8 (a)	For B: $1 = \frac{1}{2}a.2^2 \Rightarrow a = \frac{1}{2}$ m s^{-2}	M1 A1 (2)
(b)	$R = 3mg$; $F = \mu R$	B1 ; B1
	$T - F = 3m \times 0.5$	M1 A1ft
	$2mg - T = 2m \times 0.5$	M1 A1 ft
	Solving for μ	DM1
	$\mu = 0.58$ or 0.582	A1 (8)
(c)	$v = \frac{1}{2} \times 2 = 1$	B1 ft
	$-\mu\ 3mg = 3ma$	M1
	$0 = 1^2 - 2\mu gs$	M1
	$s = 0.0877\ldots$(.0.09 or better)	A1
	$s < 0.3$ correct conclusion,	DM1A1 cso (6)
		16

NOTES

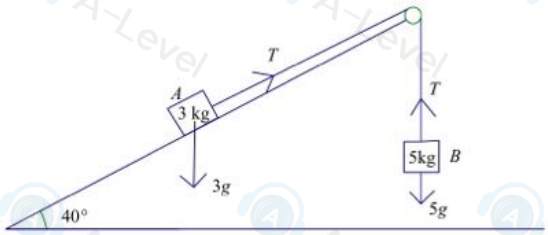
Question 8(a)
First M1 for a complete method to find a. M0 if s =1.3 is used
First A1 for a =0.5

Question 8(b)
First B1 for $R = 3mg$
Second B1 for $F = \mu R$ seen (could be on diagram)
First M1 for resolving horizontally for A (this M mark can be scored if they just use m for mass but M0 if no mass used)
First A1ft on their a, for correct equation. (allow F)
Second M1 for resolving vertically for B (this M mark can be scored if they just use m for mass but M0 if no mass used)
Second A1ft on their a, for correct equation.
(Allow M2A2 for 'whole system' equation but M0 if not using $5m$)
Third M1 dependent on both previous M marks for solving for μ
N.B. If m omitted consistently throughout (b), can score max B0B1M1A0M1A0M1A0

Question 8(c)
B1 **ft** for (their a x 2) oe to find v
First M1 for resolving horizontally for A with $T = 0$
Second M1 for a complete method (must have found a new 'a') to find distance moved by A.
First A1 for 0.09 or better (0.087719..)
Third M1, dependent on first and second M marks, for comparison with 0.3 or 1.3 (Must explicitly refer to either 0.3 or 1.3 or an appropriate equivalent)
Second A1 **cso** for does not reach pulley.

Question Number	Scheme	Marks
8.	**N.B.** In parts (a) and (c), $g = 9.8$ could appear in the working but final answers must be using g. In (b), $g = 9.8$ could be used in their answer. In (d), $g = 9.8$ could appear throughout in the working. **N.B.** For any equation of motion, if they use an incorrect mass in the 'ma' term, award M0 for the equation. However, if the correct mass has been used in (c), treat an error in the 'ma' term in (d) as a slip.	
8(a)	$R = 2mg\cos\alpha$	M1A1
	$F = \frac{11}{36} \times 2mg \times \frac{12}{13} = \frac{22mg}{39}$ *	A1* (3)
8(b)	$3mg - T = 3ma$	M1A1 (2)
8(c)	$T - \frac{22mg}{39} - 2mg\sin\alpha = 2ma$ $\quad (T - \frac{4mg}{3} = 2ma)$ **OR:** $3mg - \frac{22mg}{39} - 2mg\sin\alpha = 5ma$	M1A1
	Solve for a in terms of g **N.B.** Must reach $a = kg$ from **their** equations	M1
	$a = \frac{1}{3}g$ *	A1* (4)
8(d)	$v^2 = \frac{2gh}{3}$	B1
	$-\frac{22mg}{39} - 2mg\sin\alpha = \pm 2ma$ **OR** PE Gain $= 2mgd\sin\alpha$	M1
	$\pm\frac{2g}{3} = a$ $\quad = \frac{10mgd}{13}$	A1
	$0 = \frac{2gh}{3} - 2 \times \frac{2g}{3} \times d$ $\frac{22mgd}{39} = \frac{1}{2} \times 2m \times \frac{2gh}{3} - \frac{10mgd}{13}$	M1
	$d = \frac{1}{2}h$ $\quad d = \frac{1}{2}h$	A1
	Total distance $= \frac{1}{2}h + h = \frac{3}{2}h$	A1 ft (6)
		(15)

