Kinematics

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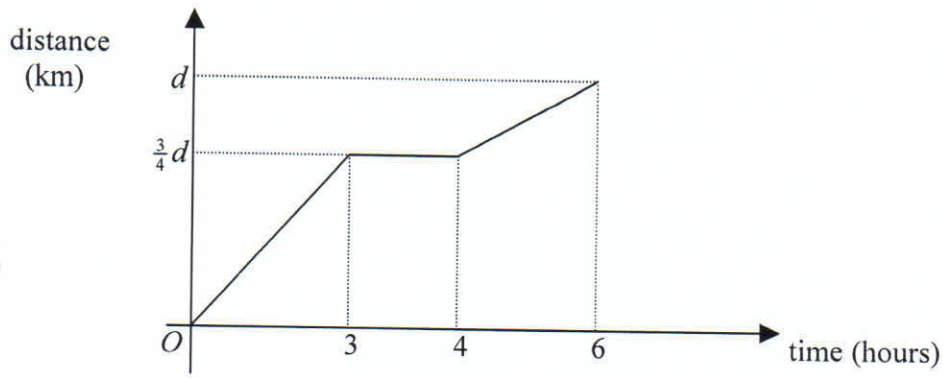

Fig. 1

Figure 1 shows a distance-time graph for a car journey from Birmingham to Newquay which included a stop for lunch at a service station near Exeter. During the first part of the journey three-quarters of the total distance, d, was covered in 3 hours. After a 1 hour stop, the remaining distance was completed in 2 hours.

(a) Calculate, in the form $k : 1$, the ratio of the average speed during the first 3 hours of the journey to the average speed during the last 2 hours of the journey.

(4 marks)

Given that the average speed of the car over the whole journey (excluding the stop) was 80 km h^{-1},

(b) find the average speed of the car on the first part of the journey. **(4 marks)**

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2. A sports car is being driven along a straight test track. It passes the point O at time $t = 0$ at which time it begins to decelerate uniformly. The car passes the points L and M at times $t = 1$ and $t = 4$ respectively.

Given that OL is 54 m and LM is 90 m,

(a) find the rate of deceleration of the car. **(5 marks)**

The car subsequently comes to rest at N.

(b) Find the distance MN. **(4 marks)**

3. A car and a motorbike are at rest adjacent to one another at a set of traffic lights on a long, straight stretch of road. They set off simultaneously at time $t = 0$. The motorcyclist accelerates uniformly at 6 $m\,s^{-2}$ until he reaches a speed of 30 $m\,s^{-1}$ which he then maintains. The car driver accelerates uniformly for 9 seconds until she reaches 36 $m\,s^{-1}$ and then remains at this speed.

(C,5)

(a) Find the acceleration of the car. **(2 marks)**

(b) Draw on the same diagram speed-time graphs to illustrate the movements of both vehicles.

(4 marks)

(c) Find the value of t when the car again draws level with the motorcyclist. **(7 marks)**

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4. Anila is practising catching tennis balls. She uses a mobile computer-controlled machine which fires tennis balls vertically upwards from a height of 2.5 metres above the ground. Once it has fired a ball, the machine is programmed to move position rapidly to allow Anila time to get into a suitable position to catch the ball.

The machine fires a ball at 24 $m\,s^{-1}$ vertically upwards and Anila catches the ball just before it touches the ground.

(A,6)

(a) Draw a speed-time graph for the motion of the ball from the time it is fired by the machine to the instant before Anila catches it.

(3 marks)

(b) Find, to the nearest centimetre, the maximum height which the ball reaches above the ground.

(4 marks)

(c) Calculate the speed at which the ball is travelling when Anila catches it. **(4 marks)**

(d) Calculate the length of time that the ball is in the air. **(3 marks)**

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5. Whilst looking over the edge of a vertical cliff, 122.5 metres in height, Jim dislodges a stone. The stone falls freely from rest towards the sea below.

Ignoring the effect of air resistance,

(D,3)

(a) calculate the time it would take for the stone to reach the sea, **(3 marks)**

(b) find the speed with which the stone would hit the water. **(2 marks)**

Two seconds after the stone begins to fall, Jim throws a tennis ball downwards at the stone. The tennis ball's initial speed is u $m\,s^{-1}$ and it hits the stone before they both reach the water.

(c) Find the minimum value of u. **(5 marks)**

(d) If you had taken air resistance into account in your calculations, what effect would this have had on your answer to part *(c)*? Explain your answer.

(2 marks)

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6. An underground train accelerates uniformly from rest at station A to a velocity of 24 $m\,s^{-1}$. It maintains this speed for 84 seconds, until it decelerates uniformly to rest at station B. The total journey time is 116 seconds and the magnitudes of the acceleration and deceleration are equal.

