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Mark Scheme (Results)

October 2022

Pearson Edexcel International Advanced Level In Mechanics M2 (WME02) Paper 01

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October 2022
Question Paper Log Number P72153A
Publications Code WME02_01_2210_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.

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General Instructions for Marking

1. The total number of marks for the 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 √ 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 affected 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 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

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Q	Mark Scheme	Marks	Marking guidance
1 (a)	M(*x* axis)	M1	Need all terms. Dimensionally consistent. Condone if *m* missing throughout. Accept as part of a vector equation
	$2m\times -+\times +\times =\times(2)\ 3m\ 24m\ 3\bar{k}\qquad 9m\qquad x$ $\bar{x}=\dfrac{2+12k}{9}*$	A1*	Obtain given result
		2	
(b)	M(*y* axis)	M1	Need all terms. Dimensionally consistent. Might be seen as part of a vector equation in (a). It does not score any marks until referred to in part (b). Condone if *m* missing throughout.
	$2m\times +\times -+\times =\times 5\ 3m(3)\ 4m\bar{k}\qquad 9m\qquad y$ $\square\ \bar{1}\ 4+k\ \square$ $\square\ y=\ \ \square$ $\square\qquad 9\ \square$	A1	Correct unsimplified equation. Allow if *m* missing throughout.
	Form and solve equation in *k* $(2+12k++=2\qquad 8k\ \ 27)$	DM1	Use their $\bar{y}$ and $x+\bar{}=2\bar{y}\ \ 3$ Dependent on the two preceding M marks
	$k=\dfrac{23}{20}\ (1.15)$	A1	Correct answer only
		4	
		(6)	

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2	Use of $P = Fv$	M1	Seen or implied e.g. $F = \frac{15000}{16}$ $(= 937.5)$ Condone 15 in place of 15000 or extra zeros on 15000
	Equation of motion	M1	Need all terms. Condone sign errors and sin / cos confusion. Dimensionally consistent
	$F + 900g\sin\theta - 400 = 900a$	A1	Unsimplified equation in P or their F with at most one error
	$\frac{15000}{16} + 900g \times \frac{1}{12} - 400 = 900a$	A1	Correct unsimplified equation with F and $\sin\theta$ substituted
	$a = 1.41 \quad (1.4)\ (\text{ms}^{-2})$	A1	3sf or 2sf
		(5)	

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Q	Mark Scheme	Marks	Marking guidance
3.	Use of $\mathbf{I} = m\mathbf{v} - m\mathbf{u}$	M1	Accept equivalent e.g. $\mathbf{I} + m\mathbf{u} = m\mathbf{v}$. Dimensionally correct and must be using subtraction (but could be the wrong way round). The use of 7 in place of the velocity in the impulsemomentum equation is M0 unless they recover. **See below**
	$0.2(\mathbf{v} - + = 4\mathbf{i}3\mathbf{j}) \quad \lambda(\mathbf{i} + \mathbf{j})$ $((x - + + 4)\mathbf{i} \; (y3)\mathbf{j} = 5\lambda \; \lambda\mathbf{i} + 5 \; \mathbf{j})$	A1	Correct unsimplified vector equation or pair of separate equations for the **i** and **j** components. Condone column vectors with **i** and **j** included in the components.
	Use of Pythagoras for the speed	M1	Correct use of Pythagoras and 49 for their speed
	$x^2 + = y^2 \; 49$	A1ft	Correct unsimplified equation for their x, y
	Form quadratic in x y, orλ and reach $\lambda = ...$	DM1	Dependent on both previous M marks. $x^2 + -(x \; 7)^2 = 49$ or $(y + 7)^2 + = y^2 \; 49$ or$(5\lambda + 4)^2 + (5\lambda - = 3)^2 \; 49$
	$\lambda = {}_5{}^3$——or $\lambda = - {}_5{}^4$	A1	Or equivalent
** ** ** ** ** ** **	Special case: Candidates who use 7 as a vector can score a **maximum** of M1A0M1A0 for $1.4^2 = +(\lambda \; 0.8)^2 + -(\lambda \; 0.6)^2$ or equivalent DM1A0 for forming and solving a quadratic in λ .		This maximum of 3 marks is only available for those candidates who "recover". So, **if all you see** is $\lambda \; \lambda\mathbf{i} + = -\mathbf{j}$ 1.4 0.2 4($\mathbf{i} - 3\mathbf{j})$ they score M0M0M0

