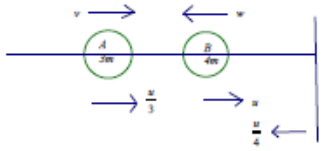
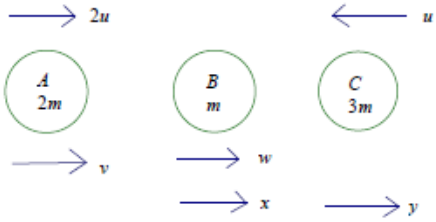
Mark Scheme

Q1.

Question Number	Scheme	Marks	Notes
a			
	Impulse on A: $8mu = 3mv - 3m \times \frac{u}{3}$	M1	Terms dimensionally correct. Must be subtracting. Condone sign errors. Must be combining correct mass and speed
	$v = 3u$	A1	
	Impulse on B: $8mu = 4mu + 4mw$	M1	Terms dimensionally correct. Condone sign errors Or use CLM: $9mu - 4mw = 3m\frac{u}{3} + 4mu$ Must be combining correct mass and speed
	$w = u$	A1	
	Impact law: $u - \frac{u}{3} = e(3u + u)$	M1	Used the right way round. Condone sign errors
	$e = \frac{1}{6}$	A1	
	Award first 4 marks in order on the scheme. Marks for CLM equation, if used, should be given in place of whichever impulse equation is not used.		
	Watch out for sign errors in the equations If they have $3mv + 4mw$ in the equation for CLM they might combine this with $w = -u$ to obtain a "correct" answer. The sign error in the CLM is due to a misread so the maximum score for this double sign error is 4/6		
		[6]	

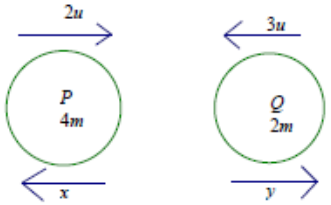
b	Gap when B hits wall $=\frac{2d}{3}$	B1	Or find distances from the first impact: $s_A=\frac{d}{3}+\frac{u}{3}t$ and $s_B=d-\frac{u}{4}t$
	Speed of rebound from wall $=\frac{u}{4}$	B1	Allow + / -
	Time to close gap $=\frac{\frac{2d}{3}}{\frac{u}{3}+\frac{u}{4}}$	M1	
	$=\frac{8d}{7u}$	A1	
	Distance from wall $=\frac{8d}{7u}\times\frac{u}{4}$	DM1	Dependent on the preceding M1
	$=\frac{2d}{7}$	A1 [6]	
balt	Time for A $\frac{d-x}{u/3}$ $\left(=\frac{3d-3x}{u}\right)$	B1	
	Speed of rebound from wall $=\frac{u}{4}$	B1	
	Time for $B=\frac{d}{u}+\frac{x}{u/4}$	M1	
	$\left(=\frac{d+4x}{u}\right)$	A1	
	$3d-3x=d+4x$	DM1	Solve for x Dependent on the preceding M1
	$x=\frac{2d}{7}$	A1 [6]	
		[12]	

Q2.

Q	Solution	Mark	Notes
a			
	Use CLM: $4mu = 2mv + mw$	M1	Need all terms. Condone sign errors. Dimensionally correct but allow with m cancelled
	$(4u = 2v + w)$	A1	Correct unsimplified. Signs correct for their v, w
	Use Impact law	M1	Used the right way round. Condone sign errors.
	$w - v = 2ue$	A1	Correct unsimplified. Signs consistent with CLM equation.
	$\Rightarrow 4u = 2(w - 2ue) + w$	DM1	Solve for v or w. Dependent on previous 2 M marks
	$3w = 4u + 4ue, \quad w = \frac{4}{3}u(1+e)$ *	A1*	Obtain **given result** from correct working
	$v = \frac{2}{3}u(2-e)$	A1	Or equivalent. Must be positive
		(7)	

b	$2 > e$ so A moving towards centre	B1	Correct statement about direction of travel for A or B
	$mw - 3mu = mx + 3my$ $y - x = e\left(u + \frac{4u}{3} + \frac{4eu}{3}\right)$	M1	Use CLM and impact law correctly to form simultaneous equations in x and y.
	$\frac{4}{3}eu - \frac{5}{3}u = x + 3y$ $3y - 3x = e(7u + 4ue)$	A1	Both equations correct unsimplified
	$4x = \frac{4}{3}ue - \frac{5}{3}u - 7ue - 4ue^2$	DM1	Solve for x
	$x = -\frac{5}{12}u - \frac{17}{12}ue - ue^2$	A1	
	$e > 0, u > 0$ so B moving towards centre from opposite direction, hence they collide.*	A1*	Obtain **given answer** from correct working
		(6)	
	Alternative for last 3 marks;		
	C moving towards centre implies B moving towards centre, so collision. C moving away from centre , so $y > 0$,	DM1	Consider direction of C
	$x = w - 3u - 3y = -\frac{8u}{3} + \frac{4eu}{3} - 3y$		
	$= -\frac{u}{3}(8 - 4e) - 3y$	A1	
	< 0 because $e \leq 1$ and $y > 0$ hence B moving towards centre from opposite direction, and they will collide.*	A1*	Obtain **given answer** from correct working
		[13]	

Q3.

Question	Scheme	Mark	Notes
a			
	Equation for CLM	M1	Dimensionally correct. All terms required. Condone sign errors.
	$8mu-6mu=2my-4mx$ $(u=y-2x)$	A1	Correct unsimplified equation
	Equation for kinetic energy ($\frac{1}{2}$ or 2 must be used)	M1	Dimensionally correct. Correct masses paired with correct velocities. All terms required. No sign errors. Condone 2 on the wrong side.
	$2mx^2+my^2=\frac{1}{2}\left(2m\times4u^2+m\times9u^2\right)$ $\left(17u^2=4x^2+2y^2\right)$	A1	Correct unsimplified equation
	Solve for y: $17u^2=2y^2+(y-u)^2$ $\Rightarrow 3y^2-2yu-16u^2=0$	DM1	Some working must be shown to obtain the quadratic in y (and u). Dependent on the preceding M marks $\left((3y-8u)(y+2u)=0\right)$
	$\Rightarrow y=\frac{8}{3}u$ *	A1*	Obtain given answer from correct working
		[6]	

b	Use of Impact Law: $x+y=e\times5u$	M1	Condone sign errors but must be used the right way round.
	$e=\dfrac{\frac{1}{2}\left(\frac{8}{3}u-u\right)+\frac{8}{3}u}{5u}$	A1	Correct unsimplified equation. $\left(x=\frac{5u}{6}\right)$
	$=\dfrac{7}{10}$	A1	Correct only
		[3]	
c	Velocity of Q after impact $=f\times\frac{8}{3}u$	B1	Allow $\pm$
	No collision if $f\times\frac{8}{3}u\le\frac{5}{6}u$ i.e. speed of $P\ge$ speed of Q	M1	Correct inequality with their values Accept strict inequality. Dimensionally correct.
	$\Rightarrow 0<f\le\frac{5}{16}$	A1	Both ends required. $\left(0<f\le0.3125\right)$
		[3]	
d	Use of $I=\pm2m\left(y-\left(-\frac{1}{4}y\right)\right)$	M1	Subtraction seen or implied with *their* $\frac{1}{4}y$ Requires correct mass Requires correct impact law
	$\lvert I\rvert=\dfrac{20}{3}mu$	A1	Or equivalent. Must be positive $6.7mu$ or better Condone $-\frac{20}{3}mu\rightarrow\frac{20}{3}mu$ with no explanation
		[2]	
		(14)	

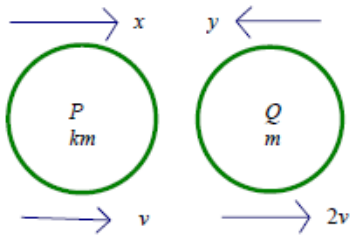
Q4.

Q	Solution	Mark	Notes
a	$\updownarrow T-(15g+25g)=(15+25)\times 0.2$	M1	All terms required. Must be in T only. Condone sign errors
		A1	Correct unsimplified equation in T
	$T=400$ (N)	A1	Must be positive
		(3)	
b	$\updownarrow 12g-R=-0.1\times 12$	M1	All terms required. Condone sign errors
		A1	Correct unsimplified equation in R only. Allow + R at this stage
	$R=119$ (N) (120)	A1	Must be positive
		(3)	
		[6]	

Q5.

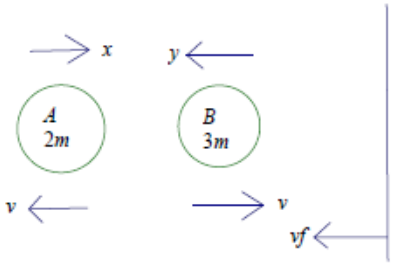
Q	Solution	Mark	Notes
	Use of $s = ut + \frac{1}{2}at^2$	M1	Form equation in u and a. **N.B.** Marks are available if they use two other unknowns, rather than u and a
	$20 = 3u + \frac{9a}{2}$	A1	Correct unsimplified equation
	Use of *suvat*	M1	Form second equation in u and a. **N.B.** Marks are available if they use the same two other unknowns, rather than u and a
	$10 = (u + 3a) + \frac{a}{2}$ or $30 = 4u + 8a$	A1	Correct unsimplified equation
	$30 = 3u + \frac{21a}{2} \Rightarrow 10 = 6a,\ a = \frac{5}{3}$	M1	Solve for u or a **Or** for one of their unknowns.
	$u = \frac{25}{6}$	A1	u and a both correct **or** both their unknowns correct. Accept equivalent forms. 1.7, 4.2 or better
	Use of $v = u + at$, $20 = \frac{25}{6} + \frac{5}{3}t$	M1	Complete method using *suvat* to find t. Correct unsimplified for their u, a.
	$t = 9.5$ (s)	A1	cao
		[8]	

Q6.

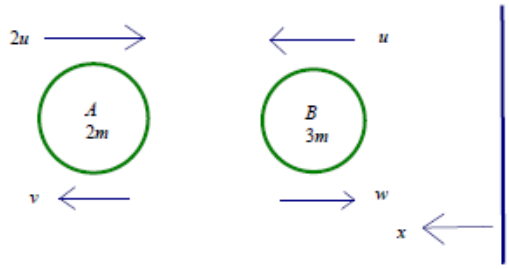
a			
	They need to form three equations, one of which must be the impact law. Mark them as you see them, so the first M1A1 on epen is available for the first equation seen, the second M1A1is for the second equation seen etc. If there are more than 3 equations, mark this as multiple attempts and all the marks for the equations actually used in the solution. **Treat the second and third A marks as follow through marks if they are substituting values they have already found.**		
	Use of $I = mv - mu$ for P or Q	M1	Dimensionally correct. Need all terms. M0 if m is missing on RHS
	$5mv = m\left(2v-\left(-y\right)\right)$ or $-5mv = km\left(v-x\right)$	A1	Correct unsimplified equation
	Use of CLM or second use of $I = mv - mu$	M1	Dimensionally correct. Need all terms. In CLM allow cancelled m and extra common factor (eg g) throughout
	$kmx - my = kmv + 2mv$ $(kx - y = kv + 2v)$ or $-5mv = km\left(v-x\right)$	A1	Correct unsimplified equation
	Use of impact law	M1	Must be used with e on the correct side. Condone sign errors
	$2v - v = \frac{1}{5}\left(x+y\right)$	A1	Correct unsimplified equation
	$y = 3v$	A1	cao
	$x = 2v$	A1	cao
	$k = 5$	A1	cao
		[9]	

b	KE lost	M1	Dimensionally correct. Accept change in KE. Not scored until they form the complete substituted equation.
	$= \frac{1}{2}\times km\left(x^2 - v^2\right) + \frac{1}{2}\times m\left(y^2 - 4v^2\right)$ $\left(= \frac{15}{2}mv^2 + \frac{5}{2}mv^2\right)$	A1ft	Correct unsimplified expression. Follow their x, y, k Condone sign change without explanation. $\left(\text{KE before} = 14.5mv^2\right.$ $\left.\text{KE after} = 4.5mv^2\right)$
	$= 10mv^2$	A1	Only
		[3]	
		(12)	

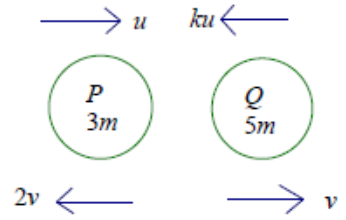
Q7.

Q	Solution	Mark	Guidance
a			
	$5mv = 2m\left(v-\left(-x\right)\right)$	M1	Use of $I = mv - mu$
	$x = \frac{3v}{2}$	A1	Seen or implied
	$5mv = 3m\left(v-\left(-y\right)\right)$ or $2mx - 3my = 3mv - 2mv$	M1	Use of $I = mv - mu$ or use of CLM
	$y = \frac{2v}{3}$	A1	Seen or implied
	$2v = e\left(\frac{3v}{2} + \frac{2v}{3}\right)$	M1	Correct use of impact law (not necessarily with values in terms of v) **Allow $v - v$ on LHS**
	$e = \frac{12}{13}$	A1	0.92 or better
		(6)	
b	Speed of B after collision with wall $= vf$	B1	Seen or implied
	$2\times\frac{1}{2}\times 3m\left(y^2-\left(vf\right)^2\right) = \frac{1}{2}\times 2m\left(x^2-v^2\right)$	M1	Use KE to form an equation in f. Condone use of change in KE rather than loss **Condone 2 on wrong side**
	$3\left(\frac{4}{9}-f^2\right) = \left(\frac{9}{4}-1\right)$	A1	Correct unsimplified equation for f
	$\left(f^2 = \frac{1}{36}\right)\quad f = \frac{1}{6}$	A1	cao NB: $\frac{\sqrt{31}}{6}$ comes from inconsistent subtraction.
		(4)	
		[10]	

Q8.

a			
	Use of CLM	M1	Need all terms, dimensionally correct. Condone sign errors.
	$4mu-3mu=3mw-2mv$ $(u=3w-2v)$	A1	Correct unsimplified equation
	Use of impact law	M1	Used correctly. Condone sign errors
	$v+w=3eu$	A1	Correct unsimplified equation. Signs consistent with their CLM equation
	$\begin{cases} u=3w-2v \\ 6eu=2w+2v \end{cases}$	DM1	Dependent on both preceding M marks. Solve to find speed of B.
	$\Rightarrow 5w=u+6eu, \quad w=\frac{1}{5}u(1+6e)$ *	A1*	Obtain **given answer** from correct working
		[6]	
b	$v=3eu-w=\frac{u}{5}(9e-1)$	B1	Check their diagram / directions and allow $v=\frac{u}{5}(1-9e)$ if correct for their working. Any equivalent form. Must be seen or used in (b)
	$x=\frac{u}{7}(1+6e)$	B1	Seen or implied. Accept $\pm$
	Second collision if $\frac{u}{7}(1+6e)>\frac{u}{5}(9e-1)$	M1	Correct inequality to find the upper limit for e, using their v and x
	$(0<)e<\frac{4}{11}$	A1	Final answer. Or equivalent Do not need to mention the lower limit, but if they do it must be stated correctly (strict inequality).
		[4]	

Q9.

Q	Scheme	M	Notes
a			
	Impulse-momentum equation for P:	M1	Correct use of $I = mv - mu$: Evidence of subtraction (can go straight to + you do not need to see $-(-)$) and dimensionally correct. Use of $3m$
	$15mv = 3m(2v-(-u))$	A1	Correct unsimplified equation
	$9mv = 3mu \Rightarrow u = 3v$ *	A1*	Obtain **given answer** from correct working
a alt	Impulse-momentum equation for Q and CLM:	M1	CLM dimensionally consistent, all 4 terms, condone sign error(s). Correct use of $I = mv - mu$: Evidence of subtraction and dimensionally correct. Use of $5m$
	$15mv = 5m(v+ku)$, $k = 2\frac{v}{u}$ and substitute into CLM: $3mu - 5m\frac{2v}{u}u = 5mv - 6mv$	A1	Correct unsimplified equation in u and v
	$\Rightarrow u = 3v$ *	A1*	Obtain **given answer** from correct working
		(3)	

b	Impulse-momentum equation for Q or use of CLM:	M1	Dimensionally consistent. All relevant terms.
	$15mv = 5m(v-(-ku))$ or $3mu - 5mku = 5mv - 6mv$	A1	Correct unsimplified equation
	$10v = 5ku = 15kv \Rightarrow k = \frac{2}{3}$	A1	Correct only. Accept 0.67 or better
		(3)	
c	Use of impact law:	M1	Must be used the right way round. Condone sign error(s)
	$2v + v = e(u+ku)$ $\left(= e \times 3v \times \frac{5}{3}\right)$	A1ft	Correct unsimplified equation. Follow their k.
	$\Rightarrow e = \frac{3}{5}$	A1	Correct only
		(3)	

d	Change in KE	M1	Allow for gain rather than loss. Dimensionally correct. Need to use all 4 terms and to be using the correct values for mass.
	$\frac{1}{2}\times 3m\left(u^2-(2v)^2\right)+\frac{1}{2}\times 5m\left((ku)^2-v^2\right)$	A1	Correct unsimplified equation. Allow for gain rather than loss. A0 if an error occurs before they form a single expression
	$\left(\frac{1}{2}\times 3m\left(5v^2\right)+\frac{1}{2}\times 5m\left(3v^2\right)=15mv^2\right)$		NB: $15mv^2=\frac{5}{3}mu^2$
	$\lambda=15$	A1	Correct only. Accept $15mv^2$
		(3)	

Q10.

