Pearson Edexcel

Mark Scheme (Results)

January 2023

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

1a	Equation of motion	M1	Dimensionally correct. Condone sign error.
	$F - R = 1500a$	A1	Correct unsimplified equation in *F* or *P*
	Use of $P = Fv$: $\left(\frac{30\,000}{20} - R = 1500 \times 0.6\right)$	M1	Must be trying to use 30 kW but condone error in zeros
	$R = 600$	A1	Correct answer only
		4	
1b	Equation of motion	M1	Dimensionally correct. Need all relevant terms. Condone sign errors and sin/cos confusion. Allow with *F*.
	$\frac{30\,000}{V} - 1500g \times \frac{1}{8} - 500 = -1500 \times 0.2$	A1 A1	Unsimplified equation with *F* substituted and at most one error Correct unsimplified equation with *F* substituted. If *F* is never substituted, A0A0
	$V = 14.7 \quad (15)$	A1	3 sf or 2 sf
		4	
		(8)	
2	1st equation e.g. Equation for change in KE	M1	Dimensionally correct. Must be subtracting but condone sign error.
	$\frac{1}{2} \times 0.5\left(x^2 + y^2 - \left(5^2 + 3^2\right)\right) = 22$ $\left(x^2 + y^2 = 122\right) \ \left(1^2 + (2\lambda + 3)^2 = 122\right)$	A1	Correct unsimplified equation seen or implied (They might have used impulse-momentum first and done some work before substituting *x* and *y*.)
	2nd equation e.g. Impulse-momentum equation	M1	Dimensionally correct. Must be subtracting but condone sign error.
	$0.5(x\mathbf{i} + y\mathbf{j}) - 0.5(5\mathbf{i} + 3\mathbf{j}) = (-2\mathbf{i} + \lambda\mathbf{j})$ $\left((x-5)\mathbf{i} + (y-3)\mathbf{j} = -4\mathbf{i} + 2\lambda\mathbf{j}\right)$	A1	Correct unsimplified equation
	NB: epen has M1A1A1 for the final 3 marks but this should be marked DM1DM1A1		
	Form a quadratic equation in λ	DM1	e.g. $1^2 + (3 + 2\lambda)^2 = 122$ Dependent on the 2 preceding M marks
	Solve for 2 values of λ	DM1	e.g. solve $4\lambda^2 + 12\lambda - 112 = 0$ or $(3 + 2\lambda)^2 = 121$ Dependent on the preceding M1
	$\Rightarrow \lambda = 4 \quad \text{or} \quad \lambda = -7$	A1	Correct only and no errors seen (watch out for $x = -1$ used)
alt	Form a quadratic in *y*	DM1	e.g. $1 + y^2 = 122 \quad \left(y^2 = 121\right)$ Dependent on the 2 preceding M marks
	Solve for 2 values of *y* and use these to obtain 2 values of λ	DM1	Dependent on the preceding M1
	$\Rightarrow \lambda = 4 \quad \text{or} \quad \lambda = -7$	A1	
		7	

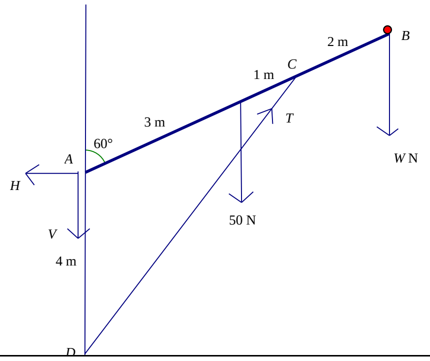
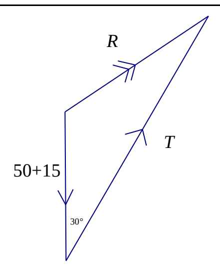
<table>
<tr><td>3a</td><td><table><tr><td></td><td>area</td><td>distance from AE</td></tr><tr><td>rectangle</td><td>$48a^2$</td><td>$4a$</td></tr><tr><td>triangle</td><td>$18a^2$</td><td>$8a-2a(=6a)$</td></tr><tr><td>lamina</td><td>$30a^2$</td><td></td></tr></table></td><td>B1