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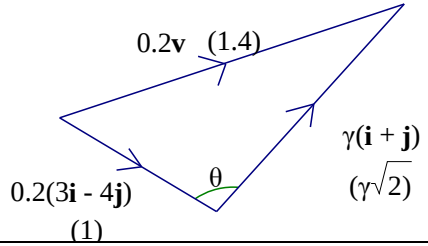
			If they recover to go on to form a "sensible" equation using Pythagoras then they can score the first 2 M marks, and potentially the third M1 as well.
		(6)	
3 alt			
	Form vector triangle	M1	Dimensionally correct. Allow incorrect configuration
	Correct triangle and correct lengths	A1	In speeds or momentum but not a mixture
	Use scalar product to find cosine of angle	M1	Or equivalent method
	$\cos\theta = -\frac{1}{5\sqrt{2}}$	A1	Allow ±
	Form equation in λ $(2\lambda\ \lambda^2 + .4 - 0.96 = 0)$	DM1	e.g. by use of cosine rule Dependent on the first 2 M marks
	$\lambda = \frac{3}{5}$ or $\lambda = -\frac{4}{5}$	A1	Or equivalent
		(6)	

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Q	Mark Scheme	Marks	Marking guidance
4 (a)	$\lambda\lambda^2 + - = = +2 \quad 3 \quad 0((\lambda\lambda 3)(-1))$	M1	Set **j** component = 0 and solve for λ
	$\Rightarrow = \lambda\ 1$	A1	Only. Seen or implied. Accept $t = 1$
	Use $\mathbf{a} = \frac{d\mathbf{v}}{dt}$	M1	Attempt derivative of both components with respect to t. Powers going down. Condone errors in dealing with the signs / indices for the square root. The answer must be a vector.
	$= \mathbf{i} + \frac{-1}{2\sqrt{5-t}} + (2t\ 2)\mathbf{j}$	A1	Any equivalent form
	$= -\frac{1}{4} + 4\mathbf{ij}$	A1	Only. Any equivalent form. ISW if they go on to find the magnitude.
		5	
4 (b)	Use $\mathbf{s} = \int \mathbf{v}dt$	M1	Attempt integral of both components. (M0 if they have assumed that one component is zero) Powers going up. Condone errors in dealing with the signs / indices for the square root.
	$\mathbf{s} = -\frac{2}{3}(5-t)^{\frac{3}{2}} + A\mathbf{i} + \frac{1}{3}t^3 + -t^2 3t + B\mathbf{j}$	A1 A1	Unsimplified expression with error in at most one term Correct unsimplified expression. Allow with no constant(s) of integration

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	Use $t = = - +1$, **s** 2**i** **j**	DM1	Use of initial condition to find constant(s) of integration. Dependent on the previous M1.
	s $= \square\square - \_2(5-T)_{32} + \overline{10}\square\square\mathbf{i} + \overline{\square\square}1T_3 + T_2 - 3T + \_8\square\square\mathbf{j}$ $\square\ 3 \qquad 3\ \square \quad \square 3 \qquad 3\square$	A1	Any equivalent form for the position vector
		5	
		(10)	

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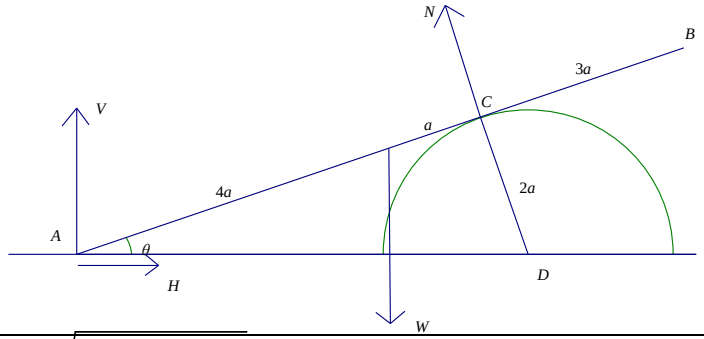
Q	Mark Scheme	Marks	Marking guidance
			
5 (a)	$AD = \sqrt{(2a)^2 + (5a)^2} = \sqrt{29}a$ *	B1*	Correct use of Pythagoras to show **given answer** from correct working (need a on both sides)
		1	
5 (b)	M(A): $W \times 4a\cos\theta = N \times 5a$	M1	Dimensionally correct equation in a. Allow if a cancelled. Condone sin/cos confusion
	$W \times \frac{5}{\sqrt{29}} \times 4a = N \times 5a$	A1	Correct unsimplified equation in a. Allow if a cancelled. Allow with cos .θ NB: $5a = \sqrt{29}a\cos\theta$
	$N = \frac{4}{\sqrt{29}}W$ *	A1*	Obtain **given answer** from correct working
		3	
5 (c)	The candidates need to form sufficient equations to solve for k and tanα. There should be two independent equations. On epen, allow M1A1 for the first equation seen, and M1A1 f ɔr the second equation. If there are more than 2 equations, award the marks for the equations used to solve for k and tanα. If they stop after forming the equations allow the marks for the best 2 equations.		

