

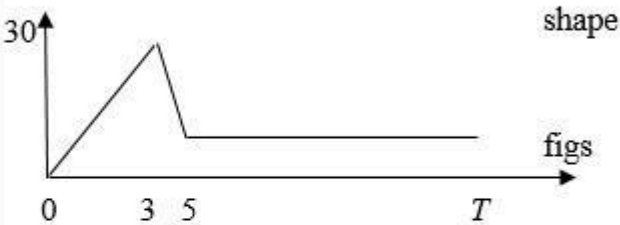
Mark Scheme

Q1.

Question	Scheme	Marks	AOs
(a)	Because the distances travelled or displacements are equal oe. If they mention the times are the same as well, ignore it.	B1	2.4
		(1)	
(b)	0.8 or $4/5 \text{ (m s}^{-2}\text{)}$	B1	1.1b
		(1)	
(c)	$\frac{1}{2} \times 5 \times 4 + (4 \times 22.5)$ OR $\frac{1}{2} (27.5 + 22.5) \times 4$ OR $27.5 \times 4 - \frac{1}{2} \times 5 \times 4$	M1	3.1b
	100 (m)	A1	1.1b
		(2)	
(d)	Total area under graph = their answer for part (c)	M1	3.1b
	$\frac{1}{2} X \times X + X(27.5 - X) = 100$	A1ft	1.1b
	OR $\frac{1}{2} (27.5 + 27.5 - X) \times X = 100$	A1ft	1.1b
	OR $27.5X - \frac{1}{2} X^2 = 100$		
	$X = 3.92 \text{ to } 3\text{sf}$	A1	1.1b
		(4)	
(8 marks)			

Notes:		
a	B1	Must mention distances being equal specifically.
b	B1	cao
c	M1	Clear attempt to find the total area under the <i>P</i> graph, with the correct structure i.e. (triangle + rectangle) OR trapezium OR (rectangle – triangle); must see use of $\frac{1}{2}$ where appropriate. OR they may use <i>suvat</i> to find the distance covered by <i>P</i> in one or more of the sections. N.B. M0 for use of a single <i>suvat</i> formula for the whole motion
	A1	cao
d	M1	Clear attempt to equate the total area under the <i>S</i> graph, with the correct structure, i.e. (triangle + rectangle) OR trapezium OR (rectangle – triangle), must see use of $\frac{1}{2}$ where appropriate, to their answer for (c) to give a <u>quadratic equation in <i>X</i> only</u> N.B. they may use <i>suvat</i> to find the distance covered by <i>S</i> in one or more of the sections. N.B. M0 for use of a single <i>suvat</i> formula for the whole motion
	A1ft	Correct unsimplified quadratic equation in <i>X</i> only with at most one error, follow their answer for (c)
	A1ft	Correct unsimplified quadratic equation in <i>X</i> only, follow their answer for (c)
	A1	cao

Q2.

Question	Scheme	Marks	AOs	Notes
(a)	$V = 30 \text{ (m s}^{-1}\text{)}$	B1	3.4	cao
		(1)		
(b)		B1	1.1 b	Overall shape of the graph, starting at the origin. Dotted vertical line at end is OK but solid vertical line is B0
		B1ft	1.1 b	3, 5 and T marked on the t -axis, and ft on their 30 marked on the speed axis. 3 must be where graph reaches a peak. Allow delineators: 3, 2 and $T - 5$ or a mixture
		(2)		
(c)	Using total area = 550 to set up an equation in one unknown, Or they may use <i>suvat</i> on one or more of the sections (but must still be considering all sections) M0 if they use one <i>suvat</i> equation for the whole motion	M1	2.1	Need all sections to be included, with <u>correct structure for each section</u>. e.g. triangle + trapezium + rectangle oe = 550 to give an equation in one unknown (may not be T)