Question Number	Scheme	Marks
(a)	$\frac{2mge_1}{2a}$ *or* $\frac{6mg(4a-e_1)}{4a}$	B1
	$mg+\frac{2mge_1}{2a}=\frac{6mg(4a-e_1)}{4a}$	M1A1
	Solve to find either extension	dM1
	$e_1=2a$ and $e_2=4a-e_1=2a$*	A1*
		(5)
ALT (a)	$mg+\frac{2mge_1}{2a}=\frac{6mge_2}{4a}$, $e_1+e_2=4a$	M1A1
	Solve simultaneously to find either extension	dM1
	$e_1=2a$ and $e_2=4a-e_1=2a$*	A1*

(b)		
	$mg+\frac{2mg(2a-x)}{2a}-\frac{6mg(2a+x)}{4a}=m\ddot{x}$	M1A1A1
	$\ddot{x}=-\frac{5g}{2a}x$ $\quad\therefore$ SHM	A1
		(4)
(c)	$\omega^2=\frac{5g}{2a}$	B1ft
	$v^2=\frac{5g}{2a}\left(a^2-\left(\frac{a}{2}\right)^2\right)$	M1A1
	$v=\sqrt{\frac{15ga}{8}}=\frac{\sqrt{30ga}}{4}$	A1 cso
		(4)
ALT (c)	$\frac{2mga^2}{4a}$ *or* $\frac{6mg(3a)^2}{8a}$ *or* $\frac{2mg(\frac{3a}{2})^2}{4a}$ *or* $\frac{6mg(\frac{5a}{2})^2}{8a}$	B1
	$\frac{2mga^2}{4a}+\frac{6mg(3a)^2}{8a}=\frac{2mg(\frac{3a}{2})^2}{4a}+\frac{6mg(\frac{5a}{2})^2}{8a}+\frac{mga}{2}+\frac{mv^2}{2}$	M1A1
	$v=\sqrt{\frac{15ga}{8}}$	A1
		(4)
		[13]

(a)

B1 Correct use of Hooke's law for either string. Must include an unknown extension.

M1 Resolve vertically, with two variable tensions and weight (M0 for setting both extensions as e)

A1 Correct equation.

dM1 Solve to find either extension.

A1* Correct extensions found for both strings, from fully correct working.

(b)

M1 Vertical equation of motion with two different variable tensions, weight and $m\ddot{x}$ (allow ma)

A1 Equation with at most one error (allow ma for this mark, which does not count as an error).

A1 Fully correct equation. Must now be $m\ddot{x}$

A1 $\ddot{x} = -\frac{5g}{2a}x$ $\therefore$ SHM. **Must have concluding statement.**

(c)

B1ft Use of their ω^2

M1 Complete method to find speed at $\frac{7}{2}a$ above A. Follow through their ω. Needs amplitude a and $x = \frac{1}{2}a$

A1 Correct equation. No follow through now.

A1 cso

ALT (a) using simultaneous equations

B1 Correct use of Hooke's law for either string. Must include an unknown extension.

M1 Resolve vertically with two tensions in e_1 and e_2 and weight AND give a second equation for $e_1 + e_2$

A1 Both equations correct.

dM1 Solves both equations simultaneously to find either extension.

A1* Correct extensions found for both strings, from fully correct working.

ALT (c)

B1 Use of correct EPE

M1 Complete method to find speed at $\frac{7}{2}a$ above A. Allow with $EPE = k\frac{\lambda x^2}{l}$. Must have all terms.

A1 Correct equation.

A1 Correct final answer

Q11.

Question Number	Scheme	Marks
(a)	$0.5u = 4 \rightarrow u = 8$	B1
	$F_{max} = \frac{\sqrt{5}}{5} \times 0.5g \times \frac{\sqrt{45}}{7} \left(= \frac{3g}{14} = 2.1\right)$	B1
	$\frac{1}{2} \times 0.5 \times 8^2 = 0.5g(x+2)\sin\theta + F_r(x+2) + \frac{3x^2}{2 \times 2}$	M1A1A1
	$64 = 14(x+2) + 3x^2$	
	$3x^2 + 14x - 36 = 0$	M1
	$x = 1.8(m) \quad (1.84m)$	M1A1
		(8)
(b)	$T = \frac{3 \times 1.84}{2} (= 2.76)$	B1ft
	$0.5a = 2.76 + 1.4 - 2.1 \quad (= 2.06)$ Acceleration down slope, so particle does not remain at A.	M1A1
		(3)
		[11]

ALT (a)	$0.5u = 4 \rightarrow u = 8$	B1
	$F_{max} = \frac{\sqrt{5}}{5} \times 0.5g \times \frac{\sqrt{45}}{7} (= 2.1)$	B1
	$\frac{1}{2} \times 0.5 \times 8^2 = 0.5gd\sin\theta + F_r d + \frac{3(d-2)^2}{2 \times 2}$	M1A1A1
	$64 = 14d + 3(d-2)^2$	
	$3d^2 + 2d - 52 = 0$	M1
	$d = 3.8 \rightarrow x = 1.8(m) \quad (1.84m)$	M1A1
		(8)
ALT (b)	$T = \frac{3 \times 1.84}{2} (= 2.76)$	B1ft
	Upslope: $F_{max} (= 2.1)$, Downslope: $0.5g\sin\theta + T \ (= 4.16)$	M1
	4.16 > 2.1 so there is a resultant force down slope, so the particle does not remain at A	A1 **(3)**

(a)

B1 Initial speed seen.

B1 Maximum friction seen/used. Award if only seen in (b).

M1 Energy equation with KE, GPE, EPE and WD. If they split the motion up to find the speed when the string begins to extend (= 6 ms^{-1}) only award this mark once they have the equation containing EPE. Allow with $EPE = k\frac{\lambda x^2}{l}$.

A1 Equation with at most one error.

A1 Fully correct equation.

M1 Produce a 3 term in x or d equalling zero (see ALT). This is independent.

M1 Solve a 3 term quadratic to find the extension or distance travelled.

A1 Correct extension. Must be 2 or 3 s.f.

(b)

B1ft Correct expression for the tension at A ft their extension.

M1 Consider the three forces parallel to the plane.

A1 Correct conclusion from comparison of the three forces. Correct working with numerical values seen. Could be an acceleration or correct statement about the forces up/down the slope.

Q12.

Question Number	Scheme	Marks
a)	$F_r = \frac{1}{7}\times 0.4\times 9.8\ (=0.56)(\text{N})$	B1
	$\frac{1}{2}\times 0.4v^2 = \frac{1}{2}\times 0.4(1.8)^2 - 0.8\times\text{"0.56"}$	M1A1A1 (ft their F_r)
	$v^2 = 1.00 \Rightarrow v = 1.0$ or $1.00\ (\text{m s}^{-1})$	A1
		(5)
b)	$\frac{1}{2}\times 0.4(1.0)^2 = 0.56x + \frac{0.6x^2}{2(0.8)}$	M1A1B1
	$0.375x^2 + 0.56x - 0.2 = 0$	DM1
	$x = 0.2977...$	A1
	Total distance = 1.1 (m) (or 1.10)	A1
		(6)

ALT 1	*Work from A to C with total distance as the unknown*	
	$\frac{1}{2}\times 0.4(1.8)^2 = 0.56y + \frac{0.6(y-0.8)^2}{2(0.8)}$	M1A1B1
	$0.375y^2 - 0.046y - 0.408 = 0$	DM1
	$y = 1.0977...$	A1
	$y = 1.1$ or 1.10	A1
ALT 2	*Work from A to C with distance BC as the unknown*	
	$\frac{1}{2}\times 0.4(1.8)^2 = 0.56(y+0.8) + \frac{0.6y^2}{2(0.8)}$	M1A1B1
	Rest as main scheme	DM1A1A1
c)	$T = \frac{0.6\times "0.2977"}{0.8}$ $(=0.223)$	M1A1ft
	$0.223 < 0.56$ Tension less than F_{max}. Therefore particle will not move. cso.*	A1cso*
		(3)
		[14]

(a)		
B1	Correct friction seen. (Might be contained in WD) g or 9.8 acceptable.	
M1	Work-Energy equation with 2 KE terms and their WD by friction. All terms must be dimensionally correct.	
A1A1	One each for the KE terms.	
A1	$v = 1.0$ or 1.00 (2 or 3 sf as g has been used to obtain the speed at B)	
(b)		
M1	Work-Energy equation with KE, WD and EPE. EPE term to be of the form $\frac{\lambda x^2}{k \times \text{natural length}}$ with $k = 1$ or 2	
B1	Correct EPE term. M mark for the equation not needed for this mark.	
A1ft	Fully correct equation. Follow through their EPE	
DM1	Reducing to a 3 term quadratic in x, terms in any order. Depends on the first M of (b)	
A1	$x = 0.2977...$	
A1	1.1 (m) or 1.10 (m) (2 or 3 sf as g has been used to obtain the speed at B)	
ALT 1		
	First 4 marks as main scheme notes.	
A1A1	Award A1A1 if final answer is correct, from a correct equation. Award A1A0 if answer correct but not rounded.	
ALT 2	Notes as for main scheme.	
(c)		
M1	Use of Hooke's Law for their extension at C.	
A1ft	Correct tension. Follow through their extension. No need to simplify.	
A1cso*	Correct conclusion, from fully correct working including evaluation of tension.	

Q13.

Question Number	Scheme	Marks
(a)	$mg = \frac{kmg}{l}\frac{2l}{5}$	M1
	$k = \frac{5}{2}$*	A1* (2)
(b)	$mg - T = m\ddot{x}$	M1
	$mg - \frac{5mg}{2l}\left(x + \frac{2l}{5}\right) = m\ddot{x}$	DM1A1
	$-\frac{5g}{2l}x = \ddot{x}$, hence SHM.*	A1* (4)
(c)	$\omega = \sqrt{\frac{5g}{2l}}$; $a = \frac{1}{4}l$	B1 **ft**; B1
	$v = a\omega = \frac{1}{4}l \times \sqrt{\frac{5g}{2l}}$	M1
	$\frac{1}{4}\sqrt{\frac{5gl}{2}}$ oe	A1 (4)
(d)	$\frac{1}{4} \times \frac{2\pi}{\omega}$	M1
	$\frac{\pi}{2}\sqrt{\frac{2l}{5g}}$ oe	A1 **ft** (2)
		(12)

	Notes for question	
(a)	M1 for $mg = T$ and use of Hooke's Law	
	A1* Given answer correctly obtained	
(b)	M1 for equation of motion, dim correct with all necessary terms, allow a for acceleration and condone sign errors. Accept T or attempt at T, which may not have a variable extension.	
	DM1 for equation of motion, dim correct with correct terms, and use of Hooke's Law with a variable extension measured from E and now need $\ddot{x}$, condone sign errors. Depends on the first M mark; both M marks can be awarded together.	
	A1 for a correct unsimplified equation	
	A1* for a correct equation and conclusion	
(c)	B1 ft for a dimensionally correct ω or ω^2, seen explicitly or used. B1 for $a = \frac{1}{4}l$	
	M1 for use of $v = a\omega$ or $v^2 = \omega^2\left(a^2 - x^2\right)$ with $x = 0$ later	
	A1 cao	
	Use of energy: B1 gain of GPE B1 either EPE M1 energy equation with change in GPE, change in EPE and KE. A1 cao	
(d)	M1 for use of $\frac{1}{4} \times \frac{2\pi}{\omega}$	
	A1 cao	

Q14.

Question Number	Scheme	Marks
(a)	WD against air resistance $= kmga$; PE Gain $= \frac{1}{2}mga$; KE Gain $= \frac{1}{2}\times\frac{1}{2}m\times 3ag$	B2,1,0
	Initial EPE $= \frac{2mg}{4a}(2a)^2$; Final EPE $= \frac{2mg}{4a}a^2$	B1; B1
	$kmga = \frac{2mg}{4a}\left((2a)^2 - a^2\right) - \frac{1}{2}mga - \frac{1}{2}\times\frac{1}{2}m\times 3ag$	M1A1
	$k = \frac{1}{4}$ *	A1* (7)
(b)	$\frac{1}{2}mg - \frac{1}{4}mg - T = 0$	M1
	$\frac{1}{2}mg - \frac{1}{4}mg - \frac{2mg}{2a}x = 0$	A1
	$x = \frac{1}{4}a$	A1
	$OB = \frac{9a}{4}$	A1 ft (4)
		(11)
	Notes for question	
(a)	B2 for all 3 unsimplified terms. B1 B0 for 2 out of 3 correct	
	B1 for the initial EPE	
	B1 for the final EPE	
	M1 for the work-energy equation with all necessary terms, condone sign errors.	
	A1 for a correct equation.	
	A1* for the given answer correctly obtained. At least one step of working to be seen.	
(b)	M1 for a vertical resolution with the correct terms (T does not need to be substituted) Must have acceleration = 0 for this mark	
	A1 for a correct equation with T replaced.	
	A1 cao	
	A1ft $2a$ + their x	
	Use of uniform aceleration equations scores 0/4	
	Alternative, using work-energy	
	M1 for an equation with GPE, EPE, KE and WD terms – all but KE using a variable distance (OB or the extension).	
	A1 correct equation	
	DM1 (A1 on e-pen) Obtain an expression for v^2 in terms of their unknown distance **and** find their distance when this is maximum by calculus or completing the square	
	A1 cao	

Q15.

(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 WD $= \mu R \times$ distance with their R
	$= 8.47(8.5)(\text{J})$	A1	3 sf or 2 sf
		3	
(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	
(c)	Time to ground:	M1	Complete method using *suvat* to form an equation in t
	$-15\sin\alpha = 7t - \frac{1}{2}gt^2$	A1	Correct unsimplified equation in t
	$t = 1.88 \quad (1.9) \quad (\text{s})$	A1	3 sf or 2 sf $\frac{5+\sqrt{67}}{7}$ is A0
		3	
(d)	Vertical component of speed	M1	Or use energy to find the speed
	$= \pm(7 - (\text{their } t) \times g) \quad (\pm 11.459....)$	A1ft	or $0.15 \times 625 + .3 \times 9.8 \times$ their $4.2 = 0.15v^2 \quad (v = 26.59....)$ 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)	

Q16.

Question Number	Scheme	Marks
	$(\uparrow)\ R+200\sin 15^o+T\sin 25^o=20g$	M1A2
	$(\leftarrow)\ 200\cos 15^o-T\cos 25^o-F=0$	M1A2
	$F=0.3R$	B1
	Solving for T (192.31..)	**D**M1
	$T=190$ or 192	A1
		(9)
	Notes for question	
	M1 Resolving vertically, correct no. of terms, condone sign errors and sin/cos confusion.	
	A2 Correct equation, -1 each error.	
	M1 Resolving horizontally, correct no. of terms, condone sign errors and sin/cos confusion.	
	A2 Correct equation, -1 each error.	
	B1 $F=0.3R$ seen anywhere, e.g. on a diagram	
	DM1 Dependent on previous two M marks for solving for T	
	A1 cao (allow units)	
	N.B. For the first two M marks, forces and angles must be paired up correctly but allow slips.	

Q17.

Question Number	Scheme	Marks
(i)	**R = F + G**	
	$R^2 = 8^2 + 10^2 - 2\times 8\times 10\cos 120°$ oe (244) **OR:** $R^2 = 8^2 + 10^2 + 2\times 8\times 10\cos 60°$ **OR:** $R^2 = (8\sin 60)^2 + (10 + 8\cos 60°)^2$ **OR:** $R^2 = (10\sin 60)^2 + (8 + 10\cos 60°)^2$	M1A1
	$R = \sqrt{244} = 15.620499...$ **N**	A1
(ii)	$\frac{\sin\alpha}{8} = \frac{\sin 120°}{\sqrt{244}}$ (allow sin60°) **OR** $\frac{\sin\beta}{10} = \frac{\sin 120°}{\sqrt{244}}$ (allow sin60°) **OR** $8^2 = (\sqrt{244})^2 + 10^2 - 2\times\sqrt{244}\times 10\cos\alpha$ **OR** $10^2 = (\sqrt{244})^2 + 8^2 - 2\times\sqrt{244}\times 8\cos\beta$ **OR** $\tan\alpha = \frac{8\sin 60}{10 + 8\cos 60°}$ or $\sin\alpha = \frac{8\sin 60}{\sqrt{244}}$ or $\cos\alpha = \frac{10 + 8\cos 60°}{\sqrt{244}}$ (or reciprocal of tan) **OR** $\tan\beta = \frac{10\sin 60}{8 + 10\cos 60°}$ or $\sin\beta = \frac{10\sin 60}{\sqrt{244}}$ or $\cos\beta = \frac{8 + 10\cos 60°}{\sqrt{244}}$ (or reciprocal of tan)	M1A1
	$\alpha = 26.(3..)°$ **OR** $\beta = 33.67...°$ (accept 34)	A1
	Bearing is 206° (nearest degree)	A1
		(7)
	Notes for question	
(i)	M1 for an equation in R **only** (M0 for $R^2 = 8^2 + 10^2 - 2\times 8\times 10\cos 60°$ or if they clearly misquote the cosine rule) For the second alternative, condone sin/cos confusion and sign errors	
	A1 for a correct equation	
	A1 for $\sqrt{244}$ or 16 or better (N)	
(ii)	M1 for an equation in a relevant angle **only**, using their R value. For the SOHCAHTOA alternatives, allow sin/cos confusion and sign errors	
	A1 for a correct equation	
	A1 for a relevant angle which is correct to the nearest degree	
	A1 cao	

Q18.

