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Mark Scheme (Results)

January 2023

Pearson Edexcel International Advanced Level In Mechanics M1 (WME01) Paper 01

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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.

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General Instructions for Marking

1. The total number of marks for this paper is 75.

2. The Edexcel Mathematics mark schemes use the following types of marks:

'M' marks
These are marks given for a correct method or an attempt at a correct method. In Mechanics they are usually awarded for the application of some mechanical principle to produce an equation.
e.g. resolving in a particular direction, taking moments about a point, applying a suvat equation, applying the conservation of momentum principle etc.
The following criteria are usually applied to the equation.

To earn the M mark, the equation
(i) should have the correct number of terms
(ii) be dimensionally correct i.e. all the terms need to be dimensionally correct
e.g. in a moments equation, every term must be a 'force x distance' term or 'mass x distance', if we allow them to cancel 'g' s.
For a resolution, all terms that need to be resolved (multiplied by sin or cos) must be resolved to earn the M mark.

M marks are sometimes dependent (DM) on previous M marks having been earned.
e.g. when two simultaneous equations have been set up by, for example, resolving in two directions and there is then an M mark for solving the equations to find a particular quantity – this M mark is often dependent on the two previous M marks having been earned.

'A' marks
These are dependent accuracy (or sometimes answer) marks and can only be awarded if the previous M mark has been earned. e.g. M0 A1 is impossible.

'B' marks
These are independent accuracy marks where there is no method (e.g. often given for a comment or for a graph).

A few of the A and B marks may be f.t. – follow through – marks.

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3. General 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 $\surd$ 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. All A marks are 'correct answer only' (cao), unless shown, for example as A1 ft to indicate that previous wrong working is to be followed through. After a misread however, the subsequent A marks are treated as A ft, but manifestly absurd answers should never be awarded A marks.

5. 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.

6. If a candidate makes more than one attempt at any question:
   - If all but one attempt is crossed out, mark the attempt which is NOT crossed out.
   - If either all attempts are crossed out or none are crossed out, mark all the attempts and score the highest single attempt.

7. Ignore wrong working or incorrect statements following a correct answer.

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General Principles for Mechanics Marking

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

- 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 penalized *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 conversation of linear momentum
RHS, LHS	Right hand side, left hand side

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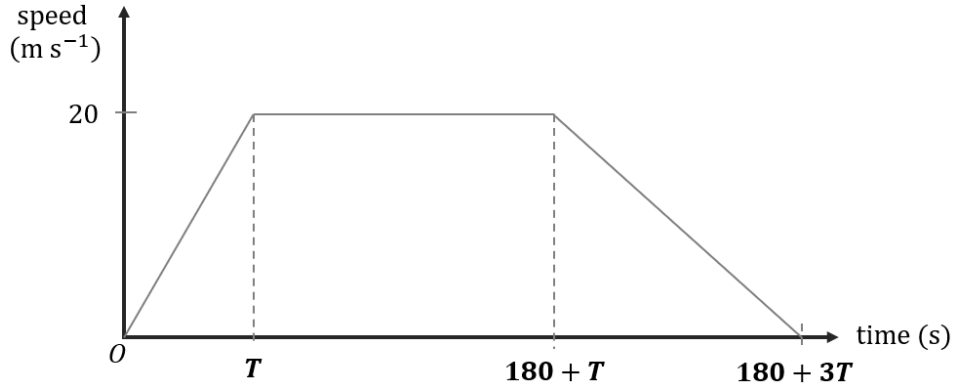
Question Number	Scheme	Marks
1(a)		B1 shape B1 20 B1 T, T+180, 3T+180
		(3)
1(b)	T and $2T$ seen or implied, for acceleration and deceleration in that order	B1
	Any of: $4800 = \left(\frac{20\times T}{2}\right) + (180\times 20) + \left(\frac{20\times 2T}{2}\right)$ $4800 = \left(\frac{20\times T}{2}\right) + \frac{1}{2}\times 20(180 + (180 + 2T))$ $4800 = \frac{1}{2}\times 20(180 + T + 180) + \left(\frac{20\times 2T}{2}\right)$ $4800 = \frac{1}{2}\times 20(180 + 3T + 180)$ $4800 = 20\times(180 + 3T) - \left(\frac{20\times T}{2}\right) - \left(\frac{20\times 2T}{2}\right)$	M1 A1 A1
	$T = 40$ (allow t)	A1
		(5)
1(c)	$20 = a$ x their T oe	M1
	Acceleration = $\frac{1}{2}\left(\text{m s}^{-2}\right)$	A1 **ft**
		(2)
		(10)

NOTES

(a) **B1** **B1** **B1**	Correct shape with acceleration steeper than deceleration (**ignore** entries on the axes). Correct vertical label. Correct horizontal labels. Accept use of their T or appropriately labelled delineators.

