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EDEXCEL A LEVEL MATHEMATICS: QUESTIONS BY TOPIC

Kinematics (17)

A Level Mathematics Topic 17

25 questions · 217 marks · Mark schemes included

Pearson Edexcel A Level Mathematics (9MA0), June 2018 - June 2025

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 info@guidemygrades.com

 Piccadilly Business Centre, Unit C, Aldow Enterprise Park
Blackett Street, Manchester, M12 6AE

HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic and run from the lowest mark tariff to the highest within each one.

Click any row below to jump straight to that sub-topic or question.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

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QUESTIONS

25 questions · 217 marks · 4 sub-topics



SUB-TOPIC 17.2

DISPLACEMENT-TIME AND VELOCITY-TIME GRAPHS

Sub-topic 17.2 · 2 questions · 12 marks · lowest tariff first



2.

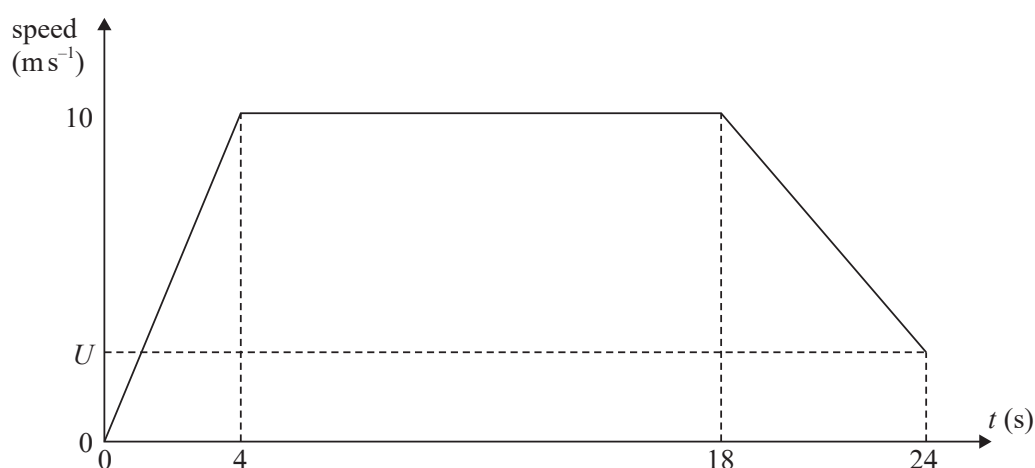


Figure 2

Figure 2 shows a speed-time graph for a model of the motion of an athlete running a **200 m** race in 24 s.

The athlete

- starts from rest at time $t = 0$ and accelerates at a constant rate, reaching a speed of 10 m s^{-1} at $t = 4$
- then moves at a constant speed of 10 m s^{-1} from $t = 4$ to $t = 18$
- then decelerates at a constant rate from $t = 18$ to $t = 24$, crossing the finishing line with speed $U \text{ m s}^{-1}$

Using the model,

- (a) find the acceleration of the athlete during the first 4 s of the race, stating the units of your answer,

(2)

- (b) find the distance covered by the athlete during the first 18 s of the race,

(3)

- (c) find the value of U .

(3)

Question 2 continued



Question 2 continued



Question 2 continued

(Total for Question 2 is 8 marks)



Question 1 continued

(Total for Question 1 is 4 marks)



SUB-TOPIC 17.3

CONSTANT ACCELERATION (SUVAT)

Sub-topic 17.3 · 11 questions · 86 marks · lowest tariff first



(Total for Question 1 is 3 marks)



Question 1 continued

(Total for Question 1 is 4 marks)



2. A particle, P , moves with constant acceleration $(2\mathbf{i} - 3\mathbf{j})\text{ m s}^{-2}$

At time $t = 0$, the particle is at the point A and is moving with velocity $(-\mathbf{i} + 4\mathbf{j})\text{ m s}^{-1}$

At time $t = T$ seconds, P is moving in the direction of vector $(3\mathbf{i} - 4\mathbf{j})$

- (a) Find the value of T .

(4)

At time $t = 4$ seconds, P is at the point B .

- (b) Find the distance AB .

(4)





Question 2 continued

(Total for Question 2 is 8 marks)



Question 7 continued



Question 7 continued



Question 7 continued

(Total for Question 7 is 8 marks)



Question 8 continued



Question 8 continued

Question 8 continued

(Total for Question 8 is 8 marks)



Question 2 continued



Question 2 continued

Lined area for writing the answer to Question 2 continued.

Question 2 continued

(Total for Question 2 is 10 marks)



Question 4 continued



Question 4 continued

(Total for Question 4 is 10 marks)



2.

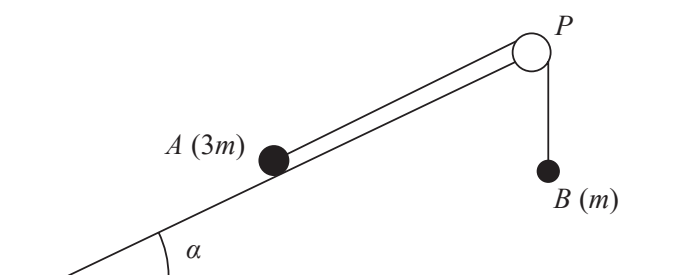


Figure 1

A small stone A of mass $3m$ is attached to one end of a string.

A small stone B of mass m is attached to the other end of the string.

Initially A is held at rest on a fixed rough plane.

The plane is inclined to the horizontal at an angle α , where $\tan \alpha = \frac{3}{4}$

The string passes over a pulley P that is fixed at the top of the plane.

The part of the string from A to P is parallel to a line of greatest slope of the plane.

Stone B hangs freely below P , as shown in Figure 1.

The coefficient of friction between A and the plane is $\frac{1}{6}$

Stone A is released from rest and begins to move down the plane.

The stones are modelled as particles.

The pulley is modelled as being small and smooth.

The string is modelled as being light and inextensible.

Using the model for the motion of the system before B reaches the pulley,

(a) write down an equation of motion for A (2)

(b) show that the acceleration of A is $\frac{1}{10}g$ (7)

(c) sketch a velocity-time graph for the motion of B , from the instant when A is released from rest to the instant just before B reaches the pulley, explaining your answer. (2)

In reality, the string is not light.

(d) State how this would affect the working in part (b). (1)

Question 2 continued

Lined area for writing the answer to Question 2 continued.

Question 2 continued



Question 2 continued

(Total for Question 2 is 12 marks)





Question 3 continued



Question 3 continued

(Total for Question 3 is 8 marks)



SUB-TOPIC 17.4

CALCULUS IN KINEMATICS

Sub-topic 17.4 · 7 questions · 64 marks · lowest tariff first



1. [In this question position vectors are given relative to a fixed origin O]

At time t seconds, where $t \geq 0$, a particle, P , moves so that its velocity $\mathbf{v} \text{ m s}^{-1}$ is given by

$$\mathbf{v} = 6t\mathbf{i} - 5t^{\frac{3}{2}}\mathbf{j}$$

When $t = 0$, the position vector of P is $(-20\mathbf{i} + 20\mathbf{j})\text{m}$.

- (a) Find the acceleration of P when $t = 4$

(3)

- (b) Find the position vector of P when $t = 4$

(3)

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This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

(Total for Question 1 is 6 marks)



6. At time t seconds, where $t \geq 0$, a particle P moves in the x - y plane in such a way that its velocity $\mathbf{v} \text{ m s}^{-1}$ is given by

$$\mathbf{v} = t^{-\frac{1}{2}}\mathbf{i} - 4t\mathbf{j}$$

When $t = 1$, P is at the point A and when $t = 4$, P is at the point B .

Find the exact distance AB .

(6)

(Total for Question 6 is 6 marks)









(continued)















SUB-TOPIC 17.5

PROJECTILES

Sub-topic 17.5 · 5 questions · 55 marks · lowest tariff first



4.

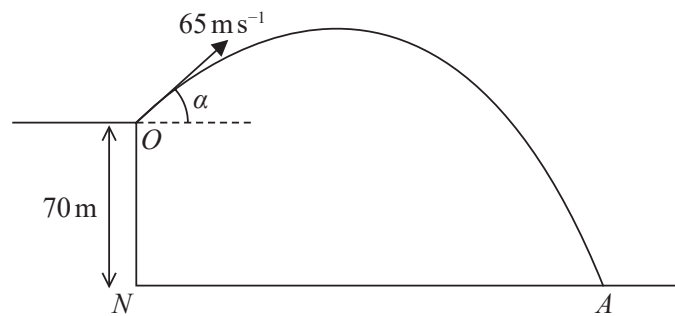


Figure 3

A small stone is projected with speed 65 m s^{-1} from a point O at the top of a vertical cliff.

Point O is 70 m vertically above the point N .

Point N is on horizontal ground.

The stone is projected at an angle α above the horizontal, where $\tan \alpha = \frac{5}{12}$.

The stone hits the ground at the point A , as shown in Figure 3.

The stone is modelled as a particle moving freely under gravity.

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

Using the model,

(a) find the time taken for the stone to travel from O to A ,

(4)

(b) find the speed of the stone at the instant just before it hits the ground at A .

(5)

One limitation of the model is that it ignores air resistance.

(c) State one other limitation of the model that could affect the reliability of your answers.

(1)





Question 4 continued

(Total for Question 4 is 10 marks)









(Room for Question 3 is 12 marks)



5.

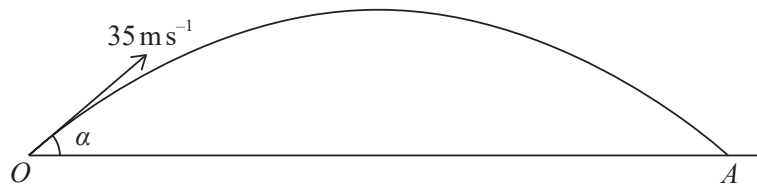


Figure 4

At time $t = 0$, a small stone is projected with velocity 35 m s^{-1} from a point O on horizontal ground.

The stone is projected at an angle α to the horizontal, where $\tan \alpha = \frac{3}{4}$

In an initial model

- the stone is modelled as a particle P moving freely under gravity
- the stone hits the ground at the point A

Figure 4 shows the path of P from O to A .

