EDEXCEL | A-LEVEL MATHS | 9MA0/32

9MA0-32 A Level Mechanics - June 2024

June 2024 exam series

MARK SCHEME

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Mark Scheme

Summer 2024

Pearson Edexcel GCE
In Mathematics (9MA0)
Paper 32 Mechanics

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Summer 2024
Question Paper Log Number P75696A
Publications Code 9MA0_32_2406_MS
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General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.

EDEXCEL GCE MATHEMATICS
General Instructions for Marking

1. The total number of marks for the paper is 50.

2. The Edexcel Mathematics mark schemes use the following types of marks:
   - **M** marks: method marks are awarded for 'knowing a method and attempting to apply it', unless otherwise indicated.
   - **A** marks: Accuracy marks can only be awarded if the relevant method (M) marks have been earned.
   - **B** marks are unconditional accuracy marks (independent of M marks)
   - Marks should not be subdivided.

3. Abbreviations

These are some of the traditional marking abbreviations that will appear in the mark schemes.

- bod – benefit of doubt
- ft – follow through
- the symbol √ will be used for correct ft
- cao – correct answer only
- cso - correct solution only. There must be no errors in this part of the question to obtain this mark
- isw – ignore subsequent working
- awrt – answers which round to
- SC: special case
- oe – or equivalent (and appropriate)
- dep – dependent
- indep – independent
- dp decimal places
- sf significant figures
- ∗ The answer is printed on the paper
- ⌐ The second mark is dependent on gaining the first mark

4. For misreading which does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, in that part of the question affected.

5. Where a candidate has made multiple responses <u>and indicates which response they wish to submit</u>, examiners should mark this response.
   If there are several attempts at a question <u>which have not been crossed out</u>, examiners should mark the final answer which is the answer that is the <u>most complete</u>.
6. Ignore wrong working or incorrect statements following a correct answer.

7. Mark schemes will firstly show the solution judged to be the most common response expected from candidates. Where appropriate, alternatives answers are provided in the notes. If examiners are not sure if an answer is acceptable, they will check the mark scheme to see if an alternative answer is given for the method used.

General Principles for Mechanics Marking

(But note that specific mark schemes may sometimes override these general principles)

- Rules for M marks: correct no. of terms; dimensionally correct; all terms that need resolving (i.e. multiplied by cos or sin) are resolved.
- Omission or extra g in a resolution is an accuracy error not method error.
- Omission of mass from a resolution is a method error.
- Omission of a length from a moments equation is a method error.
- Omission of units or incorrect units is not (usually) counted as an accuracy error.
- DM indicates a dependent method mark i.e. one that can only be awarded if a previous specified method mark has been awarded.
- Any numerical answer which comes from use of g = 9.8 should be given to 2 or 3 SF.
- Use of g = 9.81 should be penalised once per (complete) question.

  N.B. Over-accuracy or under-accuracy of correct answers should only be penalised *once* per complete question. However, premature approximation should be penalised every time it occurs.
- Marks must be entered in the same order as they appear on the mark scheme.
- In all cases, if the candidate clearly labels their working under a particular part of a question i.e. (a) or (b) or (c),……then that working can only score marks for that part of the question.
- Accept column vectors in all cases.
- Misreads – if a misread does not alter the character of a question or materially simplify it, deduct two from any A or B marks gained, bearing in mind that after a misread, the subsequent A marks affected are treated as A ft
- Mechanics Abbreviations

  M(A) Taking moments about A.

  N2L Newton's Second Law (Equation of Motion)

  NEL Newton's Experimental Law (Newton's Law of Impact)

  HL Hooke's Law

  SHM Simple harmonic motion

  PCLM Principle of conservation of linear momentum

  RHS, LHS Right hand side, left hand side.

Question	Scheme	Marks	AOs
1(a)	$0.5g$, $\frac{1}{2}g$ or 4.9 (N) seen	B1	3.4
		(1)	
1(b)	$\frac{2}{7}\times 4.9$ oe seen	M1	3.1a
	1.4, 1.40 or $\frac{1}{7}g$	A1	1.1b
		(2)	
			(3 marks)

Notes: Ignore units in this question.

N.B. Use of g = 9.81 should only be penalised **once** for the whole question as should two fractional answers (a) 49/10 (b) 7/5.

Penalise the use of g = 9.81 the first time you see it.

N.B.

If g = 9.81 is used in (a), B0. If it is then used again in part (b), and they give the answer as 1.4 or 1.40, they can score M1A1 in part (b).