Question Number	Scheme	Marks
(a)	$(11\mathbf{i}+11\mathbf{j})+t(3\mathbf{i}-\mathbf{j})$	M1A1 (2)
(b)	When $t=6$, $\mathbf{r}_A=(29\mathbf{i}+5\mathbf{j})$	M1
	$\mathbf{r}_B=(7\mathbf{i}+16\mathbf{j})+t(4\mathbf{i}-2\mathbf{j})=(29\mathbf{i}+5\mathbf{j})$	M1
	Solve **both** $4t+7=29$ and $16-2t=5$ **explicitly** to give $t=5.5$ for **both equations** (Division by vectors is DM0)	**D**M1 A1* (4)
(c)	$\overrightarrow{AB}=(7\mathbf{i}+16\mathbf{j})+t(4\mathbf{i}-2\mathbf{j})-\{(11\mathbf{i}+11\mathbf{j})+t(3\mathbf{i}-\mathbf{j})\}$	M1
	$\overrightarrow{AB}=[(t-4)\mathbf{i}+(5-t)\mathbf{j}]$ m GIVEN ANSWER	A1* (2)
(d)	$AB^2=(t-4)^2+(5-t)^2$ oe seen or implied by a numerical calculation	M1
	$=2(t-4.5)^2+0.5$	A1
	Complete method using the above to find the minimum	M1
	Minimum $AB=\sqrt{0.5}=0.71$ m (or better)	A1
	OR $AB^2=(t-4)^2+(5-t)^2$ oe seen or implied by a numerical calculation M1	
	$4t-18$ **or** $2(t-4)-2(5-t)$ A1 **N.B.** Either of these could be implied by seeing $t=4.5$	
	Complete method using the above to find the minimum M1	
	Minimum $AB=\sqrt{0.5}=0.71$ m (or better) A1	(4)
	OR $AB^2=(t-4)^2+(5-t)^2$ oe seen or implied by a numerical calculation M1	
	$2t^2-18t+(41-d^2)=0$ $(d=AB)$ A1	
	Complete method using $b^2-4ac=0$: $(-18)^2-4\times2(41-d^2)=0$ to find minimum M1	
	Minimum $AB=\sqrt{0.5}=0.71$ m (or better) A1	
	Accept column vectors throughout except in (c)	**(12)**

	Notes for question	
(a)	M1 for an attempt at $\mathbf{r}_A$ with a correct structure	
	A1 cao	
(b)	M1 for putting $t = 6$ into their $\mathbf{r}_A$ to find $\mathbf{r}_P$	
	M1 for equating their $\mathbf{r}_B$ at time t (with correct structure) to their $\mathbf{r}_P$	
	DM1 Solve their vector equation for **both** components, dependent on both previous M marks. Need to see 5.5 occurring **twice**. **N.B.** One ratio equation is not sufficient for this mark	
	A1* cao	
(c)	M1 for finding their $\mathbf{r}_B$ – their $\mathbf{r}_A$ or their $\mathbf{r}_A$ – their $\mathbf{r}_B$ M0 if they start with $\mathbf{r}_A = \mathbf{r}_B$	
	A1* for correctly establishing *exactly* (i.e. not a column vector) the given expression (allow omission of m), writing out **in full** the difference between the vectors before simplifying correctly to the given answer.	
(d)	M1 for a correct expression for either AB or AB^2 seen or implied.	
	A1 for a correct quadratic in completed square form	
	M1 for a complete method using the completed square form to find the minimum value of AB.	
	A1 cao	
	OR:	
	M1 for a correct expression for either AB or AB^2 seen or implied	
	A1 for a correct derivative (**N.B.** can be implied by $t = 4.5$)	
	M1 for a complete method using the derivative to find the minimum value of AB.	
	A1 cao	
	OR:	
	M1 for a correct expression for either AB or AB^2 seen or implied	
	A1 for a correct equation	
	M1 for a complete method using the discriminant = 0 to find the minimum value of AB.	
	A1 cao	

Q19.

Question Number	Scheme	Marks
(a)	$F = 5\cos 30°$ oe (Resolving perp to string or from triangle of forces or Lami's Theorem: $\frac{F}{\sin 120°} = \frac{5}{\sin 90°}$) **OR** $\frac{F\sin 30°}{\sin 60°}\cos 60° + F\cos 30° = 5$	M1 A1
	$F = \frac{5\sqrt{3}}{2}$ 4.3 or better	A1
	N.B. $F\sin 30° = T\sin 60°$	(3)
(b)	$T = 5\sin 30°$ oe (Resolving along string or from triangle of forces or Lami's Theorem: $\frac{T}{\sin 150°} = \frac{5}{\sin 90°}$) **OR** $T\cos 60° + \frac{T\sin 60°}{\sin 30°}\cos 30° = 5$	M1 A1
	$T = \frac{5}{2}$ (N)	A1
	N.B. $F\sin 30° = T\sin 60°$	(3)
		(6)
	Notes for question	
(a)	M1 Complete method to obtain equation in F only - correct no. of terms, condone sign errors and sin/cos confusion (If they resolve horizontally and vertically, they will need to eliminate T to obtain this M mark, with the usual rules applying to each equation they use) **N.B.** If they do (b) first and find an incorrect value for T and then use that value in (a), using an equation that would earn M1, with usual rules, to find F, give M1A0A0 in (a). M0 if using wrong angles e.g. 45°	
	A1 Correct equation	
	A1 cao (4.3301..)	
(b)	M1 Complete method to obtain equation in T only - correct no. of terms, condone sign errors and sin/cos confusion (If they resolve horizontally and vertically, they will need to eliminate F to obtain this M mark, with the usual rules applying to each equation they use) **N.B.** If they find an incorrect value for F in (a) and then use that value in (b), using an equation that would earn M1, with usual rules, to find T, give M1A0A0 in (b). M0 if using wrong angles e.g. 45°	
	A1 Correct equation	
	A1 cao	

Q20.

QUESTION NUMBER	SCHEME	MARKS
(a)	$F = 10\cos\theta - 0.2g$ **or** $F = 0.2g - 10\cos\theta$	M1 A1
	$\lvert F \rvert$ = 1.9 or1.89 (N)	A1
		(3)
(b)	Friction acts downwards or down.	A1
	A0 for anything else.	
		(1)
(c)	$R = T\sin\theta$ $\left(R = \frac{12T}{13}\right)$	M1 A1
	$F = \frac{1}{4}R$	B1
	Resolve vertically For min value $T\cos\theta = 0.2g - F$ For max value $T\cos\theta = 0.2g + F$	M1 A1 A1
(i)	Min T 3.2 or 3.19 (N)	A1
(ii)	Max T 13 or 12.7 (N)	A1
	N.B. Penalise over accuracy once for the whole question and penalise the FIRST time it is seen.	
	N.B. If 2 instead of 0.2 is used throughout the WHOLE question, treat as a MR.	
		(8)
		(12)

	Notes for question
(a) M1	Resolve vertically, dimensionally correct, condone sin/cos confusion and sign errors.
A1	Correct unsimplified equation.
A1	Correct value for Friction, must be positive **N.B.** If they use μR as their notation for F and never separate μ and R, allow M1A1A1. If, however, they do separate them, give M1A1A0.
(b) A1	Correct direction from **a correct, but possibly unrounded, answer to part (a).**
(c) M1	Resolve perpendicular to the rod. Must be dimensionally correct and have correct no of terms. Condone sin/cos confusion. **N.B.** M0 if they use $T = 10$
A1	Correct unsimplified equation
B1	$F = \frac{1}{4}R$ seen or implied
M1	Resolve parallel to the rod for either case. Must be dimensionally correct and have correct no of terms. Condone sin/cos confusion. **N.B.** M0 if they use $T = 10$ or if they use F from part (a).
A1	Correct minimum case equation
A1	Correct maximum case equation
(i)A1	cao for min T. Allow 0.325g
(ii)A1	cao for max T Allow 1.3g
	N.B. If only one found and no labels, allow the A mark for the equation but must state which one it is to score the A mark for the answer. **N.B.** If both correctly found and no labels, allow all the marks. **N.B.** If both correctly found but the answers are labelled wrongly, lose the final two A marks.

Q21.

Question	Scheme		Marks
(a)	$F = 0.25R$		B1
	$\sin\alpha = \frac{3}{5}$ or $\cos\alpha = \frac{4}{5}$ $\sin\beta = \frac{4}{5}$ or $\cos\beta = \frac{3}{5}$	Use of correct trig ratios for α or β	B1
	$R = 4g\cos\alpha$ (31.36)	Normal reaction on P Condone trig confusion (using α)	M1
		Correct equation	A1
	$T + F = 4g\sin\alpha$	Equation of motion for P. Requires all 3 terms. Condone consistent trig confusion Condone an acceleration not equated to 0 : $T + F - 4g\sin\alpha = 4a$	M1
	$(T + 7.84 = 23.52)$ $(T = 15.68)$	Correct equation	A1
	$T = mg\sin\beta$	Equation of motion for Q Condone trig confusion Condone an acceleration not equated to 0: $T - mg\sin\beta = -ma$	M1
	$(T = 7.84m)$	Correct equation	A1
	Solve for m	Dependent on the 3 preceding M marks Not available if their equations used $a \neq 0$	DM1
	$m = 2$		A1
	NB Condone a whole system equation $4g\sin\alpha - F = mg\sin\beta$ followed by $m = 2$ for 6/6 M2 for an equation with all 3 terms. Condon trig confusion. Condone an acceleration $\neq 0$ A2 (-1 each error) for a correct equation:		
			(10)

(b)	$F = \sqrt{T^2 + T^2}$ or $2T\cos 45°$ or $\frac{T}{\cos 45}$	Complete method for finding F in terms of T Accept $\sqrt{(R_h)^2 + (R_v)^2}$	M1
	Correct expression in T		A1
	Substitute their T into a correct expression. Dependent on the previous M mark		DM1
	$F = \sqrt{2}\frac{8g}{5} = 22$ or 22.2 (N)	Watch out - resolving vertically is not a correct method and gives 21.9 N.	A1
			(4)

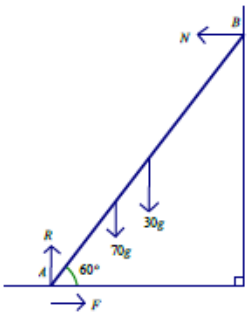
(c)	Along the angle bisector at the pulley	Or equivalent - accept angle + arrow shown on diagram. (8.1° to downward vertical) Do not accept a bearing	
			(1)
			(15 marks)

Q22.

Question Number	Scheme	Marks
	$M(D)$, $900\times5=W(5-x)$ Other possible equations: $(\uparrow)$, $900+R_D=W$ M(A), $Wx=5R_D$ M(B), $(900\times6)+(R_D\times1)=W(6-x)$ M(C), $(900\times1)+W(x-1)=4R_D$ M(G), $900x=R_D(5-x)$ **BUT** R_D then needs to be eliminated to produce an equation in W and x **only** in order to earn the M mark. **N.B.** M0 if they never put $R_C=0$ Allow consistent use of Mg for W	M1A1
	$M(C)$, $1500\times5=W(x-1)$ Other possible equations: $(\uparrow)$, $1500+R_C=W$ M(A), $(1500\times6)+(R_C\times1)=Wx$ M(B), $W(6-x)=5R_C$ M(D), $W(5-x)+(1500\times1)=4R_C$ M(G), $1500(6-x)=R_C(x-1)$ **BUT** R_C then needs to be eliminated to produce an equation in W and x **only** in order to earn the M mark. **N.B.** M0 if they never put $R_D=0$ Allow consistent use of Mg for W	M1A1
	Solving for x	**DM1**
	$x=3.5$	A1
		(6)

	Notes for question	
	M1 For an equation in W and one unknown length. Correct no. of terms, dim correct but condone sign errors. An extra g on one side is an A error.	
	A1 Correct equation	
	M1 For an equation in W and the same unknown length. Correct no. of terms, dim correct but condone sign errors. An extra g on one side is an A error.	
	A1 Correct equation	
	DM1 Solving for x, dependent on the two previous M marks.	
	A1 cao with no wrong working seen.	

Q23.

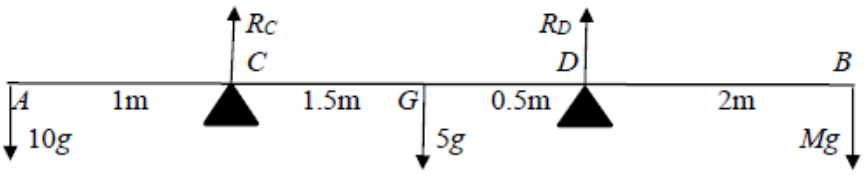
Question Number	Scheme	Marks	Notes
a			
	M(*A*): $3\times30g\times\frac{1}{2}+70g\times2\times\frac{1}{2}=N\times\frac{6\sqrt{3}}{2}$	M1	All terms required. Must be dimensionally correct. Condone sin/cos confusion and sign errors. Allow with sin/cos 60°
	$\left(45g+70g=3\sqrt{3}N\right)$	A1	Correct unsimplified
	$\updownarrow$: $R=100g$,	B1	B0 if they have $F_B\neq0$
	$\leftrightarrow$: $F=N=217\,(\text{N})$ $\left(\frac{115g}{3\sqrt{3}}\right)$	B1	Solve for F (216.891… seen or implied)
			NB Either of these B marks could be earned for a second moments equation
	$\sqrt{(100g)^2+217^2}$	DM1	Use of Pythagoras with *their* R, F Dependent on the preceding M mark
	$=1000$ (N)	A1	

Alt a	M(B): $30g\times 3\cos 60° + 70g\times 4\cos 60° = R\times 6\cos 60° - F\times 6\sin 60°$ M(base wall) $3R = \frac{3}{2}.30g + 2.70g + 3\sqrt{3}N$	M1	All terms required. Must be dimensionally correct. Condone sin/cos confusion and sign errors. Allow with sin/cos 60°
	$\left(45g+140g = 3R - 3\sqrt{3}F\right)$	A1	
	$\updownarrow$: $R = 100g$,	B1	
	$3\sqrt{3}F = 115g$, $F = \frac{115g}{3\sqrt{3}}$	B1	Solve for F 216.891……
	$\sqrt{(100g)^2 + 217^2}$	DM1	Use of Pythagoras with *their R, F*
	$=1000$ (N)	A1	
		[6]	
b	$F = 0.4\times 100g\,(=392)$	M1	Use of $F = \mu R$ with their value for R
	M(A): $F\times 3\sqrt{3} = 70g\times\frac{x}{2} + 30g\times\frac{3}{2}$	M1	$(F \neq 217)$ Allow for moments about B to find distance from the top
	$40g\times 3\sqrt{3} = 35gx + 45g$	A1	Equation in x (distance from ground) only
	$(AD=)\,x = 4.65$ (m)	A1	4.7 or better (4.65274….)
		[4]	
c	e.g. The ladder does not bend The ladder meets the wall/floor at a point The weight acts at a single point	B1	With no incorrect statement(s) seen
		[1]	**[11]**

Q24.

Question Number	Scheme	Marks
(a)	$(\uparrow)\ \pm F = 0.2g - 2.5\cos\alpha$ Allow use of (μR) for F	M1 A1
	$F = 0.46$ (N) oe including fractions , upwards	A1
		(3)
(b)	$(\uparrow) F + 0.2g = 6.125\cos\alpha$	M1A1
	$(\rightarrow)\ R = 6.125\sin\alpha$ (4.9)	M1A1
	$F = \mu R$	B1
	Solve for μ	DM1
	$\mu = 0.35$ oe including fractions.	A1
	N.B. If F and R are interchanged in their equations, max B1 can be scored.	(7)
		(10)
	Notes for question	
(a)	M1 Correct no. of terms, condone sin/cos confusion and sign errors, allow if they have T instead of 2.5	
	A1 Correct equation . Allow + F or $-F$	
	A1 Need both magnitude (must be positive) and direction	
(b)	M1 Correct terms, condone sin/cos confusion and sign errors errors allow if they have T instead of 6.125 (but M0 if using $T = 2.5$)	
	A1 Correct equation	
	M1 Correct terms, condone sin/cos confusion and sign error allow if they have T instead of 6.125 (but M0 if using $T = 2.5$)	
	A1 Correct equation	
	B1 $F = \mu R$ seen but B0 if they use a value for R found in (a)	
	DM1 Dependent on both M's	
	A1 cao	

Q25.

Question Number	Scheme	Marks
		
(a)	M(D), $2\times R_C + 2Mg = 0.5\times 5g + 3\times 10g$	M1 A1
	$R_C = 16.25g - Mg$ oe or $R_C = 159 - 9.8M$ or $160 - 9.8M$	A1
		(3)
	Other possible equations that could be used in (a), to obtain an equation in R_C and M **only**, or in (b), to obtain an equation in R_D and M **only** ($\uparrow$), $R_C + R_D = 10g + 5g + Mg$ M(A), $R_C + 3R_D = 5g\times 2.5 + 5Mg$ M(B), $4R_C + 2R_D = 5g\times 2.5 + 5\times 10g$ M(G), $1.5R_C + 2.5Mg = 0.5R_D + 2.5\times 10g$	
(b)	M(C), $2\times R_D + 1\times 10g = 1.5\times 5g + 4\times Mg$	M1A1
	$R_D = 2Mg - 1.25g$ oe or $R_D = 19.6M - 12.3$ or $20M - 12$	A1
		(3)
(c)	Use of when $R_C \geq 0$ or $R_D \geq 0$ Allow equality or > 0 **N.B.** They may take moments about D or C again, with respectively $R_C = 0$ or $R_D = 0$	M1
	$M \leq 16.25$ **OR** $M \geq 0.625$ Allow equality **N.B.** Allow 2SF or better.	A1ft
	$0.625 \leq M \leq 16.25$ **N.B.** Allow 2SF or better. If either critical value appears, without working or from working done in parts (a) and/or (b), they can score M1A1ft and also potentially, the final A1.	A1
		(3)
		(9)

	Notes for question	
	N.B. Only penalise over accuracy, after use of $g = 9.8$, ONCE in this question.	
(a)	M1 Complete method to give an equation in R_C and M **only**, correct number of terms, condone sign errors, dim correct M0 if they assume that the reactions are equal.	
	A1 Correct equation(s)	
	A1 Correct expression (g's must be collected)	
(b)	M1 Complete method to give an equation in R_D and M **only**, correct number of terms, condone sign errors, dim correct	
	M0 if they assume that the reactions are equal.	
	A1 Correct equation(s)	
	A1 Correct expression (g's must be collected)	
(c)	M1 Use of either of their reactions to find one critical value	
	A1ft Critical value of R_C **OR** Critical value of R_D but must be POSITIVE.	
	A1 cao Allow $0.625\text{kg} \leq M\text{kg} \leq 16.25\text{kg}$	

Q26.

Q	Solution	Mark	Notes
	Allow use of column vectors		
a	$(5\mathbf{i}+2\mathbf{j})+(-3\mathbf{i}+\mathbf{j})+\mathbf{F}_3=\mathbf{0}$ oe	M1	Use equilibrium to find $\mathbf{F}_3$
	$\mathbf{F}_3=-2\mathbf{i}-3\mathbf{j}\ (\Rightarrow a=-2,\quad b=-3)$	A1	Correct $\mathbf{F}_3$
	$\tan\theta=\frac{2}{3}$	M1	For an equation in a relevant angle using their a and b
	$\theta=33.7°$	A1	34° or better. 0.588 (0.59) rads
		(4)	
b	Resultant force $=(2+\lambda)\mathbf{i}+(3+3\lambda)\mathbf{j}$	B1	Seen or implied. They must collect the **i**'s and **j**'s.
	$\mathbf{F}=4\mathbf{a}$ oe, where **F** is their resultant, seen or implied (could be implied by $\lvert\mathbf{F}\rvert=13$)	M1	Must have attempted to add all 3 forces. **N.B.** $3.25=\frac{1}{4}\left[(2+\lambda)\mathbf{i}+(3+3\lambda)\mathbf{j}\right]$ oe Scores B1M1M0M0A0 but allow recovery.
	Finding magnitude of their **a** or **F** $\sqrt{\left(\frac{2+\lambda}{4}\right)^2+\left(\frac{3+3\lambda}{4}\right)^2}$ or $\sqrt{(2+\lambda)^2+(3+3\lambda)^2}$	M1	
	Use of $\lvert\mathbf{a}\rvert=3.25$ or $\lvert\mathbf{F}\rvert=13$ to form (3 term quadratic in λ) $=0$ $(10\lambda^2+22\lambda-156=0)$	M1	
	$\lambda=3$	A1	A0 if they give 2 values.
		(5)	
		[9]	

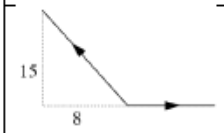
Q27.

