

Question Number	Scheme	Marks
1.	<p>Work done by force = $\begin{pmatrix} 1 \\ 2 \\ -2 \end{pmatrix} \cdot \mathbf{AB}$</p> <p>Attempt at equating work done to KE</p> $\begin{pmatrix} 1 \\ 2 \\ -2 \end{pmatrix} \cdot \begin{pmatrix} \lambda \\ 2\lambda \\ 0 \end{pmatrix} \text{ or } \begin{pmatrix} 1 \\ 2 \\ -2 \end{pmatrix} \cdot \begin{pmatrix} x-2 \\ y+2 \\ z+3 \end{pmatrix} = \frac{1}{2}(0.1)5^2$ <p>Solving for λ ($\lambda = 0.25$) or forming sufficient equations in x, y [e.g $x + 2y = -0.75$, $y + 2 = 2(x - 2)$]</p> <p>Method to find OB</p> $[\mathbf{OB} = \begin{pmatrix} 2 \\ -2 \\ -3 \end{pmatrix} + \lambda \begin{pmatrix} 1 \\ 2 \\ 0 \end{pmatrix} \text{ or solving for } x, y]$ <p>OB = $2\frac{1}{4}\mathbf{i} - 1\frac{1}{2}\mathbf{j} - 3\mathbf{k}$ any form</p>	<p>M1</p> <p>M1</p> <p>A1</p> <p>M1</p> <p>M1</p> <p>A1</p> <p style="text-align: right;">(6 marks)</p>
Alt.	<p>Non-vector approach:</p> <p>$\mathbf{F} \cos \theta = ma$ applied; $[a = 10\sqrt{5}]$</p> <p>Method to find “s”: $5^2 = 2(10\sqrt{5})s$ $[s = \frac{\sqrt{5}}{4}]$</p> <p>Finding λ M1</p> <p>Method to find OB M1 A1</p>	<p>M1</p> <p>M1 A1</p> <p>M1</p> <p>M1 A1</p>

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<p>2. (a)</p>	<p><i>Integrating factor approach:</i></p> $IF = e^{\int 1 dt} = e^t$ <p>Multiplying through $\Rightarrow \frac{d}{dt} (\mathbf{r}e^t) = (\mathbf{i} - \mathbf{j}) e^{-t}$</p> <p>Integrating $\Rightarrow \mathbf{r} e^t = -(\mathbf{i} - \mathbf{j}) e^{-t} (+ \mathbf{c})$</p> <p>Using $\mathbf{r} = \mathbf{0}, t = 0$ to find \mathbf{c} [$\mathbf{c} = \mathbf{i} - \mathbf{j}$]</p> $\Rightarrow \mathbf{r} = -(\mathbf{i} - \mathbf{j}) e^{-2t} + (\mathbf{i} - \mathbf{j}) e^{-t}$	<p>B1</p> <p>M1A1</p> <p>M1 A1 ft</p> <p>M1</p> <p>A1 (7)</p>
<p>(b)</p>	<p>Writing $\mathbf{r} = f(t)\mathbf{i} + g(t)\mathbf{j}$ or $x = f(t), y = g(t)$ and attempt to eliminate t</p> $y = -x$	<p>M1</p> <p>A1 (2)</p> <p>(9 marks)</p>
<p>Alt. (a)</p>	<p>AE $m + 1 = 0 \Rightarrow \mathbf{r} = \mathbf{A}e^{-t}$ [Form of PI: $\mathbf{r} = \mathbf{B}e^{-2t}$]</p> <p>Equation for PI: $-2 e^{-2t} \mathbf{B} + \mathbf{B}e^{-2t} = (\mathbf{i} - \mathbf{j})e^{-2t}$</p> $\mathbf{B} = -(\mathbf{i} - \mathbf{j})$ <p>General Solution: $\mathbf{r} = \mathbf{A}e^{-t} + (-\mathbf{i} + \mathbf{j}) e^{-2t}$</p> <p>Using $\mathbf{r} = \mathbf{0}, t = 0$ to find \mathbf{A}</p> $\mathbf{r} = (\mathbf{i} - \mathbf{j})e^{-t} + (-\mathbf{i} + \mathbf{j})e^{-2t}$	<p>B1</p> <p>M1 A1</p> <p>A1 ft</p> <p>M1</p> <p>M1</p> <p>A1 (7)</p>

