Forces and Motion - Answers

June 2017 Mathematics Advanced Paper 1: Mechanics 1

1.

Question Number	Scheme	Marks
1	$(15\mathbf{i}+\mathbf{j})+(5q\mathbf{i}-p\mathbf{j})+(-3p\mathbf{i}-q\mathbf{j})=\mathbf{0}$ $3p-5q=15$ $p+q=1$ $p=2.5 \quad q=-1.5$	M1 M1 A1 M1 A1 A1 **6**
	Notes	
	First M1 for equating the sum of the three forces to zero (can be implied by subsequent working) Second M1 for equating the sum of the **i** components to zero AND the sum of the **j** components to zero oe to produce TWO equations, each one being in p and q ONLY. First A1 for TWO correct equations (in any form) **N.B.** It is possible to obtain TWO equations by using $\lambda(3p-5q-15)=\mu(p+q-1)$ with TWO different pairs of values for λ and μ, with one pair not a multiple of the other e.g $\lambda=1$, $\mu=1$ AND $\lambda=1$, $\mu=2$. Third M1(independent) for attempt (either by substitution or elimination) to produce an equation in either p ONLY or q ONLY. Second A1 for $p = 2.5$ (any equivalent form, fractions do not need to be in lowest terms) Third A1 for $q = -1.5$ (any equivalent form, fractions do not need to be in lowest terms)	

2.

Question Number	Scheme	Marks
5	$T - 0.5g = 0.5a$ $15 - T - 0.75g = 0.75a$ (OR: $15 - 0.5g - 0.75g = 1.25a$) $(a = 2.2 \text{ m s}^{-2})$ $T = 6$ N	M1 A1 M1 A1 M1 A1 **6**
	Notes	
	First M1 for an equation of motion for either P or Q with usual rules i.e. correct no. of terms, dimensionally correct but condone sign errors First A1 for a correct equation (allow T replaced by $-T$ and/or a replaced by $-a$) Second M1 for another equation of motion (for either P or Q or whole system) with usual rules as above Second A1 for a correct equation (allow T consistently replaced by $-T$ and/or a consistently replaced by $-a$) Third M1 for solving two THREE term equations of **motion** for T Third A1 for 6 (N). Must be positive but allow a change from – 6 to 6, if they have consistently used $-T$ instead of T.	

3.

Question Number	Scheme	Marks
8(a) **(i)** **(ii)**	For A : $T - F = 2ma$ For B : $mg - T = ma$	M1 A1 M1 A1 (4)
(b)	$R = 2mg$ $mg(1-2\mu) = 3ma$ $\frac{g}{3}(1-2\mu) = a$	B1 M1 A1 (3)
(c)	$v^2 = \frac{2gh}{3}(1-2\mu)$ $v = \sqrt{\frac{2gh}{3}(1-2\mu)}$	M1 A1 (2)

(d)	$-\mu R = 2ma'$ $0^2 = \text{their } u^2 - 2a's$ $0 = \frac{2gh}{3}(1-\frac{2}{3}) - 2(\frac{1}{3}g)s$ (or $s = (d-h)$) $s = \frac{1}{3}h$ $d = \frac{1}{3}h + h = \frac{4}{3}h$	M1 M1 A1 (A1) A1 A1 (5)
(e)	A (or B) would not move; **OR** A (or B) would remain in (limiting) equilibrium; **OR** the system would remain in (limiting) equilibrium	B1 (1) **15**

