

Mark Scheme (Final)

October 2019

Pearson Edexcel IAL Mathematics

Mechanics 2 (WME02/01)

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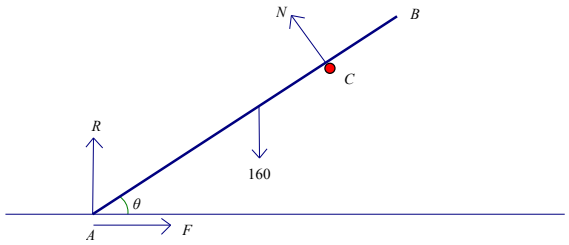
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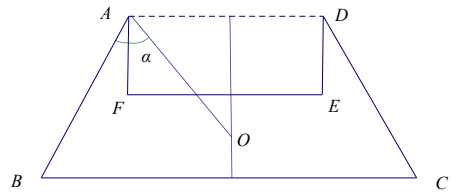
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October 2019
Mechanics 2 – WME02
Mark Scheme – Final

Q	Scheme	Marks	Notes
1	Moments about y-axis	M1	Or a parallel axis. Require all terms and dimensionally correct. Condone sign errors $3m\bar{x}$ or $3\bar{x}$ is a method error
	$(k+4)m\bar{x} = 2m+12m+km$	A1	Or equivalent
	Moments about x-axis	M1	Or a parallel axis. Require all terms and dimensionally correct. Condone sign errors $3m\bar{y}$ or $3\bar{y}$ is a method error
	$(k+4)m\bar{y} = m+9m+5km$	A1	Or equivalent
			Allow the first 4 marks for a combined equation in vector format
	Use of $\bar{y} = 2\bar{x}$ to form equation in k	M1	
			Allow the first 5 marks if they go straight to an equation equating the right hand sides e.g. $m+9m+5km = 2(2m+12m+km)$ with no incorrect statement about the total mass seen
	$10+5k = 2(14+k) \Rightarrow k = 6$	A1	With no errors seen
		(6)	
		[6]	
2	Use of $F = \dfrac{16000}{U}$	M1	$\dfrac{16}{U}$ scores M0
	Equation of motion.	M1	All terms required. Dimensionally correct. Condone sign errors and sin/cos confusion.
	$F - 30U - 750g\sin\theta = 0$	A1	Correct unsimplified equation in F or their F
	$\Rightarrow \dfrac{16000}{U} - 30U - 490 = 0$ $30U^2 + 490U - 16000 = 0$	DM1	Form and solve a quadratic equation in U Horizontal form seen or implied. Dependent on the two preceding M marks Need to see working if solving an incorrect quadratic or obtain an incorrect answer.
	$U = 16.3$ or $U = 16$ only	A1	Max 3 sf
		(5)	
		[5]	

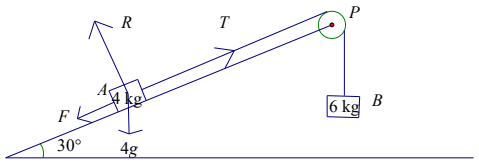
Q	Scheme	Marks	Notes
3a	Use of $\mathbf{a}=\dfrac{\mathrm{d}\mathbf{v}}{\mathrm{d}t}$ $\left(\mathbf{a}=2\mathbf{i}+\dfrac{9}{2}t^{-\frac{1}{2}}\mathbf{j}\right)$	M1	Powers going down by 1 Must be in vector form.
	Use of $\mathbf{F}=2\mathbf{a}$ and $t=4$	M1	For their **a** Must be working in vector form.
	$\mathbf{F}=4\mathbf{i}+4.5\mathbf{j}$	A1	Any equivalent simplified form ISW if go on to find magnitude
		(3)	
3b	Use of $\mathbf{r}=\int \mathbf{v}\mathrm{d}t$	M1	Powers going up by 1 Must be in vector form.
	$\mathbf{r}=\left(t^2+10t\,(+a)\right)\mathbf{i}+\left(6t^{\frac{3}{2}}(+b)\right)\mathbf{j}$	A1	Condone missing constant of integration
	$\mathbf{r}=56\mathbf{i}+28\mathbf{j}$	A1	ISW if go on to find magnitude
		(3)	
3c	Equate components of **v** $\left(2t+10=9t^{\frac{1}{2}}\right)$	M1	
	Form quadratic in $t^{\frac{1}{2}}$ and solve for t $\left(2\alpha^2-9\alpha+10=0\right)$	M1	Alternatively could square both sides to obtain $4t^2-41t+100=0$ Need to see working if solving an incorrect quadratic equation or obtain incorrect answers.
	$\left((2\alpha-5)(\alpha-2)=0\right)$ $\quad t=4,\ \ t=6.25\ \ (6.3)$	A1	
		(3)	
		[9]	

