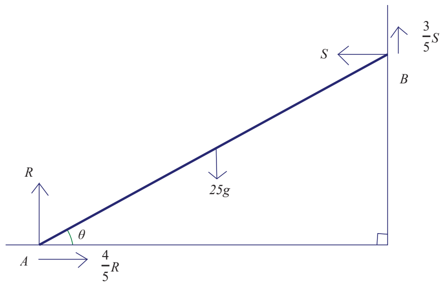
Question Number	Solution	Marks	Notes
1.	$\mathbf{I} = 2[\lambda\mathbf{i} + \lambda\mathbf{j} - 5\mathbf{i} - 3\mathbf{j}]$	M1	Use of $\mathbf{I} = m(\mathbf{v} - \mathbf{u})$
	$= 2(\lambda - 5)\mathbf{i} + 2(\lambda - 3)\mathbf{j}$	A1	Any equivalent form
	$\lvert I \rvert = \sqrt{40} \Rightarrow (\lambda - 5)^2 + (\lambda - 3)^2 = 10$	M1	Correct use of Pythagoras and their impulse to form an equation in λ
	$\lambda^2 - 8\lambda + 12 = 0 \Rightarrow \lambda = 2$ or $\lambda = 6$	DM1	Solve to find both values for λ. Dependent on the 2 preceding M marks
	$\mathbf{I} = -6\mathbf{i} - 2\mathbf{j}$ or $\mathbf{I} = 2\mathbf{i} + 6\mathbf{j}$ $(a = -6, b = -2$ or $a = 2, b = 6)$	A1	And no others
		(5)	
	Alternative working:		
	$\mathbf{I}(= a\mathbf{i} + b\mathbf{j}) = 2(\mathbf{v} - (5\mathbf{i} + 3\mathbf{j}))$	M1A1	
	$\mathbf{v} = \frac{a+10}{2}\mathbf{i} + \frac{b+6}{2}\mathbf{j} \quad \Rightarrow \quad (\Rightarrow a + 10 = b + 6)$		
	$a^2 + b^2 = 40 \Rightarrow b^2 - 4b - 12 = 0$ or $a^2 + 4a - 12 = 0$	M1	Correct use of Pythagoras and impulse to form an equation in a or b Any equivalent form
	$b^2 - 4b - 12 = 0 \quad \Rightarrow b = 6$ or $b = -2$	DM1	
	$\mathbf{I} = -6\mathbf{i} - 2\mathbf{j}$ or $\mathbf{I} = 2\mathbf{i} + 6\mathbf{j}$	A1	Or simplified equivalent
		[5]	

Question Number	Solution	Marks	Notes
2	Driving force $=\frac{3P}{12}$	B1	Use of $P=Fv$ Allow for $\frac{P}{12}$ in second equation if not awarded here
	Motion up the hill $F-R-W\sin\theta=0$	M1	Need all terms. Condone sign errors and sin/cos confusion.
	$\frac{3P}{12}-R-\frac{9000}{15}=0$ $\left(\frac{3P}{12}-R=600\right)$	A1	Correct substituted equation Any equivalent form
	Motion down the hill $F+W\sin\theta-R=\frac{9000}{9.8}\times\frac{9.8}{20}$	M1	Need all terms. Condone sign errors and sin/cos confusion.
	$\frac{P}{12}+\frac{9000}{15}-R=450$ $\left(\frac{P}{12}-R=-150\right)$	A1 A1	Substituted equation with at most one error. Any equivalent form. Correct substituted equation. Any equivalent form.
	Solve for P or R	DM1	Dependent on both preceding M marks
	$\left(\frac{2P}{12}=750\right)\Rightarrow P=4500$	A1	One correct
	$R=525\ (530)$	A1	Both correct
		(9)	
SC1	Misread mass = 9000kg Gives equations $\frac{P}{4}=R+5880$ $\frac{P}{12}=R-1470$ Solutions: $P=44100,\ R=5145$		B1 M1A0 M1A1ftA0 M1A1ftA1ft Total 7/9
SC2	Use of mass = weight = 9000 Gives equations $\frac{P}{4}=R+600$ $\frac{P}{12}=R+3810$ Solutions: $P=-19260,\ R=-5415$		B1 M1A1 M1A1A0 M1A0A0 Total 6/9
		[9]	

