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Mark Scheme (Results)

October 2018

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.

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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.

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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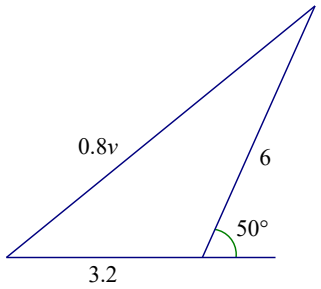
Q	Scheme	Marks	Notes
1.	Impulse-momentum equation:	M1	Must be working in 2 dimensions. Dimensionally correct. Condone subtraction in wrong order
	$\begin{pmatrix}6\cos 50°\\6\sin 50°\end{pmatrix} = 0.8\mathbf{v} - 0.8\begin{pmatrix}4\\0\end{pmatrix}$	A1	Correct unsimplified equation
	$\Rightarrow \mathbf{v} = \begin{pmatrix}4+7.5\cos 50°\\7.5\sin 50°\end{pmatrix}$	A1	$\begin{pmatrix}8.82\\5.74\end{pmatrix}$
	Pythagoras: $\lvert\mathbf{v}\rvert = \sqrt{(4+7.5\cos 50°)^2 + (7.5\sin 50°)^2}$	M1	Must have 2 components
	$\lvert\mathbf{v}\rvert = \left(=\sqrt{8.82^2 + 5.75^2}\right) = 10.5\,(\text{m s}^{-1})$	A1	Accept 10.52 and 10.53
		[5]	
Alt1	Impulse-momentum equation:	M1	Dimensionally correct. Condone subtraction in wrong order
	$\begin{pmatrix}6\\0\end{pmatrix} = 0.8\begin{pmatrix}v\cos\theta - 4\cos 50°\\v\sin\theta - 4\sin 50°\end{pmatrix}$	A1	Working parallel and perpendicular to the impilse
	$\Rightarrow \begin{pmatrix}v\cos\theta\\v\sin\theta\end{pmatrix} = \begin{pmatrix}7.5+4\cos 50°\\4\sin 50°\end{pmatrix}$	A1	$\begin{pmatrix}10.071...\\3.064..\end{pmatrix}$
	Use of Pythagoras	M1	
	$\lvert\mathbf{v}\rvert = 10.5\,(\text{m s}^{-1})$	A1	
		[5]	
Alt2			Momentum (or velocity) triangle

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Q	Scheme	Marks	Notes
	Cosine rule: $(0.8v)^2 = 3.2^2 + 6^2 - 2\times 3.2\times 6\cos 130°$	M1	
		A2	Unsimplified equation -1 each error
	Solve for v	M1	
	$\Rightarrow v = 10.5\,(\text{m s}^{-1})$	A1	
		[5]	

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Q	Scheme	Marks	Notes
2a	Any two of KE change / PE change / work done against resistance	B1 B1	Correct unsimplified expression required
	Work done: $\frac{1}{2}\times 1200\left(8^2-5^2\right)+1200g\times 90\sin\alpha+250\times 90$	M1	All terms required. Dimensionally correct. Condone sign errors and sin/cos confusion.
	(23400) (70560) (22500)	A1	Correct unsimplified equation
	(=116460) =116000 (J) (120000)	A1	Max 3 sf
		(5)	
2a alt	Use *suvat* to obtain $a=\frac{13}{60}\left(\text{m s}^{-2}\right)$	B1	Accept correct equation in a e.g. $8^2=5^2+2\times a\times 90$
	Use $F=ma$ to obtain net force $=260\,(\text{N})$	B1	Accept $1200a$
	Work done: $90\times$ driving force $=90\left(260+250+1200g\sin\alpha\right)$	M1	All terms required. Dimensionally correct. Condone sign errors and sin/cos confusion.
	(=116460) =116000 (J) (120000)	A1	Correct unsimplified equation
		A1	Max 3 sf
		(5)	
2b	Equation of motion: $F+1200g\sin\alpha-250=1200a$	M1	All terms required. Condone sign errors and sin/cos confusion
		A1	Correct unsimplified equation
	Use of $F=\frac{P}{v}$: $F=\frac{8000}{6}$	M1	Independent
	$a=\frac{1867....}{1200}=1.56$ (m s^{-2}) (1.6)	A1	Max 3 sf
		(4)	
		[9]	