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(b)		
B1	Correct relationship seen or implied between the time accelerating and the time decelerating.	
M1	**A clear attempt** to use the total area under the graph (or use *suvat* formulae) and equate to 4800 (or 4.8) to form an equation in T only or their unknown only (e.g. replace T by $\frac{20}{a}$). Must involve a triangle or a trapezium (M0 if they use a *single suvat* formula for the whole motion)	
A1	An equation with at most one error. (use of 3 instead of 180 is one error) Having T and $2T$ round the wrong way, treat as one error	
A1	A fully correct equation	
A1	cao **N.B.** If attempting to use a single trapezium, and '180' appears in the bracket i.e. $\frac{1}{2}\times 20(\text{'}T\text{ terms'} + 180)$, allow at least M1A1 for one correct parallel side. **N.B.** $\frac{1}{2}\times 20(x + 180) = 4800$ => $x = 300$ ONLY scores B0M1A1A0A0	
(c)		
M1	Correct equation in a, using their T	
A1 ft	Correct answer, follow through on their '40'	

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Question Number	Scheme	Marks
2(a)	Correct relationship between the speeds after the collision. v and $v+1$ OR $w-1$ and w	B1
	$(3m\times1.5)+(m\times-1.5)=3mv+m(v+1)$ [Or $(3m\times1.5)+(m\times-1.5)=3m(w-1)+mw$]	M1 A1
	Speed of $A=\frac{1}{2}$ (m s^{-1}) Speed of $B=\frac{3}{2}$ (m s^{-1})	A1 A1
		(5)
2(b)	For B: $\pm m(1.5--1.5)$ **OR** For A: $\pm3m(0.5-1.5)$	M1 A1**ft**
	$3m$ (Ns)	A1
		(3)
		(8)

	NOTES
(a)	
B1	*speed* of B = 1 + *speed* of A . Must be seen **before** the CLM equation is used i.e. algebraic not numerical quantities
M1	Dimensionally correct CLM equation with correct number of terms. Allow consistent extra g 's or cancelled m 's. Ignore sign errors. Allow the use of 2 unknowns for speeds after. (M0 if same speeds)
A1	Correct equation in 1 unknown
A1	Correct speed of A
A1	Correct speed of B
(b)	
M1	Dimensionally correct impulse-momentum equation using A or B with correct number of appropriate terms. Condone sign errors but must be difference of momenta. M0 if g is included.
A1ft	Correct unsimplified equation. Follow through their answer in (a),but if using B, terms must have same signs, if using A, terms must have opposite signs.
A1	Cao (must be positive)

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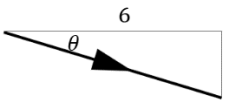
Question Number	Scheme	Marks
3(a)	Velocity $= (14\mathbf{i} - 5\mathbf{j}) + 2(-4\mathbf{i} + \mathbf{j})$	M1
	Speed $= \sqrt{6^2 + (-3)^2}$	M1
	Speed $= \sqrt{45} = 3\sqrt{5} = 6.7\left(\text{ms}^{-1}\right)$ or better	A1 cso
		(3)
3(b)	 $\tan^{-1}\left(\frac{3}{6}\right)$	M1 A1ft
	27° or better **OR** 333° or better 0.46 rads or better **OR** 5.8 rads or better	A1
		(3)
3(c)	$\mathbf{v} = (14\mathbf{i} - 5\mathbf{j}) + (-4\mathbf{i} + \mathbf{j})T$ (allow t) **OR** $\mathbf{v} = (6\mathbf{i} - 3\mathbf{j}) + (-4\mathbf{i} + \mathbf{j})t$ $(t = T - 2)$	M1
	$\frac{14 - 4T}{-5 + T} = \frac{2}{-3}$	M1 A1
	$T = 3.2$	A1
		(4)
(10)		
	NOTES	
	Accept the use of column vectors throughout	
(a) **M1** **M1** **A1**	Correct use of $t = 2$ to find the velocity (unsimplified). Use of Pythagoras to find the speed when $t = 2$ with <u>their</u> velocity. $\sqrt{45} = 3\sqrt{5} = 6.7\left(\text{ms}^{-1}\right)$ or better $(6.70820\ldots)$. Must come from correct velocity.	
(b) **M1** **A1ft** **A1**	Use trig to find an equation in a relevant angle e.g. $(90° - \theta)$ for their *velocity*. Correct equation for a relevant angle, ft on their **v** Cao. No isw (A0 for a negative answer)	

