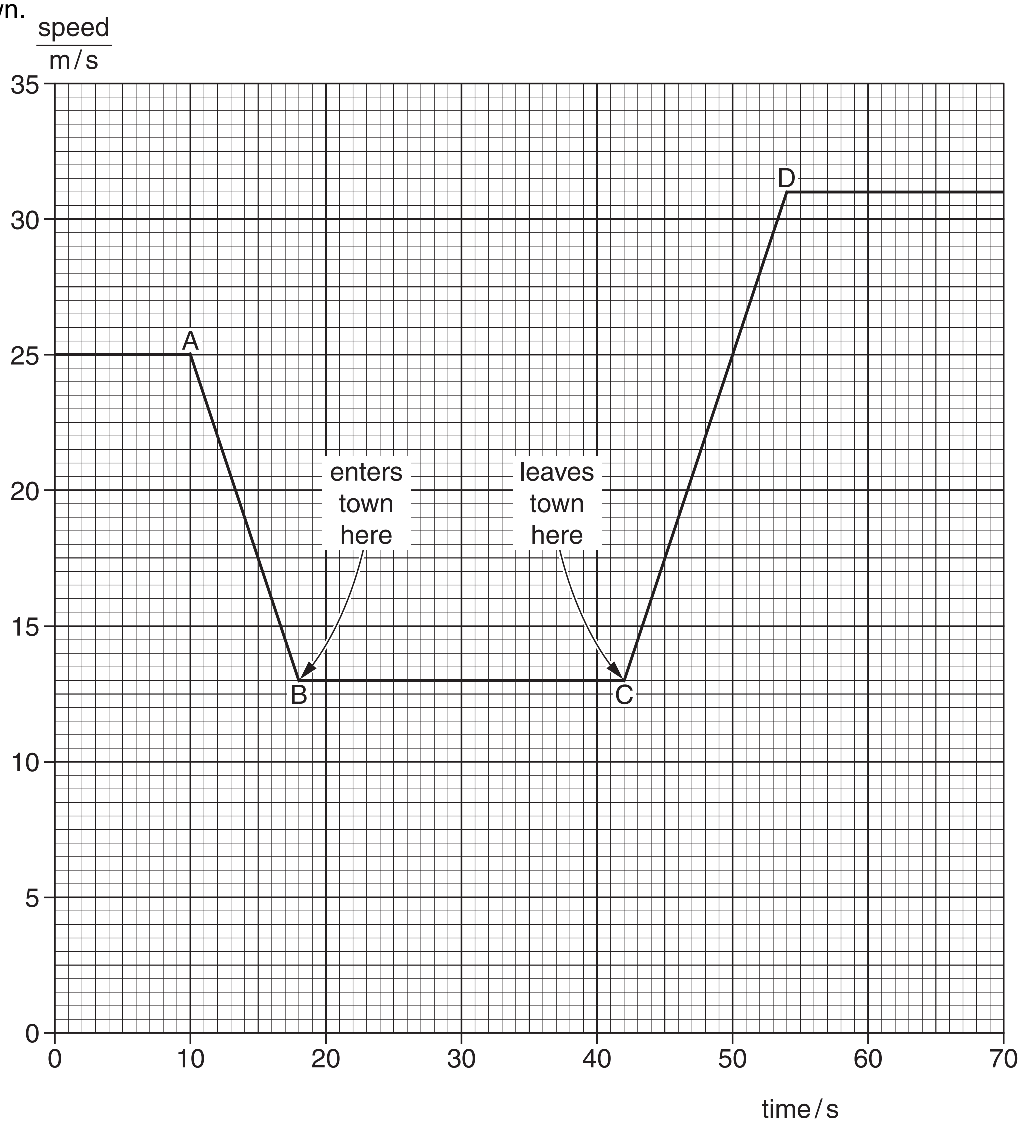


Fig. 1.1

(a) Describe what happens to the speed of the car

(i) between A and B, ...

(ii) between B and C, ...

(iii) between C and D. ....

[1]

(b) Calculate the distance between the start of the town and the end of the town.

distance = ... [3]

(c) Calculate the acceleration of the car between C and D.

acceleration = ... [3]

(d) State how the graph shows that the deceleration of the car has the same numerical value as its acceleration.

....

.... [1]

[Total: 8]

8 **(a)** Define *acceleration*. Explain any symbols in your definition.

....

....[1]

(b) Fig. 1.1 shows a graph of speed against time for a train. After 100 s the train stops at a station.

