# Kinematics of motion in a straight line 2 M

Q1.

| | | | | | |
|---|---|---|---|---|---|
| 7 | (i) | | M1 | | For using $v(t) = \int a\,dt$ |
| | | $v = \frac{1}{160}t^3 - \frac{1}{3200}t^4 \quad (+ C_1)$ | A1 | | |
| | | $[0 = 8000/160 - 160000/3200 + C_1 \rightarrow C_1 = 0]$ | M1 | | For using v(20) = 0 |
| | | Initial speed is zero | A1 | [4] | AG |
| | (ii) | $[t^2/800(15 - t) = 0]$ | M1 | | For solving a = 0 |
| | | $v_{max} = v(15) = 5.27 \text{ ms}^{-1}$ | A1 | [2] | |
| | (iii) | | M1 | | For using $s(t) = \int v\,dt$ |
| | | $s = \frac{1}{640}t^4 - \frac{1}{16000}t^5 \quad (+ C_2)$ | A1ft | | |
| | | [250 – 200] | M1 | | For using limits 0 and 20 (or equivalent) |
| | | Distance AB is 50 m | A1 | [4] | |

Q2.

| | | | | | |
|---|---|---|---|---|---|
| 7 | (i) | v(100) = 0.16 × 1000 – 0.016 × 10000 = 0 | B1 | 1 | AG |
| | (ii) | $a = 1.5 \times 0.16t^{½} - 0.032t$ | M1 | | For using a = dv/d$t$ |
| | | | A1 | | |
| | | $[t^{½} = 0.24/0.032 \rightarrow t = 56.25 \rightarrow$ $v_{max} = 0.16 \times 421.875 - 0.016 \times 3164.0625]$ | M1 | | For solving a = 0 and subst into $v(t)$ |
| | | Maximum speed is 16.9 $\text{ms}^{-1}$ (or $16\frac{7}{8}$ $\text{ms}^{-1}$) | A1 | 4 | |
| | (iii) | $s = 2/5 \times 0.16t^{5/2} - 0.016t^3/3$ | M1 | | For using $s = \int v\,dt$ |
| | | | A1 | | |
| | | Distance is 1070 m | A1 | 3 | |
| | (iv) | $\frac{1}{3}t^{5/2}(0.192 \ - 0.016\sqrt{t}) = 0$ | M1 | | For attempting to solve s($t$) = 0 |
| | | Value of $t$ is 144 | A1 | 2 | |

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Q3.

| | | | | |
|---|---|---|---|---|
| **3** | | M1 | | For using $s = ut + \frac{1}{2}at^2$ for $AB$ or $AC$ |
| | $55 = 5u + 12.5a$ | A1 | | |
| | $(55 + 65) = 10u + 50a$ or<br>$65 = 5v_B + 12.5a$ and $v_B = u + 5a$ | A1 | | |
| | | M1 | | For solving for $a$ or $u$ |
| | $a = 0.4$ (or $u = 10$) | A1 | | |
| | $u = 10$ (or $a = 0.4$) | A1ft | 6 | |
| | Alternative | | | |
| | $v_B = (55 + 65) \div (5 + 5)$ | M1 | | For calculating the speed at $B$ as the mean speed for the motion from $A$ to $C$. |
| | $v_B = 12\text{ms}^{-1}$ | A1 | | |
| | For calculating the speed at X, where X is the point where the car passes 2.5 s after passing through $A$, as $55 \div 5 = 11\text{ms}^{-1}$ | B1 | | |
| | $[a = (12 - 11) \div 2.5]$ | M1 | | For using $a = (v_B - v_X) \div 2.5$ |
| | $a = 0.4$ | A1 | | |
| | $u = v_X - a \times 2.5 = 11 - 0.4 \times 2.5 = 10$ | B1 | | |

Q4.

| | | | | | |
|---|---|---|---|---|---|
| **3** | **(i)** | $[0 = 8^2 - 2gs]$ | M1 | | For using $0 = u^2 - 2gs$ |
| | | Maximum height is 3.2 m | A1 | | |
| | | $[v^2 = 8^2 - 2g \times 1.6]$ | M1 | | For using $v^2 = u^2 - 2gs$ |
| | | Speed is 5.66 $\text{ms}^{-1}$ | A1 | 4 | |
| | **(ii)** | $[5.65685... = 8 - 10t]$ | M1 | | For using $v = u - gt$ |
| | | Time is 0.234 s | A1 | 2 | |

# Kinematics of motion in a straight line 2 M

Q5.

