3.5 Mechanics: Kinematics Depth

EDEXCEL 9MA0 · Calculator allowed · about 230 minutes · Write-in edition

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 A particle P moves in a straight line with velocity $v = 5 - 2t$ m/s. State the initial velocity of P (at $t = 0$).

(Total for Question 1 is 1 mark)

2 A particle passes point A with speed 6 m/s and accelerates uniformly at 2 m/s^2. Find its speed 5 seconds later, at point B.

(Total for Question 2 is 1 mark)

3 A ball is thrown vertically upwards with speed 19.6 m/s. Using $g = 9.8$ m/s^2, find the time taken to reach its greatest height.

(Total for Question 3 is 1 mark)

4 A particle moves in a straight line with initial speed 4 m/s and constant acceleration 1.5 m/s^2. Find the distance it travels in the first 6 seconds.

(Total for Question 4 is 2 marks)

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5 A ball is thrown vertically upwards from ground level with speed 24.5 m/s. Using g = 9.8 m/s^2, find the greatest height reached, giving your answer to 3 significant figures.

(Total for Question 5 is 2 marks)

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6 A ball is thrown vertically upwards from a point 2 m above the ground with speed 12 m/s. Using g = 9.8 m/s^2, find the greatest height above the ground reached by the ball, giving your answer to 3 significant figures.

(Total for Question 6 is 2 marks)

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7 A particle P moves along the x-axis with acceleration a = 6t - 4 m/s^2 at time t seconds. Given that P has velocity 3 m/s when t = 0, find an expression for the velocity of P at time t.

(Total for Question 7 is 2 marks)

8 A particle P moves along the x-axis. At time t seconds, the velocity of P is $v = t^2 - 4t$ m/s. Find the acceleration of P when t = 5 seconds.

(Total for Question 8 is 2 marks)

9 A particle P moves along the x-axis with displacement $x = t^2 - 5t$ metres at time t seconds. Find the velocity of P when t = 0.

(Total for Question 9 is 1 mark)

10 Two runners pass the same point at the same instant, moving in the same direction along a straight track. Runner A moves at a constant speed of 5 m/s. The distance runner B has covered t seconds after passing the point is t^2 metres. Find the value of t (other than t = 0) at which B catches up with A.

(Total for Question 10 is 2 marks)

11 A particle P moves along the x-axis. Its displacement from the origin at time t seconds ($t \geq 0$) is $x = t^3 - 12t$ metres. Find the value of t at which P is instantaneously at rest.

(Total for Question 11 is 2 marks)

12 Priya cycles from rest along a straight, horizontal cycle path with constant acceleration 1.5 m/s^2 for 8 seconds. Model Priya as a particle.

(a) Find Priya's speed at the end of the 8 seconds. **(2)**

(b) Find the distance Priya travels in these 8 seconds. **(2)**

(Total for Question 12 is 4 marks)

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13 A cyclist passes point A with speed 4 m/s and constant acceleration 0.6 m/s^2. She passes point B, 10 m from A in the direction of motion, T seconds after passing A. Show that $3T^2 + 40T - 100 = 0$, and hence find the value of T, giving your answer to 3 significant figures.

(Total for Question 13 is 3 marks)

14 A stone is thrown vertically upwards from a point 5 m above the ground with speed 16 m/s. Using $g = 9.8$ m/s^2, find the time taken for the stone to hit the ground, giving your answer to 3 significant figures.

(Total for Question 14 is 3 marks)

15 A particle has velocity $v = 3\sin(t)$ m/s at time t seconds. Find an expression for the acceleration of the particle at time t.

(Total for Question 15 is 2 marks)

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16 Amara throws a ball vertically upwards from a point 1.2 m above horizontal ground with speed 14 m/s. Model the ball as a particle moving freely under gravity, and use $g = 9.8$ m/s^2.

(a) Find the greatest height above the ground reached by the ball. **(3)**

(b) Find the time taken for the ball to hit the ground, giving your answer to 3 significant figures. **(3)**

(Total for Question 16 is 6 marks)

17 A train travels along a straight section of track between station P and station Q. It starts from rest at P and accelerates uniformly to a speed of 30 m/s in 40 seconds. It then travels at this constant speed for 90 seconds, before decelerating uniformly to rest at Q, coming to rest 25 seconds after the deceleration begins. Model the train as a particle.