QUESTION NUMBER	SCHEME	MARKS
(a)(i)	For A: $\frac{4mg}{3} - mg\sin\alpha - F = ma$	M1A1
	$R = mg\cos\alpha$	M1 A1
	Use of $F = \frac{1}{3}R$ in an equation.	M1
	$a = \frac{11g}{15}$ or $0.73g$ or better	A1
(ii)	For B: $kmg - \frac{4mg}{3} = kma$	M1 A1
	$k = 5$	A1
	N.B. Either equation of motion could be replaced by a whole system equation: $kmg - mg\sin\alpha - F = (k+1)ma$	
		(9)
(b)	Complete method to find resultant force $2T\cos\left(\frac{90° - \alpha}{2}\right)$	M1 A1
	Substitute $T = \frac{4mg}{3}$ and trig $\frac{32mg}{15}$ or $2.1mg$ or better.	**d**M1 A1
ALT 1	Use of cosine rule: $\sqrt{T^2 + T^2 - 2(T)(T)\cos(90+\alpha)}$	M1 A1
ALT 2	Use of vert and horiz components to find the resultant: $\sqrt{(T\cos\alpha)^2 + (T + T\sin\alpha)^2}$	M1 A1
		(4)
		(13)

	Notes for question
(a) M1	For A use $F=ma$ parallel to the plane. Must be dimensionally correct and have correct no of terms. Condone sin/cos confusion. **N.B.** If they use T in this equation and never replace it, allow M1.
A1	Correct unsimplified equation. **N.B**. a could be replaced by $-a$
M1	Resolve perpendicular to the plane Must be dimensionally correct and have correct no of terms. Condone sin/cos confusion.
A1	Correct equation
M1	Use of $F = \frac{1}{3}R$
A1	Correct answer
M1	For B use $F=ma$ vertically. Must be dimensionally correct and have correct no of terms. Condone sin/cos confusion. **N.B**. Must have km on *both* sides for this mark. **N.B.** If they use T in this equation and never replace it, allow M1.
A1	Correct unsimplified equation **N.B**. a could be replaced by $-a$, but must be consistent with the equation for A.
A1	correct answer

(b) M1	Complete method to find resultant force on pulley , allow sin/cos confusion
A1	Correct expression
dM1	Substitute $T = \frac{4mg}{3}$ and trig, dependent on previous M mark
A1	Correct answer.
(b) ALT1	
M1	Complete method – must involve α or its numerical value
A1	Correct expression
dM1	Substitute $T = \frac{4mg}{3}$ and trig, dependent on previous M mark
A1	Correct answer. Allow $\sqrt{\frac{1024m^2g^2}{225}}$ or similar.
(b) ALT2	
M1	Complete method, allow sin/cos confusion
A1	Correct expression
dM1	Substitute $T = \frac{4mg}{3}$ and trig, dependent on previous M mark
A1	Correct answer. Allow $\sqrt{\frac{1024m^2g^2}{225}}$ or similar.

Q28.

Question Number	Scheme	Marks
(a)	$\mathbf{F}_3 + (3c\mathbf{i} + 4c\mathbf{j}) + (-14\mathbf{i} + 7\mathbf{j}) = \mathbf{0}$ oe	M1
	$\mathbf{F}_3 = (14 - 3c)\mathbf{i} + (-7 - 4c)\mathbf{j}$	A1
		(2)
(b)	Resultant force $\mathbf{F}_1 + \mathbf{F}_2 = (6-14)\mathbf{i} + (8+7)\mathbf{j}$ $(= -8\mathbf{i} + 15\mathbf{j})$	M1
	 Find any relevant angle for **their (even if they've subtracted)** resultant (need not be acute nor positive)	M1
	any of $\tan^{-1}\left(\pm\frac{8}{15}\right), \tan^{-1}\left(\pm\frac{15}{8}\right), \sin^{-1}\left(\pm\frac{8}{17}\right), \cos^{-1}\left(\pm\frac{8}{17}\right), \ldots$	A1ft
	120° or better (118.0724…) **OR** 240° or better (241.9276..) In radians 2.1 or better (2.0607..) **OR** 4.2 or better (4.2224…)	A1
		(4)

(c)	Use of Pythagoras on their resultant : $\sqrt{(-8)^2+15^2}$ or their acceleration: $\sqrt{(\frac{-8}{m})^2+(\frac{15}{m})^2}$	M1
	Use of $\lvert$their **R**$\rvert = 8.5m$ or their Resultant $= ma$	M1
	A correct equation in m only eg $17 = m \times 8.5$	A1ft
	$m = 2$	A1
	N. B. $\sqrt{\left(\frac{-8}{8.5}\right)^2+\left(\frac{15}{8.5}\right)^2}$ M1 $-8\mathbf{i}+15\mathbf{j} = 8.5m$ M1 $\sqrt{\left(\frac{-8}{8.5}\right)^2+\left(\frac{15}{8.5}\right)^2} = m$ A1ft $2 = m$ A1	
		(4)
		(10)

Notes	
	Accept column vectors throughout apart from answer for (a)
(a)	
M1	Uses the vector **sum** of all 3 forces being equal to zero oe **N.B.** $\mathbf{F}_3 = \mathbf{F}_1 + \mathbf{F}_2$ is M0
A1	cao Must be in terms of c, **i** and **j** but allow uncollected **i**'s and **j**'s and apply isw if necessary.
(b)	
M1	Finds the resultant using $\mathbf{F}_1 + \mathbf{F}_2$ or $-$ their $\mathbf{F}_3$
M1	Uses trig to find a relevant angle **for their resultant**
A1ft	Any **correct** relevant angle (does not need to be acute), ft on their resultant
A1	Cso.
(c)	
M1	Use of Pythagoras to find the magnitude of their resultant force **or** their acceleration
M1	Allow their **R** = 8.5 m
A1ft	A correct scalar equation in m only eg $17 = m \times 8.5$, ft on their resultant
A1	cso

Q29.

Question Number	Scheme	Marks
	Vertical $R - P\sin\alpha = W$	M1 A1
	Horizontal $F = P\cos\alpha$ **OR** $F_{MAX} \geqslant P\cos\alpha$	 M1 A1
	$F \leqslant \frac{1}{4}R$ or $F = \frac{1}{4}R$ seen or implied	M1
	Produce a dimensionally correct inequality or equation in P and W only, trig does not need to be substituted	M1
	Reach the **given** answer, with exact working. $P \leqslant \frac{5W}{8}$* or $\frac{5W}{8} \geqslant P$	A1* cso
		(7)
		(7)

Notes for Question	
M1	Equation for vertical equilibrium. Correct number of terms, forces resolved where appropriate, condone sign errors and sin/cos confusion. M0 for an inequality
A1	Correct unsimplified equation.
M1	Equation for horizontal equilibrium. Correct number of terms, forces resolved where appropriate, condone sign errors and sin/cos confusion. **N.B.** Allow $F \geqslant P\cos\alpha$
A1	Either $F = P\cos\alpha$ or $F_{MAX} \geqslant P\cos\alpha$ where F_{MAX} may be implied by use of $\frac{1}{4}R$
M1	M0 for $F < \frac{1}{4}R$ or $F > \frac{1}{4}R$ or $F \geqslant \frac{1}{4}R$
M1	Eliminate F and R to form an inequality or equation in P and W only but allow trig to be unsubstituted. e.g. $\frac{1}{4}(W + P\sin\alpha) \geqslant P\cos\alpha$ or $\frac{1}{4}(W + P\sin\alpha) = P\cos\alpha$ M0 for use of $F < \frac{1}{4}R$ or $F > \frac{1}{4}R$ or $F \geqslant \frac{1}{4}R$ to form their inequality
A1* cso	Reach the **given** answer with at least one line of working. Must come from exact working and correct use of the inequality

Q30.

Question Number	Scheme	Marks
(a)	$3616-250g-565-226=250a$	M1 A1
	$a=1.5$ (m s^{-2})	A1
		(3)
(b)	$565-mg=m\times1.5$	M1A1ft
	m = 50 (kg)	A1
		(3)
		(6)
(a)	M1 Equation in a **only**, correct no. of terms, condone sign errors	
	A1 Correct equation	
	A1 oe	
(b)	M1 Equation in m (mass of A) **only**, correct terms, condone sign errors	
	A1ft Correct equation ft on their a	
	A1 cao	

Q31.

Question Number	Scheme	Marks
(a)	$F=\mu mg$	B1
	For P: $mg-kmg=ma$ Allow $mg-T=ma$	M1A1
	For Q: $kmg-F=ma$ Allow $T-F=ma$	M1A1
	Either of these may be replaced by : $mg-F=2ma$ (whole system)	
	Produce an equation in k and μ only using $T=kmg$	M1
	$k=\frac{1}{2}(1+\mu)$	A1
		(7)
(b)	Attempt to find the acceleration. [Note that some possible correct forms are: $a=\frac{1}{2}g(1-\mu)$ or $g(1-k)$ or $g(k-\mu)$]	M1
	$d=\frac{1}{2}\times\frac{1}{2}g(1-\mu)t^2$	M1A1
	$t=\sqrt{\frac{4d}{g(1-\mu)}}$	A1
		(4)
(c)	P or Q (or the system) would not move	B1
	Accept any of $T=mg$, $T>mg$, $T\geq mg$, $a=0$, $a<0$, $a\leq0$ $F=T$, $F>T$, $F\geq T$, $F>mg$. Allow F replaced by μR **N.B.** Forces referred to must be clearly defined so e.g. use of vague terms like 'forward force' , 'opposite force', 'force to the left or right' is B0.	**D**B1
		(2)
		(13)

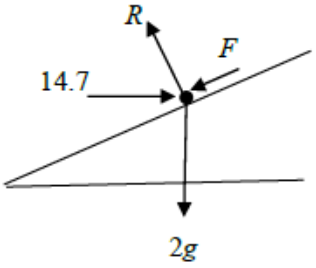
(a)	B1 for $F = \mu mg$ seen e.g. on a diagram	
	M1 Equation of motion for P with correct no. of terms, condone sign errors	
	A1 Correct equation (allow $-a$)	
	M1 Equation of motion for Q with correct no. of terms, condone sign errors	
	A1 Correct equation (allow $-a$) **N.B.** ($-a$) must be used in both equations	
	M1 for producing **an equation** in k and μ only	
	A1 oe Must appear in (a)	
(b)	M1 Attempt to find the acceleration in terms of g and μ or g and k or g, k and μ	
	M1 Complete method to find an equation in d, g, t and μ only, condone a sign error.	
	A1 Correct equation in d, g, t and μ only	
	A1 Any equivalent form	
(c)	B1 Correct statement. B0 if incorrect extras.	
	DB1 Correct reason	

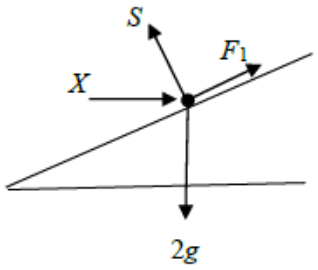
Q32.

Question Number	Scheme	Marks
	Resolve perp to the plane: $R = mg\cos\alpha$	M1A1
	Resolve parallel to the plane:	M1
	$mg\sin\alpha + F = 2P$	A1
	$mg\sin\alpha - F = P$	A1
	Use of $F = \mu R$	M1
	Substitute correctly for trig, eliminate P and F and solve for μ	M1
	$\mu = 0.25$	A1
	N.B. If they consistently omit g and obtain the correct answer, max marks are: M1A0M1A0A0M1M1A1	(8)
		(8)
	Notes for question	
	M1 First resolution, correct no. of terms, condone sign errors and sin/cos confusion **N.B.** If they use cos (4/5) etc, treat as an A error but allow recovery.	
	A1 Correct equation	
	M1 Second (or third) resolution, correct no. of terms, condone sign errors and sin/cos confusion **N.B.** M0 if they don't substitute for X, but full marks is possible if they use X and $2X$ oe. If they use sin (3/5) etc, treat as an A error but allow recovery.	
	A1 Correct equation (A0 if they use different R's or F's)	
	A1 Correct equation (A0 if they use different R's or F's)	
	M1 Use of $F = \mu R$	
	M1 Substitute for trig, eliminate P and F and solve for μ	
	A1 cao	

	Other possible equations:	
	$(\rightarrow) 2P\cos\alpha = R\sin\alpha + F\cos\alpha$ (1)	
	$(\rightarrow)\ P\cos\alpha = R\sin\alpha - F\cos\alpha$ (2)	
	$(\uparrow) mg - 2P\sin\alpha = R\cos\alpha - F\sin\alpha$ (3)	
	$(\uparrow) mg - P\sin\alpha = R\cos\alpha + F\sin\alpha$ (4)	
	SC: (Only needs 2 equations)	
	Equation (1): M1A1	
	Equation (2): M1A1	
	(1) + (2): $3P\cos\alpha = 2R\sin\alpha$	
	$(1)-(2)$: $P\cos\alpha = 2F\cos\alpha$	
	Divide $\frac{1}{3} = \frac{F}{R}\cot\alpha$. A1	
	Use of $F = \mu R$ M1	
	Substitute for trig and solve for μ M1	
	$\mu = 0.25$ A1	

Q33.

Question Number	Scheme	Marks
(a)		
	$(\square),\ 14.7\cos\alpha = 2g\sin\alpha + F$ (could be $-F$) **OR:** $(\rightarrow),\ 14.7 + F\cos\alpha = R\sin\alpha$ $(\uparrow),\ R\cos\alpha + F\sin\alpha = 2g$ **AND** eliminate R to give an equation in F only. <u>Verificaton methods</u> $14.7\cos\alpha = (11.76) = 2g\sin\alpha$ (i.e. verification that $X = 14.7 \Rightarrow F = 0$) **OR:** $X\cos\alpha = 2g\sin\alpha \Rightarrow X = 14.7$ (i.e. verification that $F = 0 \Rightarrow X = 14.7$)	M1 A1
	so $F = 0$* oe	A1*

		(3)
		
(b)	$F_1 = 0.5S$	B1
	Two equations taken from: ( ), $X\cos\alpha + F_1 = 2g\sin\alpha$ ( ), $S = X\sin\alpha + 2g\cos\alpha$ $(\rightarrow), X + F_1\cos\alpha = S\sin\alpha$ $(\uparrow), S\cos\alpha + F_1\sin\alpha = 2g$	M1A2 M1A2

	N.B. M0 for both equations if they put $X = 14.7$ anywhere	
	$X = 4g/11$, 3.6 or 3.56 or 3.57	A1
	N.B. Enter marks for the equations on ePen in the order in which they appear above.	
		(8)
		(11)
(a)	M1 Equation in F only, correct no of terms, condone sign errors and sin/cos confusion (M0 if they use $F = 0.5R$) **N.B.** Allow the equation without F Allow use of m instead of 2 for the Mmark	
	A1 Correct equation	
	A1* cao Must state a conclusion or , if verifying, must state clearly $X = 14.7 \Rightarrow F = 0$ **OR** $F = 0 \Rightarrow X = 14.7$	
(b)	B1 $F_1 = 0.5S$ *seen* e.g. on a diagram (even if wrong direction)	
	M1 A resolution, correct no of terms, condone sign errors and sin/cos confusion Allow use of m instead of 2 for the A mark	
	A2 Correct equation, -1 each error	
	M1 A resolution, correct no of terms, condone sign errors and sin/cos confusion Allow use of m instead of 2 for the A mark	
	A2 Correct equation, -1 each error	
	A1 cao	

Q34.

Question Number	Scheme	Marks
(a) (i)	$T - 2mg\sin\alpha - F = 2ma$	M1A1
(ii)	$3mg - T = 3ma$	M1A1
	N.B. Ignore the labelling (i) and (ii)	(4)
(b)	$R = 2mg\cos\alpha$ Allow if this appears in (a).	M1A1
	$F = \frac{1}{2}R$	B1
	Substitute for trig. and solve for a,	DM1
	$a = \frac{1}{5}g$	A1
		(5)
(c)	$T = \frac{12mg}{5}$ $(23.52m)$	DM1
	$2T\cos\left(\frac{90^o - \alpha}{2}\right)$ **OR** $\sqrt{T^2 + T^2 - 2T^2\cos(90^o + \alpha)}$ **OR** $\sqrt{(T\cos\alpha)^2 + (T + T\sin\alpha)^2}$	M1
	Substitute for trig and T to obtain an expression in m or mg	DM1
	$\frac{48\sqrt{5}mg}{25}$; Accept $4.3mg$ or better, $42m$ or $42.1m$	A1
		(4)
(d)	Tension is the same on **either side of the pulley**, tension across the pulley is the same.	B1
	B0 for tension is same for A and B or is the same for both strings etc	(1)
		(14)

	Notes for question	
	N.B. If m's are consistently missing, mark (a) and (b) as a MR	
(a)	M1 Correct no. of terms, condone sin/cos confusion and sign errors	
	A1 Correct equation	
	M1 Correct no. of terms, condone sign errors	
	A1 Correct equation **N.B.** Could have a replaced by $(-a)$ in both	
(b)	M1 Correct no. of terms, condone sin/cos confusion and sign errors	
	A1 Correct equation	
	B1 Seen, possibly on a diagram or in (a)	
	DM1, dependent on the two M's in (a), for solving 2 simultaneous equations or using a whole system equation to find a	
	A1 cao	
(c)	DM1, dependent on the relevant 1st or 2nd M1 in (a), for attempt to find their T, must be of form km or kmg . Apply isw if they 'cancel' m's.	
	M1 for a **correct** expression in terms of T and α only; α does not need to be substituted	
	DM1, dependent on previous M, for substituting in their T **and** for trig, to give an expression of form km or kmg	
	A1 cao	
(d)	B1 for any equivalent statement. B0 for incorrect extras.	

