Exercise 1A

1 How long will an athlete take to run 1500 metres at 7.5 m s^{-1}?

2 A train maintains a constant velocity of 60 m s^{-1} due south for 20 minutes. What is its displacement in that time? Give the distance in kilometres.

3 How long will it take for a cruise liner to sail a distance of 530 nautical miles at a speed of 25 knots? (A knot is a speed of 1 nautical mile per hour.)

4 Some Antarctic explorers walking towards the South Pole expect to average 1.2 miles per hour. What is their expected displacement in a day in which they walk for 14 hours?

5 On the Ml motorway Junction 15 (Northampton South) is 13 miles north-west of Junction 14 (Milton Keynes). A coach travels from Junction 14 to Junction 15 in 15 minutes, and a car travels from Junction 15 to Junction 14 in 12 minutes. Both travel at constant speed. Find the approximate velocities of the coach and the car

(a) in miles per hour, (b) in metres per second.

6 Here is an extract from the diary of Samuel Pepys for 4 June 1666.

'We find the Duke at St James's, whither he is lately gone to lodge. So walking through the Parke we saw hundreds of people listening to hear the guns.'

These guns were at the battle of the English fleet against the Dutch in the Downs off Deal in Kent, a distance of between 110 and 120 km away. The speed of sound in air is 344 m s^{-1}. How long did it take the sound of the gunfire to reach London?

7 Light travels at a speed of $3.00 \times 10^8 \text{ m s}^{-1}$. Light from the star Sirius takes 8.65 years to reach the earth. What is the distance of Sirius from the earth in kilometres?

8 The speed limit on a Belgian motorway is 120 km per hour. What is this in SI units?

9 A train travels from Newcastle to London, a displacement of 440 km south, in $2\frac{1}{2}$ hours. Model the journey by drawing

(a) a velocity–time graph, (b) a displacement–time graph.

Label your graphs to show the numbers 440 and $2\frac{1}{2}$ and to indicate the units used. Suggest some ways in which your models may not match the actual journey.

10 An aircraft flies at 800 km per hour from Birmingham to Berlin, a displacement of 1000 km due east. Model the flight by drawing

(a) a displacement–time graph, (b) a velocity–time graph.

Label your graphs to show the numbers 800 and 1000 and to indicate the units used. Can you suggest ways in which your models could be improved to describe the actual flight more accurately?

Exercise 1A (page 3)

1 200 s

2 72 km south

3 21.2 hours

4 16.8 miles south

5 (a) 52 m.p.h. north-west, 65 m.p.h. south-east
(b) 23.1 m s^{-1} north-west, 28.9 m s^{-1} south-east

6 About $5\frac{1}{2}$ minutes

7 8.2×10^{13} km

8 $33\frac{1}{3} \text{ m s}^{-1}$

Exercise 1B

1 A police car accelerates from 15 m s^{-1} to 35 m s^{-1} in 5 seconds. The acceleration is constant. Illustrate this with a velocity–time graph. Use the equation $v = u + at$ to calculate the acceleration. Find also the distance travelled by the car in that time.

2 A marathon competitor running at 5 m s^{-1} puts on a sprint when she is 100 metres from the finish, and covers this distance in 16 seconds. Assuming that her acceleration is constant, use the equation $s = \frac{1}{2}(u + v)t$ to find how fast she is running as she crosses the finishing line.

3 A train travelling at 20 m s^{-1} starts to accelerate with constant acceleration. It covers the next kilometre in 25 seconds. Use the equation $s = ut + \frac{1}{2}at^2$ to calculate the acceleration. Find also how fast the train is moving at the end of this time. Illustrate the motion of the train with a velocity–time graph.

How long does the train take to cover the first half kilometre?

4 A long-jumper takes a run of 30 metres to accelerate to a speed of 10 m s^{-1} from a standing start. Find the time he takes to reach this speed, and hence calculate his acceleration. Illustrate his run-up with a velocity–time graph.

5 Starting from rest, an aircraft accelerates to its take-off speed of 60 m s^{-1} in a distance of 900 metres. Assuming constant acceleration, find how long the take-off run lasts. Hence calculate the acceleration.