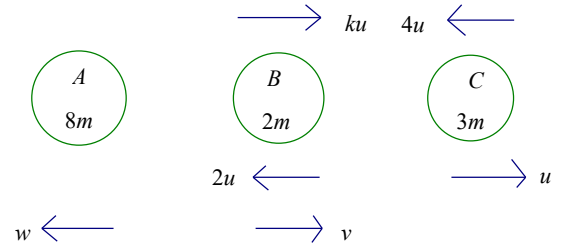
Q	Scheme	Marks	Notes
4a			
	Take moments about A	M1	Or a complete alternative method to form an equation in N. Dimensionally correct. Condone sin/cos confusion.
	$3N = 2\cos\theta \times 160$	A1	Correct unsimplified equation
	$3N = 2\times\frac{3}{4}\times 160 = 240,\quad N = 80$ (newtons) **(Given answer)**	A1	Deduce **given answer** correctly. Must see evidence of fully substituted equation
		(3)	
4b			Two independent equations needed. Mark in the order seen.
	Resolve horizontally	M1	Form one equation in F and/or R
	$F = N\sin\theta \left(= 80\times\frac{\sqrt{7}}{4} = 52.9..... \right)$	A1	Correct unsimplified equation
	Resolve vertically	M1	Form a second equation in F and/or R
	$R + N\cos\theta = 160 \quad (R = 160 - 60 = 100)$	A1	Correct unsimplified equation
	Use $F = \mu R$ to obtain μ	DM1	Dependent on two previous M marks
	$\mu = \frac{20\sqrt{7}}{100} = \frac{\sqrt{7}}{5}$	A1	0.53 or better (0.52915...)
		(6)	
	Alternative equations:		
	Resolving parallel to the rod: $R\sin\theta + F\cos\theta = 160\sin\theta$		
	Resolving perpendicular to the rod: $N + R\cos\theta = F\sin\theta + 160\cos\theta$		
	M(C): $3R\cos\theta = 3F\sin\theta + 160\cos\theta$		
	M(midpt): $2R\cos\theta = 2F\sin\theta + N$		
		[9]	

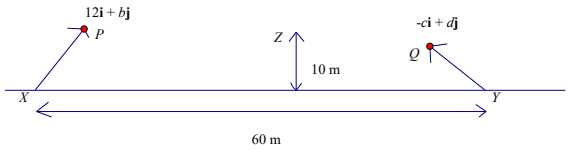
Q	Scheme	Marks	Notes
5a	<table><tr><td></td><td>Mass ratio</td><td>From BC</td></tr><tr><td>Large Δ</td><td>60 (4)</td><td>$4a$</td></tr><tr><td>Small Δ</td><td>15 (1)</td><td>$8a$</td></tr><tr><td>rectangle</td><td>15 (1)</td><td>$4.5a$</td></tr><tr><td>T</td><td>30 (2)</td><td>$\bar{y}$</td></tr></table>	B1 B1	Mass ratios correct Vertical distances correct
	Moments about BC	M1	Or a parallel axis. Signs correct for their split.
	$2\bar{y} = 16a - 8a - 4.5a = \frac{7}{2}a$	A1	Correct unsimplified equation
	$\bar{y} = \frac{7}{4}a$	A1	**Given Answer** Need to see a linear equation in $\bar{y}$
		(5)	
5b			
	$\bar{x} = 5a$ from B	B1	Or equivalent. Seen or implied Might be seen in (a) but needs to be used here.
	$\alpha = \tan^{-1}\left(\frac{5}{2}a \Big/ 6a - \bar{y}\right)$	M1	Trig ratio of a relevant angle in a triangle involving the c of m
	$\theta = \alpha + \tan^{-1}\frac{5}{12}$	M1	Correct method to find the required angle e.g $\theta = 180° - \tan^{-1}\frac{6}{2.5} - \tan^{-1}\frac{6a-\bar{y}}{2.5a}$
	$= \tan^{-1}\frac{10}{17} + \tan^{-1}\frac{5}{12}$	A1	Correct unsimplified expression for θ seen
			$\tan^{-1}\frac{10}{17} = 30.46..., \tan^{-1}\frac{17}{10} = 59.5..,$ $\tan^{-1}\frac{5}{12} = 22.6.., \tan^{-1}\frac{12}{5} = 67.38...$
	$\theta = 53$	A1	Q asks for a whole number
		(5)	
			See over for alternatives