Question	Solution	Marks	Notes
3			
	Use of $F = \mu R$	B1	At least once
	Resolve horizontally	M1	Allow with their horizontal friction
	$S = \frac{4}{5}R \quad (S = F_A)$	A1	Correct unsimplified equation
	Resolve vertically	M1	Allow with their vertical friction
	$\frac{3}{5}S + R = 25g \quad F_B + R = 25g$ $\left(\frac{3}{5}S + \frac{5}{4}S = 25g, \quad S = \frac{500}{37}g\right)$	A1	Correct unsimplified equation
	Moments equation	M1	Any moments equation. Need all terms & dimensionally correct
	M(*A*): $25g \times 1.5\cos\theta = S \times 3\sin\theta + \frac{3}{5}S \times 3\cos\theta$ $\left(25g\cos\theta - \frac{6}{5}S\cos\theta = 2S\sin\theta\right)$ M(*B*): $R \times 3\cos\theta = 25g \times 1.5\cos\theta + \frac{4}{5}R \times 3\sin\theta$	A1	Correct unsimplified equation
	M1A1 for first equation, M1A1 for second equation, M1A1 for third equation (i.e. mark in the order in which they appear rather than as listed on the mark scheme). If there are more than 3 equations, mark the 3 used or the best 3 if they go no further. Can also be solved using one resolution and two moments equations. Friction acting in the wrong direction scores A0.		
	$\tan\theta = \left(\frac{25g - \frac{6}{5}S}{2S} = \frac{25 - \frac{600}{37}}{\frac{1000}{37}}\right)$	DM1	Substitute to form equation in $\tan\theta$ only Condone in decimals Dependent on M marks for the equations
	$= \frac{325}{1000}\left(= \frac{13}{40}\right)$	A1	Or exact equivalent (0.325)
		(9)	
SC	It is possible to solve by resolving horizontally or vertically and taking moments about the centre: $1.5\cos\theta \times R = 1.5\cos\theta \times \frac{3}{5}S$ $+ 1.5\sin\theta \times S + 1.5\sin\theta \times \frac{4}{5}R$		M1A1 for a correct resolution M2A2 for a complete sets of equations to solve
		[9]	

<table>
<tr><th>Question Number</th><th>Solution</th><th>Marks</th><th>Notes</th></tr>
<tr><td>4a</td><td>
<table>
<tr><th></th><th>ABCD</th><th>PQRV</th><th>RSTU</th><th>L</th></tr>
<tr><td>Mass ratio</td><td>64</td><td>4</td><td>16</td><td>44</td></tr>
<tr><td>c of m from AD</td><td>4a</td><td>2a</td><td>5a</td><td>(d)</td></tr>
</table>
</td><td>B1

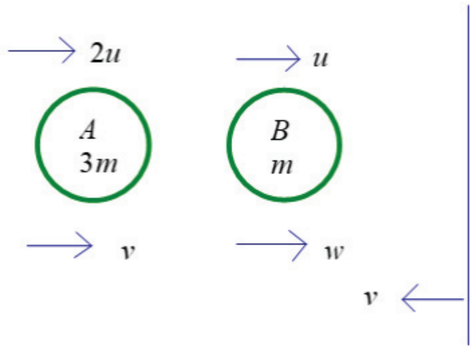
B1</td><td>Correct mass ratios for their split

Correct distances from vertical axis for their split
Must be multiples of a</td></tr>
<tr><td></td><td>M(AD)</td><td>M1</td><td>Moments about AD or a parallel axis. Need all terms and dimensionally consistent.</td></tr>
<tr><td></td><td>$64\times 4a-4\times 2a-16\times 5a=44d$</td><td>A1</td><td>Correct unsimplified equation
Accept as part of a vector equation</td></tr>
<tr><td></td><td>$\Rightarrow d=\frac{168}{44}a=\frac{42}{11}a$ *</td><td>A1*</td><td>Obtain given answer from correct working</td></tr>
<tr><td></td><td></td><td>(5)</td><td></td></tr>
<tr><td>4b</td><td>C of M of L lies at midpt of AC</td><td>B1</td><td>Seen or implied</td></tr>
<tr><td></td><td>M(Mid pt AB)</td><td>M1</td><td>Use of moments to form equation in k.</td></tr>
<tr><td></td><td>$\left(4-\frac{42}{11}\right)aM=4akM$</td><td>A1</td><td>Correct unsimplified equation.
Allow with a not seen</td></tr>
<tr><td></td><td>$k=\frac{1}{22}$</td><td>A1</td><td>0.05 or better (0.0454545…)
Allow with a not seen</td></tr>
<tr><td></td><td></td><td>(4)</td><td></td></tr>
<tr><td>4b alt</td><td>C of M of L lies at midpt of AC</td><td>B1</td><td>Seen or implied by use of $\bar{x}=\bar{y}$ or $\tan 45°=1$</td></tr>
<tr><td></td><td>Find $\bar{x}$ and $\bar{y}$ for system</td><td>M1</td><td></td></tr>
<tr><td></td><td>From AB: $\frac{42}{11}Ma+8akM=(1+k)M\bar{y}$
From BC: $\frac{46}{11}aM=(1+k)M\bar{x}$</td><td>A1</td><td>Correct unsimplified equations in $\bar{x}$ and $\bar{y}$
Allow with a not seen</td></tr>
<tr><td></td><td>$\bar{x}=\bar{y}\Rightarrow\frac{42}{11}+8k=\frac{46}{11}\Rightarrow k=\frac{1}{22}$</td><td>A1</td><td>Allow with a not seen</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>4b alt</td><td>C of M of L lies at midpt of AC</td><td>B1</td><td>Seen or implied in moments equation</td></tr>
<tr><td></td><td>If G is c of m of L then $\tan ABG=\frac{42}{46}$ and take moments about B</td><td>M1</td><td>Complete method for moments about B</td></tr>
<tr><td></td><td>$8a\sin 45°\times kM$
$=\frac{Ma\sqrt{46^2+42^2}}{11}\sin(45°-ABG)$</td><td>A1</td><td>Correct unsimplified equation in k

