Pearson Edexcel

Mark Scheme (Results)

Summer 2019

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

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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.

PEARSON EDEXCEL IAL MATHEMATICS

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: 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 $\sqrt{}$ 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)
   - d… or dep – dependent
   - indep – independent
   - dp decimal places
   - sf significant figures
   - $\ast$ The answer is printed on the paper or ag- answer given
   - $\llcorner$ or d… 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.

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.

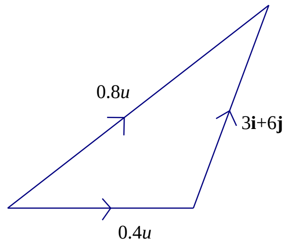
June 2019
Mechanics 2 - WME02
Mark Scheme

Question Number	Scheme	Marks
1a	Equation of motion: $F = R + 800g\sin\theta$ $= R + 80g$ Use of $P = Fv$: $F = \frac{15000}{12}(= 1250)$ $R(= 1250 - 80g) = 470\text{N}$ or 466	M1 A1 B1 A1 cao **(4)**
1b	Equation of motion: $\frac{15000}{12} + 80g - 500 = 800a$ $a = 1.9$ (m s^{-2}) or $a = 1.92$	M1A1 A1 cao **(3)**
		Total 7

Notes	
(a)	
M1	Equation of motion with Driving Force, Resistance and resolved Weight.
A1	Correct equation
B1	Use of $P = Fv$. Might be on diagram.
A1cao	470 N (466 N). **Must be 2 or 3 s.f.**
(b)	
M1	Equation of motion with Driving Force, Resistance, resolved Weight and *ma*.
A1	Correct equation, including correct driving force.
A1cao	$a = 1.92$ (m s^{-2}) or 1.9 (m s^{-2}) Accept -1.92. **Must be 2 or 3 s.f., but do not penalise if lost in (a).**

Question Number	Scheme	Marks
2	Integrate to find v: $v = 8t - 3t^2 \left(+C\right)$	M1A1
	Use $t = 0, v = 3$: $v = 3 + 8t - 3t^2$	A1
	Integrate to find s: $s = 3t + 4t^2 - t^3$	M1A1ft
	At rest when $v = 0$	M1
	Solve a 3 term quadratic for t: $\left(0 = 3t^2 - 8t - 3 = (t-3)(3t+1)\right)$ $t = 3$	M1
2(i)	$s = 9 + 36 - 27 = 18$ (m)	A1 cao
2(ii)	Complete strategy for total distance e.g. $s(3) + s(3) - s(4)$	M1
	$= 18 + \left(18 - \left(12 + 64 - 64\right)\right) = 24$ (m)	A1 cao
		(10)
		Total 10

Notes	
M1	Integrate a . Must see at least one power increased.
A1	Correct integral. Constant not needed.
A1	Correct v with initial velocity used to find C.
M1	Integrate their v with at least one power increasing.
A1ft	Correct integration of **their** velocity. Constant not needed, but if included must become zero.
	If they state the correct integral with the correct limits and get 18, award M1A1
M1	Setting $v = 0$ to find times at which particle is at rest.
M1	Solving their **3 term** quadratic. Implied by correct solutions from a correct equation, but if their equation or solutions are incorrect then use of a correct formula or factorising with correct products must be seen for this mark.
A1cao	Correct distance when particle comes to rest.
	If they state the correct integral with the correct limits and get 18, award A1
M1	Attempt to find distance travelled between “3” and 4 seconds and add to their answer to (i). They should use their time to come to rest, as long $0 < t < 4$
A1 cao	24 m. Must have come from correct algebraic integration and limits.
	If they state the correct integrals with the correct limits and strategy and get 24, award M1A1

Question Number	Scheme	Marks
3		
	Components of final momentum: **i** direction $0.4u+3$ **j** direction 6	M1
	Use of Pythagoras' theorem: $(0.4u+3)^2+6^2=(0.8u)^2$	M1
	$(4u^2-20u-375=0)$	A1
	Solve a 3 term quadratic for *v*: $(2u+15)(2u-25)=0$	M1
	$u=\frac{25}{2}(=12.5)$	A1
		(5)
3alt 1	Modulus and direction of impulse	M1
	Use of cosine rule: $(0.8u)^2=(0.4u)^2+45-2\times0.4u\times3\sqrt{5}\times-\frac{1}{\sqrt{5}}$	M1
	$(4u^2-20u-375=0)$	A1
	Solve a 3 term quadratic for *v*: $(2u+15)(2u-25)=0$	M1
	$u=\frac{25}{2}(=12.5)$	A1
		(5)
3alt 2	Components of final velocity: **i** direction $u+7.5$ **j** direction 15	M1
	Use of Pythagoras' theorem: $(u+7.5)^2+15^2=(2u)^2$	M1
	$(u^2-5u-93.75=0)$	A1
	Solve a 3 term quadratic for *v*: $(u+7.5)(u-12.5)=0$	M1
	$u=12.5$	A1
		(5)
		Total 5