If g = 9.81 is only used in (b), they can score max M1A0 for (b).

1a	B1	cao. (must be positive) B0 for a fraction ($\frac{49}{10}$) B0 if they have $0.5g$ and then clearly use g = 9.81 i.e. **NOT** isw This answer must appear in (a) to earn this mark. If no labelling, give BOD and award as many marks as possible.
1b	M1	$\frac{2}{7}\times$ their (a) (must be a numerical value) If no answer for (a) or if (a) is incorrect and they don't use it, allow a correct restart i.e. $\frac{2}{7}\times 4.9$ or $\frac{2}{7}\times 0.5g$ or $\frac{2}{7}\times 0.5$ (missing g is not an M error)
	A1	A0 for a fraction **N.B.** X = is not needed **BUT** A0 for F (or P or horizontal force) = a correct answer if they don't go on to state X =... If they obtain the correct answer for F and they have said $F = X$ they can score A1.
		N.B. 1.4, 1.40 or $\frac{1}{7}g$ **with no working,** scores M1A1

Question	Scheme	Marks	AOs
2(a)	$\frac{10}{4}$	M1	3.4
	2.5, $\frac{5}{2}, \frac{10}{4}$ 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 – their (b)) with correct structure **OR** s = (200 – their (b)), using *suvat* 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 *suvat* method: $(10\times 6)+\frac{1}{2}a\times 6^2=200-\text{their (b)}$ => **AND** $U=10+6\times\text{their } a$	A1**ft**	1.1b

	$\frac{10}{3} = 3\frac{1}{3}$ oe	A1	1.1b
		(3)	
			(8 marks)

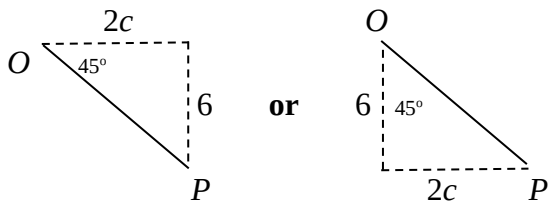
Notes:

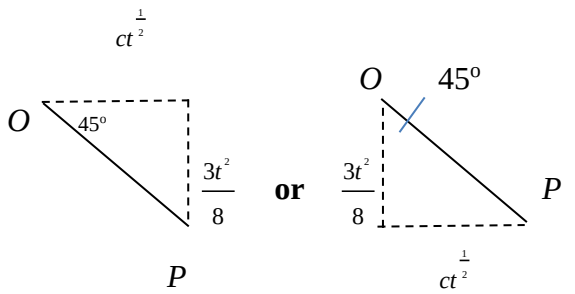
2a	M1	Any complete *suvat* method to find *a* e.g. use *s* = 20 and $20 = \frac{1}{2}a \times 4^2$ **N.B**. Ignore units at this stage
	A1	**Any** equivalent number **with** correct units. Accept m/s^2, m/s/s, m per s per s.
2b	M1	Complete method, they may use s*uvat* on one or more sections, to find the **TOTAL** area. M0 if a single *suvat* 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 *suvat*, to give an equation in *U* 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
	A1**ft**	Correct unsimplified equation in *U* only (allow *V* or *v* instead of *U*), **ft on their 160**.
	A1	Accept 3.3 or better. Ignore units. Allow use of *V* throughout instead of *U*, <u>including in the answer</u>. **N.B.** Correct answer, **with no working,** can score all 3 marks.

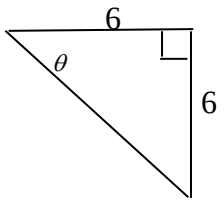
Question	Scheme	Marks	AOs
3(a)	$(R=)mg\cos\alpha$	M1	3.4
	$=\frac{12}{13}mg$	A1	1.1b
		(2)	
3(b)	Equation of motion down the plane	M1	2.1
	$mg\sin\alpha - F = ma$ or $mg\sin\alpha - F = -ma$	A1	1.1b
	$(F=)\ \mu\times$ their R	M1	3.4
	$\frac{1}{13}g(5-12\mu)$ *	A1*	2.2a
		(4)	
3(c)	P wouldn't move	B1	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	$\mu\times$ **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	AOs
4(a)	**ALTERNATIVES** when $t = 4$ is substituted at the beginning.		
	$2c\mathbf{i} - 6\mathbf{j}$ or as a column vector, seen or implied.	B1	1.1b
	ALT 1  **AND** **either** $\tan 45^o = \frac{2c}{6}$ => $2c = 6$ **or** **states** isosceles triangle so $2c = 6$ **N.B.** In both of the above,we must see the justification for the equation. **ALT 2** $\tan 135^o = \frac{2c}{-6}$ => $2c = 6$ **N.B.** M0 if they are using the wrong bearing.	M1	3.1a
	$c = 3$ *	A1*	2.2a
	SC 1 M1A0: no right-angled triangle $2c\mathbf{i} - 6\mathbf{j} = k(\mathbf{i} - \mathbf{j})$ => $2c = 6$ **or** **i**-cpt = − **j**-cpt => $2c = 6$ **N.B.** In both of the above,we must see the justification for the equation. **SC 2 M1A0:** no right-angled triangle $\tan 45^o = \frac{2c}{6}$ or $\frac{6}{2c}$ => $2c = 6$ **N.B.** In the above,we must see the justification for the equation.		