For the motion of P from O to A

- at time t seconds, the horizontal distance of P from O is x metres
- at time t seconds, the vertical distance of P above the ground is y metres

(a) Using the model, show that

$$y = \frac{3}{4}x - \frac{1}{160}x^2 \quad (6)$$

(b) Use the answer to (a), or otherwise, to find the length OA .

(2)

Using the model, the greatest height of the stone above the ground is found to be H metres.

(c) Use the answer to (a), or otherwise, to find the value of H .

(2)

- The model is refined to include air resistance.

Using this new model, the greatest height of the stone above the ground is found to be K metres.

(d) State which is greater, H or K , justifying your answer.

(1)

(e) State one limitation of this refined model.

(1)





(Total for Question 3 is 12 marks)



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Question 5 continued

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

Question 5 continued

(Total for Question 5 is 13 marks)









MARK SCHEMES

official mark schemes



Question	Scheme	Marks	AOs
2(a)	$\frac{10}{4}$	M1	3.4
	$2.5, \frac{5}{2}, \frac{10}{4} \text{ m s}^{-2}$ units needed.	A1	1.1b
		(2)	
2(b)	Find the area, with correct structure, from $t = 0$ to 18	M1	3.1b
	$\frac{1}{2} \times 4 \times 10 + (14 \times 10)$ triangle + rectangle or $\frac{1}{2} \times 10 \times (14 + 18)$ trapezium or $(18 \times 10) - \frac{1}{2} \times 4 \times 10$ rectangle – triangle N.B. $\frac{1}{2} \times 4 \times 10$ may be replaced by $\frac{1}{2} \times 2.5 \times 4^2$ using $s = ut + \frac{1}{2}at^2$ or by $\frac{10^2 - 0^2}{2 \times 2.5}$ using $v^2 = u^2 + 2as$	A1	1.1b
	160 (m)	A1	1.1b
		(3)	
2(c)	Using area, from $t = 18$ to $t = 24$, = $(200 - \text{their (b)})$ with correct structure OR $s = (200 - \text{their (b)})$, using <i>suvat</i> to find s N.B. If their (b) is incorrect and they don't use it, allow a correct restart.	M1	3.1b
	$6U + \frac{1}{2} \times 6 \times (10 - U) = 200 - \text{their (b)}$ rectangle + triangle or $\frac{1}{2} \times 6 \times (10 + U) = 200 - \text{their (b)}$ trapezium ($s = \left(\frac{u+v}{2}\right)t$) or $(6 \times 10) - \frac{1}{2} \times 6 \times (10 - U) = 200 - \text{their (b)}$ rectangle – triangle or $(10 \times 6) + \frac{1}{2} \left(-\frac{(10-U)}{6}\right) \times 6^2 = 200 - \text{their (b)}$ $s = ut + \frac{1}{2}at^2$ or $(U \times 6) - \frac{1}{2} \left(-\frac{(10-U)}{6}\right) \times 6^2 = 200 - \text{their (b)}$ $s = vt - \frac{1}{2}at^2$ N.B. Two stage <i>suvat</i> method: $(10 \times 6) + \frac{1}{2}a \times 6^2 = 200 - \text{their (b)} \Rightarrow$ AND $U = 10 + 6 \times \text{their } a$	A1ft	1.1b

		$\frac{10}{3} = 3\frac{1}{3}$ oe	A1	1.1b
			(3)	
(8 marks)				
Notes:				
2a	M1	Any complete <i>suvat</i> method to find <i>a</i> e.g. use $s = 20$ and $20 = \frac{1}{2}a \times 4^2$ N.B. Ignore units at this stage		
	A1	Any equivalent number with correct units. Accept m/s^2 , m/s/s , m per s per s .		
2b	M1	Complete method, they may use <i>suvat</i> on one or more sections, to find the TOTAL area. M0 if a single <i>suvat</i> equation is used for the whole motion M0 if $\frac{1}{2}$ not seen used in an area method		
	A1	Correct unsimplified expression.		
	A1	cao. Ignore units. N.B. Correct answer, with no working , can score all 3 marks.		
2c	M1	Complete method, using area or <i>suvat</i> , to give an equation in <i>U</i> only, with correct structure M0 if $\frac{1}{2}$ not seen used in an area method M0 if 10 is used instead of $(10 - U)$ or $(10 - U)$ is used instead of $(10 + U)$ in any equation		
	A1ft	Correct unsimplified equation in <i>U</i> only (allow <i>V</i> or <i>v</i> instead of <i>U</i>), ft on their 160 .		
	A1	Accept 3.3 or better. Ignore units. Allow use of <i>V</i> throughout instead of <i>U</i> , <u>including in the answer</u> . N.B. Correct answer, with no working , can score all 3 marks.		

Question	Scheme		Marks	AOs
1(a)	$v = 15 + (2 \times 4)$		M1	3.1b
	$= 23 \text{ (m s}^{-1}\text{)}$		A1	1.1b
			(2)	
1(b)	$D - 400 = 800 \times 2$		M1	3.1b
	$(D =) 2000$		A1	1.1b
			(2)	
(4 marks)				
Notes:				
1(a)	M1	Use of $v = u + at$ or any other complete method to form an equation in v only. Condone sign errors. e.g. May find s first: $s = (15 \times 4) + \frac{1}{2} \times 2 \times 4^2 = 76$ then either: $76 = 4v - \frac{1}{2} \times 2 \times 4^2$ or: $76 = \frac{(15+v)}{2} \times 4$ or: $v^2 = 15^2 + 2 \times 2 \times 76$ N.B. If they use $v = u + at$ and have $15 = u + (2 \times 4)$, M1A0 M0 if they clearly use an incorrect <i>suvat</i> formula or $u = 0$		
	A1	cao. Must be positive. A0 if they get 23 but go on and do something with it. i.e. not ISW N.B. 23 with no working can score both marks.		
1(b)	M1	Use of $F = ma$ to form an equation in D or a complete expression for D , with correct number of terms, condone sign errors and g in the ma term.		
	A1	cao N.B. 2000 with no working can score both marks.		

Question		Scheme	Marks	AOs
1(a)		16 (m s ⁻¹) seen as the answer	B1	1.1b
			(1)	
1(b)		$s = \frac{1}{2} \times 3.2 \times 5^2$ OR $s = \frac{(0+16)}{2} \times 5$ OR $s = (16 \times 5) - \frac{1}{2} \times 3.2 \times 5^2$ OR $16^2 = 2 \times 3.2 \times s$ OR from a v-t graph, $s = \frac{1}{2} \times 5 \times 16$	M1	3.1b
		s = 40 (m)	A1	1.1b
			(2)	
(3 marks)				
Notes:				
1a	B1	cao. Must be positive. Ignore any working.		
1b	M1	Complete method to find an equation in s only, possibly using their '16' Allow 'reversed motion': use of $s = vt - \frac{1}{2}at^2$ with $v = 0$ i.e. $s = -\frac{1}{2} \times 3.2 \times 5^2$ can score M1 and $s = -40$ so distance is 40 (m) can score the A1		
	A1	cao. Must be positive.		
		N.B. correct answer only, in (b), can score both marks.		

Question	Scheme		Marks	AOs
1(a)	Use of $\mathbf{v} = \mathbf{u} + \mathbf{at}$ with $t = 2$: $\mathbf{v} = 4\mathbf{i} + 2(2\mathbf{i} - 3\mathbf{j})$ OR integration: $\mathbf{v} = (2\mathbf{i} - 3\mathbf{j})t + 4\mathbf{i}$, with $t = 2$		M1	3.1a
	$\mathbf{v} = 8\mathbf{i} - 6\mathbf{j}$		A1	1.1b
			(2)	
1(b)	Use of $\mathbf{r} = \mathbf{ut} + \frac{1}{2}\mathbf{at}^2$ at $t = 3$: $(\mathbf{i} + \mathbf{j}) + \left[3 \times 4\mathbf{i} + \frac{1}{2} \times (2\mathbf{i} - 3\mathbf{j}) \times 3^2 \right]$ OR: find $\mathbf{v}$ at $t = 3$: $4\mathbf{i} + 3(2\mathbf{i} - 3\mathbf{j}) = (10\mathbf{i} - 9\mathbf{j})$ then use $\mathbf{r} = \frac{1}{2}(\mathbf{u} + \mathbf{v})t$ $(\mathbf{i} + \mathbf{j}) + \left[\frac{1}{2} [4\mathbf{i} + (10\mathbf{i} - 9\mathbf{j})] \times 3 \right]$ or $\mathbf{r} = \mathbf{vt} - \frac{1}{2}\mathbf{at}^2$ $(\mathbf{i} + \mathbf{j}) + \left[3 \times (10\mathbf{i} - 9\mathbf{j}) - \frac{1}{2} \times (2\mathbf{i} - 3\mathbf{j}) \times 3^2 \right]$ OR integration: $\mathbf{r} = (\mathbf{i} + \mathbf{j}) + \left[(2\mathbf{i} - 3\mathbf{j})\frac{1}{2}t^2 + 4t\mathbf{i} \right]$, with $t = 3$		M1	3.1a
	$\mathbf{r} = 22\mathbf{i} - 12.5\mathbf{j}$		A1	2.2a
			(2)	
(4 marks)				
Notes: Accept column vectors throughout				
1a	M1	Complete method to find $\mathbf{v}$, using ruvat or integration (M0 if $\mathbf{i}$ and/or $\mathbf{j}$ is missing)		
	A1	Apply isw if they also find the speed		
1b	M1	Complete method to find the p.v. but this mark can be scored if they omit $(\mathbf{i} + \mathbf{j})$ i.e. the M1 is for the expression in the square bracket If they integrate, the M1 is earned once the expression in the square bracket is seen with $t = 3$ (M0 if $\mathbf{i}$ and/or $\mathbf{j}$ is missing)		
	A1	cao		

Question	Scheme	Marks	AOs
	Mark parts (a) and (b) together		



Question		Scheme	Marks	AOs
3(a)		$(R=)mg \cos \alpha$	M1	3.4
		$= \frac{12}{13} mg$	A1	1.1b
			(2)	
3(b)		Equation of motion down the plane	M1	2.1
		$mg \sin \alpha - F = ma$ or $mg \sin \alpha - F = -ma$	A1	1.1b
		$(F =) \mu \times \text{their } R$	M1	3.4
		$\frac{1}{13} g(5-12\mu)$ *	A1*	2.2a
			(4)	
3(c)		P wouldn't move	B1	2.4
			(1)	
(7 marks)				
Notes:				
3a	M1	Correct no. of terms, condone sin/cos confusion and sign errors, dimensionally correct. Allow use of a different symbol for the angle.		
	A1	Accept $0.92mg$ or better. Must be positive.		
3b	M1	Correct no. of terms, condone sin/cos confusion and sign errors (M0 if they use g for a) N.B. Must be using mg or m not W for the weight.		
	A1	Any correct equation e.g. $mg \sin \alpha = ma + F$ N.B. F does not need to be substituted.		
	M1	$\mu \times \text{their } R$ seen (possibly on a diagram), any trig does not need to be replaced. M0 if they use $\mu = \frac{5}{12}$ M0 for just μR with R not replaced.		
	A1*	Given answer correctly obtained, with at least one further line of working with both trig ratios substituted as fractions. Allow $\frac{g}{13}(5-12\mu)$ or $\frac{g(5-12\mu)}{13}$		
3c	B1	e.g. P (or the particle or the object) would stay at rest, P would not slide down, would not roll down the plane, static equilibrium, equilibrium at rest Allow 'it' for P or just 'stays at rest oe' B0 for wouldn't accelerate, would be in equilibrium (only), would stop N.B. Ignore reasons but not contradictions.		