	$\frac{1}{2} \times 3 \times 30 + \frac{(30+6)}{2} \times 2 + 6(T-5) = 550$ OR: $\frac{1}{2} \times 3 \times 30 + \frac{1}{2} \times 2 \times 24 + 6(T-3) = 550$ OR: $\frac{1}{2} \times 3 \times 30 + \frac{1}{2} \times 2 \times 24 + (2 \times 6) + 6(T-5) = 550$	A2 ft	1.1 b	ft on their answer to (a). -1 each error. N.B. If '6' is incorrect, treat as one error, unless it is correct ft from their 30.
	Solve for T	M1	1.1 b	<u>Attempt to solve for T provided they have tried to find the area using at least 3 sections.</u> (M0 if they only solve for their unknown and never try to find T)
	$T = 83$ (nearest whole number)	A1	1.1 b	83 is the only answer
		(5)		

(d)	New value of T would be bigger (ignore their reasons whether correct or not)	B1	3.5 a	Clear statement about <u>the value of T</u> <u>Allow 'it would increase, get larger etc'</u> B0 for 'Takes longer' or 'the value of T would be longer'
		(1)		
(e)	e.g. effect of wind; allow for dimensions of parachutist; use a more accurate value for g; parachutist does not fall vertically after chute opens; smooth changes in v; time for parachute to open; deceleration not constant (but B0 if they say <i>acceleration</i> not constant); smooth changes in a; B0 for: moves horizontally; mass/weight of parachutist; upthrust; air pressure; air resistance; terminal velocity	B1	3.5 c	Any appropriate refinement <u>of the model</u>. B0 if incorrect (or irrelevant) extras
		(1)		
(10 marks)				

Q3.

Question	Scheme	Marks	AOs
(a)	$19^2 = (-U)^2 + 2 \times 10 \times 16.8$ (Allow use of $g = 9.8$ for this M mark)	M1	2.1
	$U = 5 *$	A1*	1.1b
		(2)	
	For consistent use of $g = 9.8$ in parts (b), (c) and (d), treat as a MR. i.e. max (b) M1A0 (c)M1A0M(A)0A1ft (d)B1B1ft		
(b)	$19 = -5 + 10T$ OR $16.8 = \frac{(-5+19)}{2} T$ OR $16.8 = -5T + \frac{1}{2} \times 10T^2$ OR $16.8 = 19T - \frac{1}{2} \times 10T^2$	M1	2.1
	$T = 2.4$	A1	1.1b
		(2)	
(c)	$1.2 = -5t + \frac{1}{2} \times 10 \times t^2$	M1	2.1
	$5t^2 - 5t - 1.2 = 0$	A1	1.1b
		M(A)1	1.1b
	$t = 1.2$ (s)	A1	1.1b
		(4)	

(d)		B1 shape	1.1b
	(0,5) and (2.4, -19) Allow these to be marked on the axes.	B1ft	1.1b
		(2)	
(e)	Greater since air resistance would slow the ball down.	B1	3.5a
		(1)	
(f)	Take into account: spin, wind effects, use a more accurate value of g , not model the ball as a particle	B1	3.5c
		(1)	
(12 marks)			

Notes:

(a)	M1	Complete method to find U , condone sign errors and use of $g = 9.8$
	A1*	$U = 5$ cao correctly obtained – allow U^2 instead of $(-U)^2$. Allow verification.
(b)	M1	Complete method to find T , condone sign errors
	A1	$T = 2.4$
(c)	M1	Complete method to find t , condone sign errors
	A1	Correct equation with at most one error
	(A)1	Correct equation
	A1	$t = 1.2$ (s)
(d)	B1	Graph could be reflected in the t -axis.
	B1ft	Follow through on their T value. If graph is reflected, (0, -5) and (2.4, 19)
(e)	B1	Any similar appropriate comment
(f)	B1	B0 if any incorrect extras e.g. weight/mass included

Q4.