(a) Find the total distance from P to Q. **(4)**

(b) Find the average speed for the whole journey from P to Q, giving your answer to 3 significant figures. **(2)**

(Total for Question 17 is 6 marks)

18 A particle P moves along the x-axis. At time t seconds ($t \geq 0$), the velocity of P is $v = t^2 - 6t + 8$ m/s. Given that P is at the origin when $t = 0$, find the values of t at which P is instantaneously at rest, and hence find the total distance travelled by P in the interval $0 \leq t \leq 5$.

(Total for Question 18 is 4 marks)

19 Two cars, A and B, pass the same road sign at the same instant, travelling in the same direction along a straight road. Car A passes the sign with speed 22 m/s and then travels at this constant speed. Car B passes the sign from rest at this same instant, with constant acceleration 2 m/s^2. Let t seconds be the time after the cars pass the sign.

(a) Write down expressions, in terms of t, for the displacement from the sign of car A and of car B. **(2)**

(b) Find the value of t at which car B catches up with car A, and find the distance from the sign at which this happens. **(3)**

(c) Find the speed of car B at the instant it catches up with car A. **(2)**

(Total for Question 19 is 7 marks)

20 A particle P moves along the x-axis. At time t seconds ($t \geq 0$), the displacement of P from a fixed origin O is x metres, where $x = t^3 - 6t^2 + 9t + 2$.

(a) Find an expression for the velocity, v m/s, of P at time t seconds. **(2)**

(b) Find an expression for the acceleration, a m/s^2, of P at time t seconds. **(2)**

(c) Find the values of t for which P is instantaneously at rest. **(2)**

(d) Find the acceleration of P at the instant when $t = 3$. **(2)**

(Total for Question 20 is 8 marks)

21 A particle Q moves in a straight line. At time t seconds, the acceleration of Q is a m/s^2, where a = 4 - 6t. When t = 0, the velocity of Q is 3 m/s and the displacement of Q from a fixed point O is 0.

(a) Show that the velocity of Q at time t seconds is given by $v = 3 + 4t - 3t^2$. **(3)**

(b) Find the displacement of Q from O when t = 2 seconds. **(3)**

(c) Find the value of t, other than t = 0, at which Q returns to O. **(2)**

(Total for Question 21 is 8 marks)

22 A ball is projected from a point A, which is 6 m above horizontal ground, with speed 25 m/s at an angle of elevation α, where $\sin(\alpha) = 7/25$. The ball moves freely under gravity until it hits the ground at point B. Use $g = 9.8$ m/s^2.

(a) Show that the initial horizontal and vertical components of velocity are 24 m/s and 7 m/s respectively. **(2)**

(b) Find the greatest height above the ground reached by the ball. **(3)**

(c) Show that the time taken for the ball to reach the ground satisfies $4.9t^2 - 7t - 6 = 0$, and hence find this time, giving your answer to 3 significant figures. **(5)**

(d) Find the horizontal distance from A to B, giving your answer to 3 significant figures. **(2)**

(Total for Question 22 is 12 marks)

23 A particle is projected vertically upwards from the top of a tower 25 m high, with initial speed 18 m/s. Take the ground at the foot of the tower as the origin, with distances measured vertically upwards, and use $g = 9.8$ m/s^2.

(a) Find the greatest height above the ground reached by the particle. **(3)**

(b) Find the time taken for the particle to reach its greatest height, giving your answer to 3 significant figures. **(2)**

(c) Show that the times at which the particle is at a height of 40 m above the ground satisfy $4.9t^2 - 18t + 15 = 0$, and hence find both times, giving your answers to 3 significant figures. **(4)**

(d) Find the time taken for the particle to hit the ground, giving your answer to 3 significant figures. **(3)**

(Total for Question 23 is 12 marks)

24 A particle P moves along the x-axis. At time t seconds ($t \geq 0$), the acceleration of P is a m/s^2, where $a = 6t - 18$. When $t = 0$, P is at the origin O and moving with velocity 15 m/s in the positive x-direction.

(a) Show that the velocity of P at time t seconds is given by $v = 3t^2 - 18t + 15$. **(3)**

(b) Find the values of t at which P is instantaneously at rest. **(2)**

(c) Find an expression for the displacement, x metres, of P from O at time t seconds. **(3)**

(d) Find the total distance travelled by P in the interval $0 \leq t \leq 5$. **(5)**

(Total for Question 24 is 13 marks)

25 A train moves in a straight line with constant acceleration. It passes a point A with speed 11 m/s and reaches a point B with speed 35 m/s, after travelling a distance of 184 m from A.

