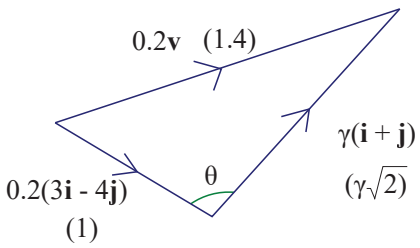
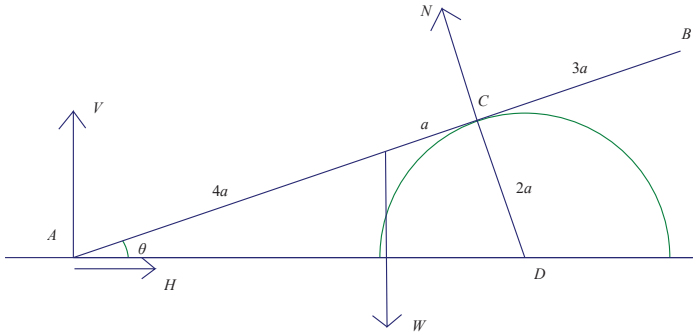
Q	Mark Scheme	Marks	Marking guidance
1 (a)	M(x axis)	M1	Need all terms. Dimensionally consistent. Condone if m missing throughout. Accept as part of a vector equation
	$2m\times(-2)+3m\times 2+4m\times 3k=9m\times\bar{x}$ $\bar{x}=\dfrac{2+12k}{9}$ *	A1*	Obtain given result
		2	
(b)	M(y axis)	M1	Need all terms. Dimensionally consistent. Might be seen as part of a vector equation in (a). It does not score any marks until referred to in part (b). Condone if m missing throughout.
	$2m\times 5+3m\times(-3)+4m\times k=9m\times\bar{y}$ $\left(\bar{y}=\dfrac{1+4k}{9}\right)$	A1	Correct unsimplified equation. Allow if m missing throughout.
	Form and solve equation in k $(2+12k+2+8k=27)$	DM1	Use their $\bar{y}$ and $\bar{x}+2\bar{y}=3$ Dependent on the two preceding M marks
	$k=\dfrac{23}{20}\quad(1.15)$	A1	Correct answer only
		4	
		(6)	

Q	Mark Scheme	Marks	Marking guidance
2	Use of $P = Fv$	M1	Seen or implied e.g. $F = \frac{15000}{16}\left(=937.5\right)$ Condone 15 in place of 15000 or extra zeros on 15000
	Equation of motion	M1	Need all terms. Condone sign errors and sin / cos confusion. Dimensionally consistent.
	$F + 900g\sin\theta - 400 = 900a$	A1	Unsimplified equation in P or their F with at most one error
	$\frac{15000}{16} + 900g \times \frac{1}{12} - 400 = 900a$	A1	Correct unsimplified equation with F and $\sin\theta$ substituted
	$a = 1.41 \quad (1.4) \quad \left(\text{m s}^{-2}\right)$	A1	3sf or 2sf
		(5)	

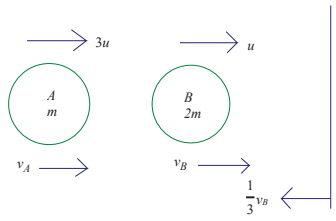
Q	Mark Scheme	Marks	Marking guidance
3.	Use of $\mathbf{I} = m\mathbf{v} - m\mathbf{u}$	M1	Accept equivalent e.g. $\mathbf{I}+m\mathbf{u}= m\mathbf{v}$. Dimensionally correct and must be using subtraction (but could be the wrong way round). The use of 7 in place of the velocity in the impulse momentum equation is M0 unless they recover. **See below**
	$0.2\left(\mathbf{v}-4\mathbf{i}+3\mathbf{j}\right)=\lambda\left(\mathbf{i}+\mathbf{j}\right)$ $\left(\left(x-4\right)\mathbf{i}+\left(y+3\right)\mathbf{j}=5\lambda\mathbf{i}+5\lambda\mathbf{j}\right)$	A1	Correct unsimplified vector equation or pair of separate equations for the **i** and **j** components. Condone column vectors with **i** and **j** included in the components.
	Use of Pythagoras for the speed	M1	Correct use of Pythagoras and 49 for their speed
	$x^2+y^2=49$	A1	Correct unsimplified equation for their x, y
	Form quadratic in x, y or λ and solve for λ	DM1	Dependent on both previous M marks. x^2+ $-(x\ 7)^2=49$ or $(y+7)^2+=y^2\ 49$ or $(5\lambda+4)^2$ $+(5\lambda-=3)^2\ 49$
	$\lambda=\frac{3}{5}$ or $\lambda=-\frac{4}{5}$	A1	Or equivalent
** ** ** ** ** ** **	Special case: Candidates who use 7 as a vector can score a **maximum** of M1A0M1A0 for $1.4^2=+(\lambda\ 0.8)^2+-(\lambda\ 0.6)^2$ or equivalent DM1A0 for forming and solving a quadratic in λ.		This maximum of 3 marks is only available for those candidates who "recover". So, **if all you see** is $\lambda\ \lambda\mathbf{i}+=-\mathbf{j}$ $1.4\quad 0.2\quad 4(\mathbf{i}-3\mathbf{j})$ they score M0M0M0 If they recover to go on to form a "sensible" equation using Pythagoras then they can score the first 2 M marks, and potentially the third M1 as well.
		(6)	
3 alt			
	Form vector triangle	M1	Dimensionally correct. Allow incorrect configuration
	Correct triangle and correct lengths	A1	In speeds or momentum but not a mixture
	Use scalar product to find cosine of angle	M1	Or equivalent method
	$\cos\theta=-\frac{1}{5\sqrt{2}}$	A1	Allow $\pm$
	Form equation in λ $\left(2\lambda^2+.4\lambda-0.96=0\right)$	DM1	e.g. by use of cosine rule Dependent on the first 2 M marks
	$\lambda=\frac{3}{5}$ or $\lambda=-\frac{4}{5}$	A1	Or equivalent
		(6)	