Question		Scheme	Marks	AO
2(a)		$(\mathbf{v} =) \mathbf{C} + (2\mathbf{i} - 3\mathbf{j})t$	M1	3.1a
		$(\mathbf{v} =) (-\mathbf{i} + 4\mathbf{j}) + (2\mathbf{i} - 3\mathbf{j})t$	A1	1.1b
		$\frac{4-3T}{-1+2T} = \frac{-4}{3}$ oe	M1	3.1a
		$T = 8$	A1	1.1b
			(4)	
(b)		$(\mathbf{s} =) \mathbf{C}t + (2\mathbf{i} - 3\mathbf{j})\frac{1}{2}t^2$ (+ D)	M1	3.1a
		$(\mathbf{s} =) (-\mathbf{i} + 4\mathbf{j})t + \frac{1}{2}(2\mathbf{i} - 3\mathbf{j})t^2$ (+ D)	A1	1.1b
		$AB = \sqrt{12^2 + 8^2}$ N.B. Beware you may see $4(2\mathbf{i} - 3\mathbf{j})$ which leads to $\sqrt{(8^2 + 12^2)}$ this is M0A0M0A0.	M1	3.1a
		$= 4\sqrt{13} (= 14.422051....)$ (m)	A1cso	1.1b
			(4)	
			(8)	
Marks		Notes		
2a	M1	Use of $\mathbf{v} = \mathbf{u} + \mathbf{at}$ OR integration to give an expression of the form $\mathbf{C} + (2\mathbf{i} - 3\mathbf{j})t$, where C is a non-zero constant vector M0 if $\mathbf{u}$ and $\mathbf{a}$ are reversed Condone use of $\mathbf{a} = (2\mathbf{i} + 3\mathbf{j})$ for this M mark		
	A1	Any correct unsimplified expression seen or implied		
	M1	Correct use of ratios, <u>using a velocity vector</u> (must be using $\frac{-4}{3}$) to give equation <u>in T only</u> M0 if they equate $4 - 3T = -4$ and/or $-1 + 2T = 3$ and therefore M0 if they then divide to produce their equation		
	A1	Correct only		
		N.B. (i) Can score the second M1A1 if they get $T = 8$, using a calculator to solve two simultaneous equations, but if answer is wrong, and no equation in T only, second M0 (ii) Can score M1A1 M1A1 if they get $T = 8$, using trial and error, but if they don't get $T = 8$, can only score max M1A1M0A0		

2b	M1	Use of $\mathbf{s} = \mathbf{ut} + \frac{1}{2}\mathbf{at}^2$ with $\mathbf{a} = (2\mathbf{i} - 3\mathbf{j})$ OR integration to give an expression of the form $\mathbf{Ct} + (2\mathbf{i} - 3\mathbf{j})\frac{1}{2}t^2$, where C is their non-zero constant <u>vector</u> from (a) Condone use of $\mathbf{a} = (2\mathbf{i} + 3\mathbf{j})$ for this M mark OR any other complete method using vector suvat equations
	A1	Correct unsimplified expression seen or implied
	M1	Use of $t = 4$ in their $\mathbf{s}$ (which must be a displacement vector) and then Pythagoras with the root sign N.B. This M mark can be implied by a correct answer, otherwise we need to see Pythagoras used, with the root sign, for the M mark.
	A1cso	Any surd form or 14 or better



Question	Scheme		Marks	AOs
2(a)	Use of $\mathbf{v} = \mathbf{u} + \mathbf{a}t$ or integrate to give: $\mathbf{v} = (-2\mathbf{i} + 2\mathbf{j}) + 2(4\mathbf{i} - 5\mathbf{j})$		M1	3.1a
	$(6\mathbf{i} - 8\mathbf{j}) \text{ (m s}^{-1}\text{)}$		A1	1.1b
			(2)	
2(b)	Solve problem through use of $\mathbf{r} = \mathbf{u}t + \frac{1}{2}\mathbf{a}t^2$ or integration (M0 if $\mathbf{u} = \mathbf{0}$) Or any other complete method e.g use $\mathbf{v} = \mathbf{u} + \mathbf{a}T$ and $\mathbf{r} = \frac{(\mathbf{u} + \mathbf{v})T}{2}$:		M1	3.1a
	$-4.5\mathbf{j} = 2t\mathbf{j} - \frac{1}{2}t^2 5\mathbf{j}$ ($\mathbf{j}$ terms only)		A1	1.1b
	The first two marks could be implied if they go straight to an algebraic equation.			
	Attempt to equate $\mathbf{j}$ components to give equation in T only $(-4.5 = 2T - \frac{5}{2}T^2)$		M1	2.1
	$T = 1.8$		A1	1.1b
			(4)	
2(c)	Solve problem by substituting <u>their</u> T value (M0 if $T < 0$) into the $\mathbf{i}$ component equation to give an equation in λ only: $\lambda = -2T + \frac{1}{2}T^2 \times 4$		M1	3.1a
	$\lambda = 2.9$ or 2.88 or $\frac{72}{25}$ oe		A1	1.1b
			(2)	
Notes: Accept column vectors throughout (8 marks)				
2a	M1	For any complete method to give a $\mathbf{v}$ expression with correct no. of terms with $t = 2$ used, so if integrating, must see the initial velocity as the constant. Allow sign errors.		
	A1	Cao isw if they go on to find the speed.		
2b	M1	For any complete method to give a vector expression for $\mathbf{j}$ component of displacement in t (or T) only, using $\mathbf{a} = (4\mathbf{i} - 5\mathbf{j})$, so if integrating, RHS of equation must have the correct structure. Allow sign errors.		
	A1	Correct $\mathbf{j}$ vector equation in t or T . Ignore $\mathbf{i}$ terms.		
	M1	Must have earned 1 st M mark.		

		Equate j components to give equation in T (allow t) only (no j 's) which has come from a displacement. Equation must be a 3 term quadratic in T .
	A1	cao
2c	M1	Must have earned 1 st M mark in (b) Complete method - must have an equation in λ only (no i 's) which has come from an appropriate displacement.. (e.g M0 if a = 0 has been used) Expression for λ must be a quadratic in T
	A1	cao

Question	Scheme	Marks	AOs
3(i)(a)	Integrate a wrt t to obtain velocity	M1	3.4
	$\mathbf{v} = (t - 2t^2)\mathbf{i} + \left(3t - \frac{1}{3}t^3\right)\mathbf{j} (+C)$	A1	1.1b
	$8\mathbf{i} - \frac{28}{3}\mathbf{j} \text{ (m s}^{-1}\text{)}$	A1	1.1b
		(3)	
3(i)(b)	Equate i component of v to zero	M1	3.1a
	$t - 2t^2 + 36 = 0$	A1ft	1.1b
	$t = 4.5$ (ignore an incorrect second solution)	A1	1.1b
		(3)	

Question	Scheme	Marks	AOs
7(a)	Resolve vertically	M1	3.1b
	$R + 40\sin\alpha = 20g$	A1	1.1b
	Resolve horizontally	M1	3.1b
	$40\cos\alpha - F = 20a$	A1	1.1b
	$F = 0.14R$	B1	1.2
	$a = 0.396$ or $0.40 \text{ (m s}^{-2}\text{)}$	A1	2.2a
		(6)	
(b)	Pushing will increase R which will increase available F	B1	2.4
	Increasing F will <u>decrease</u> a * GIVEN ANSWER	B1*	2.4
		(2)	
(8 marks)			
Notes:			
(a) M1: Resolve vertically with usual rules applying A1: Correct equation. Neither g nor $\sin\alpha$ need to be substituted M1: Apply $F = ma$ horizontally, with usual rules A1: Neither F nor $\cos\alpha$ need to be substituted B1: $F = 0.14R$ seen (e.g. on a diagram) A1: Either answer			
(b) B1: Pushing increases R which produces an increase in available (limiting) friction B1: F increase produces an <u>a decrease</u> (need to see this) N.B. It is possible to score B0 B1 but for the B1, some “explanation” is needed to say why friction is increased e.g. by pushing into the ground.			

