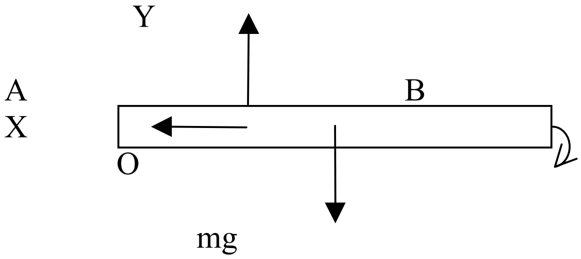
Question Number	Scheme	Marks
1. (*a*)	$\overrightarrow{AB} = (\mathbf{i} - 5\mathbf{j})$ m	B1
	$(14\mathbf{i} + 2\mathbf{j} + 3\mathbf{k})\ (\mathbf{i} - 5\mathbf{j}) = 4$J	M1 A1 (3)
(*b*)	$\frac{1}{2} \times 0.125 \times v^2 = 4$	M1
	$v = 8$ ms^{-1}	A1 ft (2)
		(5 marks)
2. (*a*)	$I = \int_{-a}^{a} \frac{m}{2a} x^2 \, dx$	M1 A1
	$= \frac{ma^2}{3}$	A1 (3)
(*b*)	$I_x = I_y = 2\left(\frac{ma^2}{3} + ma^2\right) = \frac{8ma^2}{3}$	M1 A1
	$\therefore$ by perpendicular axes, $I_z = \frac{16ma^2}{3}$	M1 A1 ft (4)
		(7 marks)
3. (a)	$\mathbf{F} = (3\mathbf{i} + 4\mathbf{j}) + (2\mathbf{i} - \mathbf{j} + \mathbf{k})$	M1
	$= (5\mathbf{i} + 3\mathbf{j} + \mathbf{k})$ N	A1 (2)
(b)	Moment of $\mathbf{F}_1, \mathbf{F}_2$ about 0 $= \begin{pmatrix} 2 \\ 0 \\ 0 \end{pmatrix} \times \begin{pmatrix} 3 \\ 4 \\ 0 \end{pmatrix} + \begin{pmatrix} 1 \\ 1 \\ 0 \end{pmatrix} \times \begin{pmatrix} 2 \\ -1 \\ 1 \end{pmatrix}$	M1
	$= \begin{pmatrix} 0 \\ 0 \\ 8 \end{pmatrix} + \begin{pmatrix} 1 \\ -1 \\ -3 \end{pmatrix}$	A1 A1
	$\therefore \begin{pmatrix} 1 \\ -1 \\ 5 \end{pmatrix} + \mathbf{G} = \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix} \Rightarrow \mathbf{G} = \begin{pmatrix} -1 \\ 1 \\ -5 \end{pmatrix}$ Nm $= (-\mathbf{i} + \mathbf{j} - 5\mathbf{k})$ Nm	M1 A1 (5)
		(7 marks)

Question Number		Scheme	Marks
4.	(*a*)	$I = \left(\frac{1}{2} \times 2ma^2 + 2ma^2\right) + m\left(a\sqrt{2}\right)^2$	M1 A1 A1
		$= 5\ ma^2$	A1
		$ma\sqrt{20ag} \quad = 5ma^2\ \omega$	M1 A1
		$\omega = \sqrt{\frac{4g}{5a}}$	A1 (7)
	(*b*)	PE Gain = 2 mga	A1
		KE Loss $= \frac{1}{2} \times 5ma^2 \times \frac{4g}{5a} = 2mga$	M1 A1 (3)
			(10 marks)
5.	(a)	$I_{AB} = \frac{1}{3}ma^2$	B1
		$I_A = 2 \times \frac{1}{3}ma^2$ (perpendicular axes)	M1 A1 (3)
	(b)	$M(A),\ mg\frac{a}{\sqrt{2}}\sin\theta = -\frac{2}{3}ma^2\ \ddot{\theta}$	M1 A1 A1
		$\ddot{\theta} \approx \frac{-3g}{2a\sqrt{2}}\theta$ for small θ, hence SHM	M1 A1 (5)
	(c)	t = ¼ × period $= \frac{\pi}{2}\sqrt{\frac{2a\sqrt{2}}{3g}}$	M1 A1 (2)
		$\left(= \pi\sqrt{\frac{a\sqrt{2}}{6g}}\right)$	
			(10 marks)