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(c)		
M1	Use of $\mathbf{v} = \mathbf{u} + \mathbf{a}T$ to obtain a velocity vector in T (allow t)	
M1	Use ratios, using *their* **velocity**, to produce an equation in T only (Allow reciprocal and incorrect sign)	
A1	Correct equation in T only	
A1	Cao **N.B.** If they use their answer to (a) instead of $\mathbf{u} = (14\mathbf{i} - 5\mathbf{j})$ but never correct their value of t, can score M1M1A0A0 **N.B.** If they use $\mathbf{v} = k(2\mathbf{i} - 3\mathbf{j})$ to produce 2 simultaneous equations in k and T, and then they use a calculator to solve and get $T = 3.2$, award all the marks, but if they get the wrong answer, they lose the last 3 marks.	

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Question Number	Scheme	Marks
4.	$R_D = 0$ for scenario 1 or $R_C = 0$ for scenario 2	B1
	Scenario 1 $\text{M}(C) \quad (150 \times 1.26) = Wx$	M1 A1
	Scenario 2 $\text{M}(D) \quad (225 \times 0.36) = W \times (0.9 - x)$	M1 A1
	Solve simultaneously for W (or x) e.g. $0.81W = 243$	dM1
	$W = 300$	A1
	$x = 0.63$	A1
		(8)

NOTES

B1	**N.B**. B0 means there are no other marks available. $R_D = 0$ for scenario 1 seen on a diagram or implied by working. OR: $R_C = 0$ for scenario 2 seen on a diagram or implied by working.
M1	Complete method to form an equation in W and a consistent unknown distance *only*, for scenario 1. All equations used must be dimensionally correct and have the correct no. of terms but condone sign errors. (M0 if $R_D = 0$ is never used)
A1	Correct unsimplified equation in W and x or their defined unknown distance.
M1	Complete method to form an equation in W and a consistent unknown distance *only*, for scenario 2. All equations used must be dimensionally correct and have the correct no. of terms but condone sign errors. (M0 if $R_C = 0$ is never used)
A1	Correct unsimplified equation in W and x or their defined unknown distance
dM1	Dependent on both M's, solve simultaneous equations for either W or their unknown Correct answer for W
A1	Correct answer for x This must be the distance stated in the question, from C to the centre of mass.
A1	**N.B**. If they include g in a moments equation, they lose the A mark for that equation and both final A marks.

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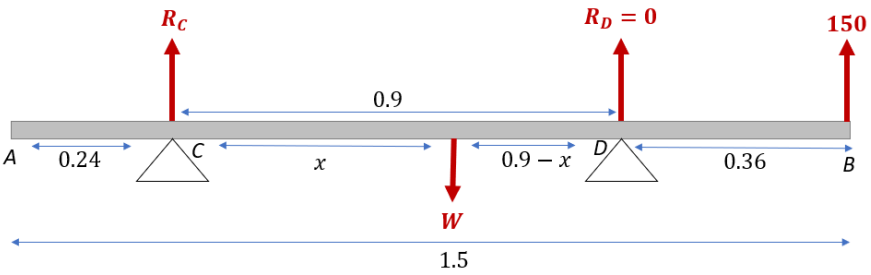
Scenario 1



Equations with unknown distance, x, measured from C.

Complete method will involve one moments equation with $R_D = 0$ or two equations with R_C eliminated and $R_D = 0$.

M0 if R_D never equals zero

Vert $R_C + 150 = W$

M(A) $(R_C \times 0.24) + (150 \times 1.5) = W(x + 0.24)$

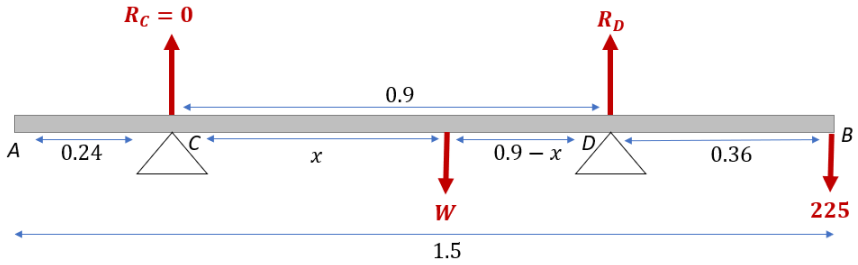
M(C) $(150 \times 1.26) = Wx$

M(G) $R_C\, x = 150(1.26 - x)$

M(D) $(R_C \times 0.9) = (150 \times 0.36) + W(0.9 - x)$

M(B) $(R_C \times 1.26) = W(1.26 - x)$

Scenario 2



Equations with unknown distance, x, measured from C

Complete method will involve one moments equation with $R_C = 0$ or two equations with R_D eliminated and $R_C = 0$.