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	Resolve vertically	M1	Requires all relevant terms. Condone sin / cos confusion
	$V + N\cos\theta = W \quad \left(V = \frac{9}{29}W\right)$ or $kW\sin\alpha + N\cos\theta = W$	A1	Correct unsimplified equation. Need not substitute for trig.
	Resolve horizontally	M1	Requires all relevant terms. Condone consistent sin / cos confusion

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	$H = N\sin\theta \left(= \frac{8}{29}W\right)$ or $kW\cos\alpha = N\sin\theta \left(= \frac{8}{29}W\right)$	A1	Correct unsimplified equation. Need not substitute for trig.
	Possible alternative equation for M1A1 using M(C) : $aW\cos\theta + 5aH\sin\theta = 5aV\cos\theta$ or $aW\cos\theta = kW \times 5a\sin(\alpha - \theta)$		
	Use Pythagoras to obtain k: $k^2 = \left(\frac{9}{29}\right)^2 + \left(\frac{8}{29}\right)^2$	DM1	Correct use of perpendicular components. Dependent on the first 2 M marks
	$k = \frac{\sqrt{145}}{29} = \sqrt{\frac{5}{29}}$	A1	Correct only. Any equivalent exact form (ISW but 0.415 with no exact answer seen is A0)
	Use trig to obtain $\tan\alpha$	DM1	Dependent on the first 2 M marks
	$\tan\alpha = \frac{9}{8}$	A1	Correct only. Must be a simplified number. Do not accept answer including W
		8	
5 (c) alt	Resolve parallel to rod	M1	Requires all relevant terms. Condone sin / cos confusion
	$F = W\sin\theta \left(= \frac{2}{\sqrt{29}}W\right)$	A1	Correct unsimplified equation. Need not substitute for trig.
	Resolve perpendicular to rod	M1	Requires all relevant terms. Condone consistent sin / cos confusion
	$E + N = W\cos\theta \quad \left(E = \frac{1}{\sqrt{29}}W\right)$	A1	Correct unsimplified equation. Need not substitute for trig.
	Possible alternative equation for M1A1 using M(C) : $aW\cos\theta + 5aH\sin\theta = 5aV\cos\theta$ or $aW\cos\theta = kW \times 5a\sin(\alpha - \theta)$		
	Use Pythagoras to obtain k	M1	Correct use of Pythagoras
	$k = \frac{1}{\sqrt{29}}\sqrt{1+4} = \sqrt{\frac{5}{29}}$	A1	Correct only
	Use trig to obtain $\tan\alpha$: $\tan(\alpha - \theta) = \frac{1}{2} = \frac{\tan\alpha - \frac{2}{5}}{1 + \frac{2}{5}\tan\alpha}$	DM1	Use of trig to obtain expression in $\tan\alpha$

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	$\tan\alpha = \frac{9}{8}$	A1	Correct only with no errors seen
		8	
		(12)	

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6 (a)	M(*PV*)	M1	Allow use of a parallel axis. Terms dimensionally consistent. Could be seen as part of a vector equation. Condone error(s) in distance(s).
	$a\times 2ka^2+\left(2a+\frac{1}{2}ka\right)2ka^2=\bar{x}\times\left(2ka^2+2ka^2\right)$	A1	Correct unsimplified equation
	$2\bar{x}=\frac{1}{2}+a \quad 2a-\frac{6+k}{4}ka \Rightarrow \bar{x}=a$ *	A1*	Obtain **given answer** from correct working
		3	
6 (b)	M(*PR*)	M1	Allow use of a parallel axis. Terms dimensionally consistent. Could be seen as part of a vector equation in (a) but needs to be used here to score mark(s) in (b). Condone error(s) in distance(s). If working from *VU* they might assume that c of m of *QRST* lies on their axis. So long as they say that this is what they have done (e.g. in a table of values) this can score M1A0A0M1A1ftA0.
	$\frac{1}{2}ka\times 2ka^2+a\times 2ka^2=\bar{y}\times 4ka^2$	A1	Correct unsimplified equation
	$\bar{y}=\frac{k+2}{4}a$	A1	Correct answer $(\pm)$ seen or implied Accept distance from $VU=\pm\frac{3k-2}{4}a$ $6-k$

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			Or distance from TS = ± $\frac{a}{4}$
	Use given ratio to form equation in k	M1	Correct use of given ratio. Allow reciprocal
	$\frac{7}{15}=\frac{y}{x}\times\frac{(k+2)a}{4(6+ka)}$	A1ft	Correct unsimplified equation using given x and their y ka e.g. $\frac{y}{x}$ or $\frac{TS}{VU}$
	$\Rightarrow k=\frac{3}{2}(1.5)$	A1	Correct only
		6	
		(9)	