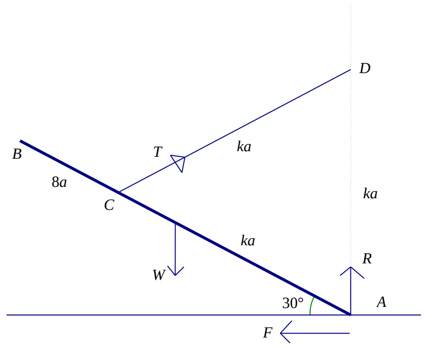
Notes	
M1	Attempt components of final momentum. Must have 0.4 with *u* and no mass with 3/6. Condone sign errors
M1	Use Pythagoras theorem to find magnitude of final momentum
A1	A correct equation reached.
M1	Solve a 3 term quadratic. Implied by correct answer to correct equation, but if either equation or answer is wrong, then clear method must be shown. (Correct use of formula or factorising with correct products for their equation).
A1	Must specify 12.5

Notes on Question 3 Alt 1	
M1	Find magnitude and direction of impulse $\lvert I \rvert = 3\sqrt{5} \quad \theta = \tan^{-1} 2$
M1	Use cosine rule to form equation in *u*.
A1	Correct equation (unsimplified)
M1	Solve a 3 term quadratic. Implied by correct answer to correct equation, but if either equation or answer is wrong, then clear method must be shown. (Correct use of formula or factorising with correct products for their equation).
A1	Must specify 12.5

Notes on Question 3 Alt 2	
M1	Attempt to find components of final velocity. Condone sign errors. Must have divided 3/6 by 0.4
M1	Use Pythagoras theorem to find magnitude of final velocity
A1	A correct equation reached.
M1	Solve a 3 term quadratic. Implied by correct answer to correct equation, but if either equation or answer is wrong, then clear method must be shown. (Correct use of formula or factorising with correct products for their equation).
A1	Must specify 12.5

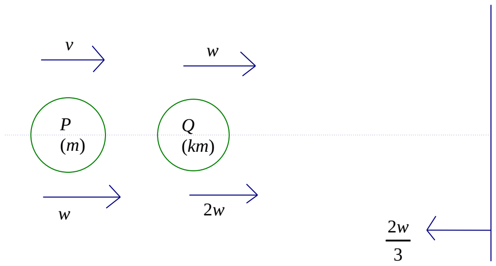
Question Number	Scheme	Marks
4a	PE lost = $4g\times1.5-2g\times1.5\sin\theta$ $\left(=6g-3g\times\frac{3}{5}\right)$ $=\frac{21g}{5}$ $=41.2$ (J) or 41 (J)	M1A1 A1 cao **(3)**
4b	Friction $=\frac{1}{5}\times2g\cos\theta$ Work done against friction $=1.5\times$ their F $=\frac{12g}{25}$ $=4.70$ (J) or 4.7(J)	B1 M1 A1 cao **(3)**
4c	Work-energy equation: gain in KE $=\frac{21g}{5}-\frac{12g}{25}=\frac{1}{2}\times4v^2+\frac{1}{2}\times2v^2$ $\Rightarrow\left(v^2=\frac{31g}{25}\right)$ $v=3.49$ or 3.5	M1A1ft A1 **(3)** **Total 9**

Notes	
a	
M1	Attempt at a difference in 2 dimensionally correct GPE terms. Distance up slope must be resolved.
A1	Correct expression for change in GPE. Trig need not be substituted.
A1 cao	Correct answer, either in terms of g or to 2/3 s.f. Must be positive, since question asks for energy lost, but condone dropping of minus without justification, if subtracted the wrong way.
b	
B1	Correct expression for friction. Allow in terms of μ, as long as they state μ = 1/5.
M1	Dimensionally correct attempt at WD with their friction. Must have found a friction.
A1 cao	Correct answer, either in terms of g or to 2/3 s.f.
c	
M1	Work energy equation with change in GPE, WD and 2 KE terms (possibly combined).
A1ft	Correct equation. Follow through their (dimensionally correct) GPE and WD terms.
A1 cao	Correct answer, either in terms of g or to 2/3 s.f.