	ALTERNATIVES when $t = 4$ is substituted at the end:		
	$ct^{\frac{1}{2}} = 2c$ **and** $(-)\dfrac{3t^2}{8} = (-)6$ when $t = 4$, seen or implied	B1	
	ALT 3  **AND** **either** $\tan 45^o = \dfrac{\frac{3t^2}{8}}{ct^{\frac{1}{2}}}$ => $2c = 6$ when $t = 4$ **or** **states** isosceles triangle, so $ct^{\frac{1}{2}} = \dfrac{3t^2}{8}$ => $2c = 6$ when $t = 4$ **N.B.** In both of the above,we must see the justification for the equation. **N.B.** M0 if they are using the wrong bearing.	M1	
	$c = 3$	A1*	
	SC 3 M1A0: no right-angled triangle $(ct^{\frac{1}{2}}\mathbf{i} - \dfrac{3t^2}{8}\mathbf{j}) = k(\mathbf{i} - \mathbf{j})$ => $2c = 6$ when $t = 4$ **or** **i**-cpt = – **j**-cpt => $ct^{\frac{1}{2}} = \dfrac{3t^2}{8}$ => $2c = 6$ when $t = 4$ **N.B.** In both of the above,we must see the justification for the equation. **SC 4 M1A0:** no right-angled triangle $\tan 45^o = \dfrac{\frac{3t^2}{8}}{ct^{\frac{1}{2}}}$ => $2c = 6$ when $t = 4$.		

	N.B. Allow a **verification**: i.e. use c = 3 and t = 4 to show that P is on a bearing of 135° from O. $6\mathbf{i} - 6\mathbf{j}$ then a diagram:  **AND** tan $\theta = \frac{6}{6}$ or isosceles triangle => $\theta = 45^{\circ}$ **N.B.** In the above,we must see the justification for the equation.	B1 M1	
	bearing = 45° + 90° = 135°	A1*	
		(3)	
4(b)	Differentiate **r** wrt t to obtain **v**	M1	2.1
	$\mathbf{v} = 3 \times \frac{1}{2} t^{-\frac{1}{2}} \mathbf{i} - \frac{3}{8} \times 2t\mathbf{j} = \frac{3}{2} t^{-\frac{1}{2}} \mathbf{i} - \frac{3}{4} t\mathbf{j}$ oe	A1	1.1b
	Put t = 4 into **both** components and use Pythagoras: $\sqrt{\left(\frac{3}{4}\right)^2 + (-3)^2}$	M1	3.1a
	$\sqrt{\frac{153}{16}}$ or $\frac{\sqrt{153}}{4}$ or $\frac{3\sqrt{17}}{4}$ or $3\sqrt{\frac{17}{16}}$ = 3.0923.. (m s^{-1})	A1	1.1b
		(4)	
4(c)	Differentiate their **v** wrt t to obtain **a**	M1	3.4
	$\mathbf{a} = -\frac{3}{4} t^{-\frac{3}{2}} \mathbf{i} - \frac{3}{4} \mathbf{j}$	A1	1.1b
	$\frac{-\frac{3}{4} T^{-\frac{3}{2}}}{-\frac{3}{4}} = \frac{-1}{-27}$ oe	M1	2.1
	(T =) 9	A1	1.1b
		(4)	