	Notes	
7(a)	M1: Condone sign errors and sin/cos confusion but both components must be resolved. Allow if they use $\cos(\frac{3}{5})$ or similar. If $12\mathbf{i}+16\mathbf{j}$ appears without working, award M1A0.	
	A1: cao	
7(b)	M1: Correct structure, condone slips	
	A1**ft**: ft on their answer to (a)	
7(c)	M1: Allow $\mathbf{r}-\mathbf{s}$. $\mathbf{r}$ and $\mathbf{s}$ must be substituted.	
	A1*: Correct given answer, correctly obtained **N.B.** Need to see $\overrightarrow{AB}$ at the start or finish for the A1* and answer must be **exactly** as printed, ignoring [] and km.	
7(d)	M1: They may use $\mathbf{r}=\mathbf{s}$ with both **i** and **j** cpts equated.	
	A1: Need both t values. Accept 0.42 or better and 1.25.	
	A1*: Correct conclusion	
7(e)	M1: Correct method	
	A1: cao	
	M1: Sub their calculated t value into $\overrightarrow{AB}$ or $\overrightarrow{BA}$, seen or implied, oe. Note that this is an independent M mark.	
	A1: cao	

Question Number	Scheme	Marks
8a		
	Motion of A : $T-3g\sin 40=3a$	M1A1
	Motion of B : $5g-T=5a$	M1A1
	Solve for T	**DM**1
	30 (N) or 30.2 (N)	A1
		(6)
8b	$5g-T=5a \Rightarrow a=\frac{1}{5}(5g-T)=\frac{g}{8}(5-3\sin 40)(=3.76)$ (ms^{-2})	M1
	Use of *suvat* : $v=u+at=3.76\times 1.5=5.64$ (ms^{-1}) or 5.6 (ms^{-1})	**DM**1A1
		(3)
8c	Distance in first 1.5 seconds: $s=\frac{1}{2}a1.5^2=4.23$ (m) **OR**: $v^2=u^2+2as$: $s=\frac{\textit{their}\ (\text{b})^2}{2\times a}=4.23$ (m)	M1A1
	New $a=-g\sin 40$ (-ve sign not needed)	B1
	Distance up plane : $v^2=u^2+2as$, $s=\frac{\textit{their}\ (\text{b})^2}{2\times \text{ new } a}$ (m)	**DM**1
	Total distance: 6.76 (m) (6.8)	A1
		(5)
		[14]
	Notes for question 8	
8a	First M1 for equation of motion for A, with usual rules	
	First A1 for a correct equation	
	Second M1 for equation of motion for B, with usual rules	
	Second A1 for a correct equation	
	N.B. Either of these can be replaced by the whole system equation:	
	$5g-3g\sin 40=8a$	
	Third **DM**1, dependent on previous two M marks, for solving for T	
	Third A1 for 30 or 30.2 (N)	
8b	First M1 for finding a value for a (possibly incorrect) This mark could be earned in part (a) BUT MUST BE USED IN (b).	
	Second **DM**1,dependent on previous M, for a complete method to find the speed of B as it hits the ground	
	A1 for 5.6 or 5.64 (m s^{-1})	
8c	First M1 for a complete method to find distance fallen by B First A1 for 4.23 or better	

Question Number	Scheme	Marks
	B1 for new $a = -g\sin 40$ (- sign not needed) (seen or implied)	
	Second **DM**1, dependent on having found a *new a*, for a complete method to find extra distance moved by A up the plane BUT M0 <u>if new a is g.</u>	
	Second A1 for 6.8 or 6.76 (m).	