	Notes	
8(a)(i) **(ii)**	First M1 for equation of motion for A with usual rules First A1 for a correct equation (allow $-T$ instead of T) Second M1 for equation of motion for B with usual rules Second A1 for a correct equation (allow consistent $-T$ instead of T)	
8(b)	B1 for $R = 2mg$ M1 for using $F = \mu R$ and eliminating to give equation in a and μ only. A1 for PRINTED ANSWER (Must be identical to printed answer)	
8(c)	M1 for using $v^2 = u^2 + 2as$ or any other complete method to find the speed of A A1 for correct answer in any form	
8(d)	First M1 for equation of motion for A with $T = 0$ and $F = \mu R$ e.g. $\mu R = 2ma'$ (must be $2m$) Second M1 for using $v^2 = u^2 + 2as$ with their u^2 from (c), $v = 0$ and a **new** a (does **not** need to be substituted) First A1 for a correct equation in s, g and h with $\mu = {}^1/_3$ Second A1 for $s = {}^1/_3\, h$ Third A1 for $d = {}^4/_3\, h$ **ALTERNATIVE** using work-energy principle: M2 for $\mu Rs = \frac{1}{2}2mu^2$ (their u^2 from (c)) (M1 if they use m) First A1 for $\frac{1}{3}2mgs = \frac{1}{2}2m\frac{2gh}{3}(1-\frac{2}{3})$ Second A1 for $s = {}^1/_3\, h$ Third A1 for $d = {}^4/_3\, h$	
8(e)	B1 for any one of the alternatives listed above.	

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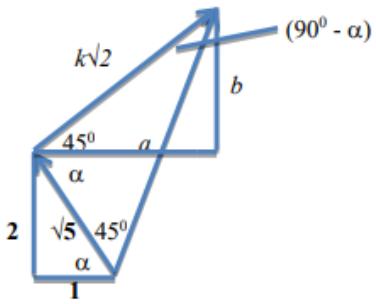
4.

Question Number	Scheme	Marks
7(a)	$\mathbf{F}_2 = k\mathbf{i} + k\mathbf{j}$	B1
	$(-1+a)\mathbf{i} + (2+b)\mathbf{j}$	M1
	$\frac{-1+a}{2+b} = \frac{1}{3}$	**DM**1 A1
	$a = b = k = 2.5;\ \mathbf{F}_2 = 2.5\mathbf{i} + 2.5\mathbf{j}$	**DM**1 A1; A1 (7)
	ALTERNATIVE:	
	$\mathbf{F}_2 = k\mathbf{i} + k\mathbf{j}$	B1
	$(-1+a)\mathbf{i} + (2+b)\mathbf{j} = p(\mathbf{i} + 3\mathbf{j})$	M1 for LHS
	$-1+a = p$	**DM**1 A1
	$2+b = 3p$	
	$a = b = k = 2.5;\ \mathbf{F}_2 = 2.5\mathbf{i} + 2.5\mathbf{j}$	**DM**1 A1; A1 (7)
(b)	$\mathbf{v} = 3\mathbf{i} - 22\mathbf{j} + 3(3\mathbf{i} + 9\mathbf{j})$	M1
	$= 12\mathbf{i} + 5\mathbf{j}$	A1
	$\lvert\mathbf{v}\rvert = \sqrt{12^2 + 5^2} = 13\ \text{ms}^{-1}$	M1 A1 **cso** (4)
		11

	Notes	
7(a)	B1 for $\mathbf{F}_2 = k\mathbf{i}+k\mathbf{j}$ $(k \neq 1)$ seen or implied in working, including for an incorrect final answer, with the wrong k value. First M1 for adding the 2 forces (for this M mark we only need $\mathbf{F}_2 = a\mathbf{i}+b\mathbf{j}$), with **i**'s and **j**'s collected (which can be implied by later working) but allow a slip. (M0 if a and b both assumed to be 1) Second M1, dependent on first M1, for ratio of their cpts = 1/3 or 3/1 (Must be correct way up for the M mark) First A1 for a correct equation which may involve two unknowns Third M1, dependent on first and second M1, for solving for k oe Second A1 for a correct k value Third A1 for $2.5\mathbf{i}+2.5\mathbf{j}$	
	ALTERNATIVE: Using two simultaneous equations B1 for $\mathbf{F}_2 = k\mathbf{i}+k\mathbf{j}$ $(k \neq 1)$ seen or implied in working. First M1 for adding the 2 forces (for this M mark we only need $\mathbf{F}_2 = a\mathbf{i}+b\mathbf{j}$), with **i**'s and **j**'s collected (LHS of equation) (M0 if a and b both assumed to be 1) but allow a slip Second M1, dependent on first M1, for equating coeffs to produce *two* equations in 2 or 3 unknowns. Must have p and $3p$ (M0 if p is assumed to be 1 or k) First A1 for two correct equations Third M1, dependent on first and second M1, for solving for k oe Second A1 for a correct k value Third A1 for $2.5\mathbf{i}+2.5\mathbf{j}$ **ALTERNATIVE: Using magnitudes and directions**  	