6 A train is travelling at 80 m s^{-1} when the driver applies the brakes, producing a deceleration of 2 m s^{-2} for 30 seconds. How fast is the train then travelling, and how far does it travel while the brakes are on?

7 A balloon at a height of 300 m is descending at 10 m s^{-1} and decelerating at a rate of 0.4 m s^{-2}. How long will it take for the balloon to stop descending, and what will its height be then?

1	4 m s^{-2}, 125 m
2	$7\frac{1}{2} \text{ m s}^{-1}$
3	1.6 m s^{-2}, 60 m s^{-1}; 15.5 s
4	6 s, $1\frac{2}{3} \text{ m s}^{-2}$
5	30 s, 2 m s^{-2}
6	20 m s^{-1}, 1500 m
7	25 s, 175 m

Exercise 1C

1 Interpret each of the following in terms of the motion of a particle along a line, and select the appropriate constant acceleration formula to find the answer. The quantities u, v, s and t are all positive or zero, but a may be positive or negative.

(a) $u = 9, a = 4, s = 5$, find v

(b) $u = 10, v = 14, a = 3$, find s

(c) $u = 17, v = 11, s = 56$, find a

(d) $u = 14, a = -2, t = 5$, find s

(e) $v = 20, a = 1, t = 6$, find s

(f) $u = 10, s = 65, t = 5$, find a

(g) $u = 18, v = 12, s = 210$, find t

(h) $u = 9, a = 4, s = 35$, find t

(i) $u = 20, s = 110, t = 5$, find v

(j) $s = 93, v = 42, t = \frac{3}{2}$, find a

(k) $u = 24, v = 10, a = -0.7$, find t

(l) $s = 35, v = 12, a = 2$, find u

(m) $v = 27, s = 40, a = -4\frac{1}{2}$, find t

(n) $a = 7, s = 100, v - u = 20$, find u

2 A train goes into a tunnel at 20 m s^{-1} and emerges from it at 55 m s^{-1}. The tunnel is 1500 m long. Assuming constant acceleration, find how long the train is in the tunnel for, and the acceleration of the train.

3 A milk float moves from rest with acceleration 0.1 m s^{-2}. Find an expression for its speed, $v \text{ m s}^{-1}$, after it has gone s metres. Illustrate your answer by sketching an (s, v) graph.

4 A cyclist riding at 5 m s^{-1} starts to accelerate, and 200 metres later she is riding at 7 m s^{-1}. Find her acceleration, assumed constant.

5 A train travelling at 55 m s^{-1} has to reduce speed to 35 m s^{-1} to pass through a junction. If the deceleration is not to exceed 0.6 m s^{-2}, how far ahead of the junction should the train begin to slow down?

6 A liner leaves the harbour entrance travelling at 3 m s^{-1}, and accelerates at 0.04 m s^{-2} until it reaches its cruising speed of 15 m s^{-1}.

(a) How far does it travel in accelerating to its cruising speed?

(b) How long does it take to travel 2 km from the harbour entrance?

1 (a) 11 (b) 16 (c) $-\frac{3}{2}$ (d) 45
(e) 102 (f) 1.2 (g) 14 (h) $2\frac{1}{2}$
(i) 24 (j) $-26\frac{2}{3}$ (k) 20 (l) 2
(m) $1\frac{1}{3}$ (n) 25

2 40 s, $\frac{7}{8} \text{ m s}^{-2}$

3 $\sqrt{\frac{1}{5}s}$

4 0.06 m s^{-2}

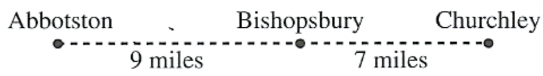
5 1500 m

6 (a) 2.7 km (b) 250 s

Exercise 1D

1 A cyclist travels from A to B, a distance of 240 metres. He passes A at 12 m s^{-1}, maintains this speed for as long as he can, and then brakes so that he comes to a stop at B. If the maximum deceleration he can achieve when braking is 3 m s^{-2}, what is the least time in which he can get from A to B?