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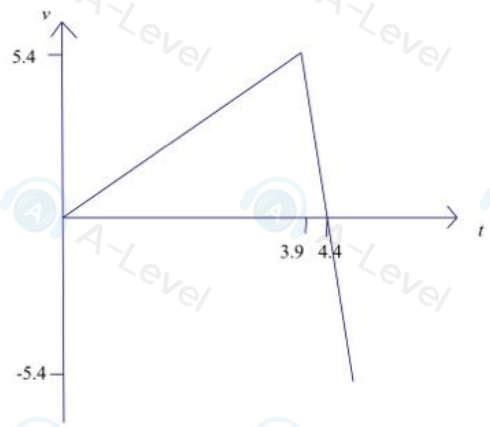
Question Number	Scheme	Marks	Notes
7			
(a)	$3g - T = 3a$	M1 A1	Eqn of motion for Q: must have the correct terms but condone sign errors Correct equation
	$T - 2g\cos 60 = 2a \qquad (T - g = 2a)$	M1 A1	Eqn of motion for P: must have the correct terms but condone sign errors. Weight must be resolved. Correct equation
	Allow M1A1 for $3g - 2g\cos 60 = 5a$ in place of either of these two equations		
	$2g = 5a \qquad a = \frac{2g}{5}$ *	DM1 A1	Use an exact method to solve for a (i.e. not the equation solver on their calculator). Dependent on the first 2 M marks or the M for the combined equation. Given answer derived correctly from exact working.
	$T = 2\times\frac{2g}{5} + g = \frac{9g}{5}$	M1 A1 (8)	Use given acceleration to solve for T. accept 18 or 17.6
(b)	$v^2 = 2\times\frac{2g}{5}\times 0.6 = \frac{2.4g}{5}$	M1	Use the given acceleration to find the speed
	$v = \frac{2}{5}\sqrt{3g}$ oe involving g	A1 (2)	Accept 2.2 or 2.17

Question Number	Scheme	Marks	Notes
(c)	String slack: accel of P (up plane) $= -g\cos 60 = -\frac{1}{2}g$	B1	
	$0 = \frac{2.4g}{5} - gs$	M1	Use of $v^2 = u^2 + 2as$ or equivalent for their acceleration $\neq \frac{2g}{5}$
	$s = \frac{2.4g}{5} \times \frac{1}{g} = \frac{2.4}{5} = 0.48$	A1	
	Total dist = 1.08 m	A1ft (4)	0.6 + their 0.48
(d)	$0 = \frac{2}{5}\sqrt{3g} - \frac{g}{2}t \quad (0 = 2.17 - 4.9t)$	M1	Use of $v = u + at$ or equivalent with their acceleration $\neq \frac{2g}{5}$ to find t.
	$t = \frac{4\sqrt{3g}}{5g} = 0.4426\ldots$ $= 0.44$ or 0.443	A1 (2)	only
		[16]	

Question Number	Scheme	Marks
7a	Motion of P: $T-3g=3a$	M1
	$\mathbf{33.6-3g=3a}$	A1
	$a=1.4\ (\text{m s}^{-2})$ ***Given Answer***	A1
		(3)
7b	Motion of Q: $mg-T=ma$	M1
	$mg-33.6=1.4m$	A1
	$m=4$	A1
		(3)
7c	Use of $s=(ut+)\frac{1}{2}at^2$: $10.5=\frac{1}{2}\times1.4\times t^2$	M1A1
	$\mathbf{T_1=\sqrt{15}=3.9}$ **or better**	A1
		(3)
7d	Use $v^2=(u^2+)2as$ to find speed of particles when Q hits ground: $v=\sqrt{2\times1.4\times10.5}\ (=\sqrt{29.4})$	M1
	Use $v=u+at$ to find additional time for P to come to rest: $0=\sqrt{29.4}-gt$	**DM**1
	Total time : $\mathbf{T_2=\sqrt{15}+\frac{\sqrt{29.4}}{9.8}=4.4}$ **or 4.43**	A1
		(3)
7e		B1 Shape **DB**1 **ft** their values for 5.4, -5.4, 3.9, 4.4 (or T_1 T_2) (2)
		[14]

Question Number	Scheme	Marks
	Notes	
7a	M1 for equation of motion for P with T not substituted, condone sign errors First A1 for a correct equation in a only (allow $\pm a$) Second A1 for **given answer** (units not needed)	
7b	M1 for equation of motion for Q with neither T nor a substituted, condone sign errors First A1 for a correct equation in m only Second A1 for $m = 4$ **N.B.** Whole system equn: $mg - 3g = a(m + 3)$ may be used	
7c	M1 for a complete method to find T_1 (M0 if g used) First A1 for a correct equation (or equations) Second A1 for $\sqrt{15}$, 3.9 or better $v = \sqrt{29.4}$ (5.4) may be found in this part but only gets credit if it appears in part (d)	
7d	First M1 for a complete method to find the speed of particles when Q hits the ground (M0 if using g) Second M1 **dependent** on first M1for a complete method to find the additional time for P to come to rest (must be using g) A1 for 4.4 or 4.43	
7e	First B1 (generous) for shape. Graph does not need to go down as far as it goes up and ignore gradients. (B0 if it goes outside the range $0 \leq t \leq T_3$ or if a continuous vertical line is included) Second **B**1, **dependent** on first B1, **ft** on their $\sqrt{29.4}$, T_1 and T_2 Allow T_1 and T_2 entered on the graph (rather than their numerical values)	