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Q	Scheme	Marks	Notes
3a	Use of $\mathbf{v}=\frac{\mathrm{d}\mathbf{r}}{\mathrm{d}t}$:	M1	Differentiate – powers going down
	$\mathbf{v}=\left(16-9t^2\right)\mathbf{i}+\left(3t^2-2t\right)\mathbf{j}$	A1	
	i component of velocity = 0:	M1	
	$16-9t^2=0 \quad \Rightarrow\ t=\frac{4}{3},$	DM1	Solve for t and find **v** or $\lvert\mathbf{v}\rvert$ Dependent on previous M1
	$\mathbf{v}=\left(3\times\frac{16}{9}-2\times\frac{4}{3}\right)\mathbf{j}=\frac{8}{3}\mathbf{j} \quad \left(2.67\mathbf{j}\right)$	A1	Answer must be a vector. ISW
		(5)	
3b	Use of $\mathbf{a}=\frac{\mathrm{d}\mathbf{v}}{\mathrm{d}t}$:	M1	Differentiate – powers going down
	$\mathbf{a}=\left(-18t\right)\mathbf{i}+\left(6t-2\right)\mathbf{j}\ \left(=-72\mathbf{i}+22\mathbf{j}\right)$	A1ft	Follow their **v**
	Use of Pythagoras' theorem: $\lvert\mathbf{a}\rvert=\sqrt{72^2+22^2}$	M1	
	$\lvert\mathbf{a}\rvert=\sqrt{5668}=75.3\,(\mathrm{m\ s^{-2}})$ (75)	A1	Or better. From correct work
		(4)	
		[9]	

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Q	Scheme	Marks	Notes
4a	Velocity at T: $\rightarrow\ 12\cos 30° = u_h \left(= u\cos\theta°\right)$	M1	
	$\left(u\cos\theta° = 6\sqrt{3} = 10.39....\right)$	A1	Correct unsimplified equation for horizontal component of u
	$\uparrow\ -12\sin 30° = u_v - 2g\left(= u\sin\theta° - 2\times 9.8\right)$	M1	
	$\left(u\sin\theta° = 13.6\right)$	A1	Correct unsimplified equation for vertical component of u
	$\tan\theta° = \dfrac{13.6}{6\sqrt{3}}$	DM1	Solve equations for u or θ Dependant on both preceding M marks
	$\theta = 52.6\ (53)$	A1	One correct (max 3 s.f.)
	$u = 17.1\ (17)$	A1	Both correct (max 3 s.f.)
		(7)	
4b	Vertical distance : $h = -12\sin 30°\times 2 + \dfrac{1}{2}\times 9.8\times 2^2$	M1	Complete method using *suvat* to find h.
	$\left(\text{or}\ \ h = 17.1\sin 52.6°\times 2 - \dfrac{1}{2}\times 9.8\times 2^2\right)$ $\left(\text{or}\ \ 6^2 = \left(u\sin\theta\right)^2 - 2gh\right)$	A1	Or equivalent correct unsimplified equation in h
	$h = 7.6\ (7.60)$	A1	
		(3)	
4b alt	Using energy: $\dfrac{1}{2}mu^2 - \dfrac{1}{2}m12^2 = mgh$	M1A1	
	$h = 7.6\ (7.60)$	A1	
		(3)	