Question	Scheme	Marks	AOs
8(a)	Use of $\mathbf{r} = \mathbf{ut} + \frac{1}{2}\mathbf{at}^2$: $(7\mathbf{i} - 10\mathbf{j}) = 2(2\mathbf{i} - 3\mathbf{j}) + \frac{1}{2}\mathbf{a}2^2$	M1	3.1b
	$\mathbf{a} = (1.5\mathbf{i} - 2\mathbf{j})$	A1	1.1b
	$ \mathbf{a} = \sqrt{1.5^2 + (-2)^2}$	M1	1.1b
	$= 2.5 \text{ m s}^{-2}$ * GIVEN ANSWER	A1*	2.1
		(4)	
(b)	Use of $\mathbf{v} = \mathbf{u} + \mathbf{at} = (2\mathbf{i} - 3\mathbf{j}) + 2(1.5\mathbf{i} - 2\mathbf{j})$	M1	3.1b
	$= (5\mathbf{i} - 7\mathbf{j})$	A1	1.1b
	$\mathbf{v} = (5\mathbf{i} - 7\mathbf{j}) + t(4\mathbf{i} + 8.8\mathbf{j}) = (5 + 4t)\mathbf{i} + (8.8t - 7)\mathbf{j}$ and $(5 + 4t) = (8.8t - 7)$	M1	3.1b
	$t = 2.5 \text{ (s)}$	A1	1.1b
		(4)	
(8 marks)			
Notes: Allow column vectors throughout			
(a) No credit for individual component calculations M1: Using a complete method to obtain the acceleration. N.B. Equation, in a only, could be obtained by two integrations ALTERNATIVE M1: Use velocity at half-time ($t = 1$) = Average velocity over time period So at $t = 1$, $\mathbf{v} = \frac{1}{2}(7\mathbf{i} - 10\mathbf{j})$ so $\mathbf{a} = \frac{1}{2}(7\mathbf{i} - 10\mathbf{j}) - (2\mathbf{i} - 3\mathbf{j})$ N.B. could see $(7\mathbf{i} - 10\mathbf{j}) = (4\mathbf{i} - 6\mathbf{j}) + 2\mathbf{a}$ as first line of working A1: Correct a vector M1: Attempt to find magnitude of their a using form $\sqrt{a^2 + b^2}$ A1*: Correct GIVEN ANSWER obtained correctly			
(b) M1: Using a complete method to obtain the velocity at A e.g. by use of $\mathbf{v} = \mathbf{u} + \mathbf{at}$ with $t = 2$ and $\mathbf{u} = 2\mathbf{i} - 3\mathbf{j}$ and their a OR: by use of $\mathbf{s} = \mathbf{vt} - \frac{1}{2}\mathbf{at}^2$ OR: by integrating their a, with addition of $\mathbf{C} = 2\mathbf{i} - 3\mathbf{j}$, and putting $t = 2$ A1: correct vector M1: Complete method to find equation in t only			

e.g. by using $\mathbf{v} = \mathbf{u} + \mathbf{a}t$, with their $\mathbf{u}$ and equating $\mathbf{i}$ and $\mathbf{j}$ components

OR: by integrating $(4\mathbf{i} + 8.8\mathbf{j})$, with addition of a constant, and equating $\mathbf{i}$ and $\mathbf{j}$ components.

N.B. Must be equating $\mathbf{i}$ and $\mathbf{j}$ components of a velocity vector and must be their velocity at A, to give an equation in t only for this M mark

A1: 2.5 (s)



Question	Scheme	Marks	AOs
2(a)(i)	Resolve vertically	M1	3.1b
	F acting UP the plane: OR F acting DOWN the plane: $(\uparrow) F \sin \alpha + 68.6 \cos \alpha = 5g$ $-F \sin \alpha + 68.6 \cos \alpha = 5g$	A1	1.1b
	Other possible equations from which X would need to be eliminated to give an equation in F only to earn the M mark are shown below. The equation in F only must then be correct to earn the A mark. Possible equations: $(\nwarrow) 68.6 = X \sin \alpha + 5g \cos \alpha$ (leads to $X = 49$ with $g = 9.8$) F acting UP the plane: OR F acting DOWN the plane: $(\nearrow) F + X \cos \alpha = 5g \sin \alpha$ $-F + X \cos \alpha = 5g \sin \alpha$ $(\rightarrow) F \cos \alpha + X = 68.6 \sin \alpha$ $-F \cos \alpha + X = 68.6 \sin \alpha$		
	9.8 (N) (49/5 is A0) N.B. If sin and cos are interchanged in all equations, this leads to an answer of 9.8 in the wrong direction and can only score (a) (i) M1A0A0 (ii) A0	A1	1.1b
		(3)	
2(a)(ii)	Down the plane (Allow down or downwards or an arrow $\swarrow$, but must appear as the answer to (a) (ii) not just on the diagram.)	A1	2.2a
		(1)	
2(b)	N.B. If they use $R = 68.6$ in this part, the maximum they can score is M1A1M0A0M0A0 If they use $F = 9.8$ or their F from (a) in this part, the maximum they can score is M1A1M0A0M0A0		
	Equation of motion down the plane	M1	2.1
	$5g \sin \alpha - F = 5a$ Allow $(-a)$ instead of a	A1	1.1b
	Resolve perpendicular to the plane	M1	3.1b
	$R = 5g \cos \alpha$	A1	1.1b
	$F = 0.5R$ seen	M1	3.4
	$a = 1.96$ or 2.0 or $2 \text{ (m s}^{-2}\text{)}$ or $\frac{1}{5}g$	A1	1.1b
		(6)	
(10 marks)			

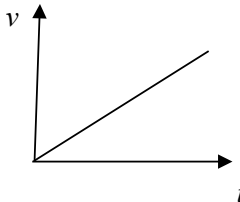
Notes:		
2a (i)	M1	Complete method to obtain an equation in F only . For each equation used, correct no. of terms, dimensionally correct, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved.
	A1	Correct equation in F only, trig does not need to be substituted
	A1	cao (must be positive)
2a (ii)	A1	cao. Note that this mark is dependent on an answer of 9.8 or -9.8 for (a)(i) <u>from a fully correct solution</u> unless they have used $g = 9.81$, in which case the answer will be 9.7 or -9.7 (2sf) see SC2 below. N.B. Allow this mark, if their answer to (a)(i) is fully correct apart from a small error due to use of inaccurate trig i.e using an angle 36.9°
		SC 1: If they use μR at any point (with an unknown μ) for F in part (a), can score (a)(i) max M1A1A0 (a) (ii) A1, where they must have obtained $\mu R = 9.8$ or -9.8 , from correct working . SC 2: If $g = 9.81$ is used consistently throughout 2(a) , (leading to $X = 48.9\dots$ and $F = 9.7$ (2sf)) can score max (a)(i) M1A1A0 (a)(ii) A1
2b	M1	Correct no.of terms, dimensionally correct, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved.
	A1	Correct equation for their F .
	M1	Correct no. of terms, dimensionally correct, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved. (N.B. M0 if $R = 68.6$ (N) is used in this equation)
	A1	Correct equation
	M1	Could be seen on a diagram (N.B. M0 if $R = 68.6$ (N) is used)
	A1	Cao. Must be positive.

Question	Scheme	Marks	AOs
4(a)	$\mathbf{v}_B = (-16\mathbf{i} - 3\mathbf{j}) + 5(2.4\mathbf{i} + \mathbf{j})$	M1	3.4
	$\mathbf{v}_B = (-4\mathbf{i} + 2\mathbf{j})$	A1	1.1b
	$\sqrt{(-4)^2 + 2^2}$	M1	3.1a
	$\sqrt{20} = 2\sqrt{5}, 4.5 \text{ or better (m s}^{-1}\text{)}$	A1	1.1b
		(4)	
4(b)	Using A as the initial position: $\mathbf{r}_C = \mathbf{v}_A t + \frac{1}{2} \mathbf{a} t^2 + \mathbf{r}_A \quad \text{where } t = T$ $(4\mathbf{i} + c\mathbf{j}) = (-16\mathbf{i} - 3\mathbf{j})T + \frac{1}{2}(2.4\mathbf{i} + \mathbf{j})T^2 + (44\mathbf{i} - 10\mathbf{j})$ OR $\begin{pmatrix} 4 \\ c \end{pmatrix} = \begin{pmatrix} -16 \\ -3 \end{pmatrix} T + \frac{1}{2} \begin{pmatrix} 2.4 \\ 1 \end{pmatrix} T^2 + \begin{pmatrix} 44 \\ -10 \end{pmatrix}$ Equating i-components, to give a quadratic equation in T only. Allow t instead of T. N.B. Allow omission of 44 for this M mark. Also allow ± 4 but M0 if 4 is not used at all i.e. $4 = -16T + \frac{1}{2} \times 2.4T^2$ scores M1A0A0	M1	3.1a
	$4 = -16T + \frac{1}{2} \times 2.4T^2 + 44$	A1	1.1b
	$(T =) 10$	A1	1.1b
	ALTERNATIVE using B as the initial position: (The position vector of B, $\mathbf{r}_B$, should be $-6\mathbf{i} - 12.5\mathbf{j}$ but no credit for finding this) $\mathbf{r}_C = \mathbf{v}_B t + \frac{1}{2} \mathbf{a} t^2 + \mathbf{r}_B \quad \text{using their } \mathbf{v}_B \text{ from (a) and their } \mathbf{r}_B$ $(4\mathbf{i} + c\mathbf{j}) = (-4\mathbf{i} + 2\mathbf{j})t + \frac{1}{2}(2.4\mathbf{i} + \mathbf{j})t^2 + (-6\mathbf{i} - 12.5\mathbf{j})$ $\begin{pmatrix} 4 \\ c \end{pmatrix} = \begin{pmatrix} -4 \\ 2 \end{pmatrix} t + \frac{1}{2} \begin{pmatrix} 2.4 \\ 1 \end{pmatrix} t^2 + \begin{pmatrix} -6 \\ -12.5 \end{pmatrix}$ Equating i-components, to give a quadratic equation in t only. Allow if they have T instead of t.	M1	3.1a

		N.B. Allow omission of their -6 or if they use 44 for this M mark. Also allow ± 4 but M0 if 4 is not used at all. e.g. $4 = -4t + \frac{1}{2} \times 2.4t^2$ scores M1A0A0		
		$4 = -4t + \frac{1}{2} \times 2.4t^2 - 6$	A1	1.1b
		$t = 5$ so ($T =$) 10	A1	1.1b
			(3)	
4(c)		Equating j-components, with <u>their value of T or t substituted</u> , to give an equation, which must have a square term, in c only. N.B. Allow $\pm c$ in their equation. (N.B. Allow omission of -10 or their -12.5 for this M mark i.e. if using A as initial position $c = (-3 \times 10) + \frac{1}{2} \times 1 \times 10^2$ scores M1M0A0 OR if using B as initial position $c = (2 \times 5) + \frac{1}{2} \times 1 \times 5^2$ scores M1M0A0)	M1	2.1
		if using A as initial position $c = (-3 \times 10) + \frac{1}{2} \times 1 \times 10^2 + (-10)$ N.B. Allow $\pm c$ and/or $\pm(-10)$ in their equation OR if using B as initial position $c = (2 \times 5) + \frac{1}{2} \times 1 \times 5^2 + (-12.5)$ N.B. Allow $\pm c$ and/or $\pm(-12.5)$ in their equation	M1	1.1b
		$c = 10$	A1	1.1b
			(3)	
(10 marks)				
Notes: Accept column vectors throughout				
4a	M1	Use of $\mathbf{v} = \mathbf{u} + \mathbf{at}$ with $t = 5$ to give an unsimplified $\mathbf{v}_B$		

		M0 if $u = 0$ N.B. If using integration, they must get to the same stage i.e. have found the constant and put $t = 5$ M0 if they omit the constant altogether
	A1	Correct $\mathbf{v}_B$ with $\mathbf{i}$'s and $\mathbf{j}$'s collected
	M1	Use of Pythagoras on <i>their</i> $\mathbf{v}_B$ to give a magnitude (need the root)
	A1	Must be positive
4b	M1	Equating components of $\mathbf{i}$ to give an equation in T or t only. N.B. (they could use integration to get to the same stage) for this M mark, they only need to be equating the $\mathbf{i}$ -components, and receive no credit until they do so. M0 if $u = 0$
	A1	A correct equation in T or t only (could be in $(T - 5)$ if using B as initial position)
	A1	$T = 10$
4c	M1	Equating components of $\mathbf{j}$ to give an equation in c only but allow omission of their initial position
	M1	With their value of T or t and must include $t = 0$ position (should be -10 if using A OR their -12.5 if using B)
	A1	cao

Question	Scheme	Marks	AOs
	N.B. In this question, allow misread of α for a .		