Q35.

Question Number	Scheme	Marks
(a)	$T = ma$ (allow $-a$)	B1
		(1)
(b)	$4mg\sin\alpha - T - F = 4ma$ **OR** $4mg\sin\alpha - F = 5ma$ (allow $-a$) (allow $-a$)	M1A1
	$F = \frac{1}{4}R$	B1
	$R = 4mg\cos\alpha$	M1A1
	Solve for T in terms of mg only	**D**M1
	$T = \frac{8mg}{25}$ oe	A1
		(7)
(c)	$2T\sin\frac{1}{2}\alpha$ oe e.g. $\sqrt{T^2+T^2-2T^2\cos\alpha}$ using cos rule Or $\frac{T\sin\alpha}{\sin(90^\circ - \frac{1}{2}\alpha)}$ using sine rule Or $\sqrt{(T-T\cos\alpha)^2+(T\sin\alpha)^2}$ using components and Pythag.	M1 A1
	Substitute for T and trig	M1
	$\frac{8mg\sqrt{10}}{125}$ oe, $2m$ or $2.0m$ or $1.98m$ or $0.2mg$ or better	A1
		(4)
(d)	e.g. Tension will be the same *throughout a* ***section*** of the string.	B1 (1)
		(13)

	Notes for question	
(a)	B1 cao The equation must appear in (a) to earn the B1.	
(b)	M1 Equation of motion for P parallel to the plane, correct no. of terms, condone sign errors and sin/cos confusion	
	A1 Correct equation	
	B1 $F = \frac{1}{4}R$ seen – could just be on the diagram	
	M1 Resolve perpendicular to the plane for P, correct no. of terms, condone sign errors and sin/cos confusion	
	A1 Correct equation	
	DM1 Dependent on both M marks, for solving for T – must be in terms of mg *only* (must be of form kmg)	
	A1 cao	
(c)	M1 If using resolving, condone cos/sin confusion and sign errors but must have correct angle	
	A1 Any correct unsimplified expression in terms of T and α	
	M1 For substituting in their T (must be of form kmg) and *correct* values for their trig	
	A1 cao	
(d)	B1 B0 for 'tension is the same throughout the string' B0 if incorrect extras	

Q36.

Question Number	Scheme	Marks
(a)	Whole system: $3000-1200g\sin\alpha-600g\sin\alpha-2R-R=1800(0.75)$	M1 A1 A1
	From exact working $R=60$ *	A1* cso
		(4)
(b)	Trailer: $T-600g\sin\alpha-60=600(0.75)$ **OR** Car: $3000-1200g\sin\alpha-2(60)-T=1200(0.75)$ (T could be replaced by $(-T)$ in either equation, leading to $T=-1000$, so tension is 1000)	M1 A1
	$T=1000$(N)	A1
		(3)
(c)	Equation of motion $-60-600g\sin\alpha=600a$ (or $-600a$) $\left[a=-\frac{11}{12}=-0.9166\ldots\right]$	M1 A1
	$0=12^2+2\left(-\frac{11}{12}\right)d$	M1
	$d=78.5$,79 (m)	A1
		(4)
		(11)

	Notes for question
(a) **M1**	Equation of motion for the whole system (**or** for car AND trailer with T eliminated) to give an equation in R only. $\sin\alpha$ does not need to be substituted Correct number of terms, forces resolved where appropriate, condone sign errors and sin/cos confusion.
A1	Correct equation with at most one error. $\sin\alpha$ does not need to be substituted
A1	Correct equation. $\sin\alpha$ does not need to be substituted
A1*	Reach the GIVEN answer with at least one intermediate line of working and must come from exact working.
(b) **M1**	Equation of motion for the trailer or for the car. Correct number of terms, forces resolved where appropriate, condone sign errors and sin/cos confusion. $\sin\alpha$ does not need to be substituted but $R = 60$ does
A1	Correct unsimplified equation. $\sin\alpha$ does not need to be substituted
A1	Correct answer for T
(c) **M1**	Form an equation of motion for the trailer to find the new acceleration. Correct number of terms, forces resolved where appropriate, condone sign errors and sin/cos confusion. $\sin\alpha$ does not need to be substituted but $R = 60$ does
A1	Correct unsimplified equation. $\sin\alpha$ does not need to be substituted
M1	Complete method, with a calculated acceleration that is not g, to find the distance travelled.
A1	Cao 2 or 3sf Must be positive. **N.B.** Allow a negative value of d and made positive for the distance.

Q37.

Question Number	Scheme	Marks
(a)	$R = 2g\cos\alpha$ (Could be earned in (b) if used there)	M1A1
	$T - 2g\sin a - F = 2a$	M1A1
	$4g - T = 4a$	M1A1
	OR $4g - 2g\sin a - F = 6a$ (whole system) M1A1	
	$F = 0.25R$ seen anywhere e.g on a diagram or in (b)	B1
	Solve for T	M1
	$T = 2.4g = \frac{12g}{5} = 24$ or 23.5 (N)	A1 (9)
(b)	$2.4g - 2g\sin a - 0.4g = 2a$ OR $4g - 2.4g = 4a$	M1
	$a = 0.4g$	A1
	$v^2 = \frac{4gh}{5}$	M1
	$-\frac{6g}{5} - \frac{2g}{5} = 2a'$ (a' is new acceleration of A up the slope) Allow +ve terms on LHS	B1
	$0 = \frac{4gh}{5} - \frac{8g}{5}s$	M1
	$s = \frac{1}{2}h$	A1
	$d > 1.5h$	A1 (7)
(c)	Weight of string; extensibility of the string; friction at pulley	B1 (1)
	N.B. Simply restating what's in the question is B0.	**(17)**

	Notes for question	
(a)	M1 Resolving perpendicular to the plane, correct no. of terms, condone sign errors and sin/cos confusion	
	A1 Correct equation	
	M1 Equation of motion parallel to the plane, correct no. of terms, condone sign errors and sin/cos confusion	
	A1 Correct equation	
	M1 Equation of motion vertically, correct no. of terms, condone sign errors.	
	A1 Correct equation	
	N.B. Either equation of motion may be replaced by a whole system equation with usual rules.	
	B1 $F = 0.25R$ seen anywhere e.g. on diagram	
	M1 Solve for T (Must have *two* equations of *motion* with a in each)	
	A1 cao	
(b)	M1 Eliminate T from their equations of motion to give an equation in a **only**. (**N.B.** May be done in (a) but must be used in (b))	
	(Must have *two* equations of *motion* with a in each)	
	A1 $a = 0.4g$ oe (**N.B.** May be found in (a) but must be used in (b))	
	M1 Complete method to give an equation in v and h only using their a, which must have been found. (M0 if $0.4g$ or g used)	
	B1 Correct equation of motion, with forces in numerical form or in terms of g, for A after B hits the ground in a' only	
	M1 for an equation in s and h only, using their a' (M0 if no a' found)	
	A1 For a correct expression for s in terms of h.	
	A1 cao	
(c)	B1 Any correct answer. B0 if any incorrect extras included.	

Q38.

Question Number	Scheme	Marks
(a)	$7400-200-6000=6000a$ $7400-200-R=8000a$ Any two of these three equations $6000-R=2000a$ **N.B.** 6000 (N) must be used as the tension to earn an M mark.	M1A1 M1A1
	$R=5600$	DM1A1
	N.B. If they consistently use tonnes in their equations treat as a MR i.e. max M1A0M1A0M1A1 Wrong figs. for mass, e.g. 6000000 etc or just m, can score M mark in that equation.	
		(6)
(b)	Same acceleration for the tractor and the block	B1
		(1)
		(7)
	Notes for question	
	N.B. Enter marks on ePen in the order in which the equations appear.	
(a)	M1 Correct no. of terms, condone sign errors (use mass to determine which equation is being attempted)	
	A1 Correct equation	
	M1 Correct no. of terms, condone sign errors	
	A1 Correct equation	
	DM1 Solve for R, dependent on both M marks	
	A1 cao	
(b)	B1 Any equivalent statement e.g 'both have the same acceleration' but not just 'same acceleration'. Need to say 'both' or mention the tractor and the block. Allow 'they have the same acceleration'. Allow 'same acceleration throughout the system' and 'both particles have the same acceleration'. **N.B.** B0 if extra wrong answers are included.	

Q39.

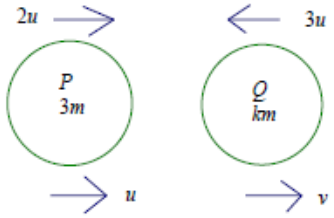
Question Number	Scheme	Marks
(a)	$(\uparrow)\ R = 5g - 14\sin 30^o$	M1 A1
	$R = 42$ (N)	A1
	(Max Friction =) $\frac{3}{7} \times 42 = 18$ (N) (18 only, with no working can score this M mark)	M1
	Horiz cpt of $P = 14\cos 30^o = 12.124\ldots$ and $12 < 18$ (their **max** friction) They must be comparing with a **maximum** friction i.e. the word '**maximum**' oe must have been clearly stated somewhere. **N.B.** M0 if they state or imply that the friction **acting** on the block is 18 N.	M1
	Friction = 12 or better (N) and block doesn't move	A1
		(6)
(b)	$(\uparrow) P\sin 30^o + S = 5g$	M1A1
	$(\rightarrow) P\cos 30^o = \frac{3}{7}S$ (Allow M1A0 if they use the max friction from (a) or $\frac{3}{7} \times$ wrong value for S) (allow M1A0 for $P\cos 30^o = F$)	M1A1
	Solve for P	DM1
	$P = 19$ or 19.4 (N)	A1
		(6)
		(12)
	Notes for question	
(a)	M1 Correct no. of terms, condone sin/cos confusion and sign errors	
	A1 Correct equation **in *R* only**.	
	A1 Correct value (seen or implied)	
	M1 Use of $F = \frac{3}{7}R$ with their R substituted.	
	M1 Condone sin/cos confusion	
	A1 cao and any equivalent correct statement and justification	
(b)	M1 Correct no. of terms, condone sin/cos confusion and sign errors	
	A1 Correct equation	
	M1 Correct no. of terms, condone sin/cos confusion and sign errors	
	A1 Correct equation	
	DM1 Dependent on both M marks; must be solving two equations in P and one other unknown	
	A1 cao	

Q40.

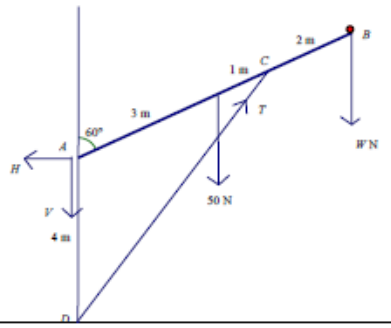
Question Number	Scheme	Marks
(a)	Perpendicular to the plane: $R+18\sin 40^\circ = 2g\cos 30^\circ$	M1 A1
	Equation of motion parallel to the plane: $18\cos 40^\circ - F - 2g\sin 30^\circ = 2a$ (or -2a)	M1 A1 A1
	$F = 0.3R$	B1
	$18\cos 40^\circ - 0.3\left(2g\cos 30^\circ - 18\sin 40^\circ\right) - 2g\sin 30^\circ = 2a$	dM1
	$a = 1.18$ or 1.2 $\left(\text{m s}^{-2}\right)$	A1 cao
		(8)
(b)	$v^2 = 2^2 + 2\left('1.18'\right)5$	M1 A1ft
	$v = 3.98$ or 4.0 or 4 (m s^{-1})	A1 cao
	N.B. For (a) and (b), penalise over accurate answers ONCE only.	(3)
(c)	$R = 2g\cos 30^\circ \left(= g\sqrt{3}\right)$	B1
	Friction = $0.3\times 2g\cos 30^\circ$ OR $0.3\times 2g\sin 30^\circ$	M1
	Compares Friction with weight component parallel to plane Eg Consider: $2g\sin 30^\circ - 0.3\left(2g\cos 30^\circ\right)$ $(=2a)$ **OR** $0.3\left(2g\cos 30^\circ\right) - 2g\sin 30^\circ$ $(=2a)$	dM1
	$(a) > 0$ **OR** $(a) < 0$ Concludes that P will not remain at rest oe	A1
		(4)
(15)		

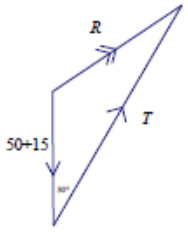
NOTES		
(a)		
M1	Correct number of terms, forces resolved *perp to the plane* where appropriate, condone sign errors and sin/cos confusion, forces and angles paired up correctly	
A1	Correct unsimplified equation.	
M1	Equation of motion parallel to the slope. Correct number of terms, forces resolved where appropriate, condone sign errors and sin/cos confusion, forces and angles paired up correctly	
A1	Correct unsimplified equation with at most one error	
A1	Fully correct unsimplified equation	
B1	Use of $F = 0.3R$	
dM1	Eliminate F and R to form an equation in a, dependent on two M's	
A1	Correct value for a. Must be 2 or 3sf	
(b)		
M1	Complete method to form an equation in v or v^2	
A1ft	Correct unsimplified equation. Follow through on their value for a.	
A1	Cao. Must be positive. Note that $a = 1.2$ leads to $v = 4$.	
(c)		
B1	Correct expression or value for **new** R	
M1	Find the max friction. M0 if the previous R is used.	
dM1	Correct comparison between max friction value and weight component (force parallel to slope), dependent on previous M	
A1	Correct statement from fully correct working. Concludes that P will not remain at rest.	

Q41.

a			
	Use CLM	M1	Need all terms and dimensionally correct. Condone sign errors. Might see them using equal (and opposite) impulses.
	$6mu - 3kmu = 3mu + kmv \quad \left((3-3k)u = kv\right)$	A1	Correct unsimplified equation
	$\Rightarrow v = \frac{(3-3k)}{k}u \quad *$	A1*	Obtain **given answer** from full and correct working
		3	
b	Use of Impulse = change in momentum	M1	Must be subtracting. Can be for either particle.
	$\left\|I_Q\right\| = \left\|I_P\right\| = \left\|3mu - 3m.2u\right\| = 3mu$ or $\left\|kmv - (-3mku)\right\| = \left\|km.\frac{3-3k}{k}u + 3mku\right\| = 3mu$	A1	Correct only (Do not need to state that $\left\|I_Q\right\| = \left\|I_P\right\|$ if find $\left\|I_P\right\|$)
		2	
c	Use impact law:	M1	Seen or implied. If stated in (a) must be used here. Must be used correctly but condone sign errors
	$\frac{v-u}{5u} = e$ or $\frac{3-3k}{k}u - u = 5ue$	A1	Correct unsimplified equation
	NB: the second and third M mark are not dependent on the first M mark		
	Use $v > u$ or $e > 0$ to form an inequality in k	M1	Could use $e \ldots 0$ followed by $v \neq u$
	Use $e \geq 1$ to form an inequality in k	M1	
	$\frac{3-3k}{k} > 1$ and $3-3k \geq 6k \quad \Rightarrow \frac{1}{3} \geq k < \frac{3}{4}$	A1	Correct answer only.
		5	
		(10)	

Q42.

a			
	M(*A*)	M1	Or equivalent method to form an equation in W only. Equation(s) must be dimensionally correct and contain all relevant terms. Condone sin / cos confusion and sign error(s)
	$50\times3\cos30°+W\times6\cos30°=60\sqrt{3}\times4\sin30°$	A1 A1	Unsimplified equation with at most one error. Correct unsimplified equation
	$W=15$ *	A1*	Correct answer only
		4	
b	First equation e.g. Resolve vertically	M1	Or resolve parallel to pole
	$(\pm)V+50+15=T\cos30°$ $(V=25)$	A1	Or: $P+50\cos60°+15\cos60°=60\sqrt{3}\times\frac{\sqrt{3}}{2}$
	Second equation e.g. Resolve horizontally	M1	Or resolve perpendicular to the pole
	$(\pm)H=T\cos60°\left(=30\sqrt{3}=51.96.....\right)$	A1	Or: $50\cos30°+15\cos30°=60\sqrt{3}\cos60°+Q$
	NB: One of the equations could be a second moments equation		
	$\lvert R\rvert=\sqrt{25^2+\left(30\sqrt{3}\right)^2}$	DM 1	Dependent on the 2 preceding M marks $\left(\sqrt{57.5^2+3\times6.25}\right)$
	$=5\sqrt{133}\,(57.662.....)$ (N)	A1	58 N or better
		6	Full marks available using $\pm V,\pm H,\pm P,\pm Q$

b alt	Form vector triangle for the vertical forces, the thrust and the resultant Correct triangle	M1 A1	
	Use cosine rule	M1	
	$R^2=T^2+(50+W)^2-2T(50+W)\cos30°$	A1	Correct unsimplified equation
	$R^2=\left(60\sqrt{3}\right)^2+(65)^2-2\times60\sqrt{3}\times65\cos30°$	DM 1	Substitute values and solve for $\lvert R\rvert$
	$\lvert R\rvert=5\sqrt{133}\,(57.662.....)$ (N)	A1	58 N or better
		6	
		(10)	

Q43.

	1st equation e.g. Equation for change in KE	M1	Dimensionally correct. Must be subtracting but condone sign error.
	$\frac{1}{2}\times 0.5\left(x^2+y^2-\left(5^2+3^2\right)\right)=22$ $\left(x^2+y^2=122\right)\ \left(1^2+(2\lambda+3)^2=122\right)$	A1	Correct unsimplified equation seen or implied (They might have used impulse-momentum first and done some work before substituting x and y.)
	2nd equation e.g. Impulse-momentum equation	M1	Dimensionally correct. Must be subtracting but condone sign error.
	$0.5(x\mathbf{i}+y\mathbf{j})-0.5(5\mathbf{i}+3\mathbf{j})=(-2\mathbf{i}+\lambda\mathbf{j})$ $\left((x-5)\mathbf{i}+(y-3)\mathbf{j}=-4\mathbf{i}+2\lambda\mathbf{j}\right)$	A1	Correct unsimplified equation
	NB: epen has M1A1A1 for the final 3 marks but this should be marked DM1DM1A1		
	Form a quadratic equation in λ	DM1	e.g. $1^2+\left(3+2\lambda\right)^2=122$ Dependent on the 2 preceding M marks
	Solve for 2 values of λ	DM1	e.g. solve $4\lambda^2+12\lambda-112=0$ or $\left(3+2\lambda\right)^2=121$ Dependent on the preceding M1
	$\Rightarrow \lambda=4$ or $\lambda=-7$	A1	Correct only and no errors seen (watch out for $x=-1$ used)
alt	Form a quadratic in y	DM1	e.g. $1+y^2=122$ $\left(y^2=121\right)$ Dependent on the 2 preceding M marks
	Solve for 2 values of y and use these to obtain 2 values of λ	DM1	Dependent on the preceding M1
	$\Rightarrow \lambda=4$ or $\lambda=-7$	A1	
		7	

Q44.