Question	Scheme	Marks	AOs
(a) (i)	24 (m s ⁻¹)	B1	1.1b
(ii)	48 (s)	B1	1.1b
(iii)		B1	1.1b
		(3)	
(b)	Equating area under graph to 4800 to give equation in one unknown	M1	3.1b
	$\frac{1}{2}(T + T + 80 + 48) \leftrightarrow 24 = 4800$ OR $(\frac{1}{2} \times 80 \times 24) + 24T + (\frac{1}{2} \times 48 \times 24) = 4800$ oe	A1ft	1.1b
	$T = 136$ so total time is 264 (s)	A1	1.1b
		(3)	
(c)	Accept Either: a smooth change from acceleration to constant velocity or from constant velocity to deceleration. Or have train accelerating and/or decelerating at a variable rate Do not accept e.g. Comments on air resistance or resistive forces, straightness of track, horizontal track, friction, length of train, mass of train, not having train moving with constant velocity. <u>B0 if either an incorrect extra is included or an incorrect reason for a valid improvement is included.</u> <u>N.B.</u> Variable acceleration due to air resistance is B0 BUT Variable acceleration due to variable air resistance is B1	B1	3.5c
		(1)	

(7 marks)

Notes:

(a)

(i) B1: 24 (m s⁻¹) Must be stated i.e. not just inserted on the graph

(ii) B1: 48 (s) (Allow - 48 changed to 48) Must be stated i.e. not just inserted on the graph

(iii) B1: A trapezium starting at the origin and ending on the *t*-axis.

(b)

M1: Complete method to find area of trapezium using trapezium rule with correct structure or using two triangles and a rectangle and equate to 4800 to give equation in *one* unknown

N.B. $\frac{1}{2}(T + 80 + 48) \times 24 = 4800$ is M0 (equivalent to using three triangles)

OR they may use *suvat* on one or more sections (must have $a = 0$ for middle section) and equate total distance travelled to 4800 to give equation in *one* unknown

Alft: For a correct equation in their unknown *ft* on their 24 and 48 (but must be positive times)

A1: For 264 (s)

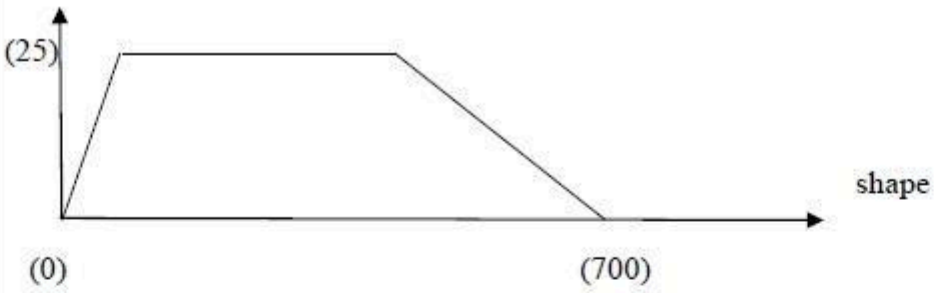
(c)

B1:

Either: Include time to change from constant accln to constant velocity and/or time to change from constant velocity to constant deceleration *oe*

Or: Have train accelerating and/or decelerating at a variable rate

Q5.