Allow with a not seen</td></tr>
<tr><td></td><td>$\Rightarrow k=\frac{1}{22}$</td><td>A1</td><td>Allow with a not seen</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>4b alt</td><td>C of M of L lies at midpt of AC</td><td>B1</td><td>Seen or implied in moments equation</td></tr>
</table>

	Take moments about the centre of *ABCD*	M1	
	$M\times\frac{2\sqrt{2}}{11}a = kM\times 4\sqrt{2}a$	A1	Correct unsimplified equation in k Allow with a not seen
	$\Rightarrow k=\frac{1}{22}$	A1	Allow with a not seen
		[9]	
Question Number	Solution	Marks	Notes
5a	$\mathbf{a}=\frac{\mathrm{d}\mathbf{v}}{\mathrm{d}t}$	M1	Differentiate to obtain **a** – powers going down
	$=(6t-9)\mathbf{i}+(2t+1)\mathbf{j}$	A1	differentiation correct
	$=9\mathbf{i}+7\mathbf{j}\ \ (\text{m s}^{-2})$	A1	ISW if go on to find $\lvert\mathbf{a}\rvert$
		(3)	
5b	Instantaneous rest $\Rightarrow \mathbf{v}=0\mathbf{i}+0\mathbf{j}$ $\Rightarrow 3(t-1)(t-2)=0$ and $(t-2)(t+3)=0$	M1	Set $\mathbf{v}=0$ and solve for t (Need **both components** equal to zero)
	$\Rightarrow t=2$	A1	
	$\mathbf{r}=\int \mathbf{v}\mathrm{d}t$	M1	Integrate to obtain **r** – powers going up. Condone if no constant of integration seen.
	$=\left(t^3-\frac{9}{2}t^2+6t\right)\mathbf{i}+\left(\frac{1}{3}t^3+\frac{1}{2}t^2-6t\right)\mathbf{j}$	A1 A1	At most one error Correct integration Allow column vector. Allow A1A0 for correct integration and non-zero constants(s) of integration
	$=2\mathbf{i}-\frac{22}{3}\mathbf{j}$, distance $=\sqrt{2^2+\left(\frac{22}{3}\right)^2}$	DM1	Correct strategy to find the distance, i.e. substitute their value for t and use Pythagoras Dependent on the two preceding M marks
	$=\frac{2\sqrt{130}}{3}=7.60\ \ (\text{m})$	A1	7.6 or better from correct work
		(7)	
		[10]	