Question Number	Scheme	Marks
(a)	Correct relationship between the speeds after the collision. v and $v+1$ OR $w-1$ and w	B1
	$(3m\times1.5)+(m\times-1.5)=3mv+m(v+1)$ [Or $(3m\times1.5)+(m\times-1.5)=3m(w-1)+mw$]	M1 A1
	Speed of $A=\frac{1}{2}$ (m s^{-1}) Speed of $B=\frac{3}{2}$ (m s^{-1})	A1 A1
		(5)
(b)	For B: $\pm m(1.5--1.5)$ **OR** For A: $\pm3m(0.5-1.5)$	M1 A1ft
	$3m$ (Ns)	A1
		(3)
		(8)

	NOTES	
(a)		
B1	*speed* of B = 1 + *speed* of A . Must be seen **before** the CLM equation is used i.e. algebraic not numerical quantities	
M1	Dimensionally correct CLM equation with correct number of terms. Allow consistent extra g 's or cancelled m 's. Ignore sign errors. Allow the use of 2 unknowns for speeds after. (M0 if same speeds)	
A1	Correct equation in 1 unknown	
A1	Correct speed of A	
A1	Correct speed of B	
(b)		
M1	Dimensionally correct impulse-momentum equation using A or B with correct number of appropriate terms. Condone sign errors but must be difference of momenta. M0 if g is included.	
A1ft	Correct unsimplified equation. Follow through their answer in (a),but if using B, terms must have same signs, if using A, terms must have opposite signs.	
A1	Cao (must be positive)	

Q45.

a	Equation of motion	M1	Dimensionally correct. Condone sign error.
	$F - R = 1500a$	A1	Correct unsimplified equation in F or P
	Use of $P = Fv$: $\left(\frac{30000}{20} - R = 1500 \times 0.6\right)$	M1	Must be trying to use 30 kW but condone error in zeros
	$R = 600$	A1	Correct answer only
		4	
b	Equation of motion	M1	Dimensionally correct. Need all relevant terms. Condone sign errors and sin/cos confusion. Allow with F.
	$\frac{30000}{V} - 1500g \times \frac{1}{8} - 500 = -1500 \times 0.2$	A1 A1	Unsimplified equation with F substituted and at most one error Correct unsimplified equation with F substituted. If F is never substituted, A0A0
	$V = 14.7 \quad (15)$	A1	3 sf or 2 sf
		4	
		(8)	

Q46.

a	Use of $F_{max} = \mu R$: $F_{max} = \frac{2}{7} \times 1.5g\cos\theta$	M1	$(3.87...)$ Condone trig confusion. Trig substitution not required. Allow M1 if there is a clear statement for F_{max} "correct" and then used in a calculation including the gain in GPE
	Use of $WD = 2.5F_{max}$	M1	Trig substitution not required. M0 if they have included the gain in GPE
			If the method for F is incorrect but involves the use of μ to obtain F and then they use the "work done" formula correctly allow M0M1
	$WD = 9.69 \quad (9.7)(J)$	A1	3 sf or 2 sf not $\frac{126}{13}$
		3	
b	Work-energy equation	M1	The Q asks for work-energy. Need all terms and dimensionally correct. Condone sign errors and sin / cos confusion
	If their answer to (a) included the GPE then it must be used for the total work done here to score the M1		
	$\frac{1}{2} \times 1.5U^2 = WD + 1.5 \times 9.8 \times 2.5 \times \sin\theta$	A1ft A1ft	Unsimplified equation with at most one error. Correct unsimplified equation Follow their WD against friction
	$U = 5.64 \quad (5.6)$	A1	3 sf or 2 sf
		4	
c	Work-energy equation for A to A	M1	The Q asks for work-energy. Need all terms and dimensionally correct.
	$\frac{1}{2} \times 1.5v^2 = \frac{1}{2} \times 1.5U^2 - 2WD$	A1ft	Correct unsimplified equation. Follow their WD against friction and their U
	$v = 2.43\,(2.4)\,(\text{ms}^{-1})$	A1	3 sf or 2 sf
		3	

c alt	Work-energy equation for B to A	M1	The Q asks for work-energy. Need all terms and dimensionally correct.
	$\frac{1}{2} \times 1.5v^2 = 1.5 \times 9.8 \times 2.5 \times \sin\theta - WD$	A1ft	Correct unsimplified equation. Follow their WD
	$v = 2.43\,(2.4)\,(\text{ms}^{-1})$	A1	3 sf or 2 sf
		3	
		(10)	

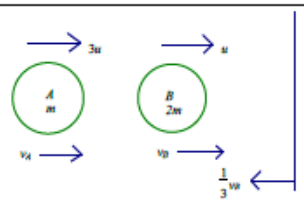
Q47.

Question Number	Scheme	Marks
(a)	Energy from C to D	
	$mg\frac{l}{4}\sin 30° = \frac{\lambda}{2l}\left(\frac{l}{4}\right)^2$	M1A1A1
	$\lambda = 4mg$ *	A1* **(4)**
(b)	The greatest speed is when the acceleration of B is zero	
	(↖) $T = mg\sin 30° = \frac{4mge}{l}$	M1
	$e = \frac{l}{8}$	A1
	Energy: $\frac{1}{2}mv^2 + \frac{4mg}{2l}\left(\frac{l}{8}\right)^2 = mg\frac{l}{8}\sin 30°$	M1A1A1
	$v = \sqrt{\left(\frac{gl}{16}\right)} = \frac{\sqrt{gl}}{4}$	DM1A1 **(7)**
		[11]

	Notes
(a)	
M1	Attempt the energy equation from C to D. Must use a vertical height for PE. EPE must have the form kx^2. Must have 1 PE term and 1 EPE term.
A1	Correct loss of PE
A1	Correct final EPE
A1*	Correct answer correctly obtained
(b)	
M1	Resolve along the plane using HL to find T
A1	Correct value for the extension
M1	Form the energy equation with an extension they have found. **M0** if $l/4$ is used for the extension. Must use a vertical height for PE. EPE must have the form kx^2 Must have 1 PE term, 1 KE term and 1 EPE term.
A1	Two correct terms
A1	Completely correct equation
DM1	Solve for v. Dependent on previous M.
A1	Correct expression for v
(b) ALT 1	**Using integration**
M1 A1	As above, for finding correct value for e. This may be embedded in a complete method.
M1	Uses F=ma to and attempts to integrate. Must have the correct number of terms and weight resolved, $\int g\sin 30 - \frac{4gx}{l}\,dx = \int v\,dv$ leading to $\frac{gx}{2} - \frac{2gx^2}{l} = \frac{v^2}{2} + c$
A1	Correct integration with at most one slip/error
A1	Completely correct integration but c may be missing
DM1	Find value for c (when $x = \frac{l}{4}$, $v=0$ gives c=0) **and** sub in e to find an expression for v
A1	Correct expression for v

4(b) ALT 2	**Using SHM**
M1 A1	As above, for finding correct value for e. This may be embedded in a complete method.
M1 A1	Correctly uses F=ma to show that the motion is SHM
A1	Correct proof of SHM
M1	Uses $v = aw$ to find an expression for v
A1	Correct expression for v

Q48.

(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
	$3mu + 2mu = mv_A + 2mv_B$ $(5u = +v_A 2v_B)$	A1	Correct unsimplified equation. Allow with v_A negative
	Use of NEL	M1	Used the right way round. Condone sign errors
	$v_B - = v_A\ e(3u - u)$ $(2ue = -v_B v_A)$	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	
(b)	Time for B to reach the wall $t_B = \frac{d}{2u}$	B1	Or equivalent seen or implied. Allow $\frac{d \times 3}{(5\ 2+\ e\ u)}$

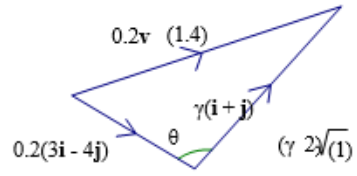
	Speed of B after impact with wall $= \frac{2}{3}u$	B1	Seen or implied. Allow $\frac{15 + 2e}{30}u$
	Distance travelled by A before B hits the wall d $= u \times \frac{d}{2u} = \frac{d}{2}$	M1	Substitute $e = \frac{1}{2}$ and use their v_A and their t_b to find distance
	Time to close the gap	M1	Correct formula with their relevant speeds
	$\frac{d}{2} = ut + \frac{5ut}{3} \times t$ $t = \frac{3d}{10u}$	A1	Correct unsimplified equation (t x speed of approach)
	Total time $= \frac{d}{2u} + \frac{3d}{10u} = \frac{8d}{10u} = \frac{4d}{5u}$	A1	ISW Any equivalent form
		6	

(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 Distance travelled by B after it hits the wall Correct formula for time Correct unsimplified equation Correct answer
		(13)	

Q49.

Q	Mark Scheme	Marks	Marking guidance
	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 impulsemomentum equation is M0 unless they recover. **See below**
	$0.2(\mathbf{v} - + = 4\mathbf{i}3\mathbf{j}) \ \lambda(\mathbf{i} + \mathbf{j})$ $((x - + +4)\mathbf{i} \ (y3)\mathbf{j} = 5\lambda \ \lambda\mathbf{i} + 5 \ \mathbf{j})$	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
	$x^2 + = y^2 \ 49$	A1ft	Correct unsimplified equation for their x, y
	Form quadratic in x y, or λ and reach $\lambda = ...$	DM1	Dependent on both previous M marks. $x^2 + -(x \ 7)^2 = 49$ or $(y + 7)^2 + = y^2 \ 49$ or $(5\lambda + 4)^2 + (5\lambda - = 3)^2 \ 49$
	$\lambda = \frac{5}{4}$ or $\lambda = -\frac{5}{4}$	A1	Or equivalent

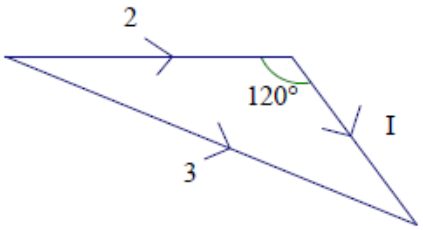
** ** ** ** ** ** **	Special case: Candidates who use 7 as a vector can score a **maximum** of M1A0M1A0 for $1.4^2 = +(\lambda \ 0.8)^2 + -(\lambda$ $0.6)^2$ or equivalent DM1A0 for forming and		This maximum of 3 marks is only available for those candidates who "recover". So, **if all you see** is $\lambda \ \lambda\mathbf{i} + = -\mathbf{j}$ 1 .4 0 .2 4(

			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)	
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 ±

	Form equation in $\lambda\left(2\lambda\lambda^2+.4-0.96=0\right)$	DM1	e.g. by use of cosine rule Dependent on the first 2 M marks
	$\lambda=\frac{5}{4}$ or $\lambda=-\frac{5}{4}$	A1	Or equivalent
		(6)	

Q50.

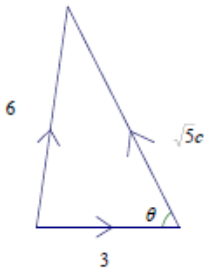
Question	Scheme	Mark	Notes
	Form impulse-momentum equation	M1	Dimensionally correct. Accept answers in "vector" form, or as separate components. Condone sine / cosine confusion.
	One correct equation	A1	e.g. one correct component of $\begin{pmatrix} I\cos 60° \\ I\sin 60° \end{pmatrix}=\frac{1}{4}\left[\begin{pmatrix} 12\cos\alpha \\ 12\sin\alpha \end{pmatrix}-\begin{pmatrix} 8 \\ 0 \end{pmatrix}\right]$ or $\left(=\begin{pmatrix} 3\cos\alpha-2 \\ 3\sin\alpha \end{pmatrix}\right)$ $\begin{pmatrix} I\cos 60° \\ I\sin 60° \end{pmatrix}=\frac{1}{4}\left[\begin{pmatrix} v_x \\ v_y \end{pmatrix}-\begin{pmatrix} 8 \\ 0 \end{pmatrix}\right]$ $\left(=\begin{pmatrix} 3\cos\alpha-2 \\ 3\sin\alpha \end{pmatrix}\right)$ if working parallel and perpendicular to the initial direction or one of $8\sin 60°=12\cos\left(30°+\alpha\right)$ or $I=0.25\left(12\sin\left(30°+\alpha\right)-8\cos 60°\right)$ if working parallel and perpendicular to the impulse
	Form a second impulse-momentum equation	M1	
	correct second equation	A1	
	Complete method to solve for I	DM1	Dependent on the two preceding M marks. e.g. from $36=(I+4)^2+3I^2 \quad \left(4I^2+8I-20=0\right)$
	$I=\sqrt{6}-1$ (or 1.45 or 1.4)	A1	
		[6]	

alt		**M1**	Use of $I = mv - mu$ to draw a vector triangle. Dimensionally consistent.
		A1	Correct diagram
	Form an equation in I	**M1**	e.g. by using cosine rule
	$4 + I^2 - 4I\cos 120° = 9$	**A1**	Correct unsimplified equation A correct cosine rule equation can imply the first M1A1 if no diagram seen
	Solve for I	**DM1**	Dependent on the 2 preceding M marks $I^2 + 2I - 5 = 0$
	$I = \sqrt{6} - 1$ (or 1.45 or 1.4)	**A1**	
		(6)	

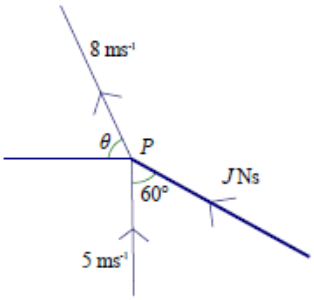
Q51.

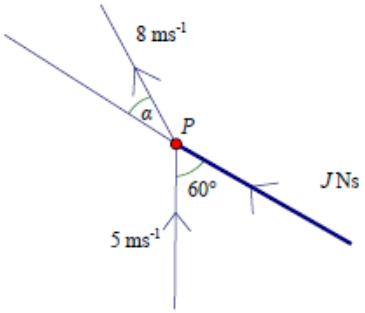
Question	Scheme	Marks	Notes
a	$\mathbf{I} = m\mathbf{v} - m\mathbf{u}$	M1	Must be subtracting but condone subtraction in wrong order
	$= 0.3\left(\left(7\mathbf{i} + 7\mathbf{j}\right) - 5\mathbf{i}\right) \quad \left(= 0.6\mathbf{i} + 2.1\mathbf{j}\right)$	A1	correct unsimplified equation Allow ±
	$\left\|\mathbf{I}\right\| = \sqrt{0.6^2 + 2.1^2}$	M1	Use of Pythagoras
	$= \frac{3\sqrt{53}}{10}$	A1	2.2 or better (2.18403…)
		(4)	
b	Correct method for a relevant angle	M1	e.g. use of trigonometry or scalar product for their **I** θ or 90 - θ
	Correct trig ratio for the required angle and no other angle involved.	A1	From correct **I** e.g. $\tan\theta = \frac{7}{2}$ or $\cos\theta = \frac{10}{\sqrt{53} \times 5}$
	$\theta = 74.1°$	A1	74° or better $(74.0546..°)$ or 360 – 74 (286) (1.29… radians)
		(3)	

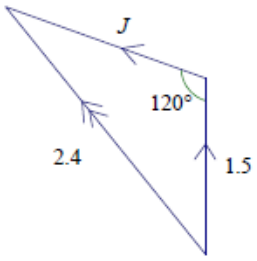
Q52.

Q	Solution	Mark	Guidance
	Use of $\mathbf{I} = m(\mathbf{v}-\mathbf{u})$	M1	As a single vector equation or two separate equations.
	$c\begin{pmatrix}-1\\2\end{pmatrix} = \frac{3}{4}\mathbf{v} - \begin{pmatrix}3\\0\end{pmatrix}$ $\left(\mathbf{v} = \frac{4}{3}\begin{pmatrix}3-c\\2c\end{pmatrix}\right)$	A1	Any equivalent substituted form
	Use of Pythagoras	M1	
	$64 = \frac{16}{9}\left((3-c)^2 + 4c^2\right)$	A1	Correct unsimplified equation in c or a component of $\mathbf{v}$. $\left(5a^2 - 32a = 0 \text{ or } 5b^2 - 16b - 192 = 0\right)$
	Simplify to 3 term quadratic and solve for c	M1	$5c^2 - 6c - 27 = 0$
	$c = 3 \quad \text{or} \quad c = -\frac{9}{5}(-1.8)$	A1	Correct only
		(6)	
Alt		M1 A1	Form vector triangle. Dimensionally correct Three correct lengths and $\lvert\cos\theta\rvert = \frac{1}{\sqrt{5}}$ seen or implied
	Use of cosine rule	M1	
	$36 = 9 + 5c^2 - 2\times 3\sqrt{5}c\cos\theta$	A1	Correct unsimplified equation in c with $\cos\theta$ or their $\cos\theta$
	Rearrange as 3 term quadratic and solve for c.	M1	$5c^2 - 6c - 27 = 0$
	$c = 3 \quad \text{or} \quad c = -\frac{9}{5}(-1.8)$	A1	Correct only
		(6)	
		[6]	

Q53.