(a) Find the acceleration. **(3)**

(b) Find the time taken to travel from A to B. **(2)**

(c) Find the distance travelled in the 4th second after passing A. **(3)**

(Total for Question 25 is 8 marks)

26 At time t = 0 a particle P has position vector (-5i - 3j) m relative to a fixed origin O, and velocity (5i - 3j) m/s. P moves with constant acceleration (i - j) m/s^2.

(a) Find the velocity of P when t = 2, and its speed, to 3 significant figures. **(3)**

(b) Find the position vector of P when t = 2. **(2)**

(Total for Question 26 is 5 marks)

27 A particle P moves in a horizontal plane. Its position vector relative to a fixed origin O at time t seconds is $\mathbf{r} = (t^2)\mathbf{i} + (-3t^3 + 4t)\mathbf{j}$ metres.

(a) Find the velocity and the acceleration of P at time t. **(3)**

(b) Find the speed of P when t = 2, to 3 significant figures. **(2)**

(c) Find the magnitude of the acceleration of P when t = 2, to 3 significant figures. **(2)**

(Total for Question 27 is 7 marks)

28 A particle P moves along a straight line. At time t seconds, $t \geq 0$, its velocity is $v = t^2 - 6t + 5$ m/s.

(a) Find the times at which P is instantaneously at rest. **(2)**

(b) Find the acceleration of P when $t = 5$. **(3)**

(c) Find the distance travelled by P in the interval $0 \leq t \leq 5$. **(4)**

(Total for Question 28 is 9 marks)

29 A particle P moves in a horizontal plane. Its position vector relative to a fixed origin O at time t seconds is $\mathbf{r} = (t^2 + 5t)\mathbf{i} + (3t^3 - 3t)\mathbf{j}$ metres.

(a) Find the velocity and the acceleration of P at time t. **(3)**

(b) Find the speed of P when t = 3, to 3 significant figures. **(2)**

(c) Find the magnitude of the acceleration of P when t = 3, to 3 significant figures. **(2)**

(Total for Question 29 is 7 marks)

30 A train moves in a straight line with constant acceleration. It passes a point A with speed 2 m/s and reaches a point B with speed 6 m/s, after travelling a distance of 16 m from A.

(a) Find the acceleration. **(3)**

(b) Find the time taken to travel from A to B. **(2)**

(c) Find the distance travelled in the 3rd second after passing A. **(3)**

(Total for Question 30 is 8 marks)

31 A cyclist moves along a straight horizontal track. It starts from rest and accelerates uniformly to a speed of V m/s in 7 s. It then moves at constant speed V for 18 s, and then decelerates uniformly to rest in 8 s. The total distance travelled is 229.5 m.

(a) Sketch the speed-time graph and find the total time for the journey. **(2)**

(b) Use the area of the graph to show that V satisfies the equation $(1/2)V(51) = 229.5$, and hence find V. **(3)**

(c) Find the acceleration in the first stage and the deceleration in the final stage. **(3)**

(d) Find the average speed for the whole journey, to 3 significant figures. **(2)**

(Total for Question 31 is 10 marks)

32 At time t = 0 a particle P has position vector (i - 3j) m relative to a fixed origin O, and velocity (i + 4j) m/s. P moves with constant acceleration (i + j) m/s^2.

(a) Find the velocity of P when t = 2, and its speed, to 3 significant figures. **(3)**

(b) Find the position vector of P when t = 2. **(2)**

(c) Find the value of t for which the velocity of P is parallel to (2i + 3j). **(3)**

(Total for Question 32 is 8 marks)

33 A particle R moves in a straight line so that its velocity, v m/s, at time t seconds ($0 \leq t \leq 6$) is given by $v = t^2 - 6t + 8$.

(a) Find the values of t at which R is instantaneously at rest. **(2)**

(b) Find the acceleration of R at time t = 5 seconds, and state, with a reason, whether R is speeding up or slowing down at this instant. **(3)**

(c) Find the total distance travelled by R in the interval $0 \leq t \leq 6$. **(4)**

(Total for Question 33 is 9 marks)

34 A particle is projected vertically upwards from the top of a tower 20 m high, with initial speed 15 m/s. Taking the ground at the foot of the tower as the origin, with distances measured vertically upwards, and using $g = 9.8$ m/s^2, show that the times at which the particle is at a height of 22 m above the ground satisfy $4.9t^2 - 15t + 2 = 0$, and hence find both times, giving your answers to 3 significant figures.