| | | | | | |
|---|---|---|---|---|---|
| **3** | **(i)** | | M1 | | For using $0 = u^2 - 2gs$ |
| | | $u^2 = 2 \times 10 \times 45$; speed is $30 ms^{-1}$ | A1 | [2] | |
| | **(ii)** | [$40 = 30t - 5t^2$ ➔ $t = 2, 4$] <br> [$5 = ½\ 10t^2$ ➔ $t = 1$] | M1 | | For using $s = ut - ½\ gt^2$ with $s = 40$, $u = 30$ and $T = t_2 - t_1$ or $s = ut + ½\ gt^2$ $s = 5$, $u = 0$ and $T = 2t$ |
| | | Time above the ground is 2 s | A1ft | [2] | |
| **Special Ruling** for candidates who assume, without justification, that the length of time required is that of the upward movement only. (maximum mark 1). | | | | | |
| | **(ii)** | $5 = ½\ 10t^2$ ➔ $t = 1$, the length of time required is 1 s | B1 | B1 | |
| | **(iii)** | Max. height above top of cliff = ½ g(17 ÷ 4) (= 21.25) | B1 | | |
| | | [$0 = V^2 - 2g(40 + 21.25)$] | M1 | | For using $0 = u^2 - 2gs$ |
| | | Speed is $35 ms^{-1}$ | A1 | [3] | |

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| **Alternative Marking Scheme for (iii)** | | | | |
| **(iii)** | | M1 | | For using $40 = Vt - 5t^2$ ➔ <br> $t_2 - t_1 =$ <br> $½\ (V/5 + \sqrt{(V^2/25 - 32)}) - ½\ (V/5 - \sqrt{(V^2/25 - 32)})$ |
| | $17 = V^2/25 - 32$ | A1 | | |
| | Speed is $35 ms^{-1}$ | A1 | [3] | |

# Kinematics of motion in a straight line 2 M

Q6.

| | | | | | |
|---|---|---|---|---|---|
| 6 | (i) | For sketch of single valued, continuous graph consisting of 3 straight line segments with $+^{ve}$, then $-^{ve}$, then $+^{ve}$ slope | B1 | | |
| | | Sketch appears to show v(0) = 0 and v(8) > v(26) >v(20) | B1 | [2] | |
| | (ii) | For shading the triangle from t = 0 to t = 8, the trapezium from t = 8 to t = 20 and the trapezium from t = 20 to a value of t seen to be between 20 and 26 | B1 | [1] | |
| | (iii) | | M1 | | For using area property to find s(20) |
| | | s(20) = ½(8 × 8) + ½(8 + 2) × 12 (= 92) | A1 | | |
| | | | M1 | | For using the gradient property to find acceleration in 3rd phase |
| | | a = (6.5 – 2)/6 (= 0.75) | A1 | | |
| | | [s(t) = 92 + 2(t – 20) + 0.375(t – 20)$^2$ | M1 | | |
| | | Displacement is $0.375t^2 - 13t + 202$ metres | A1 | [6] | |

| | | | | |
|---|---|---|---|---|
| **Alternative Marking Scheme for final 2 marks of Q6** | | | | |
| | [v(t) = 2 + 0.75(t – 20)<br>s(t) = $0.375t^2 - 13t$ + A where<br>92 = 0.375 × 400 – 13 × 20 + A] | M1 | | For finding v(t), integrating and using s(20) = 92 |
| | Displacement is $0.375t^2 - 13t + 202$ metres | A1 | | |
| **6 (iii)** | **First Alternative Marking Scheme for part (iii) of Q6** | | | |
| | a = (6.5 – 2) / (26 – 20) = 0.75 | B1 | | |
| | v = 0.75t (+ C1) | M1 | | Integrating |
| | v = 0.75t – 13 | A1 | | Using v(20) = 2 or v(26) = 6.5 |

