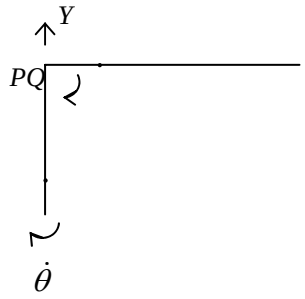
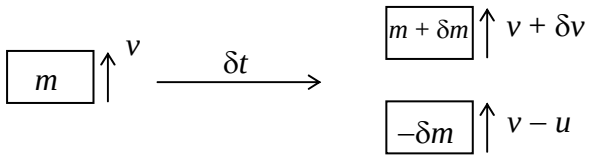
Question Number	Scheme	Marks
1. (*a*)	$\begin{pmatrix}12\\-4\\6\end{pmatrix} + \begin{pmatrix}0\\-3\\2\end{pmatrix} + \mathbf{F}_3 = \mathbf{0} \Rightarrow \mathbf{F}_3 = \begin{pmatrix}-12\\7\\-8\end{pmatrix}$ N	M1 A1 (2)
(*b*)	$\mathbf{G} = \begin{pmatrix}2\\-3\\0\end{pmatrix} \times \begin{pmatrix}12\\-4\\6\end{pmatrix} + \begin{pmatrix}1\\1\\1\end{pmatrix} \times \begin{pmatrix}0\\-3\\2\end{pmatrix} + \begin{pmatrix}2\\0\\-1\end{pmatrix} \times \begin{pmatrix}-12\\7\\-8\end{pmatrix}$	M1
	$= \begin{pmatrix}-18\\-12\\28\end{pmatrix} + \begin{pmatrix}5\\-2\\-3\end{pmatrix} + \begin{pmatrix}7\\28\\14\end{pmatrix}$	A2, 1,0 f.t
	$= \begin{pmatrix}-6\\14\\39\end{pmatrix} \Rightarrow \lvert\mathbf{G}\rvert = \sqrt{(6^2 + 14^2 + 39^2)} \approx 41.9$ Nm	M1 A1 (5)
		(7 marks)
2. (*a*)	$\mathbf{AB} = 8\mathbf{i} - 4\mathbf{j} + 12\mathbf{k}$	
	$8\mathbf{i} - 4\mathbf{j} + 12\mathbf{k} = \frac{1}{2} \times \mathbf{a} \times 4^2 \Rightarrow \mathbf{a} = \mathbf{i} - \frac{1}{2}\mathbf{j} + \frac{3}{2}\mathbf{k}$	M1 A1 ft
	$(12\mathbf{i} - 4\mathbf{j} + 6\mathbf{k}) + \mathbf{F}_2 = 2(\mathbf{i} - \frac{1}{2}\mathbf{j} + \frac{3}{2}\mathbf{k})$	M1
	$\Rightarrow \mathbf{F}_2 = (-10\mathbf{i} + 3\mathbf{j} - 3\mathbf{k})$N	A1 (5)
(*b*)	Work done = $(\mathbf{F}_1 + \mathbf{F}_2).\mathbf{AB}$	
	$= (2\mathbf{i} - \mathbf{j} + 3\mathrm{k}).(8\mathbf{i} - 4\mathbf{j} + 12\mathbf{k})$	M1
	$= 16 + 4 + 36 = 56$ J	M1 A1 (3)
		(8 marks)

Question Number		Scheme	Marks
3.	(*a*)	$I_{PQ} = \frac{4}{3} m (3a)^2 = 12\, ma^2$	M1 A1 (2)
	(*b*)	 Energy: $\frac{1}{2} \times 12\, ma^2 \times \dot{\theta}^2 = mg \times 3a$	M1 A1 ft
		$\Rightarrow \dot{\theta} = \sqrt{\left(\frac{g}{2a}\right)}$ (*)	A1 (3)
	(c)	$R(\uparrow)$: $Y - mg = m \times 3a\dot{\theta}^2$	M1 A1
		$Y = mg + m \times 3a \times \frac{g}{2a} = \frac{5}{2}\, mg$	M1 A1 (4)
			(9 marks)
4.	(*a*)	$I_C = \frac{1}{2} mr^2 + m(\frac{1}{2} r)^2 = \frac{3}{4} mr^2$	M1 A1
		M(*C*): $\frac{3}{4} mr^2 \ddot{\theta} = -mg \frac{r}{2} \sin\theta$	M1 A1 ft
		$\sin\theta \approx \theta \Rightarrow \ddot{\theta} \approx -\frac{2g}{3r}\theta$ approx. SHM	M1 A1 (6)
	(*b*)	Period $= 2\pi\sqrt{\frac{3r}{2g}} = \pi\sqrt{\frac{6r}{g}}$ (*)	A1 (1)
	(*c*)	$\dot{\theta}_{\max} = \omega\alpha \Rightarrow \frac{2}{3r}\sqrt{\frac{gr}{54}} = \sqrt{\frac{2g}{3r}}\,\alpha$	M1 A1
		$\Rightarrow \alpha = \frac{1}{9}^{c}$	A1 (3)
			(10 marks)
Alt		$mg \times \frac{1}{2} r(1 - \cos\alpha) = \frac{1}{2}(\frac{3}{4} mr^2)\left(\frac{gr}{54}\right)\left(\frac{2}{3r}\right)^2$	M1 A1
		$\cos\alpha = \frac{161}{162}$, $\alpha = 6.4°$ (AWRT) or 0.11^{c} (AWRT)	A1