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Q	Scheme	Marks	Notes
4c	Double the time from max ht to T: $-12\sin 30° = -gt$	M1	
	Time above T: $2t = 2\times\dfrac{12\sin 30}{g}$	A1	
	$= 1.22\ \ (1.2)$ (s)	A1	
		(3)	
4c alt	Vertical component of speed equal magnitude and opposite sign: $-12\sin 30° = 12\sin 30° - gT$	M1	
	$t = \dfrac{24\sin 30°}{g}$	A1	
	$t = 1.22$	A1	
		(3)	
4c alt	Equation for vertical distance and solve for values of t: $7.6 = u\sin\theta°\times t - \dfrac{1}{2}gt^2$, $4.9t^2 - 13.6t + 7.6 = 0$	M1	
	$t_2 - t_1 = \dfrac{\sqrt{13.6^2 - 4\times 4.9\times 7.6}}{4.9}$	A1	$2 - \dfrac{38}{49}\ \ (2 - 0.7785)$
	$t = 1.22$	A1	From correct work only
		(3)	
	For other alternatives: complete strategy M1; correct equation in t A1; $t = 1.22$ A1		
		[13]	

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<table>
<tr><th>Q</th><th>Scheme</th><th>Marks</th><th>Notes</th></tr>
<tr><td>5a</td><td>
<table>
<tr><td></td><td>area</td><td>From AB</td><td>From AE</td></tr>
<tr><td>rectangle</td><td>$3ka^2$</td><td>$\frac{1}{2}ka$</td><td>$\frac{3}{2}a$</td></tr>
<tr><td>Triangle -</td><td>$\frac{9}{2}a^2$</td><td>$ka-3a+2a$</td><td>a</td></tr>
<tr><td>Triangle +</td><td>$\frac{9}{2}a^2$</td><td>$ka-3a+a$</td><td>$2a$</td></tr>
<tr><td>L</td><td>$3ka^2$</td><td>$\bar{x}$</td><td>$\bar{y}$</td></tr>
</table>
</td><td></td><td></td></tr>
<tr><td></td><td>mass ratio: $3k:\frac{9}{2}:\frac{9}{2}:3k$</td><td>B1</td><td></td></tr>
<tr><td></td><td>Horizontal distances:</td><td>B1</td><td>From AB or from a parallel axis</td></tr>
<tr><td></td><td>Moments about AB: $3k\times\frac{ka}{2}-\frac{9}{2}\times(k-1)a+\frac{9}{2}\times(k-2)a=3k\bar{x}$</td><td>M1</td><td>Need all terms and dimensionally correct
Accept on vector form</td></tr>
<tr><td></td><td></td><td>A1</td><td>Correct unsimplified equation in $\bar{x}$</td></tr>
<tr><td></td><td>$\frac{3k^2}{2}a-\frac{9}{2}a=3k\bar{x}$, $\bar{x}=\frac{(k^2-3)}{2k}a$</td><td>A1</td><td>Or equivalent</td></tr>
<tr><td></td><td></td><td>(5)</td><td></td></tr>
<tr><td>5b</td><td>Vertical distances</td><td>B1</td><td>From AE or from a parallel axus</td></tr>
<tr><td></td><td>Moments about AE: $3k\times\frac{3a}{2}-\frac{9}{2}\times a+\frac{9}{2}\times 2a=3k\bar{y}$</td><td>M1</td><td>Need all terms and dimensionally correct</td></tr>
<tr><td></td><td></td><td>A1</td><td>Correct unsimplified equation in $\bar{y}$.
Distance from $BD=\frac{3a}{2k}(k-1)$</td></tr>
<tr><td></td><td>$\frac{9ka}{2}+\frac{9a}{2}=3k\bar{y}$, $\bar{y}=\frac{3(k+1)a}{2k}$</td><td>A1</td><td>Or equivalent</td></tr>
<tr><td></td><td></td><td>(4)</td><td></td></tr>
<tr><td></td><td>If there is a triangle "missing", the total marks available for the question are B0B1M1A0A0 B1M1A0A0 M1M1M1A0 (7/13)</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td>See over for alternative working</td></tr>
</table>