Question		Scheme	Marks	AOs
2(a)		Equation of motion for A	M1	3.3
		$3mg \sin \alpha - F - T = 3ma$	A1	1.1b
			(2)	
2(b)		Resolve perpendicular to the plane	M1	3.4
		$R = 3mg \cos \alpha$	A1	1.1b
		$F = \frac{1}{6}R$	B1	1.2
		Equation of motion for B OR for whole system	M1	3.3
		$T - mg = ma$ OR $3mg \sin \alpha - F - mg = 3ma + ma$	A1	1.1b
		Complete method to solve for a	DM1	3.1b
		$a = \frac{1}{10}g$ *	A1*	2.2a
			(7)	
2(c)			B1	1.1b
		e.g. acceleration (of B) is constant; dependent on first B1	DB1	2.4
			(2)	
2(d)		e.g. the tensions in the two equations of motion would be different. Tension on A would be different to tension on B	B1	3.5a
			(1)	
(12 marks)				
Notes: N.B. If m's are consistently missing treat as a MR, so max (a) M1A0 (b) M1A0B0M1A1M1A1 (c) B1B1 (d) B1 For (a) and (b), allow verification, but must see full equations of motion.				
2a	M1	Equation in T and a with correct no. of terms, condone sign errors and sin/cos confusion (If one of the 3's is missing, allow M1) N.B. Treat sin(3/5) etc as an A error but allow recovery		
	A1	Correct equation (allow $(-a)$ instead of a in <u>both</u> equations)		

2b	M1	Correct no. of terms, condone sign errors and sin/cos confusion Allow if appears in (a)
	A1	Correct equation
	B1	Seen anywhere in (a) or (b), including on a diagram
	M1	Equation (for B) in T and a with correct no. of terms, condone sign errors and sin/cos confusion OR Whole system equation with correct no. of terms, condone sign errors and sin/cos confusion
	A1	Correct equation
	DM1	Complete method (trig may not be substituted), dependent on M1 in (a) and second M1 in (b) if they use two equations, or second M1 in (b) if they use one equation.
	A1*	Correct answer correctly obtained.
2c	B1	Straight line starting at the origin (could be reflected in the t -axis). B0 if continuous vertical line at the end.
	DB1	Dependent on first B1, for any equivalent statement
2d	B1	B0 if incorrect extras

Question	Scheme	Marks	AOs
	Part (a) is a 'Show that..' so equations need to be given in full to earn A marks		

Question	Scheme		Marks	AOs
3(a)	$(\mathbf{F} =) (\mathbf{i} - 1.2\mathbf{j})$		B1	3.4
			(1)	
3(b)	$\mathbf{v} = (-7\mathbf{i} + 7.8\mathbf{j}) + 2(2\mathbf{i} - 2.4\mathbf{j})$		M1	2.1
	$= (-3\mathbf{i} + 3\mathbf{j}) \text{ (m s}^{-1}\text{)}$		A1	1.1b
			(2)	
3(c)	Use trig to find an equation in a relevant angle		M1	2.1
	e.g. $\tan \alpha = 1$ or -1 or $\sin \alpha = \frac{3}{\sqrt{3^2 + 3^2}}$ or $\frac{-3}{\sqrt{3^2 + 3^2}}$ or $\cos \alpha = \frac{3}{\sqrt{3^2 + 3^2}}$ or $\frac{-3}{\sqrt{3^2 + 3^2}}$		A1	1.1b
	315°		A1	2.2a
			(3)	
3(d)	$\overrightarrow{OA} = 5(-7\mathbf{i} + 7.8\mathbf{j}) + \frac{1}{2}(2\mathbf{i} - 2.4\mathbf{j}) \times 5^2$		M1	3.1a
	$= (-10\mathbf{i} + 9\mathbf{j}) \text{ (m)}$		A1	1.1b
			(2)	
(8 marks)				
Notes: Accept column vectors throughout apart from in the final answer for (a) and (d) which must be in terms of i and j, but only penalise ONCE for the whole question. N.B. For final answers to (a), (b) and (d) , penalise incorrect vector notation.				
3(a)	B1	Must be in terms of i and j Do not accept $0.5 \times (2\mathbf{i} - 2.4\mathbf{j})$ Do not need F =		
3(b)	M1	Use of $\mathbf{v} = \mathbf{u} + \mathbf{at}$ or any other complete method, e.g. integration, to find an unsimplified expression for v at $t = 2$, condone sign errors. N.B. If using integration, must have used $t = 0$, $\mathbf{v} = (-7\mathbf{i} + 7.8\mathbf{j})$ to find the constant of integration and included it in their expression for v at $t = 2$.		
	A1	cao. N.B. Ignore if they go on and find the speed.		
3(c)	M1	Use trig to find an equation in a relevant angle for their v		
	A1	Correct equation.		
	A1	Cao (with or without the degree sign), must come from a correct v N.B. $\pm 45^\circ, \pm 135^\circ, \pm 225^\circ, -315^\circ$ with no working scores M1A1 315° with no working scores all 3 marks.		



3(d)	M1	Use of $\mathbf{r} = \mathbf{ut} + \frac{1}{2}\mathbf{at}^2$ with $t = 5$ or any other complete method, e.g. integration of their $\mathbf{v} = f(t)$ and use of $t = 5$, to find an unsimplified expression for $\overline{OA}$ (No need to show that $\mathbf{C} = \mathbf{0}$) M0 if they use $\mathbf{u} = \mathbf{0}$
	A1	Must be in terms of $\mathbf{i}$ and $\mathbf{j}$ N.B. Ignore if they go on and find the length OA

Question		Scheme	Marks	AO
1(a)		Differentiate $\mathbf{v}$	M1	1.1a
		$(\mathbf{a} =) 6\mathbf{i} - \frac{15}{2}t^{\frac{1}{2}}\mathbf{j}$	A1	1.1b
		$= 6\mathbf{i} - 15\mathbf{j} \text{ (m s}^{-2}\text{)}$	A1	1.1b
			(3)	
1(b)		Integrate $\mathbf{v}$	M1	1.1a
		$(\mathbf{r} =)(\mathbf{r}_0) + 3t^2\mathbf{i} - 2t^{\frac{5}{2}}\mathbf{j}$	A1	1.1b
		$= (-20\mathbf{i} + 20\mathbf{j}) + (48\mathbf{i} - 64\mathbf{j}) = 28\mathbf{i} - 44\mathbf{j} \text{ (m)}$	A1	2.2a
			(3)	
			(6)	
Marks		Notes		
		N.B. Accept column vectors throughout and condone missing brackets in working but they must be there in final answers		
1a	M1	Use of $\mathbf{a} = \frac{d\mathbf{v}}{dt}$ with attempt to differentiate (both powers decreasing by 1) M0 if $\mathbf{i}$'s and $\mathbf{j}$'s omitted and they don't recover		
	A1	Correct differentiation in any form		
	A1	Correct and simplified. Ignore subsequent working (ISW) if they go on and find the magnitude.		
1b	M1	Use of $\mathbf{r} = \int \mathbf{v} dt$ with attempt to integrate (both powers increasing by 1) M0 if $\mathbf{i}$'s and $\mathbf{j}$'s omitted and they don't recover		
	A1	Correct integration in any form. Condone $\mathbf{r}_0$ not present		
	A1	Correct and simplified.		

Question	Scheme	Marks	AOs
6.	Integrate $\mathbf{v}$ w.r.t. time	M1	1.1a
	$\mathbf{r} = 2t^{\frac{1}{2}}\mathbf{i} - 2t^2\mathbf{j} (+ \mathbf{C})$	A1	1.1b
	Substitute $t = 4$ and $t = 1$ into their $\mathbf{r}$	M1	1.1b
	$t = 4, \mathbf{r} = 4\mathbf{i} - 32\mathbf{j} (+ \mathbf{C}); t = 1, \mathbf{r} = 2\mathbf{i} - 2\mathbf{j} (+ \mathbf{C})$ or $(4, -32); (2, -2)$	A1	1.1b
	$\sqrt{2^2 + (-30)^2}$	M1	1.1b
	$\sqrt{904} = 2\sqrt{226}$	A1	1.1b
		(6)	
(6 marks)			
Notes: Allow column vectors throughout			
M1: At least one power increasing by 1. A1: Any correct (unsimplified) expression M1: Must have attempted to integrate $\mathbf{v}$. Substitute $t = 4$ and $t = 1$ into their $\mathbf{r}$ to produce 2 vectors (or 2 points if just working with coordinates). A1: $4\mathbf{i} - 32\mathbf{j} (+ \mathbf{C})$ and $2\mathbf{i} - 2\mathbf{j} (+ \mathbf{C})$ or $(4, -32)$ and $(2, -2)$. These can be seen or implied. M1: Attempt at distance of form $\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$ for their points. Must have 2 non zero terms. A1: $\sqrt{904} = 2\sqrt{226}$ or any equivalent surd (exact answer needed)			