QUESTION NUMBER	SCHEME	MARKS
8(a)	Perp. to plane for P: $R = mg\cos a$	M1A1
	P: $T = mg\sin\alpha + F$ Q: $T = 0.5mg$ **N.B.** $mg\sin\alpha + F = 0.5mg$ scores M1A1 (LHS) B1 RHS)	M1 A1 B1
	Use of $F = \mu R$	B1
	$0.5mg = \frac{5mg}{13} + \mu\frac{12mg}{13}$	dM1
	$\mu = \frac{1}{8}$	A1
		(8)
8(b)	$mg\sin\alpha - F = ma$ $\left(a = \frac{7g}{26} \quad (\text{ms}^{-2})\right)$	M1 A1
	$V^2 = 0^2 + 2\left(\frac{7g}{26}\right)0.8$	M1
	$V = 2.1$ or 2.05	A1
		(4)
		(12)
	Notes for question 8	
(a)		
M1	Resolve perpendicular to find an expression for R in terms of m, condone sin/cos confusion and sign errors.	
A1	Correct unsimplified equation.	
M1	Form an equilibrium equation for P. Correct no. of terms, dimensionally correct. If $F=ma$ is used then a must be zero.	
A1	Correct unsimplified equation.	
B1	Correct equation	
B1	Use of $F = \mu R$, seen or implied, in an equation.	
dM1	Dependent on previous M mark, replace trig and form an equation in μ only.	
A1	Correct answer. Accept 0.125, 0.13	
(b)		
M1	Use of $F=ma$ for P. Correct no. of terms, dimensionally correct, ignore sin/cos confusion.	
A1	Correct equation, trig and F do not need to be substituted.	
M1	Use their calculated acceleration to form an equation in V. M0 if they use g.	
A1	Correct answer 2/3sf	

Question Number	Scheme	Marks
7(a)	For B, $S = 3mg\cos\alpha$ For B, $3mg\sin\alpha - T - F_1 = 3ma$ For A, $R = mg$ For A, $T - F_2 = ma$ $F_1 = \frac{1}{3}S$; $F_2 = \frac{1}{5}R$ Solving for T $T = \frac{3mg}{5}$ or $5.88m$	M1 A1 M1 A2 B1 M1 A1 M1 **DM1** A1 (11)
(b)	Constant tension throughout the string.	B1 (1)
(c)	$R = 2T\cos\frac{(180^o - \alpha)}{2}$ $(= 2T\sin\frac{1}{2}\alpha)$ $(2T\cos 63.4^o)$ $= 2\times\frac{3mg}{5}\times\frac{\sqrt{5}}{5}$ $= \frac{6mg\sqrt{5}}{25}$ $(5.3m$ or $5.26m)$	M1 A1 DM1 A1 (4) **16**
	OR: $R = \sqrt{(T - T\cos\alpha)^2 + (T\sin\alpha)^2}$ or $R = \sqrt{(T^2 + T^2 - 2T^2\cos\alpha}$ Substitute their expression for T (MUST be in terms of m) and a correct value of α $= \frac{6mg\sqrt{5}}{25}$ $(5.3m$ or $5.26m)$	M1A1 DM1 A1
	Notes	
	N.B. Use of sin(4/5) or similar, treat as an A error but allow recovery	
7(a)	First M1 for resolving perp to the plane , with usual rules	
	First A1 for a correct equation	
	Second M1 for equation of motion parallel to the inclined plane, with usual rules	
	Second and Third A1's for a correct equation -1 each error	
	B1 cao	
	Third M1 for equation of motion horizontally, with usual rules	
	Fourth A1 for a correct equation	
	Fourth M1 for using '$F = \mu R$' correctly twice	
	Fifth DM1, dependent on all M marks, for solving for T in terms of m *only*	
	Fifth A1 cao	
	N.B. Either equation of motion can be replaced by the whole system equation: $3mg\sin\alpha - F_1 - F_2 = 4ma$ (M1A2 or M1A1 as appropriate)	
(b)	Penalise extra wrong answers	
(c)	First M1 for attempt at correct expression for R in terms of T and α with usual rules i.e. condone cos/sin confusion but must be using the correct angle (can be in terms of α)	