	$\mathbf{F}_2 = k\mathbf{i} + k\mathbf{j}$, seen or implied Correct vector triangle $\frac{k\sqrt{2}}{\sin 45^0} = \frac{\sqrt{5}}{\sin(90^0 - \alpha)}$, $\alpha = \arctan 2$ $2k = 5$ $k = 2.5$; $\mathbf{F}_2 = 2.5\mathbf{i} + 2.5\mathbf{j}$ **ALTERNATIVE: Using magnitudes and directions** B1 for $\mathbf{F}_2 = k\mathbf{i} + k\mathbf{j}$ seen or implied in working. First M1 for a correct vector triangle (for this M mark we only need $\mathbf{F}_2 = a\mathbf{i} + b\mathbf{j}$). (M0 if a and b both assumed to be 1 and/or longest side is assumed to be $\sqrt{10}$) Second M1, dependent on first M1, for using sine rule on vector triangle First A1 for a correct equation. 45^0 may not appear exactly. Third M1, dependent on first and second M1, for solving for k oe Second A1 for a correct k value Third A1 for $2.5\mathbf{i} + 2.5\mathbf{j}$	B1 M1 **DM**1 A1 **DM**1 A1; A1 (7)
(b)	First M1 for use of $\mathbf{v} = \mathbf{u} + \mathbf{a}t$ with $t = 3$ First A1 for $12\mathbf{i} + 5\mathbf{j}$ seen or implied. However, if a wrong $\mathbf{v}$ is seen A0 Second M1 for finding magnitude of their $\mathbf{v}$ Second A1 for 13	

5.

Question Number	Scheme	Marks
8(a)	$F = \frac{1}{5}R$ $R = 1.5g$ $T - F = 1.5a$ $3g - T = 3a$ $T = 1.2g$ or 11.8 N or 12 N	M1 B1 M1 A1 M1 A1 **DM1** A1 (8)
(b)	$R = \sqrt{T^2 + T^2}$ or $2T\cos 45^0$ or $\frac{T}{\cos 45^0}$ $= 16.6$ (N) or 17(N) or $\frac{6g\sqrt{2}}{5}$ Direction is 45° below the horizontal oe	M1 A1 A1 B1 (4) **12**

	Notes	
8(a)	First M1 for *use of* $F = \frac{1}{5}R$ in an equation. B1 for $R = 1.5g$ Second M1 for resolving horizontally with usual rules First A1 for a correct equation Third M1 for resolving vertically with usual rules Second A1 for a correct equation **N.B.** Either of the above could be replaced by a *whole system* equation: $3g - F = 4.5a$ **N.B.** All of the marks for the two equations can be scored if they consistently use $-a$ instead of a. Fourth M1 dependent on first, second and third M marks for solving their equations for T Third A1 for 1.2g, 11.8 (N) or 12 (N)	
(b)	First M1 for a complete method for finding the magnitude of the resultant (**N.B.** M0 if different tensions used), First A1 for $\sqrt{T^2 + T^2}$ or $2T\cos 45^o$ Second A1 for 16.6(N) or 17 (N) B1 for 45° below the horizontal or a diagram with an arrow and a correct angle. Ignore subsequent wrong answers e.g. a bearing of 225^0, which scores B0, as does SW etc.	