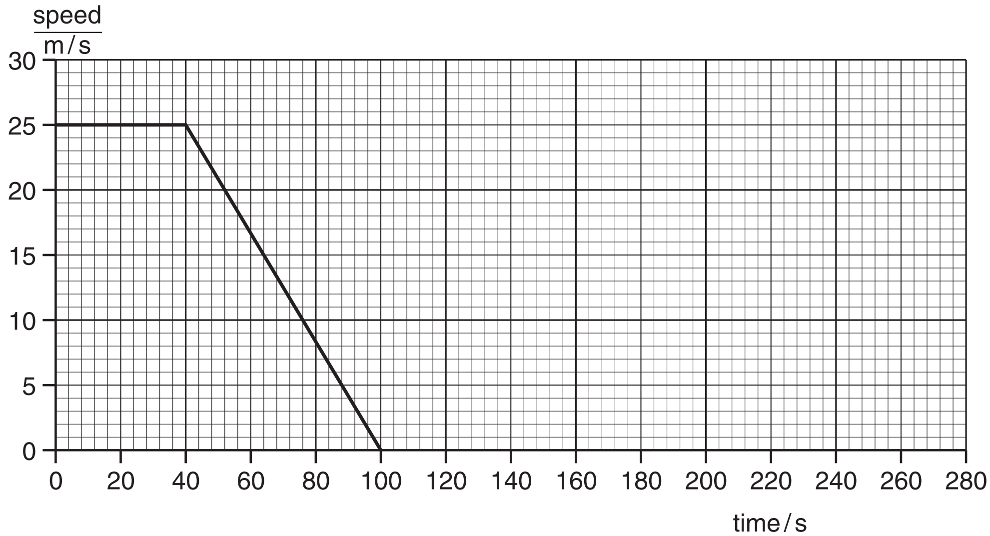


Fig. 1.1

(i) For the time interval between 40 s and 100 s, calculate the distance travelled by the train.

distance = ...[2]

(ii) The train stops for 80 s, then accelerates to 30 m/s with an acceleration of 0.60 m/s^2. It then travels at constant speed.

Complete the graph for the interval 100 s to 280 s, showing your calculations in the space below.

[5]

[Total: 8]

2.4 The distance-time graph

1 A girl rides her bicycle along a straight level road. Fig. 2.1 shows a graph of her distance moved against time.

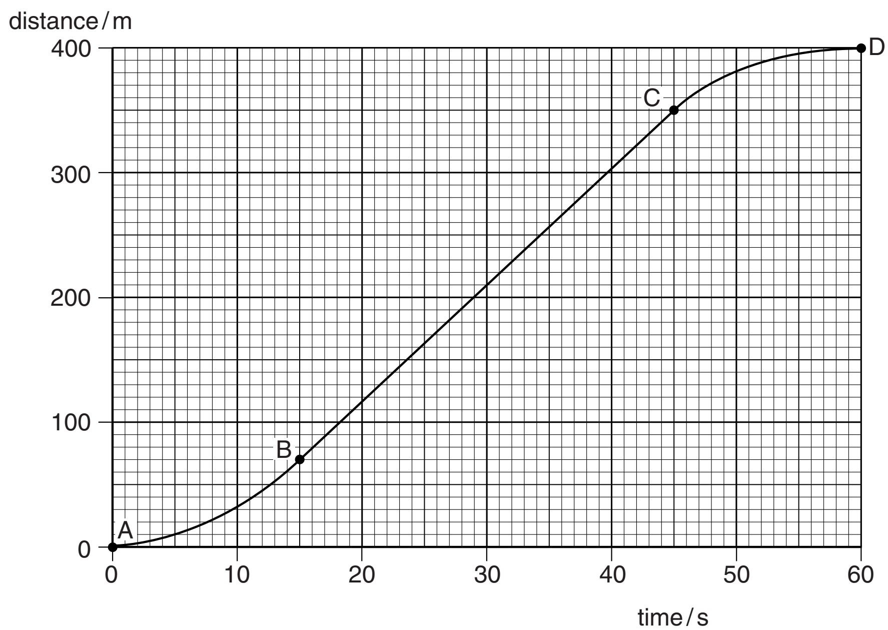


Fig. 2.1

(a) Describe her motion

(i) from A to B, ...

(ii) from B to C, ...

(iii) from C to D. .... [3]

(b) Calculate

(i) her average speed from A to D,

average speed = ... [2]

(ii) her maximum speed.

maximum speed = ... [3]

[Total: 8]