Question	Scheme		Marks	AOs
1(a)	Put $t = 2$ in $\mathbf{v}$ and use Pythagoras: $\sqrt{12^2 + (-6\sqrt{2})^2}$		M1	3.1a
	$\sqrt{216}, 6\sqrt{6}$ or 15 or better (m s ⁻¹)		A1	1.1b
			(2)	
1(b)	Differentiate $\mathbf{v}$ wrt t to obtain $\mathbf{a}$		M1	3.4
	$6\mathbf{i} - 3t^{-\frac{1}{2}}\mathbf{j}$ oe (m s ⁻²) isw		A1	1.1b
			(2)	
1(c)	Integrate $\mathbf{v}$ wrt t to obtain $\mathbf{r}$		M1	3.4
	$\mathbf{r} = t^3\mathbf{i} - 4t^{\frac{3}{2}}\mathbf{j} (+C)$		A1	1.1b
	$(\mathbf{i} - 4\mathbf{j}) = 4^3\mathbf{i} - 4 \times 4^{\frac{3}{2}}\mathbf{j} + C$		M1	3.1a
	$(-62\mathbf{i} + 24\mathbf{j})$ (m) isw e.g. if they go on to find the distance.		A1	1.1b
			(4)	
(8 marks)				
Notes: Accept column vectors throughout apart from the answer to (b).				
1a	M1	Need square root but -ve sign not required. Allow $\mathbf{i}$'s and/or $\mathbf{j}$'s to go missing from their $\mathbf{v}$ at $t = 2$, provided they have applied Pythagoras correctly.		
	A1	cao N.B. Correct answer with no working can score 2 marks.		
1b	M1	Both powers decreasing by 1. Allow a column vector. M0 if $\mathbf{i}$ or $\mathbf{j}$ is missing but allow recovery in (b).		
	A1	cao. Do not accept a column vector.		
1c	M1	Both powers increasing by 1 M0 if $\mathbf{i}$ or $\mathbf{j}$ is missing but allow recovery.		
	A1	$(\mathbf{r} =)$ not required		
	M1	Putting $\mathbf{r} = (\mathbf{i} - 4\mathbf{j})$ and $t = 4$ into their displacement vector expression which must have C (allow C) to give an equation in C only, seen or implied. Must have attempted to integrate $\mathbf{v}$ for this mark to be available. N.B. C does not need to be found and <u>this is a method mark, so allow slips.</u>		
	A1	cao		

Question	Scheme	Marks	AOs
3(a)	$7\mathbf{i} - 3\mathbf{j}$ seen or implied by Pythagoras	B1	1.1b
	Use Pythagoras: $\sqrt{7^2 + (-3)^2}$	M1	3.1a
	$\sqrt{58}$, 7.6 or better (m s ⁻¹)	A1	1.1b
		(3)	
3(b)	$t^2 - 3t + 7 = 2t^2 - 3$ OR $\frac{t^2 - 3t + 7}{2t^2 - 3} = \frac{1}{1} = 1$	M1	2.1
	$t = 2$ only	A1	1.1b
		(2)	
3(c)	Differentiate $\mathbf{v}$ wrt t to give a vector.	M1	3.1a
	$(2t - 3)\mathbf{i} + 4t\mathbf{j}$	A1	1.1b
		(2)	
3(d)	$2t - 3 = 0$	M1	3.1a
	$t = 1.5$	A1	1.1b
		(2)	
(9 marks)			
Notes: Allow column vectors throughout.			
3a	B1	cao	
	M1	Use of Pythagoras, including the square root, on a velocity vector at $t = 0$	
	A1	cao. Must come from a <u>correct</u> $\mathbf{v}$.	
3b	M1	Equating $\mathbf{i}$ and $\mathbf{j}$ components of $\mathbf{v}$ or a ratio of 1:1 to obtain a quadratic in t only. If they use a constant, e.g. $t^2 - 3t + 7 = k$ and $2t^2 - 3 = k$, k must be eliminated to earn this mark. N.B. M0 (since wrong working seen) if they write down $\mathbf{i} + \mathbf{j} = (t^2 - 3t + 7)\mathbf{i} + (2t^2 - 3)\mathbf{j}$ OR $\begin{pmatrix} 1 \\ 1 \end{pmatrix} = \begin{pmatrix} t^2 - 3t + 7 \\ 2t^2 - 3 \end{pmatrix}$ OR $t^2 - 3t + 7 = 1$ and $2t^2 - 3 = 1$	

		and then $t^2 - 3t + 7 = 2t^2 - 3$
	A1	$t = 2$
		N.B. Allow M1A1 for a correct trial and error method where they obtain $\mathbf{v} = 5\mathbf{i} + 5\mathbf{j}$ when $t = 2$ but M0 if they don't get $t = 2$
3c	M1	At least one power decreasing by 1 in each component in their $\mathbf{v}$ (M0 if clearly dividing by t) Both i and j needed in their answer or a column vector Allow recovery if the i and j disappear and then reappear.
	A1	cao (must be a vector) isw e.g. if they find the magnitude or put $t = 0$ or differentiate again i's and j's do not need to be collected. N.B. Allow M1A0 for $2t - 3\mathbf{i} + 4t\mathbf{j}$
3d	M1	$2t - 3 = 0$ or (their derivative of the i-component of $\mathbf{v}$) $= 0$ N.B. M0 if they equate the derivative of both components of $\mathbf{v}$ to zero.
	A1	cao N.B. Correct answer, with no working, can score both marks.

Question		Scheme	Marks	AOs
3(ii)		Differentiate $\mathbf{r}$ wrt to t to obtain velocity	M1	3.4
		$\mathbf{v} = (2t - 1)\mathbf{i} + 3\mathbf{j}$	A1	1.1b
		Use magnitude to give an equation in t only	M1	2.1
		$(2t - 1)^2 + 3^2 = 5^2$	A1	1.1b
		Solve problem by solving this equation for t	M1	3.1a
		$t = 2.5$	A1	1.1b
			(6)	
(12 marks)				
Notes: Accept column vectors throughout				
3(i)(a)	M1	At least 3 terms with powers increasing by 1 (but M0 if clearly just multiplying by t)		
	A1	Correct expression		
	A1	Accept $8\mathbf{i} - 9.3\mathbf{j}$ or better. Isw if speed found.		
3(i)(b)	M1	Must have an equation in t only (Must have integrated to find a velocity vector)		
	A1 ft	Correct equation follow through on their $\mathbf{v}$ but must be a 3 term quadratic		
	A1	cao		
3(ii)	M1	At least 2 terms with powers decreasing by 1 (but M0 if clearly just dividing by t)		
	A1	Correct expression		
	M1	Use magnitude to give an equation in t only, must have differentiated to find a velocity (M0 if they use $\sqrt{x^2 - y^2}$)		
	A1	Correct equation $\sqrt{(2t - 1)^2 + 3^2} = 5$		
	M1	Solve a 3 term quadratic for t which has come from differentiating and using a magnitude. This M mark can be implied by a correct answer with no working.		
	A1	2.5		

Question		Scheme	Marks	AOs
5(a)		Differentiate $\mathbf{v}$ wrt t	M1	3.1a
		$\frac{3}{2}t^{-\frac{1}{2}}\mathbf{i} - 2\mathbf{j}$ isw	A1	1.1b
			(2)	
5(b)		$3t^{\frac{1}{2}} = 2t$	M1	2.1
		Solve for t	DM1	1.1b
		$t = \frac{9}{4}$	A1	1.1b
			(3)	
5(c)		Integrate $\mathbf{v}$ wrt t	M1	3.1a
		$\mathbf{r} = 2t^{\frac{3}{2}}\mathbf{i} - t^2\mathbf{j} (+C)$	A1	1.1b
		$t = 1, \mathbf{r} = -\mathbf{j} \Rightarrow \mathbf{C} = -2\mathbf{i}$ so $\mathbf{r} = 2t^{\frac{3}{2}}\mathbf{i} - t^2\mathbf{j} - 2\mathbf{i}$	A1	2.2a
			(3)	
5(d)		$\sqrt{(3t^{\frac{1}{2}})^2 + (2t)^2} = 10$ or $(3t^{\frac{1}{2}})^2 + (2t)^2 = 10^2$	M1	2.1
		$9t + 4t^2 = 100$	M(A)1	1.1b
		$t = 4$	A1	1.1b
		$\mathbf{r} = 14\mathbf{i} - 16\mathbf{j}$	M1	1.1b
		$\sqrt{14^2 + (-16)^2}$	M1	3.1a
		$\sqrt{452} \ (2\sqrt{113}) \text{ (m)}$	A1	1.1b
			(6)	
(14 marks)				
Notes:				
5a	M1	Both powers decreasing by 1 (M0 if vector(s) disappear but allow recovery)		
	A1	cao		
5b	M1	Complete method, using $\mathbf{v}$, to obtain an equation in t only, allow a sign error		
	DM1	Dependent on M1, solve for t		

	A1	cao
5c	M1	Both powers increasing by 1 (M0 if vectors disappear but allow recovery)
	A1	Correct expression without C
	A1	cao
5d	M1	Use of Pythagoras on v and 10 to set up equation in t
	M(A)1	Correct 3 term quadratic in t
	A1	cao
	M1	Substitute their numerical t value into their r
	M1	Use of Pythagoras to find the magnitude of their r
	A1	cso