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6.

Question Number	Scheme	Marks
7(a)	$4mg - T = 4ma$	M1A1
	$T - 3mg = 3ma$	M1A1
	Condone the use of $4mg - 3mg = 4ma + 3ma$ in place of one of these equations.	M1A1
	Reach **given answer** $a = \frac{g}{7}$ correctly ***	A1
	Form an equation in T: $T = 3mg + 3\left(mg - \frac{T}{4}\right)$, $T = 3mg + 3m\frac{g}{7}$, or $T = 4mg - 4m\frac{g}{7}$	M1
	$T = \frac{24}{7}mg$ or equivalent, $33.6m$, $34m$	A1 (7)
(b)	$v^2 = u^2 + 2as = 2 \times \frac{g}{7} \times 0.7 = 1.96$, $v = 1.4$ ms^{-1}	M1A1 (2)
(c)	$3mg - T = 3ma$ $T - 2mg = 2ma$ $a = \frac{g}{5}$	M1A1 A1 A1 (4)
(d)	$0 = 1.96 - 2 \times \frac{g}{5} \times s$	M1
	$s = \frac{5 \times 1.96}{2g} = 0.5$ (m)	A1
	Total height = $0.7 + 0.5 = 1.2$ (m)	A1 **ft** (3)
Alt d	Using energy: $3mgs - 2mgs = \frac{1}{2}3m \times 1.4^2 + \frac{1}{2}2m \times 1.4^2$	M1
	$s = \frac{2.5 \times 1.96^2}{g} = 0.5$ (m)	A1
	Total height = $0.7 + 0.5 = 1.2$ (m)	A1 **ft** (3)
		[16]

Notes for Question 7

Question 7(a)(i) and (ii)

First M1 for resolving vertically (up or down) for $B+C$, with correct no. of terms.
First A1 for a correct equation.
Second M1 for resolving vertically (up or down) for A, with correct no. of terms.
Second A1 for a correct equation.
Third A1 for $g/7$, obtained correctly. **Given answer (1.4 A0)**

Third M1 for an equation in T only
Fourth A1 for $24mg/7$ oe or $33.6m$ or $34m$

N.B. If they omit m throughout (which gives $a = g/7$), can score max M1A0M1A0A0M1A0 for part (a) BUT CAN SCORE ALL OF THE MARKS in parts (b), (c) and (d).

Question 7(b)

M1 for an equation in v only (usually $v^2=u^2+2as$)
A1 for 1.4 (ms^{-1}) allow $\sqrt{(g/5)}$ oe.

Question 7(c)

First M1 for resolving vertically (up or down) for A or B, with correct no. of terms. (**N.B.** M0 if they use the tension from part (a))
First A1 for a correct equation for A.
Second A1 for a correct equation for B.
N.B. 'Whole system' equation: $3mg - 2mg = 5ma$ earns first 3 marks but any error loses all 3
Third A1 for g/5 oe or 1.96 or 2.0 (ms^{-2}) (*allow a negative answer)*

Question 7(d)

M1 for an equation in s only using their v from (b) and a from (c).
either $0 = 1.4^2 - 2(g/5)s$ or $1.4^2 = 0 + 2(g/5)s$
First A1 for $s = 0.5$ (m) correctly obtained
Second A1 **ft** for their 0.5 + 0.7 =1.2 (m)

Alternative using conservation of energy

M1 for an equation in s only, with correct number of terms, using their v from (b):-
$(3mgs - 2mgs) = ½\ 3m\ (1.4)^2 + ½\ 2m\ (1.4)^2$
First A1 for $s = 0.5$ (m) correctly obtained
Second A1 **ft** for their 0.5 + 0.7 =1.2 (m)

c

7.