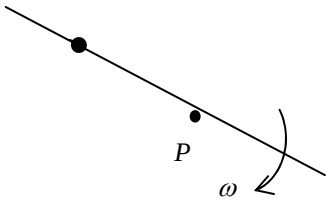
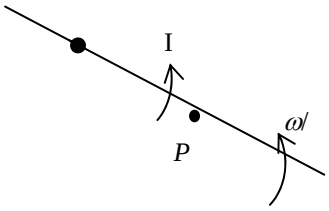
(ft = follow through mark)

Question Number	Scheme	Marks
5. (*a*)		
	$(m+\delta m)(v+\delta m)+(-\delta m)(v-u)-mv=-mg\delta t$	M1 A2 (–1ee)
	$mv+m\delta v+v\delta m-v\delta m+u\delta m-mv=-mg\delta t$	
	$m\dfrac{\mathrm{d}v}{\mathrm{d}t}+u\dfrac{\mathrm{d}m}{\mathrm{d}t}=-mg$	A1
	$m=M(1-kt)\Rightarrow\dfrac{\mathrm{d}m}{\mathrm{d}t}=-kM$	B1
	$M(1-kt)\dfrac{\mathrm{d}v}{\mathrm{d}t}+u(-kM)=-M(1-kt)g$	M1
	$\dfrac{\mathrm{d}v}{\mathrm{d}t}=\dfrac{ku}{1-kt}-g$ (*)	A1 (7)
(*b*)	$v=\displaystyle\int_0^{\frac{1}{3}k}\frac{ku}{1-kt}-g\,\mathrm{d}t$	M1
	$=\left[-u\ln(1-kt)-gt\right]_0^{\frac{1}{3}k}$	A1
	$u\ln\left(\frac{3}{2}\right)-\dfrac{g}{3k}$	A1 (3)
		(10 marks)

(ft = follow through mark)

Question Number	Scheme	Marks
6. (*a*)	Aux equ. $m^2 + 2m + 2 = 0$	
	$\Rightarrow \quad m = -1 \pm \mathbf{i}$	M1 A1
	G. soln.: $\mathbf{r} = e^{-t}(\mathbf{A}\cos t + \mathbf{B}\sin t)$	A1 ft
	$t = 0, \mathbf{r} = \mathbf{i} \Rightarrow \mathbf{A} = \mathbf{i}$	M1 A1
	$\dot{\mathbf{r}} = -e^{-t}(\mathbf{A}\cos t + \mathbf{B}\sin t) + e^{-t}(-\mathbf{A}\sin t + \mathbf{B}\cos t)$	M1
	$t = 0, \dot{\mathbf{r}} = (-\mathbf{i} + \mathbf{j}) \quad \Rightarrow \quad -\mathbf{i} + \mathbf{j} = -\mathbf{i} + \mathbf{B} \Rightarrow \mathbf{B} = \mathbf{j}$	M1
	$\therefore \mathbf{r} = e^{-t}(\cos t\,\mathbf{i} + \sin t\,\mathbf{j})$	A1 (8)
(*b*)	$\dot{\mathbf{r}} = -e^{-t}(\cos t\,\mathbf{i} + \sin t\,\mathbf{j}) + e^{-t}(-\sin t\,\mathbf{i} + \cos t\,\mathbf{j})$	M1
	$= e^{-t}\{-(\cos t + \sin t)\mathbf{i} + (\cos t - \sin t)\mathbf{j}\}$	
	Speed $= e^{-t}\sqrt{\{(\cos t + \sin t)^2 + (\cos t - \sin t)^2\}}$	M1 A1
	$= e^{-t}\sqrt{\{1 + 2\cos t \sin t + 1 - 2\cos t \sin t\}}$	M1
	$= e^{-t}\sqrt{2}$ (*)	A1 (5)
(c)	Loss of KE $= \frac{1}{2} \times 2 \times 2(1 - e^{-2})$	M1
	$= 2\left(1 - \frac{1}{e^2}\right) \quad (\approx 1.73$ (AWRT))	A1 (2)
		(15 marks)

(cso = correct solution only)

Question Number	Scheme	Marks
7. (*a*)	$I = \frac{1}{2}ma^2 + m(3a)^2 + \frac{1}{2}ma^2 + m(5a)^2$,	M1 A1 A1
	$\frac{1}{3}(3m)(4a)^2 + 3ma^2$	M1 A1
	$= 54\,ma^2$ (*)	A1 (6)
	$\frac{1}{2}\times 54ma^2\times\omega^2 = mg\times\frac{5a}{2} + 3mg\times\frac{a}{2} - mg\times\frac{3a}{2}$	M1 A2, 1, 0
	$\Rightarrow \omega = \sqrt{\frac{5g}{54a}} = \frac{1}{3}\sqrt{\frac{5g}{6a}}$	M1 A1
	$3a\times I = 54ma^2\left[\frac{1}{2}\sqrt{\frac{5g}{54a}} - \left(-\sqrt{\frac{5g}{54a}}\right)\right]$	M1 A2, 1, 0 ft
	$I = \frac{54ma^2}{3a}\times\frac{3}{2}\sqrt{\frac{5g}{54a}}$	
	$= \frac{54ma^2}{3a}\times\frac{3}{2}\times\frac{1}{3}\sqrt{\frac{5g}{6a}}$	
	$= 9m\sqrt{\frac{5ga}{6}}$	M1 A1 (10)
		(16 marks)

(cso = correct solution only; ft = follow through mark)