SECTION B: MECHANICS

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

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

6. A man throws a tennis ball into the air so that, at the instant when the ball leaves his hand, the ball is 2 m above the ground and is moving vertically upwards with speed $9\,\text{m}\,\text{s}^{-1}$

The motion of the ball is modelled as that of a particle moving freely under gravity and the acceleration due to gravity is modelled as being of constant magnitude $10\,\text{m}\,\text{s}^{-2}$

The ball hits the ground T seconds after leaving the man's hand.

Using the model, find the value of T.

(4)

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

1. At time $t = 0$, a parachutist falls vertically from rest from a helicopter which is hovering at a height of 550 m above horizontal ground.

The parachutist, who is modelled as a particle, falls for 3 seconds before her parachute opens.

While she is falling, and before her parachute opens, she is modelled as falling freely under gravity.

The acceleration due to gravity is modelled as being $10\,\text{m}\,\text{s}^{-2}$.

(a) Using this model, find the speed of the parachutist at the instant her parachute opens.

(1)

When her parachute is open, the parachutist continues to fall vertically.

Immediately after her parachute opens, she decelerates at $12\,\text{m}\,\text{s}^{-2}$ for 2 seconds before reaching a constant speed and she reaches the ground with this speed.

The total time taken by the parachutist to fall the 550 m from the helicopter to the ground is T seconds.

(b) Sketch a speed-time graph for the motion of the parachutist for $0 \leqslant t \leqslant T$.

(2)

(c) Find, to the nearest whole number, the value of T.

(5)

In a refinement of the model of the motion of the parachutist, the effect of air resistance is included before her parachute opens and this refined model is now used to find a new value of T.

(d) How would this new value of T compare with the value found, using the initial model, in part (c)?

(1)

(e) Suggest one further refinement to the model, apart from air resistance, to make the model more realistic.

(1)

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1. At time $t = 0$, a small ball is projected vertically upwards with speed $U\,\text{m s}^{-1}$ from a point A that is 16.8 m above horizontal ground.

The speed of the ball at the instant immediately before it hits the ground for the first time is $19\,\text{m s}^{-1}$

The ball hits the ground for the first time at time $t = T$ seconds.

The motion of the ball, from the instant it is projected until the instant just before it hits the ground for the first time, is modelled as that of a particle moving freely under gravity.

The acceleration due to gravity is modelled as having magnitude $10\,\text{m s}^{-2}$

Using the model,

(a) show that $U = 5$

(2)

(b) find the value of T,

(2)

(c) find the time from the instant the ball is projected until the instant when the ball is 1.2 m below A.

(4)

(d) Sketch a velocity-time graph for the motion of the ball for $0 \leqslant t \leqslant T$, stating the coordinates of the start point and the end point of your graph.

(2)

In a refinement of the model of the motion of the ball, the effect of air resistance on the ball is included and this refined model is now used to find the value of U.

(e) State, with a reason, how this new value of U would compare with the value found in part (a), using the initial unrefined model.

(1)

(f) Suggest one further refinement that could be made to the model, apart from including air resistance, that would make the model more realistic.

(1)

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7. A car is moving along a straight horizontal road with constant acceleration. There are three points A, B and C, in that order, on the road, where $AB = 22$ m and $BC = 104$ m. The car takes 2 s to travel from A to B and 4 s to travel from B to C.

Find

(i) the acceleration of the car,

(ii) the speed of the car at the instant it passes A.

(7)

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5. A small ball is projected vertically upwards from a point O with speed $14.7\,\text{m}\,\text{s}^{-1}$. The point O is 2.5 m above the ground. The motion of the ball is modelled as that of a particle moving freely under gravity.

Find

(a) the maximum height above the ground reached by the ball,

(4)

(b) the time taken for the ball to first reach a height of 1 m above the ground,

(4)

(c) the speed of the ball at the instant before it strikes the ground for the first time.

(3)

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6. Two cars A and B are moving in the same direction along a straight horizontal road. Car A is moving with uniform acceleration $0.4\,\text{m}\,\text{s}^{-2}$ and car B is moving with uniform acceleration $0.5\,\text{m}\,\text{s}^{-2}$. At the instant when B is 200 m behind A, the speed of A is $35\,\text{m}\,\text{s}^{-1}$ and the speed of B is $44\,\text{m}\,\text{s}^{-1}$. Find the speed of B when it overtakes A.

(9)

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4. A small stone is released from rest from a point A which is at height h metres above horizontal ground. Exactly one second later another small stone is projected with speed 19.6 m s^{-1} vertically downwards from a point B, which is also at height h metres above the horizontal ground. The motion of each stone is modelled as that of a particle moving freely under gravity. The two stones hit the ground at the same time.

Find the value of h.

(7)

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2. A ball is thrown vertically upwards with speed 20 m s^{-1} from a point A, which is h metres above the ground. The ball moves freely under gravity until it hits the ground 5 s later.

(a) Find the value of h.

(3)

A second ball is thrown vertically downwards with speed w m s^{-1} from A and moves freely under gravity until it hits the ground.

The first ball hits the ground with speed V m s^{-1} and the second ball hits the ground with speed $\frac{3}{4}V$ m s^{-1}.

(b) Find the value of w.

(5)

Leave blank

1. A train moves along a straight horizontal track between two stations R and S. Initially the train is at rest at R. The train accelerates uniformly at $\frac{1}{2}\,\text{m s}^{-2}$ from rest at R until it is moving with speed $15\,\text{m s}^{-1}$. For the next 200 seconds the train maintains a constant speed of $15\,\text{m s}^{-1}$. The train then decelerates uniformly at $\frac{1}{4}\,\text{m s}^{-2}$ until it comes to rest at S.

Find

(a) the time taken by the train to travel from R to S,

(3)

(b) the distance from R to S,

(4)

(c) the average speed of the train during the journey from R to S.

(2)

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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)

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4. The points P and Q are at the same height h metres above horizontal ground. A small stone is dropped from rest from P. Half a second later a second small stone is thrown vertically downwards from Q with speed $7.35\,\text{m s}^{-1}$. Given that the stones hit the ground at the same time, find the value of h.

(7)