Q	Solution	Mark	Notes
			Resolving parallel and perpendicular to the original direction of motion
	Use of $J = m(v-u)$	M1	Use of $J = m(v-u)$ parallel or perpendicular to original direction
	$J\cos 30° = 2.4\cos\theta$ or $J\cos 60° = 2.4\sin\theta - 1.5$	A1	One correct unsimplified equation
	Use of $J = m(v-u)$	M1	Use of $J = m(v-u)$ to form second equation
		A1	2nd correct unsimplified equation
	The first 4 marks are available for a correct equation in vector form.		$\begin{pmatrix} -2.4\cos\theta \\ 2.4\sin\theta \end{pmatrix} = \begin{pmatrix} -J\cos 30° \\ J\cos 60° + 1.5 \end{pmatrix}$
	$2.4^2 = \frac{3J^2}{4} + \frac{J^2}{4} + 1.5J + 1.5^2$ $\left(J^2 + 1.5J - 3.51 = 0\right)$	DM1	Form an equation in J only Dependent on previous two M1 marks
	$J = 1.3$	A1	1.3 or better (1.268….)
		(6)	

Alt 1			Resolving parallel and perpendicular to the direction of the impulse.
	Use of $J = m(v-u)$	M1	Use of $J = m(v-u)$ in any direction
	$J = 0.3(8\cos\alpha - 5\cos 60°)$ Or $5\sin 60° = 8\sin\alpha$	A1	Correct unsimplified equation $\begin{pmatrix} 2.4\cos\alpha = J + 1.5\cos 60° \\ 2.4\sin\alpha = 1.5\sin 60° \end{pmatrix}$
	Use of $J = m(v-u)$	M1	Use of $J = m(v-u)$ in perpendicular direction
		A1	Correct unsimplified equation
	$2.4^2 = \left(J + \frac{3}{4}\right)^2 + \left(\frac{3}{2}\right)^2 \times \frac{3}{4}$ $\left(J^2 + 1.5J - 3.51 = 0\right)$	DM1	Form an equation in J only Dependent on previous two M1 marks
	$J = 1.3$	A1	1.3 or better (1.268….)
	Could have a mixture of the first 2 alternatives. M1A1M1A1 for 2 independent equations. DM1A1 for solving		
		(6)	

Alt 2			Using vector triangle.
	Impulse momentum triangle	M1	Form dimensionally correct vector triangle (for impulse or momentum)
	Use of cosine rule	M1	Use of cosine rule in momentum or velocity triangle
	$2.4^2 = J^2 + 1.5^2 - 3J\cos 120°$	A1 A1	unsimplified equation in v or mv with at most one error Correct unsimplified equation
	$J^2 + 1.5J - 3.51 = 0$	DM1	Form a simplified equation in J Dependent on previous two M1 marks
	$J = 1.3$	A1	1.3 or better (1.268….)
		(6)	
		[6]	

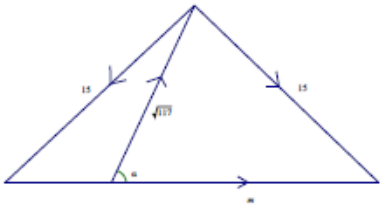
Q54.

			Allow column vectors
	Use of $\mathbf{I} = m\mathbf{v} - m\mathbf{u}$	M1	Must be subtracting
	$(\mathbf{I} =) \pm 0.5\left((4-\lambda)\mathbf{i} + (-\lambda)\mathbf{j}\right)$	A1	Accept $\pm$ correct unsimplified expression on right hand side. (Ignore the left hand side) Allow $2\mathbf{i} - \frac{4}{2}(\mathbf{i} + \mathbf{j})$ or equivalent
	Use of magnitude to form an equation in one variable	M1	Correct use of Pythagoras
	$\frac{5}{2} = \frac{1}{4}\left((4-\lambda)^2 + (-\lambda)^2\right)$	A1ft	Follow their **I**
	$0 = 2\lambda^2 - 8\lambda + 6 \quad (= (2\lambda - 6)(\lambda - 1))$	DM1	Form a 3 term quadratic (seen or implied). Not necessarily stated "= 0" From $\mathbf{I} = a\mathbf{i} + b\mathbf{j}$ can obtain $4a^2 - 8a + 3 = 0$ or $4b^2 + 8b + 3 = 0$ Dependent on the preceding M1 **Solving not required for the M1.**
	$\lambda = 3$ and $\lambda = 1$	A1cso	**From correct solution only.** Do not need to see method of solution.
		[6]	

alt	Use of $\mathbf{I} = m\mathbf{v} - m\mathbf{u}$ to form a vector triangle	M1	
	Triangle with sides of length $\sqrt{\frac{5}{2}}$, $\lvert 2\mathbf{i}\rvert$ and $\left\lvert\frac{\lambda}{2}(\mathbf{i}+\mathbf{j})\right\rvert$	A1	
	Use of cosine rule with $45°\left(\frac{\pi}{4}\right)$	M1	
	$\frac{5}{2} = 2^2 + \left(\frac{\lambda}{2}\right)^2 \times 2 - 2\times 2\times \frac{\lambda}{2}\sqrt{2}\cos 45°$	A1ft	Correct unsimplified equation Follow their magnitudes
	$0 = \lambda^2 - 4\lambda + 3 \quad (=(\lambda-3)(\lambda-1))$	DM1	Form a 3 term quadratic (seen or implied) Dependent on the preceding M1
	$\lambda = 3$ and $\lambda = 1$	A1	Correct solution only
		[6]	
		(6)	

Q55.

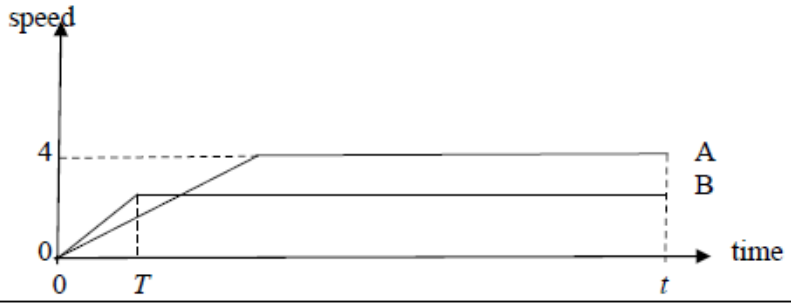
Question Number	Scheme	Marks	
	$(\mathbf{I}=)1.5\{v\mathbf{i}-(4\mathbf{i}+6\mathbf{j})\}$	M1	Use of $\mathbf{I} = m\mathbf{v} - m\mathbf{u}$. Must be using $\mathbf{i}$. Condone $\mathbf{u}$, $\mathbf{v}$ confusion. Ignore the left hand side
	$=1.5\{(v-4)\mathbf{i}-6\mathbf{j}\}$	A1	Or equivalent seen or implied Condone subtraction the wrong way round. Ignore the left hand side
	$\Rightarrow 15^2 = 1.5^2\{(v-4)^2+6^2\}$	M1	Use of modulus. Allow for $p^2+q^2=100$
	$(100=(v-4)^2+36)$	A1	Correct unsimplified equation in v
	$(v^2-8v-48=0)$	A1	Correct simplified equation in v seen or implied.
	$\Rightarrow v=12$	A1	One correct value
	or $v=-4$	A1	Both correct values
		[7]	

alt1			
	Initial momentum $=(6\mathbf{i}+9\mathbf{j})$ Ns	M1	Impulse momentum triangle. Accept $\sqrt{117}$ Ns
	$\cos\alpha=\frac{6}{\sqrt{117}}\left(=\frac{2}{\sqrt{13}}\right)$	A1	Or equivalent
	$m^2+117-2m\sqrt{117}\cos\alpha=225$	M1	Use of cosine formula (final momentum m)
	$m^2-12m-108=0$	A1	Or equivalent
	$\Rightarrow m=-6$ or $m=18$	A1	
	$\Rightarrow v=12$	A1	One correct value
	or $v=-4$	A1	Both correct values
		[7]	
alt2	Initial momentum $=(6\mathbf{i}+9\mathbf{j})$ Ns	M1	Impulse momentum triangle. Accept $\sqrt{117}$ Ns
	$\sin\alpha=\frac{3}{\sqrt{13}}$	A1	Or equivalent
	$\frac{15}{\sin\alpha}=\frac{\sqrt{117}}{\sin\theta}$	M1	Use of sine formula
	$\Rightarrow\sin\theta=\frac{3}{5}$, $\theta=36.9°$ or $\theta=143.1°$	A1	
	$\frac{m}{\sin 86.8}=\frac{15}{\sin\alpha}$ or $\frac{m}{\sin 19.4}=\frac{15}{\sin(180-\alpha)}$	A1	Correct equation in m
	$\Rightarrow v=12$	A1	One correct value
	or $v=-4$	A1	Both correct values
		[7]	

Q56.

a	Use of $\mathbf{I} = m\mathbf{v} - m\mathbf{u}$	M1	Condone subtraction in the wrong order.
	$\begin{pmatrix} -4 \\ 6 \end{pmatrix} = \frac{1}{2}\begin{pmatrix} x-2 \\ y-4 \end{pmatrix}$	A1	Correct unsimplified equation Any equivalent form. Allow with **v**
	$\mathbf{v} = -6\mathbf{i} + 16\mathbf{j}\left(\text{m s}^{-1}\right)$	A1	Correct only. Seen or implied SR: Allow 3/3 if stop at $\mathbf{v} = 6\mathbf{i} - 16\mathbf{j}\left(\text{m s}^{-1}\right)$
	$\lvert\mathbf{v}\rvert = \sqrt{(-6)^2 + 16^2}$	M1	Correct use of Pythagoras with their **v**
	$= \sqrt{292}\ \left(= 2\sqrt{73}\right)\left(\text{m s}^{-1}\right)$	A1	Correct simplified value. 17 or better (17.088……)
			Allow 5/5 if working from the negative of the velocity.
		[5]	
b	Correct use of trigonometry to find 2 relevant angles - as values or in inverse tangent form	M1	For their **v** e.g. $\pm 69.44..°, 63.43..°$ or $\pm 1.212..., 0.4636..$
	$\theta = \left(180° - \tan^{-1}\frac{16}{6}\right) - \tan^{-1}\frac{4}{2}$	A1ft	Correct unsimplified expression for θ Any equivalent form
	$= 47°$	A1	$47°$ or better (47.121..) $312.9°$ Accept radians (0.8224..)
		[3]	
b alt	Use of scalar product with two relevant vectors	M1	For their **v**
	$\theta = \cos^{-1}\left(\frac{-12+64}{\sqrt{20}\sqrt{292}}\right)$	A1ft	Correct unsimplified expression for $\cos\theta$ or equivalent
	$= 47°$	A1	$47°$ or better (47.121..) $312.9°$ Accept radians (0.8224..)
		[3]	
		(8)	

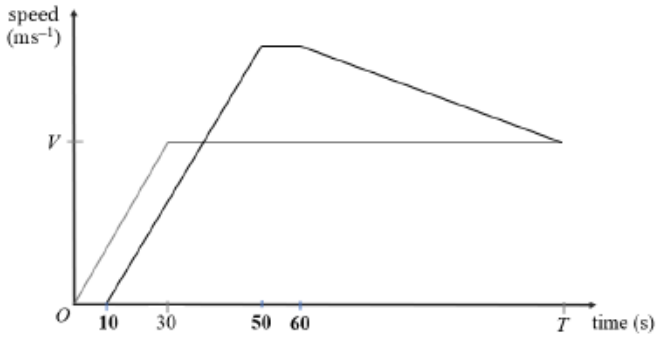
Q57.

Question Number	Scheme	Marks
(a)		B1 for A B1 for B B1 4 & T Allow their numerical value of T (3)
(b)	$\frac{4}{0.8}=5$ (s)	B1
	$100=\frac{(t+t-5)}{2}\times 4$ **OR** $100=\frac{1}{2}\times 5\times 4+4(t-5)$	M1A1ft
	$t=27.5$ (s)	A1
		(4)
(c)	$100=\frac{(27.5+27.5-T)}{2}\times T$ **OR** $100=\frac{1}{2}\times T\times T+T(27.5-T)$	M1A1ft
	$T^2-55T+200=0$ oe	A1
	$T=3.915047\ldots$ accept 3.9 or better	A1
		(4)
(d)	$4-3.915..$	M1
	0.085 or better (m s^{-1})	A1ft
		(2)
		(13)

	Notes for question	
(a)	B1 Correct shape for A's graph.	
	B1 Correct shape for B's graph with steeper gradient initially and must cross A's graph. Both graphs must end at the same time. B0 once if solid vertical line at the end	
	B1 4 and T correctly marked. Allow appropriate delineators. **N.B.** If graphs are on separate axes can score max B1B0B1 If no labels, give BOD. If incorrect labels, max B1B0B1	
(b)	B1 5 (s) seen – could be on graph	
	M1 Attempt at equation in t *only*, with correct structure i.e. trapezium or (rectangle + triangle) or (rectangle – triangle) oe including $\frac{1}{2}$ where appropriate, based on total area (OR distance using 2 or more *suvat* formulae) being 100 M0 for a *single suvat* equation for the *whole* motion. **N.B.** If they clearly use T (for t) in their equation and **in their answer**, it's M0 but give BOD where possible.	
	A1ft Correct equation in t only, ft on their 5	
	A1 cao	
(c)	M1 Attempt at equation in T *only*, with correct structure, i.e. trapezium or (rectangle + triangle) or (rectangle – triangle) oe based on total area (OR distance using 2 or more *suvat* formulae) being 100 M0 for a *single suvat* equation for the *whole* motion.	

	A1ft Correct equation in T only, ft on their 27.5	
	A1 Correct 3 term quadratic	
	A1 cao	
(d)	M1 for $4-T$. (Allow $T-4$)	
	A1 **ft** follow through on their T value provided it's < 4. Must be correct to at least **2 SF**.	

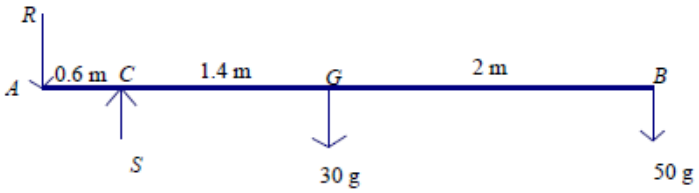
Q58.

Question number	Scheme	Marks
(a)	For car: $\left(\frac{T+T-30}{2}\right)V$	M1
	$V(T-15)$ (metres) * Allow $(T-15)V$	A1*
		(2)
(b)		B1 shape B1 Horiz labels (10,50,60)
		(2)
(c)	$\frac{speed}{40}=\frac{V}{30}$	M1
	$(\text{speed})=\frac{4V}{3}$ (m s^{-1})*	A1*
		(2)
(d)	For motorbike **OR:** $\frac{1}{2}\left(\frac{4V}{3}\times 40\right)+\left(\frac{4V}{3}\times 10\right)+\frac{1}{2}\left(\frac{4V}{3}+V\right)(T-60)$ **OR:** $\frac{1}{2}\left(\frac{4V}{3}\times 40\right)+\left(\frac{4V}{3}\times 10\right)+\frac{1}{2}\left(\frac{4V}{3}-V\right)(T-60)+V(T-60)$ **OR:** $\frac{1}{2}\times\frac{4V}{3}\times(10+50)+\frac{1}{2}\left(\frac{4V}{3}+V\right)(T-60)$ (Simplified: $\frac{7VT}{6}-30V$)	M1 A1 A1
	Equate their motorbike distance to $V(T-15)$ to give an equation in T only	M1
	$T=90$	A1
	ALT: Find area of upper trapezium **and** parallelogram (differences in areas) $\frac{1}{2}\left(\frac{V}{3}\right)(T-40+10)$ **and** $10V$	M1 A1 A1
	Equate to give an equation in T only (V cancels)	M1
	$T=90$	A1
		(5)
		(11)

Notes for Question	
(a)	
M1	Uses total area under graph to find an expression for the distance in terms of V and T only May use: Trapezium: $\left(\frac{T+T-30}{2}\right)V$ triangle + rectangle : $\frac{1}{2}(30V)+V(T-30)$ a triangle subtracted from a rectangle: $VT-\frac{1}{2}(30\times V)$ **OR** use of *suvat*: $\frac{1}{2}(30V)+V(T-30)$
A1*	Given answer correctly obtained (allow omission of 'metres'.
(b)	
	N.B. If graph is not done on either of the given graphs on the question paper, they score B0B0 .
B1	Correct shape with acceleration lines parallel and meeting at (T, V) B0 if continuous vertical line at $t = T$
B1	Correct horizontal labels. Accept appropriately labelled delineators. **N.B.** This mark is independent of the first B1.
(c)	
M1	Correct method using gradients or *suvat* to obtain an equation in V only
A1*	Given answer correctly obtained
(d)	
M1	For motorbike: find an expression for the **TOTAL** area under the graph (or use *suvat*) to find the total distance travelled in terms of V and T only. **N.B.** $\frac{1}{2}\left(\frac{4V}{3}\times 40\right)+\left(\frac{4V}{3}\times 10\right)+\frac{1}{2}\left(\frac{4V}{3}-V\right)(T-60)$ is M0 as it omits a part of the area.

A1	Correct unsimplified expression with at most one error/slip
A1	Correct unsimplified expression
M1	Clear attempt to equate their distance to the given distance in part (a) to give an equation in T only i.e. the V's **must** cancel but they do not need to be cancelled for this mark. **N.B.** This is an independent mark.
A1	cao

Q59.

Question	Scheme		Marks
(a)			
	$M(A)$ $(30\text{g} \times 2) + (50\text{g} \times 4) = 0.6S$	Moments equation. Requires all terms and dimensionally correct. Condone sign errors. Allow M1 if g missing	M1
	$M(C)$ $(0.6\times R)=(1.4\times 30\text{g})+(3.4\times 50\text{g})$ $M(G)$ $(2\times R)=(1.4\times S)+(2\times 50\text{g})$ $M(B)$ $(4\times R)+(2\times 30g)=(3.4\times S)$	Correct unsimplified equation	A1
	$(\uparrow)\ R+30g+50g=S$ $(R+784=S)$	Resolve vertically. Requires all 4 terms. Condone sign errors	M1
	Correct equation (with R or their R) NB: The second M1A1 can also be earned for a second moments equation		A1
	$R=3460$ or 3500 or $\frac{1060g}{3}$ (N) Not 353.3g	One force correct	A1
	$S=4250$ or 4200 or $\frac{1300g}{3}$ (N) Not 433.3g	Both forces correct If both forces are given as decimal multiples of g mark this as an accuracy penalty A0A1	A1
			(6)

(b)	$M(C)$ $(30\text{g} \times 1.4) + (M\text{g} \times 3.4) = 0.6 \times 5000$	Use $R=5000$ and complete method to form an equation in M or weight. Needs all terms present and dimensionally correct. Condone sign errors. Accept inequality. Use of R and S from (a) is M0	M1
		Correct equation in M (not weight) (implied by $M=77.68$)	A1
	$M=77$ kg	77.7 is A0 even is the penalty for over-specified answers has already been applied	A1
			(3)

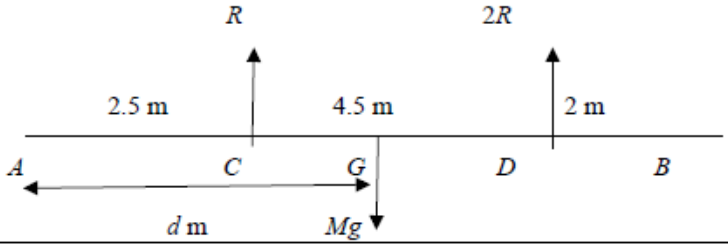
(c)	The weight of the diver acts at a point.	Accept "the mass of the diver is at a point".	B1
			(1)
			(10 marks)

Q60.