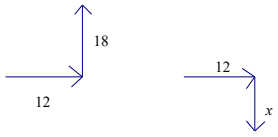
5balt 1	$\bar{x} = 5a$ from B	B1	Or equivalent. Seen or implied Might be seen in (a) but needs to be used here.
	Correct method to find all 3 sides of a triangle containing θ (or two sides of a right angled triangle containing θ)	M1	e.g.: $BO^2 = (5a)^2 + \left(\frac{7a}{4}\right)^2 = \frac{449}{16}a^2, AB^2 = \frac{169}{4}a^2$ $AO^2 = \left(\frac{5a}{2}\right)^2 + \left(6a - \frac{7a}{4}\right)^2 = \frac{389}{16}a^2$
	Correct method to find the required angle	M1	e.g. $\cos\theta = \frac{AB^2 + AO^2 - OB^2}{2AB.AO}$
	Correct unsimplified expression in θ	A1	$(\cos\theta = 0.60062)$
	$\theta = 53$	A1	Q asks for a whole number
		(5)	
5balt 2	$\bar{x} = 5a$ from B	B1	Or equivalent. Seen or implied Might be seen in (a) but needs to be used here.
	If O is c of m, $\overrightarrow{AB} = \begin{pmatrix} -2.5a \\ -6a \end{pmatrix}$, $\overrightarrow{AO} = \begin{pmatrix} 2.5a \\ -4.25a \end{pmatrix}$	M1	Expressions for $\overrightarrow{AB}$ and $\overrightarrow{AO}$
	Use of scalar product to find $\cos\theta$	M1	
	$\cos\theta = \frac{\overrightarrow{AB}.\overrightarrow{AO}}{\lvert\overrightarrow{AB}\rvert.\lvert\overrightarrow{AO}\rvert} \left(= \frac{-6.25 + 25.5}{\frac{13}{2} \times \frac{\sqrt{389}}{4}} \right)$	A1	Correct unsimplified expression for $\cos\theta$
	$\theta = 53$	A1	Q asks for a whole number
		(5)	
5balt 3	$\bar{x} = 5a$ from B	B1	Or equivalent. Seen or implied Might be seen in (a) but needs to be used here.
	If O is c of m, find coordinates of point of intersection between the line AO and the perpendicular line through B	M1	Relative to B: $A(2.5a, 6a), O(5a, 1.75a)$ $\Rightarrow AO: y = -1.7x + 10.25a$ If perpendicular through B intersects AO at L, $\Rightarrow BL: y = \frac{10}{17}x \qquad \Rightarrow L\left(\frac{3485}{778}, \frac{1025}{389}\right)$
	Correct method to find the required angle	M1	e.g. $\sin\theta = \frac{BL}{BA}$
	Correct unsimplified expression in θ	A1	$= \frac{\sqrt{\left(\frac{3485}{778}\right)^2 + \left(\frac{1025}{389}\right)^2}}{6.5}$
	$\theta = 53$	A1	Q asks for a whole number
		(5)	
			See over for alterrnative