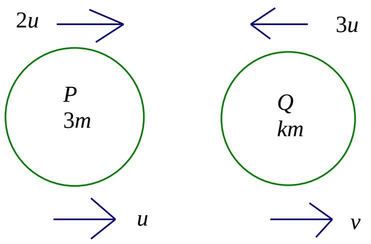
B1</td><td>Mass ratio correct

Distances from AE (or parallel axis) correct</td></tr>
<tr><td></td><td>M(AE)</td><td>M1</td><td>Allow use of a parallel axis. The moments equation should include a but condone if the mass ratio does not include a factor of a^2. Dimensionally correct.</td></tr>
<tr><td></td><td>$48a^2 \times 4a - 18a^2 \times 6a = 30a^2\bar{x}$</td><td>A1</td><td>Correct unsimplified equation for their axis.
Accept as part of a vector equation.</td></tr>
<tr><td></td><td>$\bar{x} = \frac{84}{30}a = \frac{14}{5}a$ *</td><td>A1*</td><td>Obtain given answer from correct working (including correct use of a)</td></tr>
<tr><td></td><td></td><td></td><td>If they take moments about BD they get $d = 5.2a$ Allow B1B1M1A1A0 if they get this far.</td></tr>
<tr><td></td><td></td><td>5</td><td></td></tr>
<tr><td>3b</td><td>Find trig ratio of a relevant angle</td><td>M1</td><td>Correct use of trig.</td></tr>
<tr><td></td><td>$\tan\theta° = \frac{3a}{2.8a}$</td><td>A1</td><td>Correct equation for the required angle.
(DO NOT ISW: If they obtain 47 and then use 90 – 47 = 43 they score M1A0A0)</td></tr>
<tr><td></td><td>$\theta = 47$</td><td>A1</td><td>The Q asks for a whole number of degrees.
0.82 radians scores M1A1A0</td></tr>
<tr><td></td><td></td><td>3</td><td></td></tr>
<tr><td></td><td></td><td>(8)</td><td></td></tr>
</table>

4a	Use $t=2$ and $3t^2+2t=t^3+kt$ $(12+4=8+2k)$	M1	Allow verification.
	$k=4$ *	A1*	Obtain given answer from correct working. Verification requires a clear conclusion.
		2	
4b	Use of $\mathbf{a}=\frac{\mathrm{d}\mathbf{v}}{\mathrm{d}t}$	M1	Differentiate the vector **v** Majority of powers going down
	$\mathbf{a}=(6t+2)\mathbf{i}+(3t^2+4)\mathbf{j}$	A1	Correct only
	Use $\lvert\mathbf{F}\rvert=m\lvert\mathbf{a}\rvert$	DM1	Correct use of Pythagoras and N2L Dependent on the preceding M1
	$\lvert\mathbf{F}\rvert=1.5\times\sqrt{14^2+16^2}=3\sqrt{113}$	A1	Or $\frac{3}{2}\sqrt{452}$ or 32 or better (31.89….)
		4	
4c	Use of $\mathbf{r}=\int\mathbf{v}\,\mathrm{d}t$	M1	Majority of powers going up
	$\mathbf{r}=\left(t^3+t^2(+A)\right)\mathbf{i}+\left(\frac{1}{4}t^4+\frac{4}{2}t^2(+B)\right)\mathbf{j}$	A1	Allow without constant of integration
	Correct use of $\mathbf{r}=3\mathbf{i}+4\mathbf{j}$ when $t=0$ to find r when $t=2$	DM1	$\left(\mathbf{r}=\left(t^3+t^2+3\right)\mathbf{i}+\left(\frac{1}{4}t^4+\frac{4}{2}t^2+4\right)\mathbf{j}\right)$ Dependent on the preceding M1 Use of $\mathbf{r}=-3\mathbf{i}-4\mathbf{j}$ is M0
	$\mathbf{r}=15\mathbf{i}+16\mathbf{j}$	A1	Correct answer only. Accept column vector
		4	
		(10)	

