1		$v_v = 15\sin 60 - 0.9\,g$	B1		3.99	
			M1		Ratio of vert and horiz speeds	
		$\tan\theta = (15\sin 60\text{-}0.9g)/(15\cos 60)$	A1			
		$\theta = 28(.0)^\circ$ above horizontal	A1	[4]		4
2			M1		PE/EE equated	
		$0.3g \times (0.6+e) = 45e^2/(2 \times 0.6)$	A1			
		$37.5e^2 - 3e - 1.8 = 0$	M1		Solves 3 term quadratic equation	
		e = 0.263 m	A1	[4]		4
3	**(i)**	$v = 25\ ms^{-1}$	B1		$\sqrt{(5^2 + 2\,g \times 30)}$	
		$\cos\theta = 5/25$	M1		Forms a relevant trig ratio	
		$\theta = 78.5^\circ$ (with horizontal)	A1	[3]	Ignore above/below	
	(ii)	$30 = gt^2/2$	M1		t = 2.45, award if found in (i)	
		$s = 5 \times 2.45$	M1		5 × time of flight	
		s = 12.2 m	A1	[3]		6
4	**(i)**	$\cos\theta = 0.8$, $\sin\theta = 0.6$ or $\cos\phi = 0.6$, $\sin\phi = 0.8$	B1		Either θ = string angle with vert or ϕ = string angle with horiz	
		$T\cos\theta = 0.2\,g$ or $T\sin\phi = 0.2\,g$	M1		Resolves T vertically	
		T = 2.5 N	A1	[3]		
	(ii)	$2.5\sin\theta$ or $2.5\cos\phi = 0.2\,\omega^2 \times 0.3$	M1		N2L with $acc^n = 2\,\omega^2 \times 0.3$	
		$\omega = 5\ rads^{-1}$	A1	[2]		
	(iii)		M1		N2L with 2 +ve radial forces	
		$R + 2.5\sin\theta = 0.2 \times 1.8^2/0.3$ or $R + 2.5\cos\phi = 0.2 \times 1.8^2/0.3$	A1			
		R = 0.66 N	A1	[3]		8
5	**(i)**	$0.4g = 20e/0.5$	M1		Weight = λ ext/L (e = 0.1)	
		OP = 0.6 m	A1ft	[2]	0.5 + cv(e)	
	(iia)	4 N	B1			
	(iib)	0 N	B1			
	(iic)	$T = 0.4g - 20 \times 0.04/0.5$	M1		Weight(P) – λ ext/L	
		T = 2.4 N	A1	[4]		
	(iii)		M1		PE/KE/EE energy conservation	
		$0.4v^2/2 = 0.4g(0.6\text{-}0.54) - [20(0.1)^2/(2 \times 0.5) - 20(0.04)^2/(2 \times 0.5)]$	A1		EE change (0.168 J)	
		$v = 0.6\ ms^{-1}$	A1	[3]		9

6 (i)	$38OG + 16 \times [0.4 + (0.8 - 3 \times 0.8/4)]$	M1		Table of moments idea	
	$= 54 \times (1.2 - 3 \times 1.2/4)$	A1			
	$OG = 0.174$	A1	[3]	0.17368..	
(iia)	$\mu\ (= 4/16) = 0.25,\ ¼$	B1	[1]		
(iib)	$4(1.2 - -0.4) \prec 16(1.2 - 0.4)\tan\theta$	M1		Moment equation involving toppling	
	$\theta \succ 14.0$ AG	A1	[2]		
(iii)	$\cos\theta = (0.8/\cos\theta)/(1.2 - 0.17368..)$	M1		Uses a ratio of relevant distances	
	$\cos^2\theta = 0.8/1.02631..$	A1		Accept unsimplified version with single trig ratio	
	$\theta = 28(.0)^\circ$	A1	[3]		9
OR	$\tan\theta = (0.4 - 0.17368..)/(0.8\tan\theta)$	A1		Uses a ratio of relevant distances	
	$\tan^2\theta = 0.22631../0.8$	A1		Accept unsimplified version with trig ratio	
	$\theta = 28(.0)^\circ$	A1			
OR	$\sin\theta = [(0.4 - 0.17368.)/\sin\theta]/(1.2 - 0.17368.)$	M1		Uses a ratio of relevant distances	
	$\sin^2\theta = 0.2631../1.02631..$	A1		Accept unsimplified version with single trig ratio	
	$\theta = 28(.0)^\circ$	A1			
7 (i)	$0.2a = -k/(1 - x)$	M1		N2L, single force	
	$a = -5k/(1 - x)$	M1		Attempts $\int$, accept use of dv/dt	
	$\int v\,dv = -5k \int 1/(1 - x)\,dx$				
	$v^2/2 = 5k\ln(1 - x)\ (+c)$	A1			
	$x = 0$, v = 1.2, hence c = 0.72	M1		$[v^2/2]_{1.2}^{0} = [5k\ln(1 - x)]_{0}^{0.55}$	
	$5k\ln(1 - 0.55) + 0.72 = 0$	DM1			
	$k = 0.1803$ AG	A1	6		
(ii)	$0.2v\,dv/dx = 0.2\ g - 0.1803/(1 - x)$	M1		N2L, difference of 2 forces	
	$0.2v^2/2 = 0.2\ gx + 0.\ (1 - x)\ (+c)$	A1		Accept omission of c	
	$0.2v^2/2 = 0.2\ gx\ 0.1 + 0.1803\ \ln(1 - 0.1)$	M1		nb c = 0, so can be omitted/lost	
	$v = 1.35\ \text{ms}^{-1}$	A1	4	1.345	10