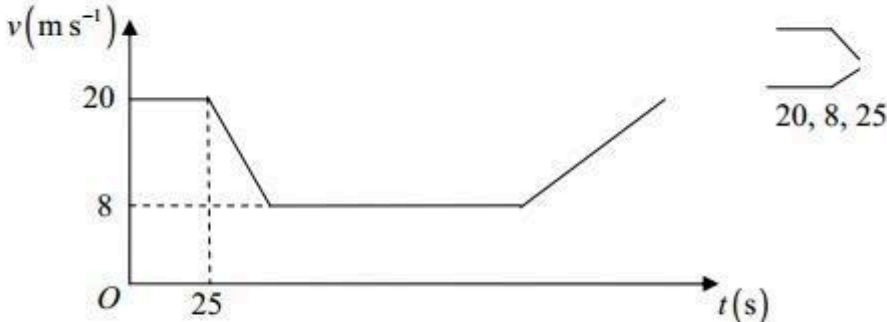
Question	Scheme	Marks	AOs
(a)		B1	1.1b
		(1)	
(b)	Using <i>total area</i> = 15000 to set up an <i>equation in one unknown</i> Or they may use <i>suvat</i> on one or more sections (but must still be considering <i>all</i> sections) Allow an attempt at a clear explicit verification using $t = 40$ e.g. the following would score M1A1A1*: $4 \times 40 = 160$ then $700 - 40 - 160 = 500$ $\frac{(700 + 500)}{2} \times 25 = 15000 = 15 \text{ km}$ Withhold A1* if they don't include $= 15 \text{ km}$ N.B. M0 if a single <i>suvat</i> formula is used for the whole journey.	M1	3.4
	$\frac{1}{2}(700 + 700 - t - 4t) \times 25 = 15000$ OR $\frac{1}{2} \times 25 \times t + 25(700 - t - 4t) + \frac{1}{2} \times 25 \times 4t = 15000$	A1	1.1b
	$t = 40 \text{ (s)}^*$	A1*	1.1b
		(3)	

(c)	0.63 or 0.625 or $\frac{5}{8}$ oe (m s ⁻²) isw	B1	1.1b/ (2.2a)
		(1)	
(d)	Complete method to find the speed or velocity at $t = 572$ e.g. $\pm\left(25 - \left(32 \times \frac{5}{32}\right)\right)$ or $\pm\left(128 \times \frac{5}{32}\right)$ oe	M1	3.1b
	20 (m s ⁻¹)	A1	1.1b
		(2)	
(e)	e.g. (the train) cannot instantaneously change acceleration, (the train) won't move with <u>constant</u> acceleration, (the train) won't move with <u>constant</u> speed Allow negatives of these:	B1	3.5b
	e.g. (The train) moving at constant speed, or just 'constant speed' or 'constant acceleration' (is a limitation of the model) Must be a limitation of the model, so friction or air resistance or size of train is B0. N.B. Ignore incorrect reasons following a correct answer.		
		(1)	
(8 marks)			

Notes:

a	B1	Overall shape of graph, starting at the origin, with deceleration phase <i>longer</i> than the acceleration phase if nothing on the t -axis but ignore the relative lengths and allow if t (or 40) and $4t$ (or 160) are clearly and correctly marked. Ignore incorrect figs on the axes. This mark can be earned if the graph appears anywhere in qu 2.
b	M1	Need <i>all</i> sections to be included, with <u>correct structure for each section</u> , with $\frac{1}{2}$'s where appropriate. <u>Allow = 15 or 150 or 1500 etc instead of 15000</u>
	A1	A correct equation in their t only, seen or implied (or with $t = 40$ for verification)
	A1*	cso. At least one line of working with brackets removed and t 's collected, or equivalent
c	B1	cao
d	M1	Any complete method, must have correct figs, but condone sign errors
	A1	cao. Must be positive and exact i.e must not come from rounding.
e	B1	Any appropriate limitation <u>of the model</u> . B0 if any incorrect extra answers.

Q6.

Question Number	Scheme	Marks
4.	(a)  (b) $v = u + at \Rightarrow 8 = 20 - 0.4t$ $t = 30 \text{ (s)}$ (c) $1960 = (25 \times 20) + (30 \times 8) + (\frac{1}{2} \times 30 \times 12) + (60 \times 8) + 8 \times t + \frac{1}{2} \times t \times 12$ $1960 = 500 + 240 + 180 + 480 + 14t$ $T = 115 + 40$ $= 155$ N.B. SEE ALTERNATIVES	B1 B1 B1 (3) M1 A1 (2) M1A3 ft (2,1,0) DM1 A1 DM1 A1 (8) [13]

(a)

First B1 for 1st section of graph
 Second B1 for 2nd section
 Third B1 for the figures 20, 8 and 25

(b)

M1 for a complete method to produce an equation in t only; allow $(20 - 8)/0.4$
 A1 for 30 N.B.
 Give A0 for $t = -30$, even if changed to 30, but then allow use of 30 in part (c), where full marks could then be scored.