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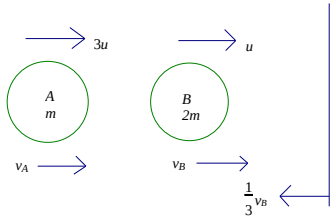
7 (a)			Check their diagram but remember that the directions used in their equations might not be consistent with the diagram. In this case, ignore their diagram.
	Conservation of momentum	M1	Need all terms. Dimensionally correct. Condone sign errors Condone *m* missing throughout or *g* present throughout
	$3mu + 2mu = mv_A + 2mv_B$ $(5u = +v_A 2v_B)$	A1	Correct unsimplified equation. Allow with v_A negative
	Use of NEL	M1	Used the right way round. Condone sign errors
	$v_B - = v_A\ e(3u - u)$ $(2ue = -v_B v_A)$	A1	Correct unsimplified equation. Allow with v_A negative. Signs consistent between the two equations.
	Solve for v_A or v_B	DM1	Dependent on two previous M marks
	Obtain $v_B = \frac{5+2e}{3}u$ *	A1*	Obtain **given answer** from correct working
	Obtain $v_A = \frac{5-4e}{3}u$	A1	Or equivalent. v_A must be positive
		7	
7 (b)	Time for *B* to reach the wall $t_B = \frac{d}{2u}$	B1	Or equivalent seen or implied. Allow $\frac{d \times 3}{(5\ 2+\ e\ u)}$

	Speed of B after impact with wall $= \frac{2}{3}u$	B1	Seen or implied. Allow $\frac{1}{3}\frac{5 + 2e}{3}u$
	Distance travelled by A before B hits the wall d $= u \times \frac{d}{2} = \frac{2u}{2}$	M1	Substitute $e = \frac{1}{2}$ and use their v_A and their t_b to find distance
	Time to close the gap	M1	Correct formula with their relevant speeds
	$\frac{d}{2} = u\,t \times \frac{2u}{3} + \frac{5ut}{3} \times t = \frac{3d}{10u}$	A1	Correct unsimplified equation (t x speed of approach)
	Total time $= \frac{d}{2u} + \frac{3d}{10u} = \frac{8d}{10u} = \frac{4d}{5u}$	A1	ISW Any equivalent form
		6	

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7(b) alt	In time *T*, *A* travels *x* metres *x* = *uT* *B* travels *d* metres in *t* sec *d* = *2ut* First B1 *B* travels *d* – *x* metres in *t*' sec *d* – *x* = 2*ut*'/3 Second B1 and first M1 t + t' = T (d + 3d – 3uT)/2u = T Second M1 And first A1 T = 4d/5u Second A1		Equivalent statement Correct value implied Distance travelled by *B* after it hits the wall Correct formula for time Correct unsimplified equation Correct answer
		(13)	

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8 (a)	Normal reaction between P and ramp $(R) = 0.3g\cos\alpha \left(= 0.3g \times \frac{24}{25} = 2.82.... \right)$	M1	Seen or implied. Condone sin / cos confusion (implied by use of $\frac{7}{25}$)
	Work done against friction $= \frac{1}{5}R \times 15$	M1	Use of WD $= \mu R \times$ distance with their R
	$= 8.47(8.5)(\text{J})$	A1	3 sf or 2 sf
		3	
8 (b)	Work-energy equation	M1	All terms required. Dimensionally correct. Condone sign errors.
	$\frac{1}{2} \times 0.3U^2 = \frac{1}{2} \times 0.3 \times 25^2 + (\text{a}) + 0.3 \times g \times (15\sin\alpha)$	A1ft A1ft	Follow their answer to (a) Correct unsimplified equation with at most one error. Correct unsimplified equation
	$U = 27.6 \quad (28)$	A1	3 sf or 2 sf
		4	
8 (c)	Time to ground:	M1	Complete method using *suvat* to form an equation in t
	$-15\sin\alpha = 7t - \frac{1}{2}gt^2$	A1	Correct unsimplified equation in t
	$t = 1.88 \quad (1.9) \quad (\text{s})$	A1	3 sf or 2 sf $\frac{5+\sqrt{67}}{7}$ is A0
		3	
8 (d)	Vertical component of speed	M1	Or use energy to find the speed
	$= \pm(7 - (\text{their } t) \times g) \quad (\pm 11.459....)$	A1ft	or $0.15 \times 625 + .3 \times 9.8 \times \text{their } 4.2 = 0.15v^2 \quad (v = 26.59....)$ condone $v = \frac{7\sqrt{67}}{5}$
	Correct use of trig: $\tan\theta° = \frac{\text{their vertical}}{24}$	M1	or $\cos\theta° = \frac{24}{\text{their speed}}$
	$\theta = 25.5\,(26)$	A1	3 sf or 2 sf
		4	
	Reminder: The accuracy penalty for overspecified answers should be applied only once in any question (the first time seen). Similarly for the use of $g = 9.81$. If they make both of these errors they lose 2 A marks. The penalty applies to the final mark in any part.		
		(14)	

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