	Special Case: Allow max M1A1DM0A0 if *m* is lost from their *T* but expression for *R* is otherwise correct.	
	First A1 for a correct expression for R in terms of T and α	
	Second DM1 for substituting in their expression for T and a correct value for α but must be in terms of m	
	Second A1 for a correct answer (any equivalent surd form)	

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Question Number	Scheme	Marks
6c	B1 for $5V$ identified appropriately First M1 for clear attempt to equate the *total* area under graph to 1500. (Must include all 3 parts (if not using the trapezium rule) with $\frac{1}{2}$ seen at least once to give equation in V only; may use (1 triangle + 1 trapezium) or (rectangle - trapezium) (May use *suvat* for one or more parts of the area) A2 for a correct equation, -1 e.e.o.o. Second **DM**1 dependent on first M1 for multiplying out and collecting terms and putting into appropriate form Third A1 for correct equation. **Given answer**	
6d	First M1 for solving their 3 term quadratic equation for V N.B. This M1 can be implied by two correct roots but if either answer incorrect then an explicit method must be shown for this M mark. First A1 for $V = 6$ Second A1 for $V = 75$ B1 on ePEN but treat as **DM**1, dependent on both previous A marks, for either reason	
7a	$T - 3mg\sin\alpha - F = 3ma$	M1A1
	$4mg - T = 4ma$	M1A1 (4)
7b	$F = \frac{1}{4}R;\ R = 3mg\cos\alpha$	B1; M1A1
	$T - 2.4mg = 3ma$ $4mg - T = 4ma$	M1
	$a = \frac{8g}{35}$ **Given answer**	A1 (5)
7c	Particles have same acceleration	B1 (1)
7d	$v^2 = 2 \times \frac{8g}{35} \times 1.75$ $(= 0.8g)$	M1 A1
	$-3mg\sin\alpha - F = 3ma'$	M1
	$a' = -0.8g$	A1
	$0 = 0.8g + 2 \times (-0.8g)s$	M1 A1
	Total distance = 0.5 + 1.75 = 2.25 (m) Accept 2.3 (m)	A1 (7)
		17
	Notes	
7a	First M1 for equation of motion for A with usual rules First A1 for a correct equation Second M1 for equation of motion for B with usual rules Second A1 for a correct equation **N.B.** If using different tension in second equation, M0 for that equation	

Question Number	Scheme	Marks
7b	B1 for $F = \frac{1}{4}R$ seen e.g. on diagram First M1 for resolving for A perp to the plane First A1 for correct equation N.B. These first 3 marks can be earned in (a). Second M1 (Hence) for substituting for R and F and trig. and solving for a (must be some evidence of this) their equations of motion from part (a) Second A1 for **given answer (Not available if not using exact values for trig ratios)**	
7c	B1 for particles have same acceleration (B0 for same velocity or if incorrect extras given)	
7d	First M1 for attempt to find speed (or speed^2) when B hits the ground (M0 if uses g) First A1 for a correct expression Second M1 for attempt to find deceleration of A Second A1 for correct deceleration Third M1 for using deceleration (must have found a deceleration) with $v = 0$ to find distance (M0 if uses g) Third A1 for a correct equation Fourth A1 for 2.25 (m)	