Question Number	Scheme	Marks
5a		
	Moments about A: $T\cos 30° \times ka = W \times 4a\cos 30°$	M1
	$\Rightarrow T = \dfrac{4W}{k}$ *	A1
		(2)
5b	$\updownarrow$: $R + T\cos 60° = W$ $\left(R + \dfrac{T}{2} = W\right)$	M1A1
	$\leftrightarrow$: $F = T\cos 30°$ $\left(F = \dfrac{T\sqrt{3}}{2}\right)$	A1
	$R = W\left(1 - \dfrac{2}{k}\right)$, $F = \dfrac{2\sqrt{3}W}{k}$	M1
	$F = \mu R$: $\dfrac{2\sqrt{3}W}{k} = \dfrac{\sqrt{3}}{2}W\left(1 - \dfrac{2}{k}\right)$	M1
	$\left(\dfrac{4}{k} = 1 - \dfrac{2}{k}\right)$ $k = 6$	A1
		(6)
5c	Substitute for k to find R or F: $\left(R = \dfrac{2W}{3} \text{ or } F = \dfrac{\sqrt{3}W}{3}\right)$	M1
	Use of Pythagoras with their R, F, k: $\sqrt{\dfrac{4W^2}{9} + \dfrac{3W^2}{9}}$	M1
	$= \dfrac{\sqrt{7}W}{3}$, $\lambda = \dfrac{\sqrt{7}}{3}$	A1
		(3)
		Total 11

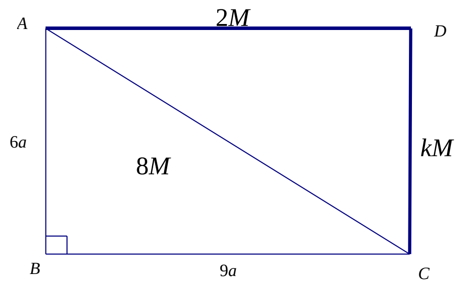
Notes	
a	
M1	Moments equation. Both sides must have a distance (condone *a* missing on both sides) and trig. It is a show that question, so we need to see the trig before it is cancelled.
A1*	given result from correct equation.
b	
M1	Form a correct resolution/moments equation, including at least one of R/N.
A1	Correct equation. Award for best equation.
A1	Second correct equation, that would allow problem to be solved.
M1	Eliminate T from all equations. This might be awarded after the next M mark, but does not depend on 2 equations being used.
M1	Use $F = \mu R$ to form equation in k (and possibly W). T must now be eliminated. They must have used 2 equations, both of which would have scored the first M1.
A1	$k = 6$
	Alternative order of working for last 3 marks: (award marks in order indicated)
	Use of $F = \mu R$: $F = \frac{T\sqrt{3}}{2} = \frac{\sqrt{3}}{2}R \Rightarrow T = R$
	Substitute for T in vertical equation: $\frac{3T}{2} = W = \frac{6W}{k}$
	$k = 6$
	Award 5bM2 when T is eliminated and 5bM3 when equation in *k* only is reached
c	
M1	Substitute their k to find R or F.
M1	Use Pythagoras to find magnitude.
A1	$\lambda = \frac{\sqrt{7}}{3}$ Accept any exact equivalent. If no exact answer seen, accept 0.882 or better.

	Other possible equations
M(D)	$W \times 4a\cos 30 = F \times 4ka$
M(W)	$T \times (k-4)a\cos 30 + F \times 4a\sin 30 = R \times 4a\cos 30$
M(C)	$W \times (k-4)a\cos 30 + F \times ka\sin 30 = R \times ka\cos 30$
M(B)	$T \times (8-k)a\cos 30 + R \times 8a\cos 60 = W \times 4a\cos 30 + F \times 8a\cos 60$

