SECTION B: MECHANICS

Answer ALL questions. Write your answers in the spaces provided.

Unless otherwise indicated, whenever a numerical value of g is required, take $g = 9.8 \text{ m s}^{-2}$ and give your answer to either 2 significant figures or 3 significant figures.

6.

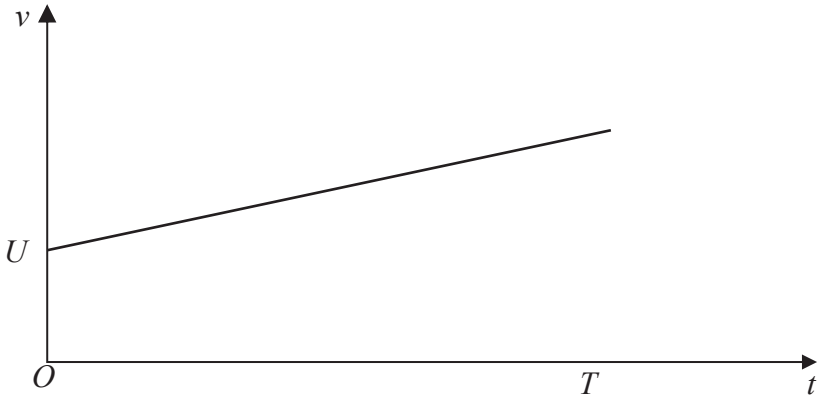

Figure 1

A car moves along a straight horizontal road. At time $t = 0$, the velocity of the car is $U \text{ m s}^{-1}$. The car then accelerates with constant acceleration $a \text{ m s}^{-2}$ for T seconds. The car travels a distance D metres during these T seconds.

Figure 1 shows the velocity-time graph for the motion of the car for $0 \leqslant t \leqslant T$.

Using the graph, show that $D = UT + \frac{1}{2} aT^2$.

(No credit will be given for answers which use any of the kinematics (*suvat*) formulae listed under Mechanics in the AS Mathematics section of the formulae booklet.)

(4)

7. A train travels along a straight horizontal track between two stations, A and B.

In a model of the motion, the train starts from rest at A and moves with constant acceleration $0.3\,\text{m s}^{-2}$ for 80 s.
The train then moves at constant velocity before it moves with a constant deceleration of $0.5\,\text{m s}^{-2}$, coming to rest at B.

(a) For this model of the motion of the train between A and B,

(i) state the value of the constant velocity of the train,

(ii) state the time for which the train is decelerating,

(iii) sketch a velocity-time graph.

(3)

The total distance between the two stations is 4800 m.

(b) Using the model, find the total time taken by the train to travel from A to B.

(3)

(c) Suggest one improvement that could be made to the model of the motion of the train from A to B in order to make the model more realistic.

(1)

Leave blank

6. An athlete goes for a run along a straight horizontal road. Starting from rest, she accelerates at $0.6\,\text{m s}^{-2}$ up to a speed of $V\,\text{m s}^{-1}$. She then maintains this constant speed of $V\,\text{m s}^{-1}$ before finally decelerating at $0.2\,\text{m s}^{-2}$ back to rest. She covers a total distance of 1500 m in 270 s.

(a) Sketch a speed-time graph to represent the athlete's run.

(2)

(b) Show that she accelerates for $\frac{5V}{3}$ seconds.

(2)

(c) Show that $V^2 - kV + 450 = 0$, where k is a constant to be found.

(6)

(d) Find the value of V, justifying your answer.

(4)

Leave blank

7. A train moves on a straight horizontal track between two stations A and B. The train starts from rest at A and moves with constant acceleration $1\,\text{m s}^{-2}$ until it reaches a speed of $V\,\text{m s}^{-1}$. The train maintains this speed of $V\,\text{m s}^{-1}$ for the next T seconds before slowing down with constant deceleration $0.5\,\text{m s}^{-2}$, coming to rest at B. The journey from A to B takes 180 s and the distance between the stations is 4800 m.

(a) Sketch a speed-time graph for the motion of the train from A to B.

(2)

(b) Show that $T = 180 - 3V$.

(2)

(c) Find the value of V.

(7)

Leave blank

5. Two trains, P and Q, move on horizontal parallel straight tracks. Initially both are at rest in a station and level with each other. At time $t = 0$, P starts off and moves with constant acceleration for 10 s up to a speed of $25\,\text{m s}^{-1}$ and then moves at a constant speed of $25\,\text{m s}^{-1}$. At time $t = 20$, where t is measured in seconds, train Q starts to move in the same direction as P. Train Q accelerates with the same initial constant acceleration as P, up to a speed of $40\,\text{m s}^{-1}$ and then moves at a constant speed of $40\,\text{m s}^{-1}$. Train Q overtakes P at time $t = T$, after both trains have reached their constant speeds.

(a) Sketch, on the same axes, the speed-time graphs of both trains for $0 \leqslant t \leqslant T$.

(3)

(b) Find the value of t at the instant when both trains are moving at the same speed.

(2)

(c) Find the value of T.

(8)

Leave blank

6.