Question Number	Solution	Marks	Notes
6a	$R = 6g\cos\alpha$	B1	Correct normal reaction
	Work done $= 15 \times 0.25 \times R$	M1	Correct method with their R
	$= 204\,(\text{J})$	A1	Or 200(J) Accept 21g or better. (20.7692...g) Not $\frac{2646}{13}$
		(3)	
6b	NB The question specifies that the work-energy principle should be used, so solutions based on *suvat* equations are not accepted.		
	Initial KE – GPE lost – WD = final KE	M1	Use of work-energy to form equation in v. Dimensionally correct. Ignore sign errors. Allow WD or their WD
	$\frac{1}{2}\times 6\times 14^2 - 6g\times 15\times\frac{5}{13} - 6g\times 15\times\frac{3}{13} = \frac{1}{2}\times 6v^2$ $\left(3\times 196 - \frac{450g}{13} - \frac{270g}{13} = 3v^2\right)$	A1ft A1ft	Unsimplified equation with at most one error Correct unsimplified equation Follow their WD
	$v = 3.88 \quad (3.9)$	A1	Max 3 sf
	Work-energy equation	M1	Complete method using work-energy to form equation in w. Dimensionally correct. Ignore sign errors.
	$\frac{1}{2}\times 6\times 14^2 - 6g\times 15\times\frac{3}{13} = \frac{1}{2}\times 6w^2$ or $\frac{1}{2}mw^2 = \frac{1}{2}mv^2 + mg\times\frac{15\times 5}{13}$	A1ft	Correct unsimplified equation Follow their WD or their v
	$w = 11.3 \quad (11)$	A1	Max 3 sf
		(7)	
		[10]	

Question Number	Solution	Marks	Notes
7			
7a	KE gain = final KE – initial KE	M1	KE equation for *B*. Allow for change in KE
	$\frac{48}{25}mu^2 = \frac{1}{2}mw^2 - \frac{1}{2}mu^2$	A1	Correct unsimplified equation to find *w*
	$\left(w^2 = \frac{121}{25}u^2, \quad w = \frac{11}{5}u\right)$		
	CLM: $3m \times 2u + mu = 3mv + mw$	M1	All terms required. Condone sign errors
	$\left(7mu = 3mv + \frac{11}{5}mu\right)$ $\left(v = \frac{8}{5}u\right)$	A1	Correct unsimplified equation in *v* and *w* or their *w*
	Impact law:	M1	Used correctly
	$w - v = e(2u - u)$	A1	Correct unsimplified equation in *v* and *w* or their *v* and *w*
	Solve for *e*	DM1	Dependent on the preceding M marks
	$\frac{3}{5}u = eu, \quad e = \frac{3}{5}$	A1	
		(8)	
7b	Impact law: $fw=v$	M1	Condone sign error
	$f = \frac{8}{11}$	A1	0.73 or better Final answer must be positive
		(2)	
		[10]	

Question Number	Solution	Marks	Notes
8a	Horizontal component: $p = 8$	B1	
	Vertical component: $-12 = q - 3g$	M1	Complete method to find q using *suvat*. Condone sign errors.
	$q = 17.4$	A1	17 or better
	Speed $= \sqrt{8^2 + 17.4^2}$	M1	Use of Pythagoras to find speed using their velocity. Independent M mark
	$= 19.2 \quad (19)\left(\text{m s}^{-1}\right)$	A1	3 sf or 2 sf
		(5)	
8b	Use of Pythagoras to find vertical component	M1	
	vertical component $= \pm 6$	A1	Seen or implied Accept without +/-
	$-6 = 6 - 9.8T$	DM1	Complete method using *suvat* to find required time Dependent on the previous M1
	$T = 1.22 \quad (1.2)$	A1	3 sf or 2 sf. Not $\frac{60}{49}$
		(4)	
8b alt	Use *suvat* and Pythagoras to form an equation in t	M1	Or an inequality
	$8^2 + (17.4 - gt)^2 = 100$	A1	Correct unsimplified equation for t Accept inequality
	Solve for T	DM1	Complete method to obtain T Dependent on the previous M1
	$T = 1.22 \quad (1.2)$	A1	3 sf or 2 sf. Not $\frac{60}{49}$
		(4)	
8c	Velocity perpendicular $\Rightarrow$ vertical component $= \frac{2}{3} \times 8$	M1	Complete method to find vertical component of velocity at B
	$= \frac{16}{3}$	A1	
	$(-12)^2 = \left(\frac{16}{3}\right)^2 - 2g(-h)$	DM1	Complete method to find the required vertical distance using their vertical component of the velocity Dependent on the previous M1
	$h = 5.90 \quad (5.9)(\text{m})$	A1	Max 3 sf
		(4)	
8c alt	$\begin{pmatrix} 8 \\ 17.4 - gt \end{pmatrix} \cdot \begin{pmatrix} 8 \\ -12 \end{pmatrix} = 0$ and time $= 3 - t$	M1	Complete method to find the time from B to A
	Time $= 3 - 1.23... = 1.768...$	A1	
	$s = vt - \frac{1}{2}gt^2 = 12t - 4.9t^2$	DM1	Complete method to find the required vertical distance using their time Dependent on the previous M1
	$s = 5.9$ (m)	A1	Max 3 sf