Q	Mark Scheme	Marks	Marking guidance
4 (a)	$\lambda^2+2\lambda-3=0\left(=(\lambda+3)(\lambda-1)\right)$	M1	Set **j** component = 0 and solve for λ
	$\Rightarrow \lambda=1$	A1	Only. Seen or implied. Accept $t=1$
	Use $\mathbf{a}=\dfrac{\mathrm{d}\mathbf{v}}{\mathrm{d}t}$	M1	Attempt derivative of both components with respect to t. Powers going down. Condone errors in dealing with the signs / indices for the square root. The answer must be a vector.
	$=\dfrac{-1}{2\sqrt{5-t}}\mathbf{i}+(2t+2)\mathbf{j}$	A1	Any equivalent form
	$=-\dfrac{1}{4}\mathbf{i}+4\mathbf{j}$	A1	Only. Any equivalent form. ISW if they go on to find the magnitude.
		5	
4 (b)	Use $\mathbf{s}=\int \mathbf{v}\,\mathrm{d}t$	M1	Attempt integral of both components. (M0 if they have assumed that one component is zero) Powers going up. Condone errors in dealing with the signs / indices for the square root.
	$\mathbf{s}=\left(-\dfrac{2}{3}(5-t)^{\frac{3}{2}}(+A)\right)\mathbf{i}+\left(\dfrac{1}{3}t^3+t^2-3t(+B)\right)\mathbf{j}$	A1 A1	Unsimplified expression with error in at most one term Correct unsimplified expression. Allow with no constant(s) of integration
	Use $t=1, \mathbf{s}=-2\mathbf{i}+\mathbf{j}$	DM1	Use of initial condition to find constant(s) of integration. Dependent on the previous M1.
	$\mathbf{s}=\left(-\dfrac{2}{3}(5-T)^{\frac{3}{2}}+\dfrac{10}{3}\right)\mathbf{i}+\left(\dfrac{1}{3}T^3+T^2-3T+\dfrac{8}{3}\right)\mathbf{j}$	A1	Any equivalent form for the position vector
		5	
		(10)	

Q	Mark Scheme	Marks	Marking guidance
			
5 (a)	$AD = \sqrt{(2a)^2 + (5a)^2} = \sqrt{29}a$ *	B1*	Correct use of Pythagoras to show **given answer** from correct working (need a on both sides)
		1	
5 (b)	M(A): $W \times 4a\cos\theta = N \times 5a$	M1	Dimensionally correct equation in a. Allow if a cancelled. Condone sin/cos confusion
	$W \times 4a \times \frac{5}{\sqrt{29}} = N \times 5a$	A1	Correct unsimplified equation. Allow with $\cos\theta$. NB: $5a = \sqrt{29}a\cos\theta$
	$N = \frac{4}{\sqrt{29}}W$ *	A1*	Obtain **given answer** from correct working
		3	
5 (c)	The candidates need to form sufficient equations to solve for k and $\tan\alpha$. There should be two independent equations. Allow M1A1 for the first equation seen, and M1A1 for the second equation. If there are more than 2 equations, award the marks for the equations used to solve for k and $\tan\alpha$. If they stop after forming the equations, allow the marks for the best 2 equations.		
	Resolve vertically	M1	Requires all relevant terms. Condone sin / cos confusion
	$V + N\cos\theta = W \quad \left(V = \frac{9}{29}W\right)$ or $kW\sin\alpha + N\cos\theta = W$	A1	Correct unsimplified equation. Need not substitute for trig.
	Resolve horizontally	M1	Requires all relevant terms. Condone consistent sin / cos confusion
	$H = N\sin\theta\left(=\frac{8}{29}W\right)$ or $kW\cos\alpha = N\sin\theta\left(=\frac{8}{29}W\right)$	A1	Correct unsimplified equation. Need not substitute for trig.
	Possible alternative equation for M1A1 using M(C): $aW\cos\theta + 5aH\sin\theta = 5aV\cos\theta$ or $aW\cos\theta = kW \times 5a\sin(\alpha - \theta)$		
	Use Pythagoras to obtain k: $k^2 = \left(\frac{9}{29}\right)^2 + \left(\frac{8}{29}\right)^2$	DM1	Correct use of perpendicular components. Dependent on the first 2 M marks