(c)

First M1 (generous) for clear attempt to find whole area under *their* graph (must include at least one "1/2"), in terms of a *single unknown time (t say)*, and equate it to 1960.
 First A3, ft on their (b), for a correct equation.
 Deduct 1 mark for each numerical error, or omission, in each of the 4 *sections of the area* corresponding

to each stage of the motion. (they may 'slice' it, horizontally into 3 sections, or a combination of the two)
 Second DM1, dependent on first M1, for simplifying to produce an equation with all their t terms collected.
 Fourth A1 for a correct equation for t or T
 Third DM1, dependent on second M1. for solving for T
 Fifth A1 155

Please note that any incorrect answer to (b) will lead to an answer of 155 in (c) and can score max 6/8;

Solutions with the correct answer of 155 will need to be checked carefully.

Solutions to (c) N.B. $t = T - 115$

- | | |
|---|--|
| <p>A. $1960 = (25 \times 20) + (30 \times 8) + (\frac{1}{2} \times 30 \times 12) + (60 \times 8) + 8 \times t + \frac{1}{2} \times t \times 12$
 $1960 = 500 + 240 + 180 + 480 + 14t$
 $T = 115 + 40$
 $= 155$</p> | <p>M1 A3 ft
 M1 A1
 M1
 A1</p> |
| <p>B. $1960 = (25 \times 20) + \frac{1}{2} \times 30 \times (20 + 8) + (60 \times 8) + \frac{1}{2} \times t \times (20 + 8)$
 $1960 = 500 + 420 + 480 + 14t$
 $T = 115 + 40$
 $= 155$</p> | <p>M1 A3 ft
 M1 A1
 M1
 A1</p> |
| <p>C. $1960 = 8T + \frac{1}{2} \times 12 \times (55 + 25) + \frac{1}{2} \times 12 \times (T - 115)$
 $1960 = 8T + 480 + 6T - 690$
 $1960 = 14T - 210$
 $155 = T$</p> | <p>M1 A3 ft

 M1 A1
 M1 A1</p> |
| <p>D. $1960 = 20T - \frac{1}{2} \times 12 \times (60 + T - 25)$
 $1960 = 20T - 6T - 210$
 $1960 = 14T - 210$
 $155 = T$</p> | <p>M1 A3 ft

 M1 A1
 M1 A1</p> |
| <p>E. $1960 = (55 \times 20) - \frac{1}{2} \times 30 \times 12 + (60 \times 8) + \frac{1}{2} \times t \times (20 + 8)$
 $1960 = 1100 - 180 + 480 + 14t$
 $T = 115 + 40$
 $= 155$</p> | <p>M1 A3 ft
 M1 A1
 M1
 A1</p> |
| <p>F. $1960 = (8 \times 115) + \frac{1}{2} \times 12 \times (55 + 25) + \frac{1}{2} \times 28 \times (T - 115)$
 $1960 = 920 + 480 + 14T - 1610$
 $1960 = 14T - 210$
 $155 = T$</p> | <p>M1 A3 ft

 M1 A1
 M1 A1</p> |

Q7.