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<table>
<tr><th>Q</th><th>Scheme</th><th>Marks</th><th>Notes</th></tr>
<tr><td></td><td>Alternative working for parts (a) and (b)</td><td></td><td></td></tr>
<tr><td></td><td>
<table>
<tr><td></td><td>mass</td><td>From AB</td><td>From AE</td></tr>
<tr><td>rectangle</td><td>$3(k-3)a^2$</td><td>$\frac{1}{2}(k-3)a$</td><td>$\frac{3}{2}a$</td></tr>
<tr><td>Triangle</td><td>$2\times\frac{9}{2}a^2$</td><td>$(k-3)a+a$</td><td>$2a$</td></tr>
<tr><td>L</td><td>$3ka^2$</td><td>$\bar{x}$</td><td>$\bar{y}$</td></tr>
</table>
</td><td></td><td></td></tr>
<tr><td></td><td>Moments about AB: $3(k-3)\times\frac{(k-3)a}{2}+9\times(k-2)a=3k\bar{x}$</td><td></td><td></td></tr>
<tr><td></td><td>Moments about AE: $3(k-3)\times\frac{3a}{2}+9\times 2a=3k\bar{y}$</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>5c</td><td>$\bar{x}=\bar{y}$: $(k^2-3)=3(k+1)$ for their values</td><td>M1</td><td></td></tr>
<tr><td></td><td>Simplify to 3 term quadratic in k: $k^2-3k-6=0$</td><td>DM1</td><td>Dependent on preceding M1</td></tr>
<tr><td></td><td>Solve for k: $k=\frac{3\pm\sqrt{9+24}}{2}$</td><td>DM1</td><td>Dependent on preceding M1</td></tr>
<tr><td></td><td>$k=4.37$ only</td><td>A1</td><td>The Q asks for 3 sf</td></tr>
<tr><td></td><td></td><td>(4)</td><td></td></tr>
<tr><td></td><td></td><td>[13]</td><td></td></tr>
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	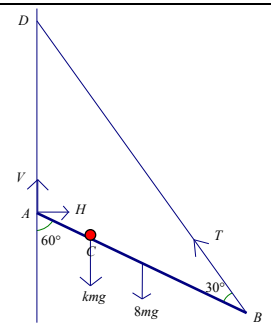		
6a	Moments about A:	M1	Need all terms and dimensionally correct
	$kmg \times 0.5a \sin 60° + 8mg \times a \sin 60° = T \sin 30° \times 2a$	A1 A1	Unsimplified equation. -1 each error $\cos 60°$ for $\sin 60°$ twice counts as one error
	$T = g \sin 60° \left(\frac{km}{2} + 8m \right) = \frac{\sqrt{3}}{4}(16+k)mg$ **Given Answer**	A1	Obtain **given answer** from correct working
		(4)	
6b	Resolving: $\rightarrow$ $T \cos 60° = H$	M1	Condone sin/cos confusion
	$\uparrow$ $V + T \cos 30° = 8mg + kmg$	M1	Condone sin/cos confusion & sign errors
		A1	Both equations correct unsimplified
			Allow M1M1A1 for alternative equations that are sufficient to solve for k
	Use $F = \mu R$ with their V and H $\left(V = \mu H \Rightarrow (8+k)mg - T \cos 30° = \frac{2}{3}\sqrt{3} \times T \cos 60° \right)$	M1	Dependent on having expressions for V and H
	Substitute for T and solve for k: $(8+k) - \frac{3}{8}(16+k) = \frac{\sqrt{3}}{3}\frac{\sqrt{3}}{4}(16+k)$	DM1	Dependent on 3 preceding M marks
	$2 + \frac{5}{8}k = 4 + \frac{1}{4}k$, $\frac{3}{8}k = 2$, $k = \frac{16}{3}$ (or 5.33)	A1	
		(6)	
		[10]	