Question Number	Scheme	Marks
8.		
(a)	For A, $T = 2ma$	B1
	For B, $3mg - T = 3ma$	M1 A1
	$3mg = 5ma$	**DM1**
	$\frac{3g}{5} = a$ (5.9 or 5.88 m s^{-2})	A1
		(5)
(b)	$T = 6mg/5$; $12m$; $11.8m$	B1
		(1)
(c)	$F = \sqrt{T^2 + T^2}$	M1 A1 **ft**
	$F = \frac{6mg\sqrt{2}}{5}$; $1.7mg$ (or better); $16.6m$; $17m$	A1
	Direction clearly marked on a diagram, with an arrow, and 45° (oe) marked	B1
		(4)
		[10]

Notes for Question 8

Q8(a)	B1 for $T = 2ma$ First M1 for resolving vertically (up or down) for B, with correct no. of terms. (allow omission of m, provided 3 is there) First A1 for a correct equation. Second M1, dependent on first M1, for eliminating T, to give an equation in a only. Second A1 for 0.6g, 5.88 or 5.9. N.B. 'Whole system' equation: $3mg = 5ma$ earns first 4 marks but any error loses all 4.	
Q8(b)	B1 for $\frac{6mg}{5}$, $11.8m$, $12m$	
Q8(c)	M1 $\sqrt{(T^2 + T^2)}$ or $\frac{T}{\sin 45^\circ}$ or $\frac{T}{\cos 45^\circ}$ or $2T\cos 45^\circ$ or $2T\sin 45^\circ$ (allow if m omitted) (M0 for $T \sin 45^\circ$) First A1 ft on their T. Second A1 cao for $\frac{6mg\sqrt{2}}{5}$ oe, $1.7mg$ (or better), $16.6m$, $17m$ B1 for the direction clearly shown on a diagram with an arrow and 45° marked.	

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8.

7.(a)	Inextensible string	B1 (1)
(b)	$4mg - T = 4ma$ $T - 2mg\sin\alpha - F = 2ma$	M1A1 M1A1 (4)
(c)	$F = 0.25R$ $R = 2mg\cos\alpha$ $\cos\alpha = 0.8$ or $\sin\alpha = 0.6$ Eliminating R, F and T $a = 0.4g = 3.92$	B1 B1 B1 M1 A1 (5)
(d)	$v^2 = 2 \text{ x } 0.4gh$ $-2mg\sin\alpha - F = 2ma'$ $a' = -0.8g$ $0^2 = 0.8gh - 2\text{x } 0.8g \text{ x } s$ $s = 0.5h$ $XY = 0.5h + h = 1.5h$	M1 M1 A1 M1 A1 A1 (6) **16**

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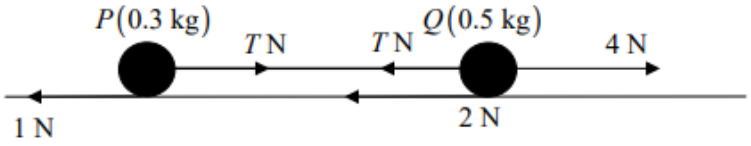
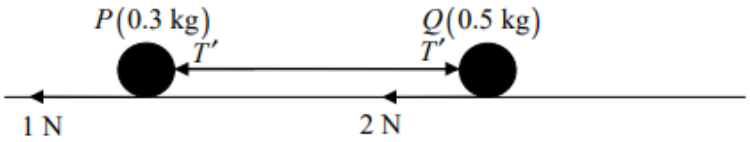
9.

Question Number	Scheme	Marks
7.		
	(a) For system N2L $4-3=0.8a$ $a=1.25\ (\text{m s}^{-2})$, 1.3	M1 A1 A1 **(3)**
	(b) $v=u+at \Rightarrow v=0+1.25\times 6=7.5\ (\text{m s}^{-1})$	M1 A1 **(2)**
	(c) For P N2L $T-1=0.3\times 1.25$ ft their a $T=1.375\ (\text{N})$ 1.38, 1.4	M1 A1ft A1 **(3)**
	OR For Q N2L $4-2-T=0.5$ x 1.25	
		