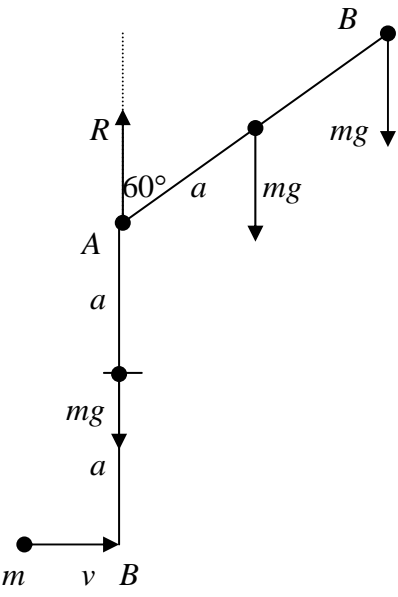
(ft = follow through mark)

Question Number	Scheme	Marks
3. (a)	$\mathbf{R} = \begin{pmatrix} 4 \\ -2 \\ 0 \end{pmatrix} + \begin{pmatrix} 4 \\ 2 \\ 0 \end{pmatrix} + \begin{pmatrix} 0 \\ -2 \\ 1 \end{pmatrix} + \begin{pmatrix} 0 \\ 2 \\ 1 \end{pmatrix} = \begin{pmatrix} 8 \\ 0 \\ 2 \end{pmatrix} \quad \text{or} \quad 8\mathbf{i} + 2\mathbf{k}$	M1 A1 (2)
(b)	<p>Finding one of $\begin{pmatrix} 3 \\ 0 \\ 0 \end{pmatrix} \times \begin{pmatrix} 4 \\ -2 \\ 0 \end{pmatrix}$, $\begin{pmatrix} 3 \\ 4 \\ 0 \end{pmatrix} \times \begin{pmatrix} 4 \\ 2 \\ 0 \end{pmatrix}$, $\begin{pmatrix} 0 \\ 0 \\ 3 \end{pmatrix} \times \begin{pmatrix} 0 \\ -2 \\ 1 \end{pmatrix}$, $\begin{pmatrix} 0 \\ 4 \\ 3 \end{pmatrix} \times \begin{pmatrix} 0 \\ 2 \\ 1 \end{pmatrix}$</p> $= \begin{pmatrix} 0 \\ 0 \\ -6 \end{pmatrix}, \begin{pmatrix} 0 \\ 0 \\ -10 \end{pmatrix}, \begin{pmatrix} 6 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} -2 \\ 0 \\ 0 \end{pmatrix}$ <p>[A1 one correct, A2 at least three correct]</p> <p>Resultant = $\begin{pmatrix} 4 \\ 0 \\ -16 \end{pmatrix}$ any form</p>	M1 A2, 1, 0 M1 A1 (5)
(c)	$\mathbf{F} = -8\mathbf{i} - 2\mathbf{k}$	B1ft (1)
(d)	<p>For equilibrium $\mathbf{r} \times \begin{pmatrix} -8 \\ 0 \\ -2 \end{pmatrix} = -\begin{pmatrix} 4 \\ 0 \\ -16 \end{pmatrix}$ or equivalent</p> $\mathbf{PX} = \begin{pmatrix} 0 \\ \lambda \\ 0 \end{pmatrix} \Rightarrow \mathbf{r} \times \begin{pmatrix} -8 \\ 0 \\ -2 \end{pmatrix} = \begin{pmatrix} -2\lambda \\ 0 \\ 8\lambda \end{pmatrix}$ <p>Finding λ ; $PX = 2.$</p>	M1 M1 A1 ft M1; A1 (5) (13 marks)

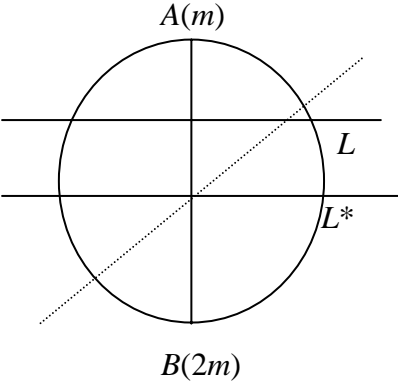
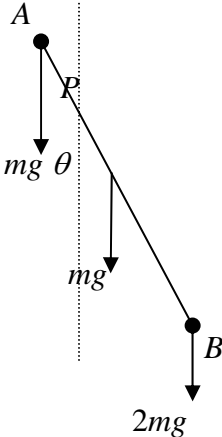
(ft = follow through mark)