5balt 4	$\bar{x} = 5a$ from B	B1	Or equivalent. Seen or implied Might be seen in (a) but needs to be used here.
	If O is c of m, find coordinates of point of intersection between the line AB and the perpendicular line through O	M1	$AB : y = \frac{12}{5}x$ If perpendicular through O intersects AB at H, $OH : y = -\frac{5}{12}x + \frac{23}{6}, \quad H\left(\frac{230}{169}, \frac{552}{169}\right)$
	Correct method to find the required angle	M1	e.g. $\sin\theta = \frac{OH}{OA}$
	Correct unsimplified expression in θ	A1	$= \frac{\frac{205}{52}}{\sqrt{\frac{389}{16}}}$
	$\theta = 53$	A1	Q asks for a whole number
		[10]	

6(a)			
	$R = 4g\cos 30°$	B1	
	$F = \frac{1}{\sqrt{3}}R\left(=2g\right)$	M1	Use of $F = \mu R$
	Work done $= 1.5F$	M1	Independent. Correct method for work done seen or implied. Allow without a value for F found
	$= 3g$ or 29.4 (J) or 29 (J)	A1	Not $\frac{147}{5}$
		(4)	
6(b)	PE lost by B − PE gained by A	M1	Dimensionally correct. Condone sin/cos confusion and sign errors.
	$= 6g\times 1.5 - 4g\times 1.5\sin 30°$	A1	Correct unsimplified expression. Allow $\pm\left(6g\times 1.5 - 4g\times 1.5\sin 30°\right)$
	$= 6g$ or 58.8 (J) or 59 (J)	A1	
		(3)	
6(c)	Work energy equation	M1	Q asks for work-energy. Need all terms. Dimensionally correct. Condone sign errors.
	$\frac{1}{2}\times 4v^2 + \frac{1}{2}\times 6v^2 + 3g = 6g$	A1ft	Correct unsimplified equation. Follow their (a) and (b). $\frac{1}{2}\times 10v^2 + \text{their}(a) = \text{their}(b)$ or starting afresh
	$5v^2 = 3g \Rightarrow v = \sqrt{\frac{3g}{5}}$ or 2.42 $\left(\text{m s}^{-1}\right)$ or 2.4 $\left(\text{m s}^{-1}\right)$	A1	not $\frac{7\sqrt{3}}{5}$
		(3)	
		[10]	

7a			
	Use of CLM	M1	Need all terms. Dimensionally correct. Condone sign errors
	$2mku - 3m \times 4u = -2m \times 2u + 3m \times u$ $(2k - 12 = -4 + 3)$	A1	Correct unsimplified
	$\Rightarrow k = \frac{11}{2}$	M1	Solve for k
	KE lost $= \frac{1}{2}2m\left(k^2 - 4\right)u^2 + \frac{1}{2}3m(16-1)u^2$	M1	Complete expression. Dimensionally correct. Allow $\pm$. In k or their k
	$\left(= mu^2\left(k^2 - 4\right) + \frac{45mu^2}{2}\right)$		
	$= \frac{195mu^2}{4}$, $\lambda = \frac{195}{4}$	A1	Or equivalent (48.75). Accept 49, 48.8 ISW once correct answer seen.
		(5)	
7b	Use of CLM: $4mu = 8mw - 2mv$	M1	Dimensionally correct. Condone incorrect signs.
	Use of impact law:	M1	Used the right way round.
	$v + w = 2eu$	A1	Both equations correct unsimplified. Signs consistent.
	Solve for v or a multiple of v	M1	(v_B)
	$(w = 2eu - v \Rightarrow 10v = 16eu - 4u)$		
	Inequality in e: $10v > 10u \Rightarrow 16eu > 14u$	M1	Complete correct method with signs consistent with the direction of their v Upper limit of 1 not necessary No extra incorrect inequality
	$\Rightarrow \frac{7}{8} < e \leq 1$	A1	Or equivalent. Want both limits. Must be ≤ 1.
			NB: The last two M marks might appear in reverse order. The inequality $v > u$ can be used with an expression for w to form the inequality in e.
		(6)	
		[11]	