		(11 marks)
Notes: Accept column vectors throughout		
4a	B1	$2c\mathbf{i}-6\mathbf{j}$ seen or implied. B0 for r = $2c\ -6$ if no evidence of components.
	M1	**ALT 1:** Use the bearing to obtain a CORRECT diagram showing a right-angled triangle with at least one 45° angle marked or clearly explained (i.e. 135° marked on the diagram and either $135^o-90^o=45^o$ or $180^o-135^o=45^o$), and $2c$ and ± 6 marked **AND** use of isosceles triangle or tan or (sin/cos and Pythag) to obtain $2c = 6$ **ALT 2: No diagram required** Use $\tan 135^o=\frac{2c}{-6}$ => $2c = 6$
	A1*	Given answer correctly obtained
		ALTERNATIVE when $t = 4$ is substituted at the end:
	B1	$ct^{\frac{1}{2}}=2c$ **and** $(-)\frac{3t^2}{8}=(-)6$ when $t = 4$, seen or implied
	M1	**ALT 3:** Use the bearing to obtain a CORRECT diagram showing a right-angled triangle with at least one 45° angle marked or clearly explained (i.e. 135° marked on the diagram and either $135^o-90^o=45^o$ or $180^o-135^o=45^o$), and $ct^{\frac{1}{2}}$ and $\pm\frac{3t^2}{8}$ marked **AND** use of isosceles triangle or tan or (sin/cos and Pythag) to obtain $2c = 6$ when $t = 4$
	A1*	Given answer correctly obtained
4b	M1	Both powers of t decreasing by 1 (M0 if **i** or **j** is missing but allow recovery or working with components only) **N.B.** This mark is available if c has not been substituted for.
	A1	Correct unsimplified derivative or two correct components
	M1	Put $t = 4$ in their **v** (must be using an attempted derivative of **r**) and then use Pythagoras with the root, allow a missing $-$sign **N.B.** If they **state** $t = 4$, allow a slip when they substitute in, for this M mark. This mark is available if c has not been substituted for.
	A1	Accept 3.1 or better
4c	M1	Both powers of t decreasing by 1 **N.B.** This mark is available if c has not been substituted for (M0 if **i** or **j** is missing but allow recovery or working with components only).
	A1	Correct unsimplified derivative
	M1	Use of an appropriate **ratio** (must be using an attempted derivative of **their v)**, condone sign error and the **reciprocal,** to obtain an equation in t or $\boldsymbol{T}$ **only**. **N.B.** If they state that $-\frac{3}{4}T^{-\frac{3}{2}}\mathbf{i}-\frac{3}{4}\mathbf{j}=k(-\mathbf{i}-27\mathbf{j})$ and then equate coefficients to give two simultaneous equations in k and T, these need to be used to produce an equation in $\boldsymbol{T}$ **only**, before the M mark is earned.
	A1	cao (allow t instead of T)

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.		
	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)	
5(b)	**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

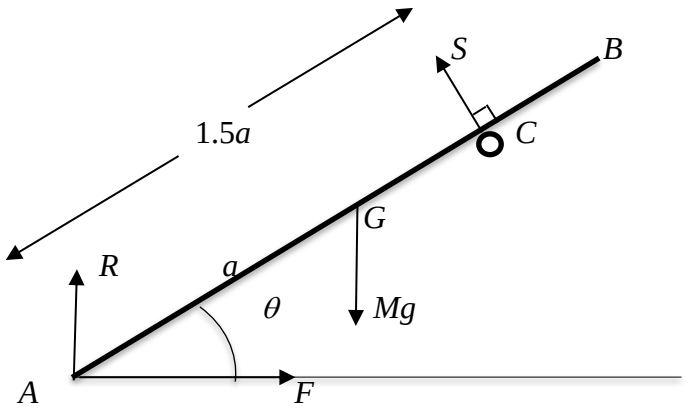
	A complete *suvat* method to find *OA*: e.g. $0 = 35\sin\alpha \times t - \frac{1}{2}gt^2$ or $0 = 35\sin\alpha - g\frac{t}{2}$ or $-35\sin\alpha = 35\sin\alpha - gt$ to find t $\left(= \frac{70\sin\alpha}{g} = \frac{30}{7}\right)$ **AND** $(OA =)35\cos\alpha \times t = 35\cos\alpha \times \frac{70\sin\alpha}{g}$ **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 (m)	A1	1.1b
		(2)	
5(c)	**ALT 1** $H = \frac{3}{4} \times 60 - \frac{1}{160} \times 60^2$ **ALT 2** $y = \frac{-1}{160}(x^2 - 120x) = 22.5 - \frac{1}{160}(x-60)^2$ so max y = 45/2 or 22.5 **ALT 3** $\frac{dy}{dx} = \frac{3}{4} - \frac{2x}{160} = 0 \Rightarrow x = 60$ then find y when x = 60 **ALT 4** A complete *suvat* 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** $H = 35\sin\alpha \times \frac{35\sin\alpha}{g} - \frac{1}{2}g\left(\frac{35\sin\alpha}{g}\right)^2$ 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)	*H* is greater (or *K* 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 *g*	B1	3.5b
		(1)	
			(12 marks)