	(d) For system N2L $-3=0.8a \Rightarrow a=-3.75$ $v^2=u^2+2as \Rightarrow 0^2=7.5^2-2\times 3.75s$ $s=7.5\ (\text{m})$	M1 A1 M1 A1 **(4)**
	(e) For P N2L $T'+1=0.3\times 3.75$ $T'=0.125\ (\text{N})$, 0.13	M1 A1 A1 **(3)** **[15]**
	Alternative for (e) For Q N2L $2-T'=0.5\times 3.75$ $T'=0.125\ (\text{N})$, 0.13	M1 A1 A1 **(3)**

Question 7(a)*(In parts (a), (c), (d) and (e) use the value of the mass being used to guide you as to which part of the system is being considered, and mark equation(s) accordingly)*
M1 for resolving horizontally to produce an equation in a ONLY.
First A1 for a correct equation
Second A1 for 1.25

Question 7(b)
M1 for a complete method to find the speed
A1 cao 7.5

Question 7(c)
M1 for resolving horizontally, for either P or Q, to produce an equation in T only.
First A1ft for a correct equation,ft on their a
Second A1 cao for 1.38 (N) or 1.375 (N)

Question 7(d)
First M1 for resolving horizontally to produce an equation in a ONLY.
First A1cao for -3.75 (or 3.75)
Second M1 for use of $v^2 = u^2 + 2as$, with $v = 0$, u= their (b) and their a, (or any other complete method which produces an equation in s only)
M0 if they haven't *calculated* a value of a.
Second A1 for 7.5 m

Question 7(e)
M1 for resolving horizontally, for either P or Q, to produce an equation in T only.
M0 if they haven't *calculated* a value of a
First A1cao for a correct equation
Second A1 cao for 0.125 or 0.13 (N) (must be positive)

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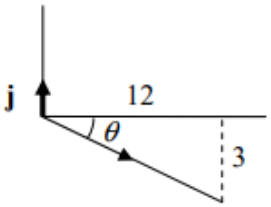
10.

Question Number	Scheme	Marks
3 (a)	$7+5+p=0$ or $-9+6+q=0$ $p=-12$ $q=3$	M1 A1 A1 (3)
(b)	$\mathbf{R}=12\mathbf{i}-3\mathbf{j}$ $\lvert\mathbf{R}\rvert=\sqrt{\left(12^2+(-3)^2\right)}=\sqrt{153}$ or $3\sqrt{17}$ or 12.4 or better (N)	M1 A1 (2)
(c)	$\tan\theta=\frac{3}{12}$ $\theta=14.03^0\ldots$ Angle with **j** is 104°, to the nearest degree cao 	M1 A1 A1 (3) **8**

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11.

6. **(a)**	$R = 0.3g\cos\alpha$ $= 0.24g = 2.35$ (3sf)=2.4 (2sf)	M1 A1 (2)
(b)	$mg - T = 1.4m$ $T - 0.3g\sin\alpha - F = 0.3$ x 1.4 $F = 0.5R$ Eliminating R and T $m = 0.4$	M1 A1 M1 A2 M1 **DM**1 A1 (8)
(c)	$v = 1.4$ x 0.5 $-0.3g\sin\alpha - F = 0.3a$ $a = -9.8$ $0 = 0.7 - 9.8t$ $t = 0.071$ s or 0.0714 s (1/14 A0)	B1 M1 A1 A1 M1 A1 (6) **16**

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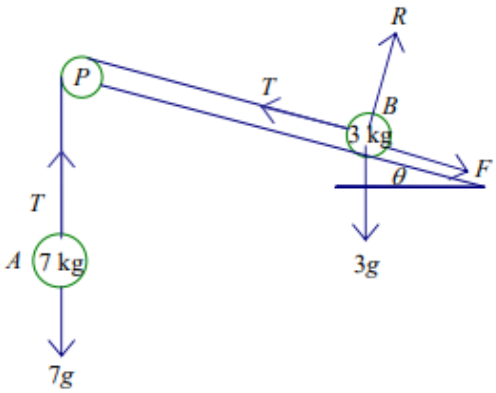
12.