(E,2)

(a) Find the time it takes the train to accelerate from rest to 24 $m\,s^{-1}$. **(2 marks)**

(b) Illustrate this information on a velocity-time graph. **(2 marks)**

(c) Using your graph, or otherwise, find the distance between the two stations. **(3 marks)**

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7. Andrew hits a tennis ball vertically upwards towards his sister Barbara who is leaning out of a window 7.5 m above the ground to try to catch it. When the ball leaves Andrew's racket, it is 1.9 m above the ground and travelling at 21 $m\,s^{-1}$. Barbara fails to catch the ball on its way up but succeeds as the ball comes back down.

(L,4)

Modelling the ball as a particle and assuming that air resistance can be neglected,

(a) find the maximum height above the ground which the ball reaches. **(4 marks)**

(b) find how long Barbara has to wait from the moment that the ball first passes her until she catches it.

(6 marks)

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8. A boy kicks a football vertically upwards from a height of 0.6 m above the ground with a speed of 10.5 $m\,s^{-1}$. The ball is modelled as a particle and air resistance is ignored.

(E,6)

(a) Find the greatest height above the ground reached by the ball. **(4 marks)**

(b) Calculate the length of time for which the ball is more than 2 m above the ground.

(6 marks)

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9. A car on a straight test track starts from rest and accelerates to a speed of V $m\,s^{-1}$ in 6 seconds. The car maintains this speed for a further 50 seconds before decelerating to rest.

In a simple model of this motion, the acceleration and deceleration are assumed to be uniform and the magnitude of the deceleration to be 1.5 times that of the acceleration.

(I,5)

(a) Show that the total time for which the car is moving is 60 seconds. **(3 marks)**

(b) Sketch a velocity-time graph for this journey. **(3 marks)**

Given that the total distance travelled is 1320 metres,

(c) find V. **(3 marks)**

In a more sophisticated model, the acceleration is assumed to be inversely proportional to the velocity of the car.

(d) Explain how the acceleration would vary during the first six seconds under this model.

(2 marks)

10. A student attempts to sketch the acceleration-time graph of a parachutist who jumps from a plane at a height of 2200 m above the ground.

The student assumes that the parachutist falls freely from rest under gravity until she is 240 m from the ground at which point she opens her parachute. The student makes the assumption that, at this point, the velocity of the parachutist is immediately reduced to a value which remains constant until she reaches the ground 140 seconds after she left the plane.

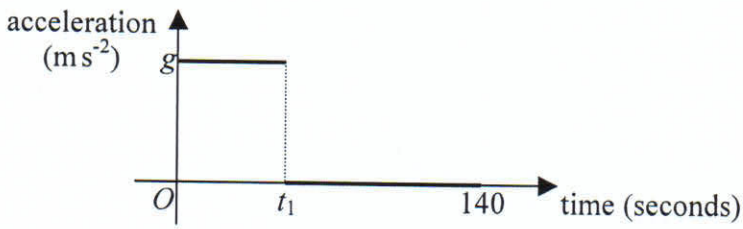

Fig. 3

The student decides to ignore air resistance and his sketch is shown in Figure 3. The value t_1 is used by the student to denote the time at which the parachute is opened.

Using the model proposed by the student, calculate

(a) the speed of the parachutist immediately before she opens her parachute, **(4 marks)**

(b) the value of t_1, **(3 marks)**

(c) the speed of the parachutist after the parachute is opened. **(2 marks)**

(d) Comment on two features of the student's model which are unrealistic and say what effect taking account of these would have had on the values which you calculated in parts *(a)* and *(b)*.

(4 marks)

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11. A particle moving in a straight line with speed $5U$ m s^{-1} undergoes a uniform deceleration for 6 seconds which reduces its speed to $2U$ m s^{-1}. It maintains this speed for 16 seconds before uniformly decelerating to rest in a further 2 seconds.

(a) Sketch a speed-time graph displaying this information. **(2 marks)**

(b) Find an expression for each of the decelerations in terms of U. **(4 marks)**

Given that the total distance travelled by the particle during this period of motion is 220 m,

(c) find the value of U. **(6 marks)**

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12 A lorry accelerates uniformly from 5 $m\,s^{-1}$ to 20 $m\,s^{-1}$ in 30 seconds.

(a) Find how far it travels while accelerating. **(3 marks)**

(#13) *(b)* Find, in seconds correct to 2 decimal places, the length of time it takes for the lorry to cover the first half of this distance.

(6 marks)

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13. Two flies P and Q, are crawling vertically up a wall. At time $t = 0$, the flies are at the same height above the ground, with P crawling at a steady speed of 4 $cm\,s^{-1}$.

Q starts from rest at time $t = 0$ and accelerates uniformly to a speed of 6 $cm\,s^{-1}$ in 6 seconds. Fly Q then maintains this speed.

(J5) *(a)* Find the value of t when the two flies are moving at the same speed. **(3 marks)**

(b) Sketch on the same diagram, speed-time graphs to illustrate the motion of the two flies.

(3 marks)

Given that the distance of the two flies from the top of the wall at time $t = 0$ is x cm and that Q reaches the top of the wall first,

(c) show that $x > 36$. **(5 marks)**