Question Number	Scheme	Marks
6. (*a*)		
	$I_0 = \frac{1}{12}m(AB)^2 + ma^2 = \frac{7}{3}ma^2$	M1 A1
	$mga = \frac{7ma^2}{3}\ddot{\theta}$	M1
	$\ddot{\theta} = \frac{3g}{7a}$	A1 (4)
(*b*)	$\frac{1}{2} \times \frac{7ma^2}{3}\dot{\theta}^2 = mga \Rightarrow a\dot{\theta}^2 = \frac{6g}{7}$	M1 A1 (2)
(*c*)	$R(\downarrow)$: $mg - Y = ma.\frac{3g}{7a} \Rightarrow Y = \frac{4mg}{7}$	M1 A1
	$R(\leftarrow)$: $X = ma\dot{\theta}^2 = \frac{6mg}{7}$	M1
	$R = \frac{mg}{7}\sqrt{4^2 + 6^2} = \frac{mg}{7}\sqrt{52}$	M1 A1 (5)
		(11 marks)

Question Number	Scheme	Marks
7. (*a*)	$m = \frac{4}{3}\pi r^3 \rho \quad (\rho \text{ constant})$	
	$\frac{\mathrm{d}m}{\mathrm{d}t} = \frac{4}{3}\pi\rho \times 3r^2 \frac{\mathrm{d}r}{\mathrm{d}t} = 4\pi\rho r^2 .kr = 3\,km$	M1 A1 (2)
(*b*)	$mg\delta t = (m + \delta m)(v + \delta v) - mv$	M1
	$mg = v\frac{\mathrm{d}m}{\mathrm{d}t} + m\frac{\mathrm{d}v}{\mathrm{d}t}$	A1
	$mg = v \times 3km + m\frac{\mathrm{d}v}{\mathrm{d}t}$	M1
	$g - 3kv = \frac{\mathrm{d}v}{\mathrm{d}t}$	A1 (4)
(*c*)	$\int \mathrm{d}t = \int \frac{\mathrm{d}v}{g - 3kv}$	M1
	$t = -\frac{1}{3k}\ln(g - 3kv)(+c)$	A1
	$t = 0, v = u: \; c = \frac{1}{3k}\ln(g - 3ku)$	A1
	$\frac{g - 3ku}{g - 3kv} = e^{3kt}$ (or equivalent)	M1
	$v = \frac{g}{3k} - \left(\frac{g}{3k} - u\right)e^{-3kt}$	A1 (5)
(d)	As $t \to \infty$, $\mathrm{e}^{-3kt} \to 0$	
	$v \to \frac{g}{3k}$	B1 (1)
		(12 marks)

Question Number	Scheme	Marks
8. (*a*)	$m^2 + 9 = 0 \Rightarrow m = \pm 3\mathbf{i}$	M1
	$r = A \sin 3t + B \cos 3t$	A1
	Let $\left.\begin{array}{l} r = p \sin t\mathbf{i} \\ \dot{r} = p \cos t\mathbf{i} \\ \ddot{r} = -p \sin t\mathbf{i} \end{array}\right\}$	M1 A1
	$-p \sin t\mathbf{i} + 9p \sin t\mathbf{i} = 8 \sin t\mathbf{i}$	M1
	$\Rightarrow p = 1$	A1
	$r = A \sin 3t + B \cos 3t + \sin t\mathbf{i}$	M1
	$t = 0$: $0 = B$	A1
	$\dot{r} = 3A \cos 3t + \cos 3t + \cos t\mathbf{i}$	M1
	$t = 0$: $\mathbf{i} + 3\mathbf{j} = 3A + \mathbf{i} \Rightarrow A = \mathbf{j}$	A1
	$\therefore r = \sin t\mathbf{i} + \sin 3t\mathbf{j}$	A1 (11)
(*b*)	$\sin t = \sin 3t = 0$	M1
	$\Rightarrow t = \pi$	A1 (2)
		(13 marks)