Question Number	Scheme	Marks
<p>4. (a)</p> <p>(b)</p>	$(m + \delta m)(v + \delta v) + (-\delta m)(v - U) - mv = -kv \delta t$ $\Rightarrow m \frac{dv}{dt} + U \frac{dm}{dt} = -kv$ $m = M - \lambda t$ $\Rightarrow (M - \lambda t) \frac{dv}{dt} = \lambda U - kv$ $\Rightarrow \frac{dv}{dt} = \frac{\lambda U - kv}{M - \lambda t} \quad (*)$ <p>Separating variables: $\int \frac{dv}{U - v} = \int \frac{10}{M - 10t} dt$ or equivalent</p> <p>Integrating: $\ln(U - v) = \ln(M - 10t) + c$</p> <p>Using limits correctly: $[\]_v^0 = [\]_t^0$ applied or $t = 0, v = 0$ to find “c”</p> $[c = \ln\left(\frac{U}{M}\right)]$ <p>Complete method to find v</p> $[\ln\left(\frac{U}{U - v}\right) = \ln\left(\frac{M}{M - 10t}\right)]$ $v = \frac{10Ut}{M}$	<p>M1A1A1</p> <p>A1</p> <p>B1</p> <p>M1</p> <p>A1 cso (7)</p> <p>M1</p> <p>M1 A1</p> <p>M1</p> <p>M1</p> <p>A1 (6)</p> <p>(13 marks)</p>

(cso = correct solution only)

Question Number	Scheme	Marks
<p>5. (a)</p> 	<p> $I_A = \left\{ \frac{4}{3} ma^2 + m(2a)^2 \right\}$ $mv(2a) = I_A \omega = \frac{16ma^2}{3} \omega$ $\omega = \frac{3v}{8a} \quad *$ no wrong working seen Gain in PE = $mg3a(1 + \cos 60^\circ)$ Attempt at $\frac{1}{2} I \omega^2 = \text{gain in PE}$ $\frac{1}{2} \left(\frac{16ma^2}{3} \right) \left(\frac{3v}{8a} \right)^2 = mg3a(1 + \cos 60^\circ)$ Finding $v \quad v = \sqrt{12ga}$ </p>	<p>M1 A1 M1 A1ft A1 cso (5) M1 A1 M1 A1 ft M1 A1 (6)</p>
(c)	<p> Acceleration of C of G = $\left(\frac{3}{2} a \omega^2 \right)$ $R - 2mg = m r \omega^2 ; = 2m \left(\frac{3}{2} a \omega^2 \right)$ Substitution of ω and v and finding $R = \dots$ $R = \frac{113}{16} mg$ </p>	<p>B1 M1 A1 M1 A1 (5) (16 marks)</p>

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

Question Number	Scheme	Marks
6 (a)	$(\delta I) = (\rho)2\pi r \delta r \times r^2$ <p>Using $(\rho) = \frac{m}{\pi a^2}$</p> <p>Completion: $I = \frac{2m}{a^2} \left[\frac{r^4}{4} \right]_0^a = \frac{1}{2} ma^2$ (*)</p>  <p>Disc: Use of $\perp r$ axis theorem to find I_{L^*}</p> $I_{L^*} = \frac{1}{2} \left(\frac{1}{2} ma^2 \right) = \frac{1}{4} ma^2$ <p>Use of parallel axis theorem</p> $I_L = \frac{1}{4} ma^2 + m \left(\frac{a}{2} \right)^2 = \frac{1}{2} ma^2$ <p>For loaded disc: $I = \frac{1}{2} ma^2 + m \left(\frac{a}{2} \right)^2 + 2m \left(\frac{3a}{2} \right)^2 = \frac{21}{4} ma^2$ (*)</p>	<p>M1</p> <p>M1</p> <p>M1 A1 (4)</p> <p>M1</p> <p>A1</p> <p>M1 A1</p> <p>M1 A1 cso (6)</p>
(c)	$I\ddot{\theta} = \left\{ mg \left(\frac{a}{2} \right) \sin \theta - mg \left(\frac{a}{2} \right) \sin \theta - 2mg \left(\frac{3a}{2} \right) \sin \theta \right\}$ <p>[A1 for signs, A1 “terms”]</p> $\left[\frac{21}{4} ma^2 \ddot{\theta} = -3mga \sin \theta \right]$ <p>For small angles $\theta \approx \sin \theta \Rightarrow$</p> $\frac{21}{4} ma^2 \ddot{\theta} = -3mga \theta$ $\ddot{\theta} = -\frac{4g}{7a} \theta$ <p>\Rightarrow SHM with $\omega^2 = \frac{4g}{7a}$</p> <p>Time = $\frac{\pi}{\omega}$; $= \pi \sqrt{\frac{7a}{4g}}$ or $\frac{\pi}{2} \sqrt{\frac{7a}{g}}$</p> 	<p>M1 A1 A1</p> <p>M1</p> <p>A1 ft</p> <p>M1</p> <p>M1; A1 (8)</p> <p>(18 marks)</p>

(cao = correct answer only; ft = follow through mark; (*) indicates final line is given on the paper)