Question Number	Scheme	Marks	Notes
7.(a)	$F = 0.25R$	B1	
	$\sin\alpha = \frac{3}{5}$ or $\cos\alpha = \frac{4}{5}$ $\sin\beta = \frac{4}{5}$ or $\cos\beta = \frac{3}{5}$	B1	Use of correct trig ratios for α or β
	$R = 4g\cos\alpha$ (31.36)	M1	Normal reaction on P Condone trig confusion (using α)
		A1	Correct equation
	$T + F = 4g\sin\alpha$	M1	Equation of motion for P. Requires all 3 terms. Condone consistent trig confusion Condone an acceleration not equated to 0 : $T + F - 4g\sin\alpha = 4a$
	$(T + 7.84 = 23.52)$ $(T = 15.68)$	A1	Correct equation
	$T = mg\sin\beta$	M1	Equation of motion for Q Condone trig confusion Condone an acceleration not equated to 0: $T - mg\sin\beta = -ma$
	$(T = 7.84m)$	A1	Correct equation
	Solve for m	DM1	Dependent on the 3 preceding M marks Not available if their equations used $a \neq 0$
	$m = 2$	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)	
7.(b)	$F = \sqrt{T^2 + T^2}$ or $2T\cos 45°$ or $\frac{T}{\cos 45}$	M1	Complete method for finding F in terms of T Accept $\sqrt{(R_h)^2 + (R_v)^2}$
		A1	Correct expression in T
		DM1	Substitute their T into a correct expression Dependent on the previous M mark
	$F = \sqrt{2}\frac{8g}{5} = 22$ or 22.2 (N)	A1	Watch out - resolving vertically is not a correct method and gives 21.9 N.
		(4)	
7.(c)	Along the angle bisector at the pulley	B1 (1)	Or equivalent - accept angle + arrow shown on diagram. ($8.1°$ to downward vertical) Do not accept a bearing
		[15]	

Question Number	Scheme	Marks	Notes
8(a)	Equation of motion for P or for Q&R.	M1	All terms required and dimensionally correct. Condone sign errors. If m missing throughout, mark as a misread
	$5mg - T = 5ma$ or $T - 4mg = 4ma$	A1	One correct unsimplified equation
	Second equation of motion.	M1	Condone if second equation is for the **whole system**
	$5mg - T = 5ma$ $T - 4mg = 4ma$	A1	A second correct unsimplified equation
	Solve for a and T	DM1	Dependent on the first M mark
	$a = \frac{g}{9}$	A1	1.09 or 1.1 not $\frac{49}{45}$
	$T = \frac{40mg}{9}$	A1	43.6m, 44m
		(7)	SC A whole system alone leading to correct a scores M0A0M1A1M0A1A0
(b)	All particles have acceleration of the same magnitude	B1 (1)	Particles all start to move at the same time B1 Extra irrelevant comments B0
(c)	$v^2 = \frac{2gd}{9}$	M1	Complete method to find v or v^2 at the instant of separation
	Two independent equations of motion	M1	Dimensionally correct and contain correct terms
	$3mg - T' = 3ma'$ $T' - 4mg = 4ma'$	A1 A1	A1 for each correct equation. Accept the combined eqn. for A2
	$a' = -\frac{g}{7}$	A1	Accept +/-
	Use of *suvat* to find distance	DM1	With $a \neq$ their $\frac{g}{9}$ or g Dependent on the two preceding M marks
	$0 = \frac{2gd}{9} - 2\frac{g}{7}s$	A1ft	Correct unsimplified equation. Follow their $a \neq$ their $\frac{g}{9}$
	$s = \frac{7d}{9}$	A1	0.78d, 0.778d or better. Must be positive. Do not ISW
		(8)	
		(16)	

Question Number	Scheme	Marks
3.	For P: $4mg-3mg=4ma$ For both: $4mg+2mg-T=(4+2)ma=6ma$ **Any two of these** For Q: $2mg+3mg-T=2ma$	M1A1 M1A1
	Solve for T	DM1
	$\frac{9mg}{2}$, $4.5mg$ oe	A1 (6)
		(6)
	Notes	
	N.B. Use the mass in the 'ma' term in each equation of motion to determine to which part of the system the equation refers. Allow a replaced by $-a$ in both equations. Enter marks on ePEN in the order in which equations appear.	
	M1: Equation of motion with correct terms, condone sign errors	
	A1: Correct equation	
	M1: Equation of motion with correct terms, condone sign errors	
	A1: Correct equation	
	DM1: Dependent on both M's, for solving for T (must be in terms of mg)	
	A1: Any equivalent expression of the form kmg.	
	N.B. For the P and Q equations, allow M1 if they have T instead of $3mg$ and it's VERY **clear** that T is the tension in the connecting string and not the tension they are trying to find.	