Question Number	Scheme	Marks
6a		
	CLM: $mv+kmw=mw+2kmw$ Impact law: $2w-w=\frac{2}{3}(v-w)$ $\left(\frac{2}{3}v=\frac{5}{3}w\right)$ $v=\frac{5}{2}w \quad \Rightarrow \quad k=\frac{3}{2}$	M1A1 M1A1 M1A1 **(6)**
6b	Speed of Q at second impact $=\frac{2w}{3}$ Time for Q to reach wall $=\frac{d}{2w}$ Distance travelled by P plus Q after hitting wall to second impact $\Rightarrow wt+\frac{2}{3}w\left(t-\frac{d}{2w}\right)=d$ $\Rightarrow t=\frac{4d}{5w}$	B1 B1 M1A1 A1 **(5)**
Alt1	Speed of Q at second impact $=\frac{2w}{3}$ Time for Q to reach wall $=\frac{d}{2w}$ Time t from wall to second impact $\Rightarrow \frac{2w}{3}t+wt=\frac{d}{2}$ $\left(t=\frac{3d}{10w}\right)$ Total time $=\frac{d}{2w}+\frac{3d}{10w}=\frac{4d}{5w}$	B1 B1 M1A1 A1 **(5)**
Alt 2	Speed of Q at second impact $=\frac{2w}{3}$ Time for Q to reach wall $=\frac{d}{2w}$ Time from wall to second impact $=\frac{\text{distance apart}}{\text{speed of approach}}=\frac{d/2}{w+\frac{2w}{3}}$ Total time $=\frac{d}{2w}+\frac{3d}{10w}=\frac{4d}{5w}$	(B1) (B1) (M1A1) (A1)

Alt 3	Speed of Q at second impact $= \frac{2w}{3}$	(B1)
	Time for Q to reach wall $= \frac{d}{2w}$	(B1)
	$AB = x \Rightarrow$ time for P to travel A to B $= \frac{x}{w}$	
	Time for Q to travel A to B $= \frac{d}{2w} + \frac{d-x}{2w/3}\left(= \frac{4d-3x}{2w}\right)$	(M1)
	$\frac{x}{w} = \frac{4d-3x}{2w} \quad \Rightarrow x = \frac{4d}{5}$	(A1)
	$\Rightarrow t = \frac{4d}{5w}$	(A1)
		Total 11

Notes	
a	
M1	Conservation of momentum. Must have 4 terms. All terms must have *m* or none.
A1	Correct equation.
M1	Impact law. Must be the correct way up.
A1	Correct equation. Note, speeds and directions are defined in the question, so the signs must be correct.
M1	Solve equations to find *k*.
A1	$\frac{3}{2}$ (accept any equivalent)
b	
All methods – The M mark requires a complete method to find the total time, so the line of working with the first A mark attached might not be sufficient to earn the M mark.	
B1	Speed of *Q* at second impact $= \frac{2w}{3}$ seen in working. Must be seen, not implied. (i.e. $3v=2w$ scores B0).
B1	Time for *Q* to reach wall $= \frac{d}{2w}$. Must be seen, not implied. (i.e. $2wt=d$ scores B0).
M1	Complete method to find total time. If time from wall found, the method must be completed to earn this mark. Condone numerical slips if a clearly sound strategy is attempted
A1	Correct initial equation to find either for total time or time from wall to impact.
A1cao	total time $= \frac{4d}{5w}$

Question Number	Scheme	Marks
7a	 Moments about *AB*: $(10+k)M\bar{x} = 8M \times 3a + 2M \times \frac{9a}{2} + kM \times 9a$ $(10+k)\bar{x} = 24a + 9a + 9ka = (33+9k)a$ $\bar{x} = \left(\frac{33+9k}{10+k}\right)a$ ***Given Answer***	M1A2 A1 **(4)**
7b	Moments about *AD*: $(10+k)M\bar{y} = 8M \times 4a + kM \times 3a$ $\bar{y} = \left(\frac{32+3k}{10+k}\right)a$ *AC* vertical: $\frac{3}{2} = \frac{\bar{x}}{\bar{y}} = \frac{33+9k}{32+3k}$ follow their $\bar{y}$ $(32+3k = 2(11+3k))$ $k = \frac{10}{3}$	M1A2 A1 M1A1ft A1
7balt	Moments about *BC*: $(10+k)M\bar{y} = 8M \times 2a + kM \times 3a + 2M \times 6a$ $\bar{y} = \left(\frac{28+3k}{10+k}\right)a$ *AC* vertical: EITHER $\frac{3}{2} = \frac{\bar{x}}{6a-\bar{y}}\left(= \frac{33+9k}{32+3k}\right)$ follow their $\bar{y}$ $(32+3k = 2(11+3k))$ $k = \frac{10}{3}$ OR $\frac{2}{3} = \frac{\bar{y}}{9a-\bar{x}}\left(= \frac{28+3k}{57}\right)$ follow their $\bar{y}$ $(114 = 84+9k)$ $k = \frac{10}{3}$	(M1A2) (A1) (M1A1) (A1) (M1A1) (A1) **(7)** **Total 11**