2



The figure shows a map of the branch line from Abbotston to Churchley. The timetable is based on the assumption that the top speed of a train is 60 miles per hour; that it takes 3 minutes to reach this speed from rest, and 1 minute to bring the train to a stop, both at a constant rate; and that at an intermediate station 1 minute must be allowed to set down and pick up passengers. How long must the timetable allow for the whole journey

(a) for trains which don't stop at Bishopsbury,

(b) for trains which do stop at Bishopsbury?

3 Two villages are 900 metres apart. A car leaves the first village travelling at 15 m s^{-1} and accelerates at $\frac{1}{2} \text{ m s}^{-2}$ for 30 seconds. How fast is it then travelling, and what distance has it covered in this time?

The driver now sees the next village ahead, and decelerates so as to enter it at 15 m s^{-1}. What constant deceleration is needed to achieve this? How much time does the driver save by accelerating and decelerating, rather than covering the whole distance at 15 m s^{-1}?

4 A car rounds a bend at 10 m s^{-1}, and then accelerates at $\frac{1}{2} \text{ m s}^{-2}$ along a straight stretch of road. There is a T-junction 400 m from the bend. When the car is 100 m from the T-junction, the driver brakes and brings the car to rest at the junction with constant deceleration. Draw a (t, v) graph to illustrate the motion of the car. Find how fast the car is moving when the brakes are applied, and the deceleration needed for the car to stop at the junction.

1	22 s
2	(a) 18 minutes (b) 21 minutes
3	30 m s^{-1}, 675 m; $1\frac{1}{2} \text{ m s}^{-2}$; 20 s
4	20 m s^{-1}, 2 m s^{-2}

Miscellaneous exercise 1

1 A car starts from rest at the point A and moves in a straight line with constant acceleration for 20 seconds until it reaches the point B. The speed of the car at B is 30 m s^{-1}. Calculate

(a) the acceleration of the car,

(b) the speed of the car as it passes the point C, where C is between A and B and $AC = 40$ m. (OCR)

2 A motorist travelling at $u \text{ m s}^{-1}$ joins a straight motorway. On the motorway she travels with a constant acceleration of 0.07 m s^{-2} until her speed has increased by 2.8 m s^{-1}.

(a) Calculate the time taken for this increase in speed.

(b) Given that the distance travelled while this increase takes place is 1050 m, find u. (OCR)

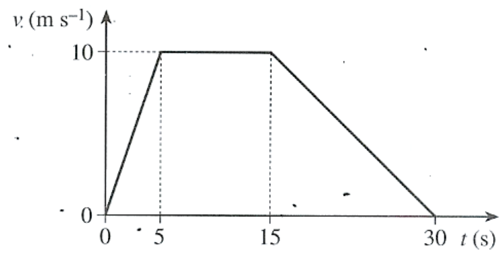
3 A cyclist, travelling with constant acceleration along a straight road, passes three points A, B and C, where $AB = BC = 20$ m. The speed of the cyclist at A is 8 m s^{-1} and at B is 12 m s^{-1}. Find the speed of the cyclist at C. (OCR)

4 As a car passes the point A on a straight road, its speed is 10 m s^{-1}. The car moves with constant acceleration $a \text{ m s}^{-2}$ along the road for T seconds until it reaches the point B, where its speed is $V \text{ m s}^{-1}$. The car travels at this speed for a further 10 seconds, when it reaches the point C. From C it travels for a further T seconds with constant acceleration $3a \text{ m s}^{-2}$ until it reaches a speed of 20 m s^{-1} at the point D. Sketch the (t, v) graph for the motion, and show that $V = 12.5$.

Given that the distance between A and D is 675 m, find the values of a and T. (OCR)

5 The figure shows the (t, v) graph for the motion of a cyclist; the graph consists of three straight line segments. Use the information given on the graph to find the acceleration of the cyclist when $t = 2$ and the total distance travelled by the cyclist for $0 \leqslant t \leqslant 30$.

Without making any detailed calculations, sketch the displacement–time graph for this motion. (OCR)



6 A car is waiting at traffic lights with a van behind it. There is a 1 metre gap between them. When the lights turn green, the car accelerates at 1.5 m s^{-2} until it reaches a speed of 15 m s^{-1}; it then proceeds at this speed. The van does the same, starting when the gap between the vehicles is 4 metres.