(Total for Question 34 is 4 marks)

Mark scheme · 3.5 Mechanics: Kinematics Depth

Question 1

5 cao **B1**

Answer: 5 m/s

Question 2

16 cao **B1**

Answer: 16 m/s

Question 3

2 cao **B1**

Answer: 2 s

Question 4

$s = ut + 1/2\ a\ t^2$ with u=4, a=1.5, t=6 **M1**

51 m cao **A1**

Answer: 51 m

Question 5

use $v^2 = u^2 - 2gs$ with v=0, u=24.5 **M1**

awrt 30.6 m **A1**

Answer: 30.6 m (3 s.f.)

Question 6

use $v^2 = u^2 - 2gs$ with v=0, u=12 to find height risen above the point of projection, then add 2 m **M1**

awrt 9.35 m **A1**

Answer: 9.35 m (3 s.f.)

Question 7

integrate a with respect to t, then use v(0)=3 to find the constant **M1**

$v = 3t^2 - 4t + 3$ cao **A1**

Answer: $v = 3t^2 - 4t + 3$

Question 8

differentiate: $a = 2t - 4$, substitute t=5 **M1**

6 m/s^2 cao **A1**

Answer: 6 m/s^2

Question 9

-5 cao **B1**

Answer: -5 m/s

Question 10

set the two distances equal: $t^2 = 5t$ **M1**

t = 5 cao (rejecting t=0) **A1**

Answer: t = 5 s

Question 11

differentiate and set $v = 3t^2 - 12 = 0$ **M1**

t = 2 cao (rejecting the negative root as $t \geq 0$) **A1**

Answer: t = 2 s

Question 12

(a) uses $v = u + at$ with u = 0, a = 1.5, t = 8 **M1**

(a) v = 12 (m/s) cao **A1**

(a) Answer: 12 m/s

(b) uses $s = ut + 0.5at^2$ (or equivalent) with correct values **M1**

(b) s = 48 (m) cao **A1**

(b) Answer: 48 m

Question 13

use $s = ut + 1/2\ a\ t^2$ with u=4, a=0.6, s=10 to form $10 = 4T + 0.3T^2$, then multiply by 10 to give the printed equation **M1**

apply the quadratic formula to $3T^2 + 40T - 100 = 0$ and reject the negative root **M1**

awrt 2.15 s **A1**

Answer: T = 2.15 s (3 s.f.)

Question 14

use $s = ut - 1/2\ g\ t^2$ with s=-5 (taking upward as positive, ground 5 m below the start): $-5 = 16t - 4.9t^2$ **M1**

form $4.9t^2 - 16t - 5 = 0$ and apply the quadratic formula, rejecting the negative root **M1**

awrt 3.55 s **A1**

Answer: 3.55 s (3 s.f.)

Question 15

differentiate v with respect to t **M1**

a = 3cos(t) cao **A1**

Answer: a = 3cos(t)

Question 16

(a) uses $v^2 = u^2 - 2gh$ with v = 0, u = 14, g = 9.8 **M1**

(a) height above point of projection = 10 (m) **A1**

(a) adds 1.2 m: greatest height above ground = 11.2 (m) cao **A1**

(a) Answer: 11.2 m

(b) uses $s = ut - 0.5gt^2$ with displacement -1.2 m from the point of projection (or equivalent, measuring from the ground) **M1**

(b) correct quadratic $4.9t^2 - 14t - 1.2 = 0$ (oe) **A1**

(b) t = awrt 2.94 (s), rejecting the negative root **A1**

(b) Answer: t = 2.94 s (3sf)

Question 17

(a) finds the distance in the acceleration phase: 0.5(0+30)(40) = 600 (m) **M1**

(a) finds the distance in the constant-speed phase: 30 * 90 = 2700 (m) **B1**

(a) finds the distance in the deceleration phase: 0.5(30+0)(25) = 375 (m) **M1**

(a) total distance = 3675 (m) cao **A1**

(a) Answer: 3675 m

(b) uses total time = 40 + 90 + 25 = 155 (s), with their total distance **M1**

(b) average speed = awrt 23.7 (m/s) cao **A1**

(b) Answer: 23.7 m/s (3sf)

Question 18

set v=0 and solve: (t-2)(t-4)=0 **M1**

t = 2 and t = 4 cao **A1**

integrate v to find $x = t^3/3 - 3t^2 + 8t$ (using x(0)=0), and evaluate at t=0,2,4,5 **M1**

total distance = |20/3 - 0| + |16/3 - 20/3| + |20/3 - 16/3| = awrt 9.33 m **A1**

Answer: t = 2 s and t = 4 s; total distance = 9.33 m (3 s.f.)

