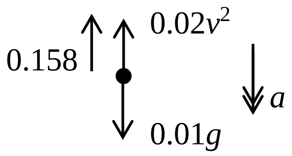
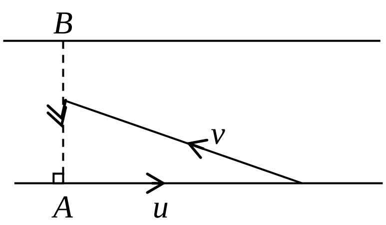
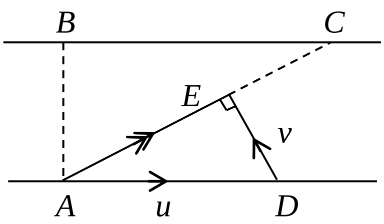
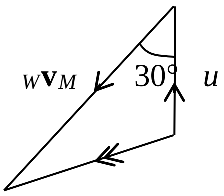
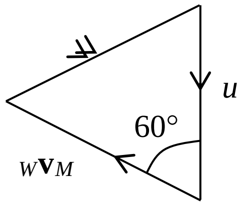
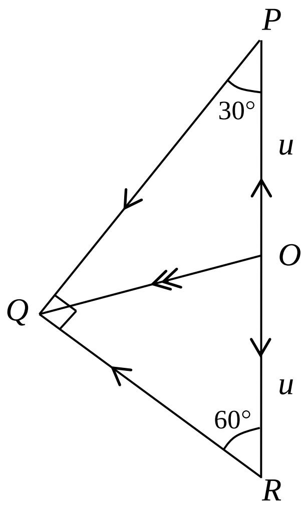
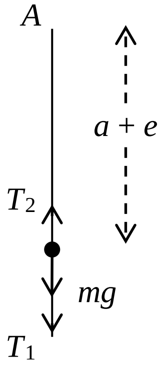
Question Number	Scheme	Marks
1. (*a*)		
	$0.01a = 0.01g - 0.158 - 0.02v^2$	M1
	$a = v\frac{\mathrm{d}v}{\mathrm{d}x}$	M1
	$v\frac{\mathrm{d}v}{\mathrm{d}x} = -2v^2 - 6$ (*)	A1 (3)
(*b*)	$-\int \frac{v\,\mathrm{d}v}{2v^2 + 6} = \int \mathrm{d}x$	M1
	$x = \frac{1}{4}\ln(2v^2 + 6)\ (+\ C)$	A1
	$x = 0,\ v = 0 \Rightarrow C = \frac{1}{4}\ln 206$	A1
	$v = 0 \Rightarrow x = \frac{1}{4}\ln\frac{206}{6} \approx 0.884$ m	M1 A1 (5)
		(8 marks)
2. (*a*)		
	vector triangle attempted	M1
	vector triangle correct	A1
	Explanation for $v > u$ (e.g. 'hypotenuse > other sides')	A1 (3)
(*b*)		
	vector triangle attempted	M1
	right angle correctly placed	A1
	$\frac{BC}{AB} = \frac{AE}{ED}$ Use of similar triangles	M1
	$= \frac{\sqrt{(u^2 - v^2)}}{v}$	M1 A1 (5)
		(8 marks)

((*) indicates final line is given on the paper)

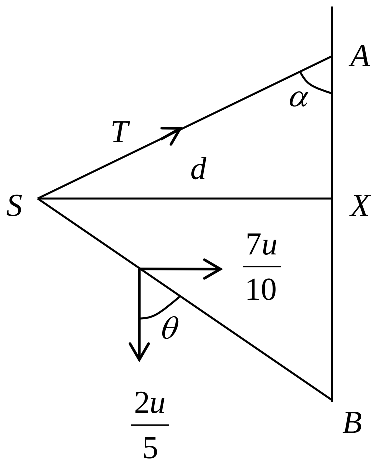
Question Number	Scheme	Marks
3.	$\mathbf{v}_W = {}_W\mathbf{v}_M + \mathbf{v}_M$ (used)	M1
	  (one vector triangle)	M1 A1 A1
	Combining	M1
		
	$P\hat{Q}R = 90°$	M1
	$QR = 2u \sin 30° = u$	M1
	$\Rightarrow$ triangle OQR is equilateral	
	$\Rightarrow OQ = \mathbf{v}_W = u$	A1
	also $\Rightarrow Q\hat{O}R = 60°$	
	Hence direction is from N 60° E	A1 (9)
		(9 marks)