Find a formula for the distance travelled by the car in the first t seconds $(0 \leqslant t \leqslant 10)$, and hence the time interval between the car starting and the van starting. Find also the distance between the vehicles when they are both going at 15 m s^{-1}. (OCR)

1	(a)	1.5 m s^{-2}	(b)	11.0 m s^{-1}
2	(a)	40 s	(b)	24.85
3	15.0 m s^{-1}			
4	$a = \frac{1}{8}, T = 20$			
5	2 m s^{-2}, 200 m			
6	$\frac{3}{4}t^2$ m, 2 s, 31 m			

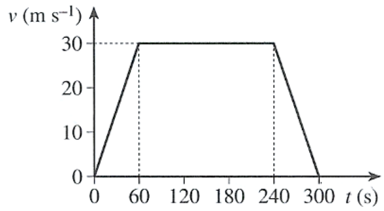
7 Two runners, Alice and Belle, are leading the field in a long-distance race. They are both running at $5\ \text{m s}^{-1}$, with Alice $10\ \text{m}$ behind Belle. When Belle is $50\ \text{m}$ from the tape, Alice accelerates but Belle doesn't. What is the least acceleration Alice must produce to overtake Belle?

If instead Belle accelerates at $0.1\ \text{m s}^{-2}$ up to the tape, what is the least acceleration Alice must produce?

8 A woman stands on the bank of a frozen lake with a dog by her side. She skims a bone across the ice at a speed of $3\ \text{m s}^{-1}$. The bone slows down with deceleration $0.4\ \text{m s}^{-2}$, and the dog chases it with acceleration $0.6\ \text{m s}^{-2}$. How far out from the bank does the dog catch up with the bone?

9 A man is running for a bus at $3\ \text{m s}^{-1}$. When he is $100\ \text{m}$ from the bus stop, the bus passes him going at $8\ \text{m s}^{-1}$. If the deceleration of the bus is constant, at what constant rate should the man accelerate so as to arrive at the bus stop at the same instant as the bus?

10 (a) A train travels from a station P to the next station Q, arriving at Q exactly 5 minutes after leaving P. The (t, v) graph for the train's journey is approximated by three straight line segments, as shown in the figure.

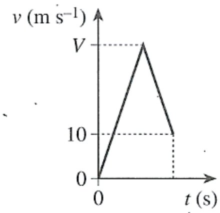


(i) Write down the acceleration of the train during the first minute of the journey.

(ii) Find the distance from P to Q.

(b) On one occasion, when the track is being repaired, the train is restricted to a maximum speed of $10\ \text{m s}^{-1}$ for the $2000\ \text{m}$ length of track lying midway between P and Q. The train always accelerates and decelerates at the rate shown in the figure. When not accelerating or decelerating or moving at the restricted speed of $10\ \text{m s}^{-1}$, the train travels at $30\ \text{m s}^{-1}$. Sketch the (t, v) graph for the train's journey from P to Q when the speed restriction is in force, and hence find how long the train takes to travel from P to Q on this occasion.

(c) The second figure shows the (t, v) graph for the train accelerating from rest up to a maximum speed of $V\ \text{m s}^{-1}$ and then immediately decelerating to a speed of $10\ \text{m s}^{-1}$. The acceleration and deceleration have the same value as shown in the first figure. Show that the distance travelled is $(2V^2 - 100)$ metres.



Determine whether the train in (b) could, by exceeding the normal speed of $30\ \text{m s}^{-1}$ when possible, make up the time lost due to the speed restriction when travelling from P to Q. Assume that the acceleration and deceleration must remain as before. (OCR)

11 If a ball is placed on a straight sloping track and then released from rest, the distances that it moves in successive equal intervals of time are found to be in the ratio 1:3:5:7:.... Show that this is consistent with the theory that the ball rolls down the track with constant acceleration.

7 $0.2\ \text{m s}^{-2}$; $0.34\ \text{m s}^{-2}$
8 $10.8\ \text{m}$
9 $0.08\ \text{m s}^{-2}$
10 (a) (i) $\frac{1}{2}\ \text{m s}^{-2}$ (ii) $7200\ \text{m}$
(b) $460\ \text{s}$; no