Question	Scheme	Marks	AOs
(a)	$14.7 = -14.7 + 9.8T$ or $0 = 14.7T - \frac{1}{2} \times 9.8T^2$ or $0 = 14.7 - 9.8 \times \left(\frac{1}{2}T\right)$ oe	M1	3.4
	$T = 3$	A1	1.1b
		(2)	
(b)	$s_1 = \frac{(14.7+0)}{2} \times 1.5$ (11.025 or $\frac{441}{40}$)	M1	1.1b
	$s_2 = \frac{1}{2} \times 9.8 \times 2.5^2$ (30.625 or $\frac{245}{8}$) OR $s_3 = 14.7 \times 1 + \frac{1}{2} \times 9.8 \times 1^2$ (19.6 or $\frac{98}{5}$) OR $-s_3 = 14.7 \times 4 - \frac{1}{2} \times 9.8 \times 4^2$ (- 19.6) (allow omission of - on LHS)	M1	1.1b
	Total distance = $s_1 + s_2$ OR $2s_1 + s_3$	M1	2.1
	= 41.7 m or 42 m	A1	1.1b
		(4)	
(c)	e.g. Take account of the dimensions of the stone (e.g. allow for spin), do not model the stone as a particle, use a more accurate value for g	B1	3.5c
		(1)	
(7 marks)			

Notes: If they use $g = 9.81$ or 10 , penalise once for whole question.

a	M1	Complete method to find T , condone sign errors (M0 if they only find time to top)
	A1	$T = 3$ correctly obtained.
b	M1	Complete method to find one key distance
	M1	Correct method to find another key distance
	M1	Complete method to find the total distance
	A1	41.7 or 42 (after use of $g = 9.8$)
c	B1	B0 if there are incorrect extra refinements but ignore extra incorrect statements.

Q8.

Question	Scheme	Marks	AOs
(a)	Attempt to find the displacement after 10 s	M1	3.1b
	$39.2 \times 10 - \frac{1}{2} g \times 10^2$ OR $-39.2 \times 10 + \frac{1}{2} g \times 10^2$	A1	1.1b
	98 (m) (must be positive)	A1	1.1b
		(3)	
(b)	Complete method to find either half the time or the full time	M1	3.1b
	Correct equation e.g. $0 = 24.5 - gt$ OR $-24.5 = 24.5 - gt$	A1	1.1b
	5 (s)	A1	1.1b
		(3)	
(c)	e.g. (include) air resistance	B1	3.5c
		(1)	
(7 marks)			

Notes: Penalise explicit use of $g = 9.81$ or 10 once for the whole question the first time it occurs.		
a	M1	Complete method, using $s = ut + \frac{1}{2}at^2$ or possibly $s = vt - \frac{1}{2}at^2$ with the motion reversed, or an 'up and down' method i.e an appropriate equation for the motion from O to the top AND an appropriate equation from the top down to the ground AND combining to give the total distance
	A1	Correct expression (s) N.B. If using an 'up and down method', this mark is for all the intermediate values: Distance up = 78.4, Time up = 4, time down = 6, distance down = 176.4 AND combining correctly i.e. (176.4 – 78.4) or (78.4 –176.4) These are the values for $g = 9.8$
	A1	cao
b	M1	Complete method to find half the time or the full time. Allow inequalities. e.g. for half the time, they may find $t = 4$ and $t = 1.5$ and subtract e.g. for the full time, they may find $t = 6.5$ and $t = 1.5$ and subtract
	A1	Correct equation or equations if they are using more than one.
	A1	cao
c	B1	e.g. (use) a more accurate value of g , (include) spin of the stone, (include) shape of the stone, (include) size of the stone, (include) wind effects, rotation B0 if any incorrect extras are included e.g. the mass or weight of the stone DO NOT ALLOW NEGATIVES OF THESE e.g there is no air resistance

Q9.

Question		Scheme	Marks	AOs
(a)		16 (m s ⁻¹) seen as the answer	B1	1.1b
			(1)	
(b)		$s = \frac{1}{2} \times 3.2 \times 5^2$ OR $s = \frac{(0+16)}{2} \times 5$ OR $s = (16 \times 5) - \frac{1}{2} \times 3.2 \times 5^2$ OR $16^2 = 2 \times 3.2 \times s$ OR from a v-t graph, $s = \frac{1}{2} \times 5 \times 16$	M1	3.1b
		s = 40 (m)	A1	1.1b
			(2)	
(3 marks)				
Notes:				
a	B1	cao. Must be positive. Ignore any working.		
b	M1	Complete method to find an equation in s only, possibly using their '16' Allow 'reversed motion': use of $s = vt - \frac{1}{2}at^2$ with v = 0 i.e. $s = -\frac{1}{2} \times 3.2 \times 5^2$ can score M1 and s = -40 so distance is 40 (m) can score the A1		
	A1	cao. Must be positive.		
		N.B. correct answer only, in (b), can score both marks.		