Question Number	Scheme	Marks
4. (*a*)	Extension of string = $7a - 2a\cos\theta - a$	B1
	$= 2a(3 - \cos\theta)$	
	PE = $8mga\cos\theta, + \frac{4mg}{5} \times \frac{4a^2}{2a}(3 - \cos\theta)^2$	B1, M1 A1
	$= 8mga\cos\theta + \frac{8mga}{5}(9 - 6\cos\theta - \cos^2\theta)$	M1
	$= \frac{8mga}{5}(\cos^2\theta - \cos\theta) + C$ (*)	A1 (6)
(*b*)	$\frac{dV}{d\theta} = \frac{8mga}{5}(-2\cos\theta\sin\theta + \sin\theta)$	M1 A1
	$= 0$	M1
	$\Rightarrow \sin\theta = 0$ *or* $\cos\theta = \frac{1}{2}$	
	$\Rightarrow \theta = 0$ or π, *or* $\theta = \frac{\pi}{3}$	A1, A1 (5)
(*c*)	$\frac{d^2V}{d\theta^2} = \frac{8mga}{5}(\cos\theta + 2\sin^2\theta - 2\cos^2\theta)$	M1 A1
	$\theta = 0$ $V'' < 0$ $(= -\frac{8mga}{5})$ unstable	
	$\theta = \pi$ $V'' < 0$ $(= -3 \times \frac{8mga}{5})$ unstable	A1
	$\theta = \frac{\pi}{3}$ $V'' > 0$ $(= 3 \times \frac{8mga}{5})$ stable	A1 (4)
		(15 marks)

((*) indicates final line is given on the paper)

Question Number	Scheme	Marks
5. (*a*)		
	$T_2 = T_1 + mg$	M1
	$\frac{mge}{a} = \frac{mg}{a}(2a - e) + mg$	M1 A1
	$e = \frac{3a}{2} \Rightarrow AE = \frac{5a}{2}$ (*)	A1 A1 cso (5)
(*b*)	$mg + \frac{mg}{a}\left(\frac{1}{2}a - x\right) - \frac{mg}{a}\left(\frac{3}{2}a + x\right) - 2m\sqrt{\frac{g}{a}}\frac{dx}{dt} = m\frac{d^2x}{dt^2}$	M1 A3 (–1eeoo)
	$\Rightarrow \frac{d^2x}{dt^2} + 2k\frac{dx}{dt} + 2k^2x = 0$ (*)	A1 (5)
(*c*)	AE: $m^2 + 2km + 2k^2 = 0$	M1
	$m = -k \pm k\mathrm{i}$	A1
	GS: $x = e^{-kt}(A\cos kt + B\sin kt)$	A1 ft
	$t = 0,\ x = \frac{1}{2}a \Rightarrow A = \frac{1}{2}a$	B1
	$\frac{dx}{dt} = ke^{-kt}(A\cos kt + B\sin kt) + e^{-kt}(-kA\sin kt + kB\cos kt)$	M1
	$t = 0,\ \frac{dx}{dt} = 0 \Rightarrow -kA + kB = 0 \Rightarrow B = A = \frac{1}{2}a$	M1
	$x = \frac{1}{2}a\,e^{-kt}(\cos kt + \sin kt)$	A1 (7)
		(17 marks)

(cso = correct solution only; ft = follow through mark; (*) indicates final line is given on the paper; eeoo = each error or omission)

Question Number	Scheme	Marks
6. (*a*)	No impulse perpendicular to line of centres $\Rightarrow$ velocity perpendicular to line of centres unchanged = $U\cos\alpha$ (*)	B1
	($\swarrow\!\!\nearrow$): CLM $U\sin\alpha = v + w$	M1 A1
	NLI $eU\sin\alpha = w - v$	M1 A1
	$\Rightarrow$ $v = \frac{1}{2}U\sin\alpha(1-e)$	M1 A1 (7)
(*b*)	Component perpendicular to wall = $v\sin\alpha + U\cos\alpha\cos\alpha$	M1
	$= \frac{1}{2}U\sin^2\alpha(1-e) + U\cos^2\alpha$	
	$= \frac{1}{2}U(\sin^2\alpha - e\sin^2\alpha + 2 - 2\sin^2\alpha)$	M1
	$= \frac{1}{2}U[2 - \sin^2\alpha(1+e)]$ (*)	A1
	Component parallel to wall $= U\cos\alpha\sin\alpha - v\cos\alpha$	M1
	$= U\cos\alpha\sin\alpha - \frac{1}{2}U\sin\alpha\cos\alpha(1-e)$	A1
	$= \frac{1}{2}U\cos\alpha\sin\alpha(1+e)$ (*)	A1 (6)
(*c*)	$e = \frac{2}{3}$, $\tan\alpha = \frac{3}{4}$	
	Component perpendicular to wall = $\frac{1}{2}U(2 - \frac{9}{25}\times\frac{5}{3}) = \dfrac{7u}{10}$ Component parallel to wall $= \frac{1}{2}U\times\frac{4}{5}\times\frac{3}{12}\times\frac{5}{3} = \dfrac{2u}{5}$	B1
		
	Distance of A from $X = d\cot\theta = \dfrac{4d}{3}$	B1
	$BX = d\cot\theta$	M1
	$\cot\theta = \dfrac{2u}{5}\times\dfrac{7u}{10} = \dfrac{4}{7}$	A1
	$\therefore$ Total distance $AB = \dfrac{4d}{3} + \dfrac{4d}{7}$	
	$= \dfrac{40d}{21}$	A1 (5)
		(18 marks)

((*) indicates final line is given on the paper)