Question 19

(a) displacement of A: $s_A = 22t$ **B1**

(a) displacement of B: $s_B = t^2$ (from $s = 0 + 0.5(2)t^2$) **B1**

(a) Answer: $s_A = 22t$; $s_B = t^2$

(b) sets $s_A = s_B$: $22t = t^2$ **M1**

(b) t = 22 (s), rejecting t = 0 **A1**

(b) distance from sign = 484 (m) cao **A1**

(b) Answer: t = 22 s; distance = 484 m

(c) uses v = u + at with u = 0, a = 2, their t = 22 **M1**

(c) v = 44 (m/s) cao **A1**

(c) Answer: 44 m/s

Question 20

(a) differentiates x with respect to t **M1**

(a) $v = 3t^2 - 12t + 9$ cao **A1**

(a) Answer: $v = 3t^2 - 12t + 9$

(b) differentiates their v with respect to t **M1**

(b) a = 6t - 12 cao **A1**

(b) Answer: a = 6t - 12

(c) sets v = 0 and divides by 3: $t^2 - 4t + 3 = 0$, then factorises **M1**

(c) t = 1 and t = 3 cao **A1**

(c) Answer: t = 1 s and t = 3 s

(d) substitutes t = 3 into their expression for a **M1**

(d) a = 6 (m/s^2) cao **A1**

(d) Answer: 6 m/s^2

Question 21

(a) integrates a with respect to t: $v = 4t - 3t^2 + c$ **M1**

(a) uses t = 0, v = 3 to find c = 3 **B1**

(a) $v = 3 + 4t - 3t^2$ cso **A1**

(a) Answer: $v = 3 + 4t - 3t^2$ (shown)

(b) integrates their v with respect to t: $s = 3t + 2t^2 - t^3 + c$, using s = 0 at t = 0 to give c = 0 **M1**

(b) substitutes t = 2 into their expression for s **M1**

(b) s = 6 (m) cao **A1**

(b) Answer: 6 m

(c) sets s = 0 and factorises out t: $t(3 + 2t - t^2) = 0$, then solves the quadratic factor **M1**

(c) t = 3 (s), rejecting t = -1 since $t \geq 0$ **A1**

(c) Answer: t = 3 s

Question 22

(a) uses sin(α) = 7/25 to identify cos(α) = 24/25 (7-24-25 triangle), and finds horizontal component 25 * 24/25 = 24 cso **B1**

(a) finds vertical component 25 * 7/25 = 7 cso **B1**

(a) Answer: 24 m/s and 7 m/s (shown)

(b) uses $v^2 = u^2 - 2gh$ vertically with v = 0, u = 7, to find height above A **M1**

(b) height above A = 2.5 (m) **A1**

(b) adds 6 m: greatest height above ground = 8.5 (m) cao **A1**

(b) Answer: 8.5 m

(c) sets up the vertical displacement from A to the ground (6 m below A) as $7t - 4.9t^2 = -6$ **M1**

(c) rearranges to $4.9t^2 - 7t - 6 = 0$ cso **A1**

(c) uses the quadratic formula on $4.9t^2 - 7t - 6 = 0$ **dM1**

(c) $t = (7 + \sqrt{166.6})/9.8$ evaluated correctly **A1**

(c) t = awrt 2.03 (s), rejecting the negative root **A1**

(c) Answer: $4.9t^2 - 7t - 6 = 0$ (shown); t = 2.03 s (3sf)

(d) horizontal distance = 24 * their t **M1**

(d) awrt 48.8 (m) cao **A1**

(d) Answer: 48.8 m (3sf)

Question 23

(a) uses $v^2 = u^2 - 2gh$ with v = 0, u = 18, to find height above the tower **M1**