Notes	
a	
M1	Dimensionally correct moments equation about a *AB* (or parallel). Must have 4 terms. *M* must be included in all terms or none. If numerical distances are clearly included in each term, treat consistent omission of *a* as (a single) accuracy error. Might only be seen in a vector equation.
A1A1	-1 each error. Allow correct equation about any line parallel to *AB*.
A1	Given answer reached convincingly.
b	
M1	Dimensionally correct moments equation about a *AD* (or parallel). Must have 4 terms. *M* must be included in all terms or none. If numerical distances are clearly included in each term, treat consistent omission of *a* as an accuracy error. Might be seen in part (a), but must be used in (b) to score marks.
A1A1	-1 each error. Allow correct equation about any line parallel to *AD*.
A1	Correct $\bar{y}$. Could be from *BC*.
M1	Use their CoM and the fact that *AC* is vertical to form equation in *k* only. Follow through their $\bar{y}$, but must be considering appropriate distances. Condone = 2/3 for M1.
A1ft	Correct equation. Follow through their $\bar{y}$
A1 cao	$k = \frac{10}{3}$ o.e. If no fraction seen, accept 3.33 or better.

Note: *If they have a sign error on the 15, their values for (a) and (b,c) will be swapped around. Apply follow through as per the mark scheme, for their values.*

Question Number	Scheme	Marks
8a	$\leftrightarrow$: $3u\cos\theta = 50$	B1
	$\updownarrow$: $3u\sin\theta - 4.9\times 9 = -15 \quad (3u\sin\theta = 29.1)$	M1A1
	Solve for u or θ : $\tan\theta = \frac{29.1}{50}$, $\theta = 30.2$ or 30	M1A1
	$u = 19.3$ or 19	A1
		(6)
8b	Conservation of energy: $\frac{1}{2}mv^2 = \frac{1}{2}m\times 19.3^2 + 15mg$ follow their u	M1A1ft
	$v = 25.8$ (m s^{-1}) or 26	A1
8b alt	Use of Pythagoras on horizontal and vertical components:	
	$\rightarrow \frac{50}{3} \quad \uparrow \frac{29.1}{3} - 3\times 9.8 (= -19.7)$	
	$v = \sqrt{\left(\frac{50}{3}\right)^2 + "19.7"^2}$	M1A1ft
	$v = 25.8$ (m s^{-1}) or 26	A1
		(3)
8c	Use of trig to find direction: angle $= cos^{-1}\left(\frac{\frac{"50"}{3}}{"25.8"}\right)$ or $tan^{-1}\left(\frac{"19.7"}{\frac{"50"}{3}}\right)$	M1
	Downwards at $49.8°$ to the horizontal/ground $(50°)$	A1
		(2) **Total 11**

Notes	
a	
B1	$3u\cos\theta = 50$
M1	Use of $s = ut + \frac{1}{2}at^2$ for vertical motion. Condone sign errors.
A1	Fully correct equation
M1	Solve equations for either θ or *u*.
A1	$\theta = 30.2$ or 30 (question states degrees, so radians score A0)
A1	$u = 19.3$ or 19 (N.B. Only penalise more than 3 s.f. once per question) (Note: If they get sin/cos the wrong way round, they will still get the correct value, but score A0)
b	
M1	Conservation of energy from start to finish. Must have 2 K.E. and 1 GPE.
A1ft	Correct equation. Follow through their *u*.
A1cao	$v = 25.8$ or 26
alt	
M1	Use SUVAT to find vertical component of velocity at *B* **and** use Pythagoras to find speed.
A1ft	Correct (unsimplified) components. Follow through values of *u* and θ if used. Condone slip in processing a correct expression for vertical component before putting into Pythagoras.
A1	$v = 25.8$ or 26
c	
M1	Use their components/speed, with cos or tan to find angle.
A1	50^{o} (49.8^{o}) below horizontal o.e. **Must specify downwards/below/o.e. Allow a clear diagram included in, or explicitly referred to in (c)**

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