Q10.

Question Number	Scheme	Marks
(a)	$0^2 = 19.6^2 - 2 \times gH$ $H = 19.6\text{m (20)}$	M1 A1 (2)
(b)	$14.7 = 19.6t - \frac{1}{2}gt^2$ $t^2 - 4t + 3 = 0$ $(t-1)(t-3) = 0$ $t = 1 \text{ or } 3; \text{ Answer } 2 \text{ s}$	M1 A1 DM1 A1; A1 (5) 7
(b) ALT 1	$(\text{their } h - 14.7) = \frac{1}{2}gt^2$ $t = 1$ OR $v^2 = 19.6^2 - 2g \times 14.7 \Rightarrow v = (\pm) 9.8$ $\text{and } 0 = 9.8 - 9.8t \Rightarrow t = 1$ Total = 2 x their 1 = 2 s	M1 A1 A1 DM 1 A1
(b) ALT 2/3	$v^2 = 19.6^2 - 2g \times 14.7$ $v = \pm 9.8$ EITHER: $-9.8 = 9.8 - gT$ $T = 2$ OR: $0 = 9.8t - \frac{1}{2}gt^2$ $t = (0) \text{ or } 2$	M1 A1 DM1 A1 A1 DM1 A1 A1
	Notes	
(a)	M1 is for a complete method (which could involve use of two <i>suvat</i> equations) for finding <i>H</i> i.e. for an equation in <i>H only</i>, condone sign errors A1 for 19.6 or 20 <u>correctly obtained</u> (2g is A0)	
(b)	First M1 is for a quadratic equation in <i>t</i> only (where <i>t</i> is time at 14.7 above <i>O</i>) First A1 for a correct equation Second DM1, dependent on first M1, for solving for <i>t</i> Second A1 for <u>both</u> values of <i>t</i>, 1 and 3. N.B. If answer(s) are wrong or have come from an incorrect quadratic, and the quadratic formula has been used, M1 can only be awarded if there is clear evidence that the correct formula has been used. If their expression is not correct for their quadratic, allow a slip but only if <u>we see an attempt to substitute into a stated correct formula.</u> Third A1 for 2 s N.B. Obtaining $t = 1$ at $s = 14.7$ (above <i>O</i>) only, can score max M1 A1	

Q11.

Question	Scheme	Marks	AOs
	Equation in t only	M1	2.1
	$-2 = 9t - \frac{1}{2} \leftrightarrow 10t^2$	A1	1.1b
	$5t^2 - 9t - 2 = 0 = (5t+1)(t-2)$	DM1	1.1b
	$T = 2$ (only)	A1	1.1b
		(4)	
(4 marks)			
Notes:			
M1: Complete method to give equation in t only. This mark is for a complete method for the TOTAL time i.e. for finding sufficient equations, with usual rules, correct no. of terms in each equation but condone sign errors and g does not need to be substituted A1: A correct equation or correct equations (e.g. if they find the speed, 11 ms^{-1}, when the ball strikes the ground and then use that to find the total time or if they split the time (e.g. 0.9s up and 1.1s down or $0.9\text{s} + 0.9\text{s} + 0.2\text{s}$)) N.B. $g = 10$ must be substituted in all equations used. DM1: Dependent on first M1, for solving a 3 term quadratic to find T or for solving their equations to find T or for solving their equations <u>and adding</u> their split times to find T A1: $T = 2$ only (i.e. A0 if they give two times) N.B. If solving a <u>correct</u> quadratic, the DM1 can be implied by a correct answer i.e. the method does not need to be shown, but if there is no method shown and the answer is wrong then award DM0 A0.			