Question	Scheme		Marks	AOs
4(a)	$\mathbf{r} = (32\mathbf{i} - 16\mathbf{j})$		B1	1.1b
			(1)	
4(b)	Use Pythagoras: $\sqrt{32^2 + 16^2}$ oe for their $\mathbf{r}$		M1	3.1a
	$16\sqrt{5}$ (m)		A1	1.1b
			(2)	
4(c)	Differentiate $\mathbf{r}$ wrt t to obtain $\mathbf{v}$		M1	3.4
	$6t^{\frac{1}{2}}\mathbf{i} - 2t\mathbf{j}$ oe (m s ⁻¹)		A1	1.1b
			(2)	
4(d)	Differentiate their $\mathbf{v}$ wrt t to obtain $\mathbf{a}$		M1	3.4
	$3t^{-\frac{1}{2}}\mathbf{i} - 2\mathbf{j}$		A1	1.1b
	$\frac{3T^{-\frac{1}{2}}}{-2} = -\frac{1}{3}$ must see $\frac{\mathbf{i} \text{ component of their } \mathbf{a}}{\mathbf{j} \text{ component of their } \mathbf{a}} = -\frac{1}{3}$ oe		M1	2.1
	$(T =) \frac{81}{4}$ oe		A1	1.1b
			(4)	
(9 marks)				
Notes: N.B. Accept column vectors throughout apart from in the answer to (c).				
4(a)	B1	cao. N.B. Must be using correct vector notation, including brackets if using column vectors.		
4(b)	M1	For an unsimplified expression, using their $\mathbf{r}$, with the square root		
	A1	Accept any surd equivalent isw N.B. Must come from $\mathbf{r} = (32\mathbf{i} - 16\mathbf{j})$		
4(c)	M1	Both powers of t decreasing by 1 (but not just division by t) N.B. M0 if $\mathbf{i}$ and/or $\mathbf{j}$ are missing and never reappear.		
	A1	Must be in terms of t , $\mathbf{i}$ and $\mathbf{j}$		
4(d)	M1	Both powers of t decreasing by 1 (but not just division by t) If no $\mathbf{i}$'s and/or $\mathbf{j}$'s, can score M1 if EITHER they have 2 separate components, provided they are clearly treated as such in the subsequent working OR the $\mathbf{i}$'s and $\mathbf{j}$'s reappear otherwise M0.		
	A1	Correct vector or 2 correct separate components, provided they are clearly treated as such in the subsequent working		

	M1	Complete method to form a correct equation in $T(t)$ only, for their a , using the 2 components from their a
	A1	Accept 20.3 or 20.25 or any equivalent fraction (allow t instead of T)



Question	Scheme		Marks	AOs
4(a)	Use $s = ut + \frac{1}{2}at^2$ vertically or any complete method to give an equation in t only		M1	3.4
	$-70 = 65 \sin \alpha \times t - \frac{1}{2} \times g \times t^2$		A1	1.1b
			M (A)1	1.1b
	$t = 7$ (s)		A1	1.1b
			(4)	
4(b)	Horizontal velocity component at $A = 65 \cos \alpha$ (60)		B1	3.4
	Complete method to find vertical velocity component at A		M1	3.4
	$65 \sin \alpha - g \times 7$ OR $\sqrt{(-25)^2 + 2g \times 70}$ (45)		A1ft	1.1b
	Sub for trig and square, add and square root : $\sqrt{60^2 + (-45)^2}$		M1	3.1b
	75 Accept 80 (m s ⁻¹)		A1	1.1b
			(5)	
4(c)	e.g. an approximate value of g has been used, the dimensions of the stone could affect its motion, spin of the stone, $g = 10$ instead of 9.8 has been used, g has been assumed to be constant, wind effect, shape of the stone		B1	3.5b
			(1)	
(10 marks)				
Notes:				
4a	M1	Complete method, correct no. of terms, condone sign errors and sin/cos confusion		
	A1	Correct equation in t only with at most one error		
	M(A)1	Correct equation in t only		
		N.B. For ‘up and down’ methods etc, the two A marks are for all the equations that they use, lose a mark for each error.		
	A1	Cao ($g = 9.8$, 7.1 or 7.11) ($g = 9.81$, 7.1 or 7.12)		
4b	B1	Seen, including on a diagram.		
	M1	Condone sign errors and sin/cos confusion		
	A1ft	Correct expression; accept negative of this, follow their t		
	M1	Sub for trig and use Pythagoras		
	A1	Cao ($g = 9.8$ or 9.81 , 75 or 74.8)		
Question	Scheme		Marks	AOs
	Allow column vectors throughout this question			

Question	Scheme	Marks	AOs
5(a)	Using horizontal motion	M1	3.3
	Whole Motion Half way		
	$U \cos \alpha \times t = 120$ $U \cos \alpha \times t = 60$	A1	1.1b
	Using vertical motion OR	M1	3.4
	$U \sin \alpha \times t - \frac{1}{2}gt^2 = 0$ $0 = U \sin \alpha - gt$	A1	1.1b
	Attempt to solve problem by eliminating t	DM1	3.1b
	$U^2 \sin \alpha \cos \alpha = 588^*$	A1*	2.2a
		(6)	
	N.B. No credit given if they use the given answer from (b).		
5(b)	Using vertical motion OR conservation of energy	M1	3.4
	$0^2 = (U \sin \alpha)^2 - 2g \times 10$ $\frac{1}{2}mU^2 - \frac{1}{2}m(U \cos \alpha)^2 = mg \times 10$	A1	1.1b
	ALTERNATIVE 1: If t is time to top: use of $10 = \frac{1}{2}gt^2$ oe ($t = \frac{10}{7}$) to obtain an equation in U and α only M1 $U \sin \alpha = 14$ or $U \cos \alpha = 42$ A1 ALTERNATIVE 2: If t is time to top: use of: $10 = U \sin \alpha t - \frac{1}{2}gt^2$ with $t = \frac{60}{U \cos \alpha}$ substituted to obtain an equation in U and α only : M1 $10 = U \sin \alpha \times \frac{60}{U \cos \alpha} - \frac{1}{2}g \left(\frac{60}{U \cos \alpha} \right)^2$ A1		
	Attempt to solve problem by eliminating α : e.g. $U \sin \alpha = 14 \Rightarrow U \cos \alpha = 42$, from part (a) or from using $t = \frac{10}{7}$, then square and add to give result OR: $U^2 \sin^2 \alpha = 20g = 196$ and $U^2 \sin \alpha \cos \alpha = 588$, divide to give $\tan \alpha = \frac{1}{3}$ then $\sin^2 \alpha = \frac{1}{10}$, hence result OR in ALTERNATIVE 2: sub for U^2 using part (a), to give $\tan \alpha = \frac{1}{3}$ then $\sin^2 \alpha = \frac{1}{10}$, hence result	DM1	3.1b



		N.B. Just stating that $\sin^2 \alpha = \frac{1}{10}$, with no working is DM0A0.		
		$U^2 = 1960 *$	A1*	2.2a
		N.B. Verification (i.e. starting with $U^2 = 1960$ and trying to work backwards) is not an acceptable method for this question.		
			(4)	
5(c)		V , since air resistance has to be overcome, or just ‘because of <u>air resistance</u> ’ isw	B1	3.5a
			(1)	
5(d)		e.g. wind effects, more accurate value of g , spin of ball, size of ball, shape of ball, dimensions of ball, not a particle, variable acceleration, surface area of ball, humidity. Allow wind resistance and rotational resistance (Ignore any mention of air resistance or drag)	B1	3.5c
			(1)	
(12 marks)				
Notes:				
5a		N.B. Could score 2/6 for any one of the 4 given equations if there is no corresponding second equation or there is an attempt but it's incorrect.		
	M1	Complete method to give equation in U , α and t only, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved		
	A1	Correct equation		
	M1	Complete method to give equation in U , α and t only, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved		
	A1	Correct equation		
	DM 1	Eliminate t , dependent on first and second M1's		
	A1*	Given answer correctly obtained, <u>with no wrong working seen</u> . Allow $588 = U^2 \sin \alpha \cos \alpha$ but nothing else		
5b	M1	Complete method to give equation in U and α only with correct no. of terms, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved		
	A1	Correct equation		
	DM 1	Eliminate α and rearrange, dependent on first M1		
	A1*	Given answer correctly obtained with <u>no wrong working seen</u> (N.B. If they use a value for α (18.43.°) they lose the final A1*)		
5c	B1	Clear statement isw		
5d	B1	B0 if there is an incorrect extra e.g. mass or weight		



Question	Scheme	Marks	AOs
5(a)	Using horizontal motion, $s = ut$, with 35 resolved	M1	3.3
	$x = 35 \cos \alpha \times t$	A1	1.1b
	Using vertical motion, $s = ut + \frac{1}{2}at^2$, with 35 resolved	M1	3.4
	$y = 35 \sin \alpha \times t - \frac{1}{2}gt^2$	A1	1.1b
	Eliminate t : $y = 35 \sin \alpha \times \frac{x}{35 \cos \alpha} - \frac{1}{2}g \left(\frac{x}{35 \cos \alpha} \right)^2$	DM1	3.1b
	$y = \frac{3}{4}x - \frac{1}{160}x^2$ *	A1*	1.1b
	N.B. No marks available if they just quote the equation of the path.		
5(b)	ALTERNATIVE: they do (b) and/or (c) first <u>using a suvat method</u> Assume $y = ax^2 + bx + c$ Use any three of (0,0), (120,0) from part (b), (60,22.5) from part (c) or $\frac{dy}{dx} = \frac{3}{4}$ at $x = 0$ to find a , b , and c . M1A1, M1A1, DM1A1* for finding each of a , b and c and stating final answer in correct form. N.B. If they realise that $c = 0$, and just use $y = ax^2 + bx$, that could score M1A1. Enter marks on ePEN in the order in which a , b and c are found: e.g. $x = 0, y = 0 \Rightarrow c = 0$ M1A1 $x = 0, \frac{dy}{dx} = 2ax + b = \frac{3}{4} \Rightarrow b = \frac{3}{4}$ M1 A1 $x = 120, y = 0 \Rightarrow 0 = 120^2 a + 120 \times \frac{3}{4} \Rightarrow a = \frac{-1}{160}$ DM1 so, $y = \frac{3}{4}x - \frac{1}{160}x^2$ A1*		
		(6)	
	ALT 1 $0 = \frac{3}{4}x - \frac{1}{160}x^2$ and solve for x ALT 2 $\frac{dy}{dx} = \frac{3}{4} - \frac{x}{80} = 0 \Rightarrow x = 60$ and $OA = 2 \times 60$ ALT 3	M1	3.1b