5a	Use of $F_{max} = \mu R$: $F_{max} = \frac{2}{7} \times 1.5g\cos\theta$	M1	$(3.87...)$ Condone trig confusion. Trig substitution not required. Allow M1 if there is a clear statement for F_{max} "correct" and then used in a calculation including the gain in GPE
	Use of $\text{WD} = 2.5F_{max}$	M1	Trig substitution not required. M0 if they have included the gain in GPE
			If the method for F is incorrect but involves the use of μ to obtain F and then they use the "work done" formula correctly allow M0M1
	$\text{WD} = 9.69 \quad (9.7)(\text{J})$	A1	3 sf or 2 sf not $\frac{126}{13}$
		3	
5b	Work-energy equation	M1	The Q asks for work-energy. Need all terms and dimensionally correct. Condone sign errors and sin / cos confusion
	If their answer to (a) included the GPE then it must be used for the total work done here to score the M1		
	$\frac{1}{2} \times 1.5U^2 = WD + 1.5 \times 9.8 \times 2.5 \times \sin\theta$	A1ft A1ft	Unsimplified equation with at most one error. Correct unsimplified equation Follow their WD against friction
	$U = 5.64 \quad (5.6)$	A1	3 sf or 2 sf
		4	
5c	Work-energy equation for A to A	M1	The Q asks for work-energy. Need all terms and dimensionally correct.
	$\frac{1}{2} \times 1.5v^2 = \frac{1}{2} \times 1.5U^2 - 2WD$	A1ft	Correct unsimplified equation. Follow their WD against friction and their U
	$v = 2.43(2.4)(\text{m s}^{-1})$	A1	3 sf or 2 sf
		3	
5c alt	Work-energy equation for B to A	M1	The Q asks for work-energy. Need all terms and dimensionally correct.
	$\frac{1}{2} \times 1.5v^2 = 1.5 \times 9.8 \times 2.5 \times \sin\theta - WD$	A1ft	Correct unsimplified equation. Follow their WD
	$v = 2.43(2.4)(\text{m s}^{-1})$	A1	3 sf or 2 sf
		3	
		(10)	

6a			
	M(A)	M1	Or equivalent method to form an equation in W only. Equation(s) must be dimensionally correct and contain all relevant terms. Condone sin / cos confusion and sign error(s)
	$50\times 3\cos 30° + W\times 6\cos 30° = 60\sqrt{3}\times 4\sin 30°$	A1 A1	Unsimplified equation with at most one error. Correct unsimplified equation
	$W = 15$ *	A1*	Correct answer only
		4	
6b	First equation e.g. Resolve vertically	M1	Or resolve parallel to pole
	$(\pm)V + 50 + 15 = T\cos 30°$ $(V = 25)$	A1	Or: $P + 50\cos 60° + 15\cos 60° = 60\sqrt{3}\times\frac{\sqrt{3}}{2}$
	Second equation e.g. Resolve horizontally	M1	Or resolve perpendicular to the pole
	$(\pm)H = T\cos 60°\left(= 30\sqrt{3} = 51.96......\right)$	A1	Or: $50\cos 30° + 15\cos 30° = 60\sqrt{3}\cos 60° + Q$
	NB: One of the equations could be a second moments equation		
	$\lvert R\rvert = \sqrt{25^2 + \left(30\sqrt{3}\right)^2}$	DM1	Dependent on the 2 preceding M marks $\left(\sqrt{57.5^2 + 3\times 6.25}\right)$
	$= 5\sqrt{133}\,(57.662.....)$ (N)	A1	58 N or better
		6	Full marks available using $\pm V, \pm H, \pm P, \pm Q$
6b alt	Form vector triangle for the vertical forces, the thrust and the resultant Correct triangle	M1 A1	
	Use cosine rule	M1	
	$R^2 = T^2 + (50+W)^2 - 2T(50+W)\cos 30°$	A1	Correct unsimplified equation
	$R^2 = \left(60\sqrt{3}\right)^2 + (65)^2 - 2\times 60\sqrt{3}\times 65\cos 30°$	DM1	Substitute values and solve for $\lvert R\rvert$
	$\lvert R\rvert = 5\sqrt{133}\,(57.662.....)$ (N)	A1	58 N or better
		6	
		(10)	