	$k = \frac{\sqrt{145}}{29} = \sqrt{\frac{5}{29}}$	A1	Correct only. Any equivalent exact form (ISW but 0.415 with no exact answer seen is A0)
	Use trig to obtain $\tan\alpha$	DM1	Dependent on the first 2 M marks
	$\tan\alpha = \frac{9}{8}$	A1	Correct only. Must be a simplified number. Do not accept answer including W
		8	
5 (c) alt	Resolve parallel to rod	M1	Requires all relevant terms. Condone sin / cos confusion
	$F = W\sin\theta \left(= \frac{2}{\sqrt{29}}W\right)$	A1	Correct unsimplified equation. Need not substitute for trig.
	Resolve perpendicular to rod	M1	Requires all relevant terms. Condone consistent sin / cos confusion
	$E + N = W\cos\theta \quad \left(E = \frac{1}{\sqrt{29}}W\right)$	A1	Correct unsimplified equation. Need not substitute for trig.
	Possible alternative equation for M1A1 using M(C) : $aW\cos\theta + 5aH\sin\theta = 5aV\cos\theta$ or $aW\cos\theta = kW \times 5a\sin(\alpha - \theta)$		
	Use Pythagoras to obtain k	M1	Correct use of Pythagoras
	$k = \frac{1}{\sqrt{29}}\sqrt{1+4} = \sqrt{\frac{5}{29}}$	A1	Correct only
	Use trig to obtain $\tan\alpha$: $\tan(\alpha - \theta) = \frac{1}{2} = \frac{\tan\alpha - \frac{2}{5}}{1 + \frac{2}{5}\tan\alpha}$	DM1	Use of trig to obtain expression in $\tan\alpha$
	$\tan\alpha = \frac{9}{8}$	A1	Correct only
		8	
		(12)	

Q	Mark Scheme	Marks	Marking guidance
6 (a)	M(PV)	M1	Allow use of a parallel axis. Terms dimensionally consistent. Could be seen as part of a vector equation. Condone error(s) in distance(s).
	$a\times 2ka^2+\left(2a+\frac{1}{2}ka\right)2ka^2=\bar{x}\times\left(2ka^2+2ka^2\right)$	A1	Correct unsimplified equation
	$2\bar{x}=a+2a+\frac{1}{2}ka \Rightarrow \bar{x}=\frac{6+k}{4}a$ *	A1*	Obtain **given answer** from correct working
		3	
6 (b)	M(PR)	M1	Allow use of a parallel axis. Terms dimensionally consistent. Could be seen as part of a vector equation in (a) but needs to be used here to score mark(s) in (b). Condone error(s) in distance(s). If working from VU they might assume that c of m of $QRST$ lies on their axis. So long as they say that this is what they have done (e.g. in a table of values) this can score M1A0A0M1A1ftA0.
	$\frac{1}{2}ka\times 2ka^2+a\times 2ka^2=\bar{y}\times 4ka^2$	A1	Correct unsimplified equation
	$\bar{y}=\frac{k+2}{4}a$	A1	Correct answer $(\pm)$ seen or implied Accept distance from $VU=\pm\frac{3k-2}{4}a$ Or distance from TS = $\pm\frac{6-k}{4}a$
	Use angle to form equation in k	M1	Correct use of given ratio. Allow reciprocal
	$\frac{7}{15}=\frac{\bar{y}}{\bar{x}}=\frac{(k+2)a}{4}\times\frac{4}{(6+k)a}$	A1	Correct unsimplified equation using given $\bar{x}$ and their $\bar{y}$ e.g. $\frac{ka-\bar{y}_{VU}}{\bar{x}}$ or $\frac{2a-\bar{y}_{TS}}{\bar{x}}$
	$\Rightarrow k=\frac{3}{2}(=1.5)$	A1	Correct only
		6	
		(9)	