	A complete <i>suvat</i> method to find OA: e.g. $0 = 35 \sin \alpha \times t - \frac{1}{2}gt^2$ or $0 = 35 \sin \alpha - g \frac{t}{2}$ or $-35 \sin \alpha = 35 \sin \alpha - gt$ to find $t \left(= \frac{70 \sin \alpha}{g} = \frac{30}{7} \right)$ AND $(OA =) 35 \cos \alpha \times t = 35 \cos \alpha \times \frac{70 \sin \alpha}{g}$ N.B. OR use the calculator to input the equation of the path which then gives $y_{\max} = 45/2$ when $x = 60$ with no working, so $OA = 2 \times 60$		
	$(OA =) 120 \text{ (m)}$	A1	1.1b
		(2)	
5(c)	ALT 1 $H = \frac{3}{4} \times 60 - \frac{1}{160} \times 60^2$ ALT 2 $y = \frac{-1}{160}(x^2 - 120x) = 22.5 - \frac{1}{160}(x - 60)^2 \text{ so max } y = 45/2 \text{ or } 22.5$ ALT 3 $\frac{dy}{dx} = \frac{3}{4} - \frac{2x}{160} = 0 \Rightarrow x = 60 \text{ then find } y \text{ when } x = 60$ ALT 4 A complete <i>suvat</i> method: e.g. $H = \frac{(35 \sin \alpha)^2}{2g}$ or $0 = 35 \sin \alpha - gt$ to find the time to top, $t = \frac{35 \sin \alpha}{g}$, or use half their time they found in (b) AND $H = 35 \sin \alpha \times \frac{35 \sin \alpha}{g} - \frac{1}{2}g \left(\frac{35 \sin \alpha}{g} \right)^2 \text{ or } \left(\frac{35 \sin \alpha + 0}{2} \right) \times \frac{35 \sin \alpha}{g}$ N.B. OR use the calculator to input the equation of the path which then gives $y_{\max} = 45/2$ (when $x = 60$) with no working.	M1	3.1b
	$(H =) 22.5$ Accept 23	A1	1.1b

		(2)	
5(d)		<i>H</i> is greater (or <i>K</i> is smaller), as air resistance would slow the particle down oe.	B1 3.5a
		(1)	
5(e)		e.g. the inaccuracy of using 9.8 m s^{-2} for <i>g</i>	B1 3.5b
		(1)	
(12 marks)			
Notes:			
5a	M1	Correct terms but condone sin/cos confusion and sign errors Available if they use <i>s</i> instead of <i>x</i>	
	A1	Correct equation in <i>x</i> and <i>t</i> N.B. they may have the wrong value for $\cos \alpha$	
	M1	Correct terms but condone sin/cos confusion and sign errors Available if they use a different letter for <i>y</i> provided it's not the same as they've used for <i>x</i> . N.B. M0 if they subsequently use a value for <i>y</i> e.g. 0	
	A1	Correct equation in <i>y</i> and <i>t</i> N.B. they may have the wrong value for $\sin \alpha$ They may have <i>t</i> in terms of <i>x</i> , from their first equation.	
	DM 1	Dependent on the two previous M marks for eliminating <i>t</i> to give an equation in <i>y</i> and <i>x</i> only.	
	A1*	Given answer correctly obtained, with at least one further line of working with trig ratios and $g = 9.8$ explicitly seen or 4.9 oe used for 0.5 <i>g</i> .. $\text{Allow } y = \frac{3x}{4} - \frac{x^2}{160} \text{ and with } y \text{ on the RHS}$	
5b	M1	ALT 1: Use of $y = 0$ in equation of path and solve for <i>x</i> . ALT 2 : Use calculus to find the <i>x</i> -coordinate of the max point and double it ALT 3 : Any other complete <i>suvat</i> method to find <i>OA</i> , condone sin/cos confusion and sign errors	
	A1	cao	
5c	M1	ALT 1: Use of $x = \left(\frac{1}{2} \times \text{their } OA \right)$ in equation of path ALT 2: Complete the square for the equation of the path and deduce maximum value of <i>y</i> : Need to see $p - q(x - r)^2$ with <i>p</i> as the answer ALT 3: Use $\frac{dy}{dx} = 0$ to find the <i>x</i> -coordinate of the max point and then use the path equation to find the <i>y</i> -coordinate ALT 4: Any complete <i>suvat</i> method to find <i>H</i> , condone sin/cos confusion and sign errors	

	A1	A0 for $\frac{45}{2}$
5d	B1	Possible justifications for H greater (or K smaller): air resistance will provide an extra force acting against the stone or opposing the motion air resistance would take away energy from the stone work would be done against air resistance air resistance will mean the acceleration will be less (or deceleration greater) air resistance would reduce the velocity/speed Allow 'it' for air resistance B0 if no justification given. B0 for air resistance would reduce the initial velocity of the stone B0 for air resistance will limit the vertical height (not a reason) or oppose the vertical force. Ignore extras.
5e	B1	Any single correct answer. Acceptable answer: the inaccuracy of using 9.8 m s^{-2} for g or wind or weather effects or the spin of the stone or the size (or shape or surface area) of the stone or or the stone is still modelled as a particle N.B. Allow if the stone is referred to as e.g. a ball B0 if any incorrect extras Unacceptable answers: The model (it) does not take account of: the mass or weight of the stone air resistance. The ground may not be horizontal. B0 for consequences of air resistance being included e.g. the path won't be a parabola the path won't be symmetrical

Question	Scheme	Marks	AO
5(a)	Horizontal speed = $20\cos 30^\circ$	B1	3.4
	Vertical velocity at $t = 2$	M1	3.4
	$= 20\sin 30^\circ - 2g$	A1	1.1b
	$\theta = \tan^{-1}\left(\pm \frac{9.6}{10\sqrt{3}}\right)$	M1	1.1b
	Speed = $\sqrt{100 \times 3 + 9.6^2}$ or e.g. speed = $\frac{9.6}{\sin \theta}$	M1	1.1b
	19.8 or 20 (m s^{-1}) at 29.0° or 29° to the horizontal oe	A1	2.2a
		(6)	
(b)	Using sum of horizontal distances = 50 at $t = 2$	M1	3.3
	$(u \cos \theta) \times 2 + (20 \cos 30^\circ) \times 2 = 50$ $(u \cos \theta = 25 - 20 \cos 30^\circ)$	A1	1.1b
	Vertical distances equal	M1	3.4
	$\Rightarrow (20 \sin 30^\circ) \times 2 - \frac{g}{2} \times 4 = (u \sin \theta) \times 2 - \frac{g}{2} \times 4$ $(20 \sin 30^\circ = u \sin \theta)$	A1	1.1b
	Solving for both θ and u	M1	3.1b
	$\theta = 52^\circ$ or better (52.47756849....°) $u = 13$ or better (12.6085128...)	A1	2.2a
		(6)	
(c)	It does not take account of the fact that they are not particles (moving freely under gravity) It does not take account of the size(s) of the balls It does not take account of the spin of the balls It does not take account of the wind g is not exactly 9.8 m s^{-2} N.B. If they refer to the mass or weight of the balls give B0	B1	3.5b
		(1)	
		(13)	



Marks		Notes
5a	B1	Seen or implied, possibly on a diagram
	M1	Use of $v = u + at$ or any other complete method <u>using $t = 2$</u> Condone sign errors and sin/cos confusion.
	A1	Correct unsimplified equation in v or v^2
	M1	Correct use of trig to find a relevant angle for the direction. Must have found a horizontal and a vertical velocity component
	M1	Use Pythagoras or trig to find the magnitude Must have found a horizontal and a vertical velocity component
	A1	Or equivalent. Need magnitude and direction stated or implied in a diagram. (0.506 or 0.51 rads)
5b	M1	First equation, in terms of u and θ (could be implied by subsequent working), using the horizontal motion with $t = 2$ used Condone sign errors and sin/cos confusion
	A1	Correct unsimplified equation – any equivalent form
	M1	Second equation, in terms of u and θ (could be implied by subsequent working), using the vertical motion – equating distances or just vertical components of velocities. Condone sign errors and sin/cos confusion
	A1	Correct unsimplified equation – any equivalent form
	M1	Complete strategy: all necessary equations formed and solve for u and θ N.B. This is an independent method mark but can only be earned if 50 m has been used in their solution.
	A1	Both values correct. (Here we accept 2SF or better, since the g 's cancel) Allow radians for θ : 0.92 or better (0.915906..) rads.
5c	B1	Any factor related to the model as stated in the question. Penalise incorrect extras but ignore consequences e.g. 'AB (or the ground) is not horizontal' should be penalised or 'they do not move in a vertical plane' should be penalised



Question	Scheme		Marks	AOs
5(a)	Using horizontal motion		M1	3.3
	$14 \cos \theta \times t = 40$		A1	1.1b
	Using vertical motion		M1	3.4
	$(s =) 14 \sin \theta \times t - \frac{1}{2} g t^2$ oe with down as positive.		A1	1.1b
	OR			
	Using the equation of the path			
	$(s =) 40 \tan \theta - \frac{g \times 40^2}{2 \times 14^2 \cos^2 \theta}$ oe		M2 A2	
	$(H =) 30$ or 30.0		A1	1.1b
			(5)	
5(b)	Using vertical motion	OR Using cons. of energy	M1	2.1
	$0^2 = (14 \sin \theta)^2 - 2gh$	$\frac{1}{2} m(14^2 - (14 \cos \theta)^2) = mgh$	A1	1.1b
	32 (m)		A1ft	1.1b
			(3)	
(8 marks)				
Notes: N.B. Penalise the use of $g = 9.81$ once (the first time it is used) for the whole question. All marks available if they use a different letter for θ				
5(a)	M1	Complete method, using the horizontal motion, to give an equation in t and θ only, condone sin/cos confusion and sign errors (θ may or may not be substituted for)		
	A1	Correct equation (t and/or θ may or may not be substituted for)		
	M1	Complete method, using the vertical motion, to give an equation in t and θ only, condone sin/cos confusion and sign errors (t and/or θ may or may not be substituted for)		
	A1	Correct equation (t and/or θ may or may not be substituted for) N.B. Just mark the RHS of the equation for this A mark.		
	OR			
	M2 A2	Quoting and using correctly the equation of the path. N.B. No marks if they misquote the equation and no marks if they put in 14 and/or 40 incorrectly. These 4 marks are indivisible i.e. all 4 or 0.		
	A1	$H = 30$ or 30.0 to 2 or 3 sf, after use of $g = 9.8$, obtained correctly.		



5(b)	M1	Complete method to give equation in h and θ only, condone sin/cos confusion and sign errors They may find t first: $0 = 14 \sin \theta - gt \Rightarrow t = \frac{14 \sin \theta}{g}$ then $h = (14 \sin \theta) \frac{14 \sin \theta}{g} - \frac{1}{2} g \left(\frac{14 \sin \theta}{g} \right)^2$ or $h = -\frac{1}{2} (-g) \left(\frac{14 \sin \theta}{g} \right)^2$ or $h = \frac{(14 \sin \theta + 0)}{2} \left(\frac{14 \sin \theta}{g} \right)$
	A1	Correct equation
	A1ft	their H + 2, to 2sf or 3sf