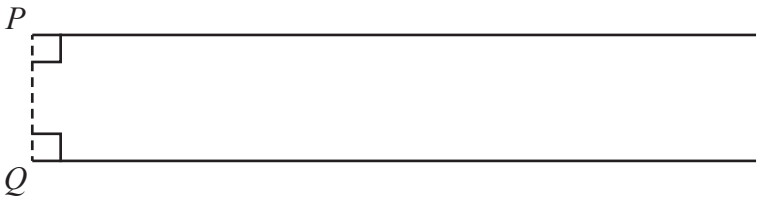

Figure 2

Two cars, A and B, move on parallel straight horizontal tracks. Initially A and B are both at rest with A at the point P and B at the point Q, as shown in Figure 2. At time $t = 0$ seconds, A starts to move with constant acceleration a m s^{-2} for 3.5 s, reaching a speed of 14 m s^{-1}. Car A then moves with constant speed 14 m s^{-1}.

(a) Find the value of a.

(2)

Car B also starts to move at time $t = 0$ seconds, in the same direction as car A. Car B moves with a constant acceleration of 3 m s^{-2}. At time $t = T$ seconds, B overtakes A. At this instant A is moving with constant speed.

(b) On a diagram, sketch, on the same axes, a speed-time graph for the motion of A for the interval $0 \leqslant t \leqslant T$ and a speed-time graph for the motion of B for the interval $0 \leqslant t \leqslant T$.

(3)

(c) Find the value of T.

(8)

(d) Find the distance of car B from the point Q when B overtakes A.

(1)

(e) On a new diagram, sketch, on the same axes, an acceleration-time graph for the motion of A for the interval $0 \leqslant t \leqslant T$ and an acceleration-time graph for the motion of B for the interval $0 \leqslant t \leqslant T$.

(3)

Leave blank

5. A car travelling along a straight horizontal road takes 170 s to travel between two sets of traffic lights at A and B which are 2125 m apart. The car starts from rest at A and moves with constant acceleration until it reaches a speed of 17 m s^{-1}. The car then maintains this speed before moving with constant deceleration, coming to rest at B. The magnitude of the deceleration is twice the magnitude of the acceleration.

(a) Sketch, in the space below, a speed-time graph for the motion of the car between A and B.

(3)

(b) Find the deceleration of the car.

(7)

Leave blank

6. A car starts from rest at a point A and moves along a straight horizontal road. The car moves with constant acceleration 1.5 m s^{-2} for the first 8 s. The car then moves with constant acceleration 0.8 m s^{-2} for the next 20 s. It then moves with constant speed for T seconds before slowing down with constant deceleration 2.8 m s^{-2} until it stops at a point B.

(a) Find the speed of the car 28 s after leaving A.

(3)

(b) Sketch, in the space provided, a speed–time graph to illustrate the motion of the car as it travels from A to B.

(2)

(c) Find the distance travelled by the car during the first 28 s of its journey from A.

(4)

The distance from A to B is 2 km.

(d) Find the value of T.

(4)

Leave blank

5. A cyclist is travelling along a straight horizontal road. The cyclist starts from rest at point A on the road and accelerates uniformly at 0.6 m s^{-2} for 20 seconds. He then moves at constant speed for $4T$ seconds, where $T < 20$. He then decelerates uniformly at 0.3 m s^{-2} and after T seconds passes through point B on the road. The distance from A to B is 705 m.

(a) Sketch a speed-time graph for the motion of the cyclist between points A and B.

(2)

(b) Find the value of T.

(7)

The cyclist continues his journey, still decelerating uniformly at 0.3 m s^{-2}, until he comes to rest at point C on the road.

(c) Find the total time taken by the cyclist to travel from A to C.

(3)

Leave blank

4. A small stone is projected vertically upwards from the point O and moves freely under gravity. The point A is 3.6 m vertically above O. When the stone first reaches A, the stone is moving upwards with speed 11.2 m s^{-1}. The stone is modelled as a particle.

(a) Find the maximum height above O reached by the stone.

(4)

(b) Find the total time between the instant when the stone was projected from O and the instant when it returns to O.

(5)

(c) Sketch a velocity-time graph to represent the motion of the stone from the instant when it passes through A moving upwards to the instant when it returns to O. Show, on the axes, the coordinates of the points where your graph meets the axes.

(4)

Leave blank

7. A train travels along a straight horizontal track between two stations A and B. The train starts from rest at A and moves with constant acceleration until it reaches its maximum speed of 108 km h^{-1}. The train then travels at this speed before it moves with constant deceleration coming to rest at B. The journey from A to B takes 8 minutes.

(a) Change 108 km h^{-1} into m s^{-1}.

(2)

(b) Sketch a speed-time graph for the motion of the train between the two stations A and B.

(2)

Given that the distance between the two stations is 12 km and that the time spent decelerating is three times the time spent accelerating,

(c) find the acceleration, in m s^{-2}, of the train.

(6)

Leave blank

8. Two trains, A and B, start together from rest, at time $t = 0$, at a station and move along parallel straight horizontal tracks. Both trains come to rest at the next station after 180 s.

Train A moves with constant acceleration $\frac{2}{3}$ m s^{-2} for 30 s, then moves at constant speed for 120 s and then moves with constant deceleration for the final 30 s. Train B moves with constant acceleration for 90 s and then moves with constant deceleration for the final 90 s.

(a) Sketch, on the same axes, the speed–time graphs for the motion of the two trains between the two stations.

(3)

(b) Find the acceleration of train B for the first half of its journey.

(5)

(c) Find the times when the two trains are moving at the same speed.

(4)

(d) Find the distance between the trains 96 s after they start.

(5)