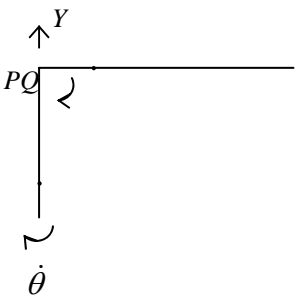
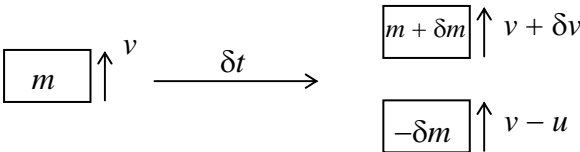


Question Number	Scheme	Marks
1.	<p>(a) $\begin{pmatrix} 12 \\ -4 \\ 6 \end{pmatrix} + \begin{pmatrix} 0 \\ -3 \\ 2 \end{pmatrix} + \mathbf{F}_3 = \mathbf{0} \Rightarrow \mathbf{F}_3 = \begin{pmatrix} -12 \\ 7 \\ -8 \end{pmatrix} \text{N}$</p> <p>(b) $\mathbf{G} = \begin{pmatrix} 2 \\ -3 \\ 0 \end{pmatrix}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

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

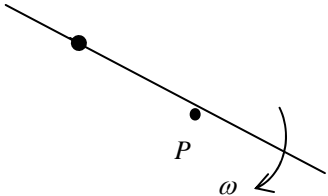
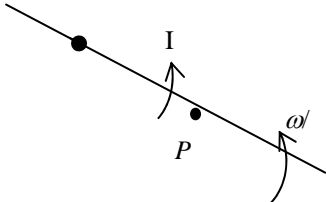
(ft = follow through mark)

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

(ft = follow through mark)

Question Number	Scheme	Marks
6. (a)	Aux equ. $m^2 + 2m + 2 = 0$	
	$\Rightarrow m = -1 \pm i$	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
	$t = 0, \dot{\mathbf{r}} = (-\mathbf{i} + \mathbf{j}) \Rightarrow -\mathbf{i} + \mathbf{j} = -\mathbf{i} + \mathbf{B} \Rightarrow \mathbf{B} = \mathbf{j}$	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
	$= 2(1 - \frac{1}{e^2}) \quad (\approx 1.73 \text{ (AWRT)})$	A1 (2)

(cso = correct solution only)

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

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