Question	Scheme		Marks
(a)	Taking moments about A:	Requires all terms - condone trig confusion and sign errors	M1
	$bF = 3mga\cos\theta + mg \times 2a\cos\theta$	-1 each error	A2
	$bF = 5mga\cos\theta$ $F = \frac{5mga}{b}\cos\theta$	*Given answer*	A1
			(4)
(b)	Component of **R** parallel to AB: $\left(R\cos(\phi-\theta)\right)$	Requires all terms - condone trig confusion	M1
	$= 3mg\sin\theta + mg\sin\theta = 4mg\sin\theta$	Correct unsimplified	A1
	Component of **R** perpendicular to AB:	Requires all terms - condone consistent trig confusion and sign errors	M1
	$\left(R\sin(\phi-\theta)\right)+F = 4mg\cos\theta$	Correct unsimplified	A1
	Alternatives for: $M(B)$	$2aR\sin(\phi-\theta)+3mga\cos\theta = F(2a-b)$	M1A1
	$M(C)$	$bR\sin(\phi-\theta)+(2a-b)mg\cos\theta = 3mg(b-a)\cos\theta$	
	$\left(R\sin(\phi-\theta)\right) = 4mg\cos\theta - \frac{5mga}{b}\cos\theta$	Correct with F substituted.	A1
	ISW for incorrect work after correct components seen		(5)
	Alternative		
	$X = F\sin\theta = \frac{5mga}{b}\cos\theta\sin\theta$	Allow with F. Requires all terms - condone trig confusion	M1
	F substituted		A1
	$Y = 4mg - F\cos\theta = 4mg - \frac{5mga}{b}\cos^2\theta$	Allow with F. Requires all terms - condone trig confusion and sign errors.	M1
	Correct unsimplified		A1
	Correct substituted		A1
			(5)

(c)	Use of $R\sin(\phi-\theta)>0$		M1
	Solve for b in terms of a: $4>\frac{5a}{b}$, $(2a\geq)b>\frac{5}{4}a$	$2a$ not required CSO	A1
			(2)
	Special case:		
	Misread of directions in (b)	**NB:** This MR can score full marks	(2)
	Alternative		
	For $\varphi>\theta$, $\tan\phi>\tan\theta$		
	$\tan\varphi=\frac{Y}{X}=\frac{4-\frac{5a}{b}\cos^2\theta}{\frac{5a}{b}\cos\theta\sin\theta}>\tan\theta$		M1
	$4-\frac{5a}{b}\cos^2\theta>\frac{5a}{b}\sin^2\theta$		
	$4>\frac{5a}{b}(\cos^2\theta+\sin^2\theta)\ \Rightarrow b>\frac{5}{4}a$	cso	A1
			(2)
			(11 marks)

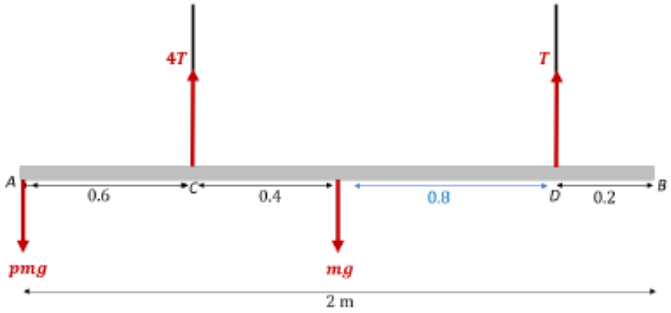
Q61.

Question Number	Scheme	Marks
		
	1st Equation in d (or another defined unknown), R and M (as appropriate) only	M1 A1
	2nd Equation in d (or the same defined unknown, R and M (as appropriate) only	M1 A1
	Possible equations: $(\uparrow), R+2R=Mg$ $\mathrm{M}(C), 2R\times 4.5=Mg(d-2.5)$ $\mathrm{M}(D), R\times 4.5=Mg(7-d)$ $\mathrm{M}(A), 2.5R+(7\times 2R)=Mgd$ $\mathrm{M}(B), 6.5R+(2\times 2R)=Mg(9-d)$ **SC**: $\mathrm{M}(G), R(d-2.5)=2R(7-d)$	M2 A2,1,0
	Solve for d, must be a numerical value	DM1
	$d=5.5$	A1 (6)
		(6)
	Notes for question	
	N.B. Allow M marks for equations if they use R_C and R_D	
	M1 Correct number of terms, dimensionally correct, condone sign errors and missing g	
	A1 Correct equation	
	M1 Correct number of terms, dimensionally correct, condone sign errors and missing g	
	A1 Correct equation	
	DM1 Dependent on previous two M marks, for solving for d	
	A1 $d=5.5$ oe Ignore an extra m (but not M)	
	N.B. If g is omitted consistently in both equations, all three A marks are available. If they use Rg consistently in both equations, all three A marks are available. If they have 3 equations, mark the ones that are used to obtain d. If R and $2R$ are consistently the wrong way round, apply the scheme, unless an MR gives a better total.	

Q62.

Question Number	Scheme	Marks
(a)	M(D), $mg \times 1.2 = 30g \times 0.8$	M1 A1
	Other possible equations: $(\uparrow)$ $R = mg + 30g$ M(A) $2.5mg + 30g \times 4.5 = 3.7R$ M(G) $30g \times 2 = 1.2R$ M(C) $mg \times 2 = 0.8R$ M(B) $2.5mg + 30g \times 0.5 = 1.3R$	
	$m = 20$ (kg)	A1
	N.B. Allow an inequality if they state $m = 20$ (kg) at the end	(3)
(b)	M(D), $Xg \times 3.7 + 20g \times 1.2 = 30g \times 1.3$ **N.B.** Allow inequality $\geq$…the correct way round for M1A1ft	M1A1ft
	Other possible equations: $(\uparrow)$ $S = mg + 30g + Xg$ M(A) $2.5mg + 30g \times 5 = 3.7S$ M(G) $30g \times 2.5 = 1.2S + Xg \times 2.5$ M(B) $2.5mg + Xg \times 5 = 1.3S$ where m is their answer from (a).	
	$X = \frac{150}{37}$, 4.1 or better (4.05405…)	A1
		(3)
(c)	The mass of the block is concentrated at a point. oe	B1
	N.B. Must mention either mass or weight and 'acting at a point' or 'concentrated at a point'.	(1)
		(7)
	Notes for question	
(a)	M1 Complete method to give an equation in m only. Allow M1 if they use weight instead of mg **N.B.** If they don't use M(D), e.g. ($\uparrow$) and M(A), they will need to eliminate the reaction at D to obtain the M mark. Each equation used must have the correct no. of terms and be dimensionally correct. M0 if they don't have the reaction acting at D.	
	A1 Correct equation	
	A1 cao	
(b)	M1 Complete method to give an equation in X only. Allow M1 if they use weight instead of Xg **N.B.** If they don't use M(D), e.g. ($\uparrow$) and M(A), they will need to eliminate the reaction at D to obtain the M mark. Each equation used must have the correct no. of terms and be dimensionally correct. M0 if they don't have the reaction acting at D.	
	A1ft Correct equation. Follow through on their 20	
	A1 cao	
(c)	B1 Any equivalent statement.	

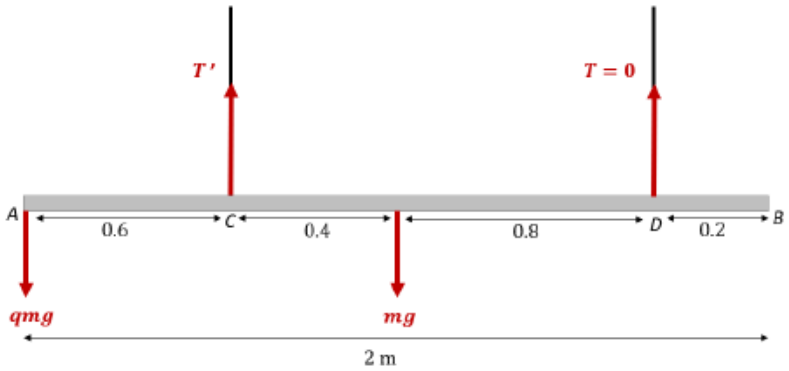
Q63.

Question Number	Scheme	Marks
(a)	T and $4T$ correctly placed	B1
	Vertical resolution $T+4T=pmg+mg$ **OR** a moments equation, see below.	M1 A1
	$\mathrm{M}(A):\ (4T\times0.6)+(T\times1.8)=(mg\times1)$  Other moments equations: $\mathrm{M}(C):\ (pmg\times0.6)+(T\times1.2)=(mg\times0.4)$ $\mathrm{M}(G):\ (pmg\times1)+(T\times0.8)=(4T\times0.4)$ $\mathrm{M}(D):\ (pmg\times1.8)+(mg\times0.8)=(4T\times1.2)$ $\mathrm{M}(B):\ (4T\times1.4)+(T\times0.2)=(pmg\times2)+(mg\times1)$	M1 A1
	Eliminate T $5\left(\frac{5mg}{21}\right)=pmg+mg$	M1
	$p=\frac{4}{21}$ (exact ratio of 2 positive integers)	A1
		(7)

(b)	Tension at D is zero, seen or implied.	B1
	$\mathrm{M}(C):\ (qmg\times0.6)=(mg\times0.4)$	M1 A1
	$q=\frac{2}{3}$ (exact ratio of 2 positive integers), accept 0.666….. or $0.\dot{6}$	A1
		(4)
(c)	The centre of mass (or gravity) of the beam is in the middle; the mass (weight) of the beam acts at the middle, mass at centre, centre of mass at the centre. Penalise incorrect extras.	B1
		(1)
		(12)

Notes for Question	
(a)	**N.B.** Full marks can be scored if consistent omission of g's in a **complete solution,** but otherwise penalise omission of g's
B1	Correct relationship between the tensions and placed correctly, seen or implied.
M1	Vertical resolution. Condone forces at C and D the wrong way round or written as T_C and T_D. This equation may be replaced with a moments equation.

A1	Correct unsimplified equation (even if T and $4T$ are the wrong way round on their diagram)
M1	Moments equation. Correct forces multiplied by a length. Condone consistent forces at C and D the wrong way round or written as T_C and T_D
A1	Correct unsimplified equation, **in a variable consistent with their first equation.**
M1	Eliminate T to give an equation in p only allow extra m's or g's or both
A1	Cao. Must be exact.
	N.B. If they write down more than two equations, award the marks for those equations which they use to solve the problem.
(b)	
B1	Recognise tension at D is 0, seen or implied
M1	Complete method to obtain an equation q only. e.g. Moments about C equation.
A1	Correct unsimplified equation in q only.
A1	Cao. Must be exact.
ALT (b)	
M1	Two other equations could be used and solved to find q. M0 if tension at D is never zero.
A1	Correct unsimplified equation in q only.

A1	Cao. Must be exact.
	 Alternative equations: vert: $T' = qmg + mg$ M(A): $(T' \times 0.6) = (mg \times 1)$ M(G): $(qmg \times 1) = (T' \times 0.4)$ M(D): $(qmg \times 1.8) + (mg \times 0.8) = (T' \times 1.2)$ M(B): $(qmg \times 2) + (mg \times 1) = (T' \times 1.4)$
(c)	
B1	Any appropriate comment

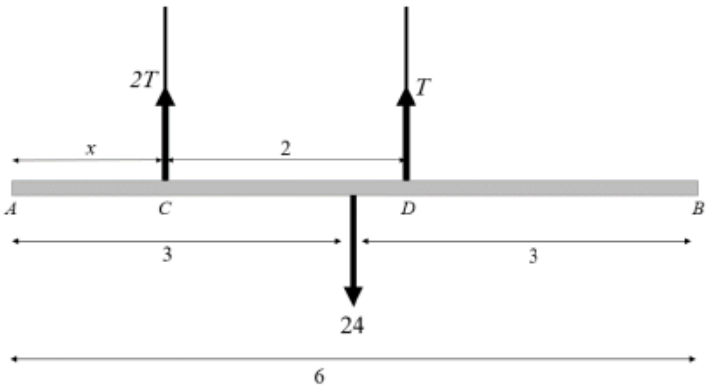
Q64.

Question Number	Scheme	Marks
(a)	M(D), $\frac{3a}{5}Xg = \frac{2a}{5}Mg$ Other possible equations: $(\uparrow) T_D = Mg + Xg$ M(A), $Mga + Xg2a = T_D\frac{7a}{5}$ M(B), $Mga = T_D\frac{3a}{5}$ T_D would then need to be eliminated M(C), $Mg\frac{3a}{5} + Xg\frac{8a}{5} = T_D a$ M(G), $Xga = T_D\frac{2a}{5}$	M1A1
	$X = \frac{2M}{3}$, 0.67 M or better	A1 (3)

(b)	M(D), $T_C a + \frac{1}{2}Mg\frac{3a}{5} = \frac{2a}{5}Mg$ Other possible equations: $(\uparrow) T_C + T_D = Mg + \frac{1}{2}Mg$ M(A), $Mga + \frac{1}{2}Mg2a = T_C\frac{2a}{5} + T_D\frac{7a}{5}$ M(B), $Mga = T_C\frac{8a}{5} + T_D\frac{3a}{5}$ T_D would need eliminating M(C), $Mg\frac{3a}{5} + \frac{1}{2}Mg\frac{8a}{5} = T_D a$ M(G), $T_C\frac{3a}{5} + \frac{1}{2}Mga = T_D\frac{2a}{5}$	M1A1
	$T_C = \frac{1}{10}Mg$ oe	A1 (3)
		(6)
(a)	M1 For an equation (or inequality,,,) in X, M and a *only* (allow consistent missing a's) with correct no. of terms. Allow if one g is missing. **N.B.** M0 if Tc appears and never becomes zero	
	A1 Correct equation or inequality	
	A1 cao	
(b)	M1 For an equation in Tc, M, g and a *only* (allow consistent missing a's or if g('s) missing) with correct no. of terms M0 if they assume that $T_C = T_D$ or if they assume their X value from (a).	
	A1 Correct equation	

	A1 cao	

Q65.

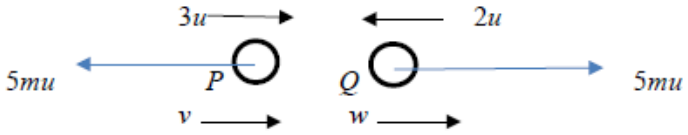
QUESTION NUMBER	SCHEME	MARKS
		
	Form a moments equation M(A): $(2T\times x)+T(x+2)=(24\times 3)$	M1 A1
	Form a second equation vert $3T=24$	M1
	Alternative moments equations in x and T M(C): $24(3-x)=T\times 2$ M(G): $2T(3-x)=T(x-1)$ M(D): $(2T\times 2)=24\times(x-1)$ M(B): $2T(6-x)+T(4-x)=(24\times 3)$ M(C): $\frac{24x}{6}\times\frac{x}{2}+2T=\frac{24(6-x)}{6}\times\frac{(6-x)}{2}$	
	$T=8$ (N)	A1
	$x=\frac{7}{3}$ accept 2.3 or better	A1
		(5)

	Notes for question
M1	Forms a moments equation in x and T only with the correct no. of terms. Allow consistent extra g' s. M0 if no x.
A1	Correct unsimplified moments equation. Where two moments equations are used, award this mark for the first correct equation.
M1	Resolves vertically to give equation in T only or a second moments equation in x and T (M0 if no x.). Must be dimensionally correct with the correct no. of terms.
A1	Correct value for tension at D
A1	Correct value for x. Accept 2.3 or better **N.B.** If T and $2T$ the wrong way round or they use $24g$, can score max M1A0M1A0A0.

Q66.

Question	Scheme		Marks
(a)	$mu-2kmu=-\frac{1}{2}mu+kmu$ or $m\left(\frac{1}{2}u+u\right)=-km(-u-2u)$	Use of CLM or Equal and opposite impulses Need all 4 terms dimensionally correct. Masses and speeds must be paired correctly Condone sign errors Condone factor of g throughout.	M1
	Unsimplified equation with at most one error		A1
	Correct unsimplified equation		A1
	$k=\frac{1}{2}$	From correct working only	A1
			(4)
(b)	For $P: I=\pm m(\frac{1}{2}u\pm -u)$ For Q : $I=\pm km(u\pm -2u)$	Impulse on P or impulse on Q. Mass must be used with the correct speeds e.g. $km\times\frac{1}{2}u$ is M0 If working on Q, allow equation using their k. Terms must be dimensionally correct. Use of g is M0	M1
	$\frac{3mu}{2}$	Only From correct working only	A1
			(2)
			(6 marks)

Q67.

Question Number	Scheme	Marks
		
(a)	For P: $-5mu = 2m(v-3u)$	M1A1
	$v = \frac{1}{2}u$	A1 (3)
(b)	For Q: $5mu = m(w-(-2u))$	M1A1
	$w = 3u$	A1 (3)
	OR: CLM: $2m\times 3u - m\times 2u = 2m\times\frac{1}{2}u + mw$ M1A1	
	$w = 3u$ A1	(6)
	Notes for question	
(a)	M1 Dimensionally correct imp-momentum equation (M0 if g is included), with correct terms, condone sign errors, but must be a difference of momenta and must be using $2m$ to give an equation in v **only**.	
	A1 Correct equation	
	A1 cao (must be positive)	
(b)	M1 Dimensionally correct imp-momentum equation (M0 if g is included), with correct terms, condone sign errors, but must be a difference of momenta and must be using m to give an equation in w **only**.	
	A1 Correct equation	
	A1 cao (must be positive)	
	OR: M1 Dimensionally correct CLM equation (Allow consistent extra g's or cancelled m's), with correct terms, condone sign errors, to give an equation in w **only**. **N.B.** They may find w first and use CLM to find v.	
	N.B. Mark parts (a) and (b) together if necessary.	