Question Number	Scheme	Marks
7. **(a)**	 $\tan\theta = \frac{5}{12}$ $\sin\theta = \frac{5}{13}$ $\cos\theta = \frac{12}{13}$	
	For A: $7g - T = 7a$	M1 A1
	For B: parallel to plane $T - F - 3g\sin\theta = 3a$	M1 A1
	perpendicular to plane $R = 3g\cos\theta$	M1 A1
	$F = \mu R = 3g\cos\theta = 2g\cos\theta$	M1
	Eliminating T, $7g - F - 3g\sin\theta = 10a$	DM1
	Equation in g and a: $7g - 2g\times\frac{12}{13} - 3g\frac{5}{13} = 7g - \frac{39}{13}g = 4g = 10a$	DM1
	$a = \frac{2g}{5}$ *oe* or 3.9 or 3.92	A1
		(10)

(b)	After 1 m, $v^2 = u^2 + 2as, \quad v^2 = 0 + 2 \times \frac{2g}{5} \times 1$ $v = 2.8$	 M1 A1 (2)
(c)	$-(F + 3g \sin\theta) = 3a$ $\frac{2}{3} \times 3g \times \frac{12}{13} + 3g \times \frac{5}{13} = 3g = -3a, \ a = -g$ $v = u + at, \ 0 = 2.8 - 9.8t,$ $t = \frac{2}{7}$ oe, 0.29. 0.286	M1 A1 DM1 A1 (4) **[16]**

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13.

Question Number	Scheme	Marks
Q8 (a) Mark together	$(\downarrow) 0.4g - T = 0.4a$ $(\uparrow) T - 0.3g = 0.3a$ solving for T $T = 3.36$ or 3.4 or $12g/35$ (N)	M1 A1 M1 A1 DM1 A1 (6)
(b)	$0.4g - 0.3g = 0.7a$ $a = 1.4$ m s^{-2}, $g/7$	DM1 A1 (2)
(c)	$(\uparrow) v = u + at$ $v = 0.5$ x 1.4 $= 0.7$	M1 A1 ft on a
	$(\uparrow) s = ut + \frac{1}{2}at^2$ $s = 0.5$ x 1.4 x 0.5^2 $= 0.175$	M1 A1 ft on a
	$(\downarrow) s = ut + \frac{1}{2}at^2$ $1.175 = -0.7t + 4.9t^2$ $4.9t^2 - 0.7t - 1.175 = 0$ $t = \frac{0.7 \pm \sqrt{0.7^2 + 19.6 \text{ x } 1.175}}{9.8}$ $= 0.5663..$or $-...$	DM1 A1 ft DM1 A1 cao
	Ans 0.57 or 0.566 s	A1 cao (9) **[17]**

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14.

Question Number	Scheme	Marks
Q6.	(a) N2L A: $5mg - T = 5m \times \frac{1}{4}g$	M1 A1
	$T = \frac{15}{4}mg$ * cso	A1 (3)
	(b) N2L B: $T - kmg = km \times \frac{1}{4}g$	M1 A1
	$k = 3$	A1 (3)
	(c) The tensions in the two parts of the string are the same	B1 (1)
	(d) Distance of A above ground $s_1 = \frac{1}{2} \times \frac{1}{4}g \times 1.2^2 = 0.18g \ (\approx 1.764)$	M1 A1
	Speed on reaching ground $v = \frac{1}{4}g \times 1.2 = 0.3g \ (\approx 2.94)$	M1 A1
	For B under gravity $(0.3g)^2 = 2gs_2 \Rightarrow s_2 = \frac{(0.3)^2}{2}g \ (\approx 0.441)$	M1 A1
	$S = 2s_1 + s_2 = 3.969 \approx 4.0$ (m)	A1 (7)
		[14]