(a) height above tower = awrt 16.5 (m) **A1**

(a) adds 25 m: greatest height above ground = awrt 41.5 (m) cao **A1**

(a) Answer: 41.5 m (3sf)

(b) uses v = u - gt with v = 0, u = 18 **M1**

(b) t = awrt 1.84 (s) cao **A1**

(b) Answer: 1.84 s (3sf)

(c) sets height $25 + 18t - 4.9t^2 = 40$ and rearranges **M1**

(c) $4.9t^2 - 18t + 15 = 0$ cso **A1**

(c) uses the quadratic formula, with discriminant $18^2 - 4(4.9)(15) = 30$ **M1**

(c) t = awrt 1.28 (s) and t = awrt 2.40 (s), both values given **A1**

(c) Answer: $4.9t^2 - 18t + 15 = 0$ (shown); t = 1.28 s and t = 2.40 s (3sf)

(d) sets $25 + 18t - 4.9t^2 = 0$, i.e. $4.9t^2 - 18t - 25 = 0$ **M1**

(d) uses the quadratic formula with discriminant $18^2 + 4(4.9)(25) = 814$ **A1**

(d) t = awrt 4.75 (s), rejecting the negative root **A1**

(d) Answer: 4.75 s (3sf)

Question 24

(a) integrates a with respect to t: $v = 3t^2 - 18t + c$ **M1**

(a) uses t = 0, v = 15 to find c = 15 **B1**

(a) $v = 3t^2 - 18t + 15$ cso **A1**

(a) Answer: $v = 3t^2 - 18t + 15$ (shown)

(b) factorises $v = 3(t-1)(t-5)$ **M1**

(b) t = 1 and t = 5 cao **A1**

(b) Answer: t = 1 s and t = 5 s

(c) integrates v with respect to t: $x = t^3 - 9t^2 + 15t + c$ **M1**

(c) uses x = 0 at t = 0 to find c = 0 **A1**

(c) $x = t^3 - 9t^2 + 15t$ cao **A1**

(c) Answer: $x = t^3 - 9t^2 + 15t$

(d) evaluates x at t = 0, t = 1 and t = 5, using their expression for x **M1**

(d) x(1) = 7 (m) **A1**

(d) x(5) = -25 (m) **A1**

(d) recognises P changes direction at t = 1 (dependent on rest values from part (b)) and combines |x(1)-x(0)| + |x(5)-x(1)| **dM1**

(d) total distance = 39 (m) cao **A1**

(d) Answer: 39 m

Question 25

(a) uses $v^2 = u^2 + 2as$ **M1**

(a) $35^2 = 11^2 + 2a(184)$ **A1**

(a) $a = 3$ m/s^2 **A1**

(a) Answer: 3 m/s^2

(b) uses $v = u + at$ **M1**

(b) $t = (35 - 11)/3 = 8$ s **A1**

(b) Answer: 8 s

(c) distance in first 4 s minus distance in first 3 s **M1**

(c) 68 - 46.5 **A1**

(c) 21.5 m **A1**

(c) Answer: 21.5 m

Question 26

(a) uses $v = u + at$ **M1**

(a) 7i - 5j **A1**

(a) speed = 8.60 m/s **A1**

(a) Answer: (7i - 5j) m/s, speed 8.60 m/s

(b) uses $r = r0 + ut + (1/2)at^2$ **M1**

(b) (7i - 11j) m **A1**

(b) Answer: (7i - 11j) m

Question 27

(a) differentiates the position vector **M1**

(a) $v = (2t)i + (-9t^2 + 4)j$ **A1**

(a) $a = 2i - 18t\ j$ **A1**

(a) Answer: $v = (2t)i + (-9t^2 + 4)j$; $a = 2i - 18t\ j$

(b) substitutes t = 2: v = 4i - 32j **M1**

(b) speed = 32.2 m/s **A1**

(b) Answer: 32.2 m/s

(c) $a = 2i - 18t\ j$ with t = 2 **M1**

(c) |a| = 36.1 m/s^2 **A1**

(c) Answer: 36.1 m/s^2

Question 28

(a) sets v = 0 and factorises **M1**

(a) t = 1 and t = 5 **A1**

(a) Answer: t = 1 s and t = 5 s

(b) differentiates v with respect to t **M1**

(b) $a = 2t - 6$ **A1**

(b) a = 4 m/s^2 **A1**

(b) Answer: 4 m/s^2

(c) integrates v to obtain the displacement function **M1**

(c) evaluates the displacements over 0 to 1 and 1 to 5 separately, since v changes sign **M1**