7a			
	Use CLM	M1	Need all terms and dimensionally correct. Condone sign errors. Might see them using equal (and opposite) impulses.
	$6mu - 3kmu = 3mu + kmv \quad ((3-3k)u = kv)$	A1	Correct unsimplified equation
	$\Rightarrow v = \dfrac{(3-3k)}{k}u \quad *$	A1*	Obtain **given answer** from full and correct working
		3	
7b	Use of Impulse = change in momentum	M1	Must be subtracting. Can be for either particle.
	$\lvert I_Q \rvert = \lvert I_P \rvert = \lvert 3mu - 3m.2u \rvert = 3mu$ or $\lvert kmv - (-3mku) \rvert = \left\lvert km.\dfrac{3-3k}{k}u + 3mku \right\rvert = 3mu$	A1	Correct only (Do not need to state that $\lvert I_Q \rvert = \lvert I_P \rvert$ if find $\lvert I_P \rvert$)
		2	
7c	Use impact law:	M1	Seen or implied. If stated in (a) must be used here. Must be used correctly but condone sign errors
	$\dfrac{v-u}{5u} = e$ or $\dfrac{3-3k}{k}u - u = 5ue$	A1	Correct unsimplified equation
	NB: the second and third M mark are not dependent on the first M mark		
	Use $v > u$ or $e > 0$ to form an inequality in k	M1	Could use $e \geqslant 0$ followed by $v \neq u$
	Use $e \leqslant 1$ to form an inequality in k	M1	
	$\dfrac{3-3k}{k} > 1$ and $3 - 3k \leqslant 6k \quad \Rightarrow \dfrac{1}{3} \leqslant k < \dfrac{3}{4}$	A1	Correct answer only.
		5	
		(10)	

8a	Condone use of θ or a mixture of θ and α throughout but final answer should be in one variable.		
	Equation for horizontal distance	M1	Complete method using *suvat.* Condone sine / cosine confusion
	$x = u\cos\alpha\, t$	A1	Correct only
	Equation for vertical distance	M1	Complete method using *suvat.* Condone sine / cosine confusion and sign error
	$y = u\sin\alpha\, t - \frac{1}{2}gt^2$	A1	Correct only
	$t = \frac{x}{u\cos\alpha} \Rightarrow$ $y = u\sin\alpha.\frac{x}{u\cos\alpha} - \frac{g}{2}\left(\frac{x}{u\cos\alpha}\right)^2$	DM1	Substitute for *t* to obtain *y* in terms of *x* and α Dependent on the 2 preceding M marks
	$\Rightarrow y = x\tan\alpha - \frac{gx^2}{2u^2}\left(1+\tan^2\alpha\right)$ *	A1*	Obtain **given answer** from full and correct working. Need some evidence for the final step. $\frac{1}{\cos^2\alpha} = 1+\tan^2\alpha$ is not sufficient.
		6	
8b	Conservation of energy:	M1	Method specified in the question. Need all terms and dimensionally correct. Condone sign errors
	$\frac{1}{2}m\times 25^2 = \frac{1}{2}mU^2 + mg\times 20$	A1	Correct unsimplified equation
	$U = 15.3\ (15)$	A1	3 sf or 2 sf only
		3	
8c	Use part (a) or work from first principles to form an equation in $\tan\theta$	M1	$\left(-20 = 30\tan\theta - \frac{9.8\times 900}{2U^2}\left(1+\tan^2\theta\right)\right)$
	Obtain $18.9\tan^2\theta - 30\tan\theta - 1.07 = 0$ $\left(\frac{4410}{233}\tan^2\theta - 30\tan\theta - \frac{250}{233} = 0\right)$	A1ft	Or 3 term equivalent Follow their *U* Can be implied by a correct final answer
	$\Rightarrow \theta = 58.3°$ or $58°$	A1	3 sf or 2 sf only
		3	
		(12)	