Notes:

5a	M1	Correct terms but condone sin/cos confusion and sign errors Available if they use *s* instead of *x*
	A1	Correct equation in *x* and *t* **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 *y* provided it's not the same as they've used for *x*. **N.B.** M0 if they subsequently use a value for *y* e.g. 0
	A1	Correct equation in *y* and *t* **N.B.** they may have the wrong value for $\sin\alpha$ They may have *t* in terms of *x*, from their first equation.
	DM 1	Dependent on the two previous M marks for eliminating *t* to give an equation in *y* and *x* 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 0.5g.. Allow $y = \frac{3x}{4} - \frac{x^2}{160}$ and with *y* on the RHS
5b	M1	**ALT 1:** Use of *y* = 0 in equation of path and solve for *x*. **ALT 2** : Use calculus to find the *x*-coordinate of the max point and double it **ALT 3** : Any other complete *suvat* method to find *OA*, 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 *y*: Need to see $p - q(x-r)^2$ with *p* as the answer **ALT 3:** Use $\frac{dy}{dx} = 0$ to find the *x*-coordinate of the max point and then use the path equation to find the *y*-coordinate **ALT 4:** Any complete *suvat* method to find *H*, 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 oe **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	AOs
6.			
6(a)	Take moments about A	M1	3.1a
	$S \times 1.5a = Mga\cos\theta = (Mga \times \frac{3}{5})$	A1	1.1b
	$S = \frac{2}{5}Mg$ *	A1*	2.2a
		(3)	
6(b)	**N.B. Marks for the equations should be awarded in the order in which they appear on the script.**		
	Resolve horizontally:	M1	3.4
	$F = S\sin\theta$	A1	1.1b
	Resolve vertically:	M1	3.3
	$R = Mg - S\cos\theta$	A1	1.1b
	Other possible equations: (any of which is worth max M1A1) (parallel to the rod): $F\cos\theta + R\sin\theta = Mg\sin\theta$ (perp to the rod): $F\sin\theta + Mg\cos\theta = S + R\cos\theta$ M(B): $(S \times 0.5a) + (R \times 2a\cos\theta) = (Mg \times a\cos\theta) + (F \times 2a\sin\theta)$ M(C): $(R \times 1.5a\cos\theta) = (Mg \times 0.5a\cos\theta) + (F \times 1.5a\sin\theta)$ M(G): $(R \times a\cos\theta) = (S \times 0.5a) + (F \times a\sin\theta)$ **N.B. If they have more than two equations, mark only those that they use to try to find μ**		
	$F = \mu R$ and two of their equations used to solve for μ	DM1	3.1a
	$\mu = \frac{8}{19} = 0.42105\ldots$	A1	2.2a

			(6)	
				(9 marks)
Notes:				
6a	M1	Correct no. of terms, dimensionally correct, condone sin/cos confusion and sign errors. Allow use of a different letter for the angle. **N.B.** They may resolve the weight into two components, parallel and perpendicular to the rod, and then take the moment of each about *A*, one of which is 0. (see **N.B**. below) **N.B.** M0 if one or both *a*'s aren't there originally.		
	A1	Correct equation, $\cos\theta$ may or may not be replaced by $\frac{3}{5}$ **N.B.** you may see: $S \times 1.5a = Mg\cos\theta \times a$		
	A1*	Given answer correctly obtained, need to see $\cos\theta = \frac{3}{5}$ used Allow: $S = \frac{2Mg}{5}$ or $\frac{2Mg}{5} = S$ A0 if *S* is missing		
6b	M1	Correct no. of terms, dimensionally correct, condone sin/cos confusion and sign errors		
	A1	Correct first equation, *S* does not need to be substituted		
	M1	Correct no. of terms, dimensionally correct, condone sin/cos confusion and sign errors		
	A1	Correct second equation, *S* does not need to be substituted		
	DM 1	Dependent on previous two M marks for using $F = \mu R$ and two equations to solve for μ		
	A1	Accept 0.42 or better (as *g* cancels)		

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