(c) displacements 7/3 and -32/3 **A1**

(c) total distance = 13 m **A1**

(c) Answer: 13 m

Question 29

(a) differentiates the position vector **M1**

(a) $v = (2t + 5)i + (9t^2 - 3)j$ **A1**

(a) $a = 2i + 18t\ j$ **A1**

(a) Answer: $v = (2t + 5)i + (9t^2 - 3)j$; $a = 2i + 18t\ j$

(b) substitutes t = 3: v = 11i + 78j **M1**

(b) speed = 78.8 m/s **A1**

(b) Answer: 78.8 m/s

(c) $a = 2i + 18t\ j$ with t = 3 **M1**

(c) |a| = 54.0 m/s^2 **A1**

(c) Answer: 54.0 m/s^2

Question 30

(a) uses $v^2 = u^2 + 2as$ **M1**

(a) $6^2 = 2^2 + 2a(16)$ **A1**

(a) $a = 1$ m/s^2 **A1**

(a) Answer: 1 m/s^2

(b) uses $v = u + at$ **M1**

(b) $t = (6 - 2) = 4$ s **A1**

(b) Answer: 4 s

(c) distance in first 3 s minus distance in first 2 s **M1**

(c) 10.5 - 6 **A1**

(c) 4.5 m **A1**

(c) Answer: 4.5 m

Question 31

(a) a trapezium: straight line rising from the origin to (7, V), horizontal until t = 25, then straight line falling to zero **B1**

(a) total time = 7 + 18 + 8 = 33 s **B1**

(a) Answer: 33 s

(b) area of trapezium = (1/2)(parallel sides)(height) = (1/2)(33 + 18)V **M1**

(b) (1/2)(51)V = 229.5 **A1**

(b) V = 9 **A1**

(b) Answer: V = 9

(c) a = (v - u)/t for each stage **M1**

(c) acceleration = 9/7 m/s^2 **A1**

(c) deceleration = 9/8 m/s^2 **A1**

(c) Answer: 9/7 m/s^2 and 9/8 m/s^2

(d) total distance / total time **M1**

(d) 6.95 m/s **A1**

(d) Answer: 6.95 m/s

Question 32

(a) uses v = u + at **M1**

(a) 3i + 6j **A1**

(a) speed = 6.71 m/s **A1**

(a) Answer: (3i + 6j) m/s, speed 6.71 m/s

(b) uses r = r0 + ut + (1/2)at^2 **M1**

(b) (5i + 7j) m **A1**

(b) Answer: (5i + 7j) m

(c) equates the ratio of the velocity components to the ratio in the given vector **M1**

(c) forms and solves a linear equation in t **M1**

(c) t = 5 **A1**

(c) Answer: t = 5

Question 33

(a) sets v = 0 and factorises: (t-2)(t-4) = 0 **M1**

(a) t = 2 and t = 4 cao **A1**

(a) Answer: t = 2 s and t = 4 s

(b) differentiates v to find a = 2t - 6, and substitutes t = 5 **M1**

(b) a = 4 (m/s^2) cao **A1**

(b) speeding up, since v(5) = 3 (> 0) and a = 4 (> 0) act in the same direction (dependent on correct a and correct v(5)) **B1**

(b) Answer: a = 4 m/s^2; R is speeding up

(c) integrates v to find s(t) = $t^3/3 - 3t^2 + 8t$, with s(0) = 0 **M1**

(c) evaluates s at t = 2, t = 4 and t = 6, recognising R changes direction at t = 2 and t = 4 **dM1**

(c) distances 20/3 m, 4/3 m and 20/3 m for the three stages (oe, e.g. decimals) **A1**

(c) total distance = 44/3 (m) (oe, awrt 14.7 m) cao **A1**

(c) Answer: 44/3 m (awrt 14.7 m)

Question 34

height above ground = 20 + 15t - $4.9t^2$, set equal to 22 **M1**

cso: rearrange 15t - $4.9t^2$ = 2 to give $4.9t^2$ - 15t + 2 = 0 **A1**

apply the quadratic formula to solve for t **M1**

awrt 0.140 s and 2.92 s **A1**

Answer: t = 0.140 s and t = 2.92 s (3 s.f.)