M0 if R_C never equals zero

Vert $R_D = 225 + W$

M(A) $(R_D \times 1.14) = (225 \times 1.5) + W(x + 0.24)$

M(C) $(225 \times 1.26) + Wx = (R_D \times 0.9)$

M(G) $R_D(0.9 - x) = 225(1.26 - x)$

M(D) $(225 \times 0.36) = W(0.9 - x)$

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	M(B) $\left(R_D \times 0.36\right) = W\left(1.26 - x\right)$	
Question Number	**Scheme**	**Marks**
5(a)	P to Q $6x = \left(\frac{u+2u}{2}\right)12$ **OR** $6x = 12u + \frac{1}{2} \times \frac{u}{12} \times 12^2$ **OR** $(2u)^2 = u^2 + 2 \times \frac{u}{12} \times 6x$	M1
	Reaches given answer from correct working $x = 3u$ *	A1*
		(2)
5(b)	Q to R e.g. $\left(3u\right)^2 = \left(2u\right)^2 + 2\left(1.5\right)\left(15u\right)$	M1 A1
	$u = 9$	A1
		(3)
5(c)	Q to S (t = 14 position) $QS = 2u \times 2 + \frac{1}{2} \times 1.5 \times 2^2$	M1 A1
	$(4u + 3) + 18u$	M1
	201 (m)	A1
		(4)
(9)		

	NOTES
(a)	
M1	Considers P to Q and forms a relevant equation in terms of u and x
A1*	Reaches given answer from correct working
(b)	
M1	Uses the given answer in (a) to form an equation in u only **N.B.** If brackets missing, allow M1, but allow recovery.
A1	Correct unsimplified equation in u only
A1	Correct answer
(c)	
M1	Complete method to find the distance travelled in the 2 seconds after passing Q
A1	Correct unsimplified expression in u only (or 39 m)
M1	Complete method to find the required distance (need $18u$ or $6x$)
A1	Correct answer

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Question Number	Scheme	Marks
6.	Perpendicular to direction of motion: $500\sin 40° = P\sin\alpha°$	M1 A1
	Parallel to direction of motion: $500\cos 40° + P\cos\alpha° = 900$	M1 A1
	(i) Form and solve an equation in α $\tan\alpha° = \dfrac{500\sin 40°}{900 - 500\cos 40°}$	M1
	$\alpha = 32$ or better $(31.8683\ldots)$	A1
	(ii) Form and solve an equation in P $P = \dfrac{500\sin 40°}{\sin 31.868\ldots°}$	M1
	$P = 610$ or better $(608.736\ldots)$	A1
	N.B. Penalise over accurate answers only once for the question.	
	ALTERNATIVE USING A TRIANGLE OF FORCES: Cosine Rule**:** $P^2 = 500^2 + 900^2 - 2\times 500\times 900\cos 40^o$ OR: $500^2 = P^2 + 900^2 - 2\times P\times 900\cos\alpha°$ OR: $900^2 = P^2 + 500^2 - 2\times P\times 500\cos(140^o - \alpha°)$	M1 A1
	Sine Rule /Lami's Theorem: $\dfrac{P}{\sin 40^o} = \dfrac{500}{\sin\alpha°} = \dfrac{900}{\sin(140^o - \alpha°)}$ (any two)	M1 A1
	(i) Solve for α $\alpha = 32$ or better $(31.8683\ldots)$	M1 A1
	(ii) Solve for P $P = 610$ or better $(608.736\ldots)$	M1 A1
		(8)
	NOTES	
M1	Form an equation perpendicular to the direction of motion. Correct number of terms, condone sign errors and sin/cos confusion.	
A1	Correct unsimplified equation	
M1	Form an equation parallel to the direction of motion. If using $F = ma$ then must have $a = 0$. Correct number of terms, condone sign errors and sin/cos confusion.	
A1	Correct unsimplified equation	
(i) M1	Form and solve an equation in α (This an M mark so do not penalise accuracy of manipulation)	
A1	Accept 32 or better (i.e 32, 31.9, 31.87,… as their **final** answer)	
(ii) M1		