# Kinematics of motion in a straight line 2 M

| | | | | |
|---|---|---|---|---|
| | $s(20) = 92$ or $s(26) = 117.5$ | B1 | | Using area in diagram |
| | $s = 0.375t^2 - 13t\ (+ C_2)$ | M1 | | Integrating |
| | $s = 0.375t^2 - 13t + 202$ | A1 | [6] | Using s(20) or s(26) to find $C_2 = 202$ |
| **6 (iii)** | **Second Alternative Marking Scheme for part (iii) of Q6** | | | |
| | s = 0.375t2 – 13t + 202 | | | Given |
| | $v = 0.75t - 13$ | M1 | | Differentiating |
| | $a = 0.75$ | M1 | | Differentiating |
| | $a = (6.5-2)/(26-20) = 0.75$ | B1 | | Check agreement from graph |
| | $v(20) = 0.75(20) - 13 = 2$ or<br>$v(26) = 0.75(26) - 13 = 6.5$ | B1 | | Check v agrees at a point between t = 20 and t = 26 |
| | Show $s(20) = 92$ or $s(26) = 117.5$ | B1 | | Using area under graph |
| | $s(20) = 0.375(20)^2 - 13(20) + 202 = 92$ or<br>$s(26) = 0.375(26)^2 - 13(26) + 202 = 117.5$ | B1 | | Check s agrees at a point between t = 20 and t = 26 |

Q7.

| | | | | |
|---|---|---|---|---|
| **5 (i)** | [T = 2 x 1.7 – 2 x 0.7]<br>[for P $17\,t - 5\,t^2 = 0$<br>and<br>for Q $7\,t = 5\,t^2 = 0$] | M1 | | T = 2 x time to max. height for P – 2 x time to max. height for Q or For using T = time for P to return to ground – time for Q to return to ground |
| | T = 2 | A1 | [2] | SR (max 1/2) for candidates who find difference in time to maximum height<br>T = 1.7 – 0.7 = 1 B1 |
| **(ii)** | | M1 | | For using $h_P - h_Q = 5$ and $s = u\,t - 5\,t^2$ for both P and Q |
| | $17(t + 2) - 5(t + 2)^2 - (7t - 5t^2) = 5$ or<br>$17t - 5t^2 - 7(t - 2) + 5(t - 2)^2 = 5$ | | | |
| | | A1 | ft | ft T from part (i) |
| | t = 0.9 or t = 2.9 | A1 | | |
| | | M1 | | For using v = u – 10 t for P and Q |

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|---|---|---|---|---|
| | $v_P = 17 - 10\,(0.9 + 2)$,<br>$v_Q = 7 - 10 \times 0.9$ ➔<br>Magnitudes are 12 m $s^{-1}$ & 2 m $s^{-1}$ | A1 | ft | ft using $t_P$ and $t_P - T$ or using $t_Q$ and $t_Q + T$ |
| | The direction for both is vertically downwards | A1 | [6] | |

Q8.

| | | | | | |
|---|---|---|---|---|---|
| **7** | **(i)** | [s = ½ 5 × 0.4 + 19 × 0.4 + ½ 4 × 0.4] | M1 | | For using the area property for distance |
| | | Distance = 9.4 | A1 | 2 | |
| | **(ii)** | Acceleration is 0.08 $ms^{-2}$ | B1 | | |
| | | Deceleration is 0.1$ms^{-2}$ | B1 | 2 | |
| | **(iii)** | [T – (800 + 100) g = (800 +100)a] | M1 | | For applying Newton's $2^{nd}$ law to the <u>elevator and box</u> |
| | | T – 900g = 900a | A1 | | |
| | | T = 9072 N in $1^{st}$ stage<br>T = 9000 N in $2^{nd}$ stage<br>T = 8910 N in $3^{rd}$ stage | A1 | 3 | |
| | **(iv)** | [R – 100g = 100a] | M1 | | For applying Newton's $2^{nd}$ law to the <u>box</u> |
| | | R = 1008 N | A1 | | For obtaining the greatest value of the force on the box |
| | | R = 990 N | A1 | 3 | For obtaining the least value of the force on the box |

Q9.

| | | | | |
|---|---|---|---|---|
| **5** **(i)** | | B1 | | The sketch requires three straight line segments with +ve, zero and –ve slopes in order, which together with a segment of the t axis form a trapezium. |
| | | M1 | | For using v = at for $T_1$ or u = –at for $T_3$ |
| | $T_1 = V \div 0.3$, $T_3 = V$ | A1 | 3 | |

| | | | | |
|---|---|---|---|---|
| **(ii)** | $[S = \frac{1}{2} T_1V + T_2V + \frac{1}{2} T_3V]$ | M1 | | For using the area property for the distance travelled |
| | | M1 | | For substituting for $T_1$, $T_2$ and $T_3$ in terms of V |
| | $S = 552V - V\{0.5(T_1 + T_3)\}$<br>$= 552V - 13V^2/6$ | A1 | | |
| | $13V^2 - 3312V + 72000 = 0$ | B1 | | AG |
| | $V = 24$ | B1 | 5 | |