Mark Scheme (Final)

October 2019

Pearson Edexcel IAL Mathematics

Mechanics 2 (WME02/01)

Edexcel Limited. Registered in England and Wales No. 4496750
Registered Office: One90 High Holborn, London WC1V 7BH

Edexcel and BTEC Qualifications

Edexcel and BTEC qualifications are awarded by Pearson, the UK's largest awarding body. We provide a wide range of qualifications including academic, vocational, occupational and specific programmes for employers. For further information visit our qualifications websites at www.edexcel.com or www.btec.co.uk. Alternatively, you can get in touch with us using the details on our contact us page at www.edexcel.com/contactus.

Pearson: helping people progress, everywhere

Pearson aspires to be the world's leading learning company. Our aim is to help everyone progress in their lives through education. We believe in every kind of learning, for all kinds of people, wherever they are in the world. We've been involved in education for over 150 years, and by working across 70 countries, in 100 languages, we have built an international reputation for our commitment to high standards and raising achievement through innovation in education. Find out more about how we can help you and your students at: www.pearson.com/uk

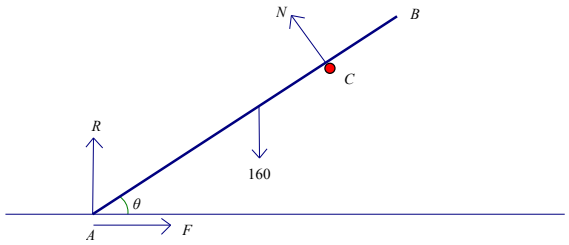
October 2019
Publications Code WME02_01_1910_MS

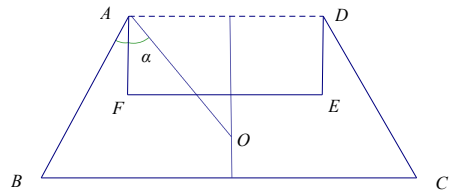
edexcel

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]	

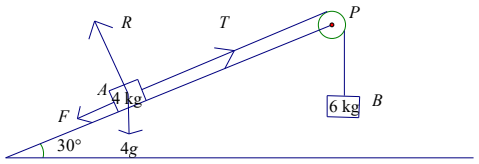
Q	Scheme	Marks	Notes
3a	Use of $\mathbf{a}=\dfrac{\mathrm{d}\mathbf{v}}{\mathrm{d}t}$ $\left(\mathbf{a}=2\mathbf{i}+\dfrac{9}{2}t^{-\frac{1}{2}}\mathbf{j}\right)$	M1	Powers going down by 1 Must be in vector form.
	Use of $\mathbf{F}=2\mathbf{a}$ and $t=4$	M1	For their **a** Must be working in vector 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]	

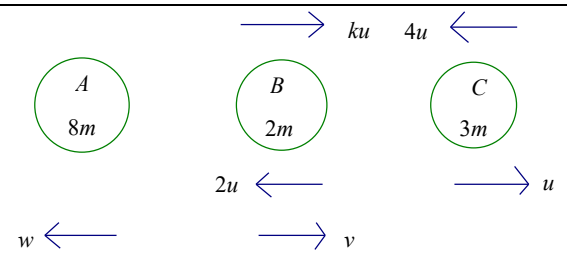
Q	Scheme	Marks	Notes
4a			
	Take moments about A	M1	Or a complete alternative method to form an equation in N. Dimensionally correct. Condone sin/cos confusion.
	$3N = 2\cos\theta \times 160$	A1	Correct unsimplified equation
	$3N = 2\times\frac{3}{4}\times 160 = 240,\quad N = 80$ (newtons) **(Given answer)**	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
	$R + N\cos\theta = 160 \quad \left(R = 160 - 60 = 100\right)$	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]	

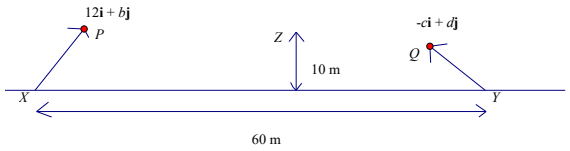
Q	Scheme	Marks	Notes
5a	<table><tr><td></td><td>Mass ratio</td><td>From BC</td></tr><tr><td>Large Δ</td><td>60 (4)</td><td>$4a$</td></tr><tr><td>Small Δ</td><td>15 (1)</td><td>$8a$</td></tr><tr><td>rectangle</td><td>15 (1)</td><td>$4.5a$</td></tr><tr><td>T</td><td>30 (2)</td><td>$\bar{y}$</td></tr></table>	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.
	$\alpha = \tan^{-1}\left(\frac{\frac{5}{2}a}{6a - \bar{y}}\right)$	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

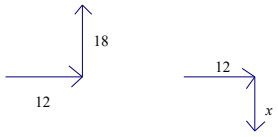
5balt 1	$\bar{x} = 5a$ from B	B1	Or equivalent. Seen or implied Might be seen in (a) but needs to be used here.
	Correct method to find all 3 sides of a triangle containing θ (or two sides of a right angled triangle containing θ)	M1	e.g.: $BO^2 = (5a)^2 + \left(\frac{7a}{4}\right)^2 = \frac{449}{16}a^2, AB^2 = \frac{169}{4}a^2$ $AO^2 = \left(\frac{5a}{2}\right)^2 + \left(6a - \frac{7a}{4}\right)^2 = \frac{389}{16}a^2$
	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 $\frac{1}{2}mv^2 - \frac{1}{2}m\left(8^2 + 18^2\right) = -mg\times 10$ $(v = 13.9)$	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 +/-
	$-8 = 18 - 9.8T$, $(-x = d - 9.8T)$	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]	