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A1	Form and solve an equation in P (This an M mark so do not penalise accuracy of manipulation) Accept 610 or better (i.e 610, 609, 608.7,… as their **final** answer)	
M1 **A1**	**ALTERNATIVE** Use cosine rule to give an equation in P (and α possibly) Correct equation	
M1 **A1**	Use sine rule to give an equation in P and α Correct equation	
	N.B. They could use the Sine or the Cosine Rule **twice** to obtain their two equations.	
(i) M1 **A1** **(ii) M1** **A1**	Form and solve an equation in α Accept 32 or better (i.e 32, 31.9, 31.87,… as their **final** answer) Form and solve an equation in P Accept 610 or better (i.e 610, 609, 608.7,… as their **final** answer)	

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Question Number	Scheme	Marks
7(a)	$\frac{42mg}{5} - (m+M)g = (m+M)\frac{2g}{5}$ where $M = (p + q)$ **OR** : $\frac{42mg}{5} - Mg = M\frac{2g}{5}$ where $M = p + q + m$	M1 A1
	$(p + q) = 5m$	dM1 A1
		(4)
7(b)	$\frac{14mg}{5} - pg = p\left(\frac{2g}{5}\right)$	M1 A1
	$p = 2m$	A1
		(3)
		(7)
	NOTES	
	N.B. Use the mass in the '*ma*' term to determine which part of the system is being considered.	
(a) **M1**	Form an equation of motion for the whole system with the combined mass of *P* and *Q*. Correct terms, condone sign errors. **N.B.** They may consider the 2 masses (*M*) and the lift separately and eliminate the normal reaction e.g. $R - Mg = M\frac{2g}{5}$ **AND** $\frac{42mg}{5} - mg - R = m\frac{2g}{5}$ AND add to eliminate *R*	
A1	Correct equation in *M* and *m*_for their *M* **N.B.** Award marks for a correct equation only if no wrong working seen.	
dM1	Rearrange to find an expression for the combined mass of *P* and *Q*. Must be a multiple of *m*	
A1	Cao	
(b) **M1**	Form an equation of motion for box *P*. Correct terms, condone sign errors. Fully correct equation.	
A1	Cao	

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A1	**N.B.** They may find q (M1A1) and subtract from $5m$	
Question Number	**Scheme**	**Marks**
8(a)	Perpendicular to the plane: $R + 18\sin 40° = 2g\cos 30°$	M1 A1
	Equation of motion parallel to the plane: $18\cos 40° - F - 2g\sin 30° = 2a$ (or -2a)	M1 A1 A1
	$F = 0.3R$	B1
	$18\cos 40° - 0.3\left(2g\cos 30° - 18\sin 40°\right) - 2g\sin 30° = 2a$	dM1
	$a = 1.18$ or 1.2 $\left(\text{m s}^{-2}\right)$	A1 cao
		(8)
8(b)	$v^2 = 2^2 + 2\left('1.18'\right)5$	M1 A1**ft**
	$v = 3.98$ or 4.0 or 4 (m s^{-1})	A1 cao
	N.B. For (a) and (b), penalise over accurate answers ONCE only.	(3)
8(c)	$R = 2g\cos 30°\left(= g\sqrt{3}\right)$	B1
	Friction = $0.3\times 2g\cos 30°$ OR $0.3\times 2g\sin 30°$	M1
	Compares Friction with weight component parallel to plane Eg Consider: $2g\sin 30^o - 0.3\left(2g\cos 30^o\right)$ (= 2a) **OR** $0.3\left(2g\cos 30^o\right) - 2g\sin 30^o$ (= 2a)	dM1
	$(a) > 0$ **OR** $(a) < 0$ Concludes that P will not remain at rest oe	A1
		(4)
(15)		
NOTES		
(a) **M1** **A1** **M1** **A1** **A1** **B1** **dM1** **A1**	Correct number of terms, forces resolved *perp to the plane* where appropriate, condone sign errors and sin/cos confusion, forces and angles paired up correctly Correct unsimplified equation. Equation of motion parallel to the slope. Correct number of terms, forces resolved where appropriate, condone sign errors and sin/cos confusion, forces and angles paired up correctly Correct unsimplified equation with at most one error Fully correct unsimplified equation Use of $F = 0.3R$ Eliminate F and R to form an equation in a, dependent on two M's Correct value for a. Must be 2 or 3sf	

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(b)		
M1	Complete method to form an equation in v or v^2	
A1ft	Correct unsimplified equation. Follow through on their value for a.	
A1	Cao. Must be positive. Note that $a = 1.2$ leads to $v = 4$.	
(c)		
B1	Correct expression or value for **new** R	
M1	Find the max friction. M0 if the previous R is used.	
dM1	Correct comparison between max friction value and weight component (force parallel to slope), dependent on previous M	
A1	Correct statement from fully correct working. Concludes that P will not remain at rest.	

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