Q	Mark Scheme	Marks	Marking guidance
7 (a)			Check their diagram but remember that the directions used in their equations might not be consistent with the diagram. In this case, ignore their diagram.
	Conservation of momentum	M1	Need all terms. Dimensionally correct. Condone sign errors. Condone *m* missing throughout or *g* present throughout.
	$3mu + 2mu = mv_A + 2mv_B \quad (5u = v_A + 2v_B)$	A1	Correct unsimplified equation. Allow with v_A negative
	Use of NEL	M1	Used the right way round. Condone sign errors
	$v_B - v_A = e(3u - u) \qquad (2ue = v_B - v_A)$	A1	Correct unsimplified equation. Allow with v_A negative. Signs consistent between the two equations.
	Solve for v_A or v_B	DM1	Dependent on two previous M marks
	Obtain $v_B = \frac{5+2e}{3}u$ *	A1*	Obtain **given answer** from correct working
	Obtain $v_A = \frac{5-4e}{3}u$	A1	Or equivalent. v_A must be positive
		7	
7 (b)	Time for *B* to reach the wall $t_B = \frac{d}{2u}$	B1	Seen or implied. Allow $\frac{d \times 3}{(5+2e)u}$
	Speed of *B* after impact with wall $= \frac{2}{3}u$	B1	Seen or implied. Allow $\frac{1}{3}\left(\frac{5+2e}{3}\right)$
	Distance travelled by *A* before *B* hits the wall $= u \times \frac{d}{2u}\left(= \frac{d}{2}\right)$	M1	Substitute $e = \frac{1}{2}$ and use their v_A and their t_b to find distance
	Time to close the gap	M1	Correct formula with their relevant speeds
	$\frac{d}{2} = u \times t + \frac{2u}{3} \times t\left(= \frac{5ut}{3}\right) \quad \left(t = \frac{3d}{10u}\right)$	A1	Correct unsimplified equation
	Total time $= \frac{d}{2u} + \frac{3d}{10u} = \frac{8d}{10u}\left(= \frac{4d}{5u}\right)$	A1	ISW Any equivalent form
		6	
7(b) alt	In time *T*, *A* travels *x* metres $x = uT$ *B* travels *d* metres in *t* sec $d = 2ut$ First B1 *B* travels $d - x$ metres in *t*' sec $d - x = 2ut'/3$ Second B1 and first M1 t + t' = T (d + 3d – 3uT)/2u = T Second M1 and first A1 T = 4d/5u Second A1		Equivalent statement Correct value implied and Distance travelled by *B* after it hits the wall Correct formula for time and Correct unsimplified equation Correct answer
		(13)	

Q	Mark Scheme	Marks	Marking guidance
8 (a)	Normal reaction between P and ramp $(R) = 0.3g\cos\alpha = \left(0.3g \times \frac{24}{25} = 2.82...\right)$	M1	Seen or implied. Condone sin / cos confusion (implied by use of $\frac{7}{25}$)
	Work done against friction $= \frac{1}{5}R \times 15$	M1	Use of $\text{WD} = \mu R \times \text{distance}$ with their R
	$= 8.47(8.5)(\text{J})$	A1	3 sf or 2 sf
		3	
8 (b)	Work-energy equation	M1	All terms required. Dimensionally correct. Condone sign errors.
	$\frac{1}{2} \times 0.3U^2 = \frac{1}{2} \times 0.3 \times 25^2 + (\text{a}) + 0.3 \times g \times (15\sin\alpha)$	A1ft A1ft	Follow their answer to (a) Correct unsimplified equation with at most one error. Correct unsimplified equation
	$U = 27.6 \quad (28)$	A1	3 sf or 2 sf
		4	
8 (c)	Time to ground:	M1	Complete method using *suvat* to form an equation in t
	$-15\sin\alpha = 7t - \frac{1}{2}gt^2$	A1ft	Correct unsimplified equation in t ft their 4.2
	$t = 1.88 \quad (1.9) \quad (\text{s})$	A1	3 sf or 2 sf $\frac{5+\sqrt{67}}{7}$ is A0
		3	
8 (d)	Vertical component of speed	M1	Or use energy to find the speed
	$= \pm(7 - (\text{their } t) \times 9.8) \quad (\pm 11.459....)$	A1ft	or $0.15 \times 625 + .3 \times 9.8 \times \text{their } 4.2 = 0.15v^2$ $(v = 26.59....)$ condone $v = \frac{7\sqrt{67}}{5}$
	Correct use of trig: $\tan\theta° = \frac{\text{their vertical}}{24}$	M1	or $\cos\theta° = \frac{24}{\text{their speed}}$
	$\theta = 25.5\,(26)$	A1	3 sf or 2 sf
		4	
	Reminder: The accuracy penalty for overspecified answers should be applied only once in any question (the first time seen). Similarly for the use of g = 9.81. If they make both of these errors they lose 2 A marks. The penalty applies to the final mark in any part.		
		(14)	