8a			
	P and Q collide $\Rightarrow$ at same vertical height $\Rightarrow bt - \frac{1}{2}gt^2 = dt - \frac{1}{2}gt^2$ $\Rightarrow bt = dt,\ b = d$	B1	Obtain **given result** correctly No incorrect statements seen
		(1)	
8b	$10 = 3d - \frac{9}{2}g$	M1	Complete method using *suvat* to form an equation in d e.g.use of $s = ut + \frac{1}{2}at^2$ with correct values substituted but condone sign error
	$\Rightarrow d = 18\ \ (18.0)$	A1	Follows use of 9.8. Not $\frac{541}{30}$ Must be a scalar
		(2)	
8c	$t = 3$, vertical speed $v = d - 3g\ (= -11.4)$	M1	Condone sign errors
	$-11.4 = 11.4 - gt$	M1	Using symmetry with their 11.4
	$t = 2.3\ \ (2.32)$(s)	A1	Not $\frac{341}{147}$
		(3)	
8calt1	Vertical distance $10 = dt - \frac{g}{2}t^2$	M1	Condone sign errors
	Solve for t and subtract $\left(3,\ \frac{200}{3\times 98}\right)$	M1	
	$t = 2.3\ \ (2.32)$(s)	A1	
		(3)	
8calt2	Time to top: $0 = d - gt,\ \ (t = 1.84)$	M1	Condone sign errors
	Solve for required time: $T = 2(3 - 1.84)$	M1	
	$= 2.3$ (s)	A1	
		(3)	
8d	Horizontal distance: $60 = 12\times 3 + 3c$	M1	Allow if seen earlier and used here
	$(\ c = 8)$	A1	Correct unsimplified **equation** for horizontal distance. Allow $c = -8$ if used correctly later
	$\mathbf{v} = -8\mathbf{i} - 11.4\mathbf{j}$	M1	For their 8 and 11.4
	Direction $\tan^{-1}\frac{11.4}{8}$	DM1	Use of trig to find a relevant angle Dependent on the previous M1

	Downwards at $54.9°$ to the horizontal $(55°)$ $(35.1°$ to the vertical)	A1	Or equivalent. Direction must be stated or clearly implied by a diagram. 0.959 rads (0.96 rads) Max 3 sf
		(5)	
8dalt	Horizontal distance: $60 = 12\times 3 + 3c$	M1	Allow if seen earlier and used here
	$(c = 8)$	A1	Correct unsimplified **equation** for horizontal distance. Allow $c = -8$ if used correctly later
	$\mathbf{v} = -8\mathbf{i} + 18.0\mathbf{j}$ and conservation of energy $\frac{1}{2}mv^2 - \frac{1}{2}m\left(8^2 + 18^2\right) = -mg\times 10$ $\left(v = 13.9\right)$	M1	For their 8 and 18.0
	Direction $\cos^{-1}\frac{8}{13.9}$	DM1	Use of trig to find a relevant angle Dependent on the previous M1
	Downwards at $54.9°$ to the horizontal $(55°)$ $(35.1°$ to the vertical)	A1	Or equivalent. Direction must be stated or clearly implied by a diagram. 0.959 rads (0.96 rads) Max 3 sf
		(5)	
8e			
	$\frac{-x}{12}\times\frac{18}{12} = -1$, $\left(\frac{-x}{12}\times\frac{d}{12} = -1\right)$	M1	Complete method (with their d) using velocity to find x Could be in scalar product format
	$x = 8$	A1	7.99 or better Allow +/-
	$-8 = 18 - 9.8T$, $\left(-x = d - 9.8T\right)$	DM1	Form equation in T. Signs correct Dependent on the previous M1
	$T = 2.7$ (2.65)	A1	Follows use of 9.8
		(4)	
8e alt	$\tan\alpha = \frac{d}{12}$, $\beta = 90 - \alpha$	M1	Complete method (with their d) to find the direction of motion
	$= 33.64°$	A1	
	$-\tan\beta = \frac{d - 9.8T}{12}$	DM1	Form equation in T. Signs correct. Dependent on the previous M1
	$T = 2.7$ (2.65)	A1	CSO – need to be convinced by any changes of sign. Follows use of 9.8
		(4)	
		[15]	

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