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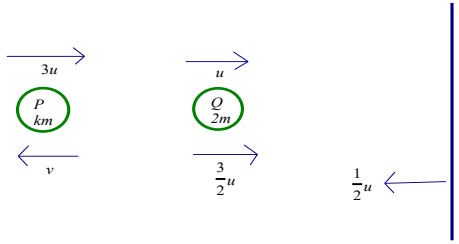
Q	Scheme	Marks	Notes
			
7a	Impact law: $\frac{3}{2}u+v=e(3u-u)\left(=2eu\right)$	M1	Used the right way round
	$\left(v=2eu-\frac{3}{2}u\right)$	A1	Correct unsimplified equation
	$v>0\ \Rightarrow\ 2e>\frac{3}{2}$	M1	Form and solve correct inequality for their v
	$\left(1\geq\right)e>\frac{3}{4}$	A1	Accept $1>e>\frac{3}{4}$ and $e>\frac{3}{4}$
		(4)	
7a alt	Impact law: $\frac{3}{2}u+v=e(3u-u)\left(=2eu\right)$	M1	Used the right way round
	$\left(v=2eu-\frac{3}{2}u\right)$	A1	Correct unsimplified equation
	CLM $\Rightarrow v=\frac{u}{k}(1-3k)>0\Rightarrow k<\frac{1}{3}$	M1	Use CLM to form inequality in k and substitute into impact equation
	$e=\frac{1}{2k}-\frac{3}{4}>\frac{3}{2}-\frac{3}{4}\Rightarrow\frac{3}{4}<e\left(\leq1\right)$	A1	
		(4)	

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Q	Scheme	Marks	Notes
7b	$e=\frac{7}{8} \Rightarrow v=\frac{7}{4}u-\frac{3}{2}u=\frac{1}{4}u$	B1	
	CLM : $3kmu+2mu=2m\times\frac{3}{2}u-kmv \qquad (3ku=u-kv)$	M1	Need all terms and dimensionally consistent. If only seen in (a) it must be used in (b) to score.
	$\left(3k+2=3-\frac{1}{4}k\right)$	A1	Correct unsimplified equation
	$k=\frac{4}{13}$	A1	
	KE lost: $\frac{1}{2}\times\frac{4}{13}m\left(9u^2-\frac{u^2}{16}\right)$	M1	Accept in terms of k e.g. $\frac{1}{2}km\left(9u^2-\frac{1}{16}u^2\right)$
	$=\frac{2}{13}m\times\frac{143}{16}u^2=\frac{11}{8}mu^2$ ***Given answer***	A1	Obtain given answer from correct working Fully correct substitution seen
		(6)	
7c	Time for Q to reach wall: $\frac{2d}{3u}$	B1	
	Speed of Q after collision with wall: $\frac{1}{3}\times\frac{3}{2}u=\frac{1}{2}u$	B1	
	P has moved $\frac{u}{4}\times\frac{2d}{3u}=\frac{d}{6}$	B1	
	Gap $d+\frac{d}{6}=\frac{7d}{6}$ closing at $\frac{1}{2}u-\frac{1}{4}u=\frac{1}{4}u$	M1	
	takes $\frac{7d}{6}\div\frac{u}{4}=\frac{14d}{3u}$	M1	Terms dimensionally correct
	Total time $\frac{14d}{3u}+\frac{2d}{3u}=\frac{16d}{3u}$	A1	
		(6)	

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Q	Scheme	Marks	Notes
7c alt	Time for Q to reach wall: $\frac{2d}{3u}$	B1	
	Speed of Q after collision with wall: $\frac{1}{3}\times\frac{3}{2}u=\frac{1}{2}u$	B1	
	Total time for Q: $\frac{2d}{3u}+\frac{2x}{u}$	B1	
	Equal times: $\frac{2d}{3u}+\frac{2x}{u}=\frac{4(x-d)}{u}$	M1	Terms dimensionally correct. Condone a sign error
	Solve for x: $2d+6x=12x-12d,\quad x=\frac{7d}{3}$	M1	
	Time $=\frac{4}{u}\times\frac{4d}{3}=\frac{16d}{3u}$	A1 (6)	
		[16]	

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