Q12.

Question	Scheme	Marks	AOs
(a)	Complete method to produce an equation in U only	M1	3.4
	e.g. $10^2 = U^2 + 2 \times g \times 1.8$ oe	A1	1.1b
	OR a complete method where they find T first and use it to find an equation in U only	M1	
	A correct equation in U only.	A1	
	$U = 8$ (<u>only</u> this answer)	A1	1.1b
		(3)	
(b)	Complete method to find an equation in T only: $10 = -8 + gT$ or $1.8 = 10T - \frac{1}{2}gT^2$ or $1.8 = \frac{(-8+10)}{2}T$ or $1.8 = -8T + \frac{1}{2}gT^2$ OR a complete method if they split the time. In both cases, the M1 is only earned on the final line when they try to add the two times to give an equation in T . ALT 1: time up + time down e.g. $0 = 8 - gt_{UP}$ ($\Rightarrow t_{UP} = 0.8$) $h_{UP} = \frac{(8+0)}{2} \times 0.8$ ($= 3.2$) $(h_{UP} + 1.8) = \frac{(0+10)}{2} \times t_{DOWN}$ ($\Rightarrow t_{DOWN} = 1$) $T = t_{UP} + t_{DOWN}$ ALT 2: time to A + time from A to ground e.g. $8 = -8 + gt_A$ ($\Rightarrow t_A = 1.6$) $1.8 = \frac{(8+10)}{2} \times t_{AG}$ ($\Rightarrow t_{AG} = 0.2$) $T = t_A + t_{AG}$	M1	3.4
	$T = 1.8$ oe e.g. $9/5$	A1	1.1b
		(2)	
(c)	e.g. Use a more accurate (less rounded) value for g (or gravity), use $g = 9.8$ or $g = 9.81$, allow for wind effects, allow for the spin of the stone, include dimensions of stone (not a particle), shape and/or size of stone, allow for variable acceleration. If air resistance is mentioned as an extra, ignore it.	B1	3.5c

		(1)	
(d)	U would be greater. Allow without U , e.g. it would be greater, or just 'greater' oe ISW	B1	3.5a
		(1)	
(7 marks)			
Notes:			
a	M1	Use the model to obtain an equation in U only, condone sign errors, but M0 if using an incorrect formula.	
	A1	A correct equation in U only, g does not need to be substituted (so allow $g = 9.8$ or 9.81)	
	A1	cao (A0 if $g = 10$ has not been used)	
b	M1	Use the model to obtain an equation in T only, g does not need to be substituted (so allow $g = 9.8$ or 9.81) condone sign errors, but M0 if using an incorrect formula. Follow through on their U where necessary	
	A1	cao (A0 if $g = 10$ has not been used) A0 if they give two answers.	
c	B1	Any appropriate refinement. B0 if an incorrect extra is given e.g. the mass or weight is mentioned	
d	B1	cao	

Q13.

Question Number	Scheme	Marks
	(a) $v^2 = u^2 + 2as \Rightarrow 28^2 = u^2 + 2 \times 9.8 \times 17.5$ Leading to $u = 21$ * (b) $s = ut + \frac{1}{2}at^2 \Rightarrow 19 = 21t - 4.9t^2$ $4.9t^2 - 21t + 19 = 0$ $t = \frac{21 \pm \sqrt{21^2 - 4 \times 4.9 \times 19}}{9.8}$ $t = 2.99$ or 3.0 $t = 1.30$ or 1.3 (c) N2L $4g - 5000 = 4a$ ($a = -1240.2$) $v^2 = u^2 + 2as \Rightarrow 0^2 = 28^2 - 2 \times 1240.2 \times s$ Leading to $s = 0.316$ (m) OR Work-Energy: $\frac{1}{2} \times 4 \times 28^2 + 4gs = 5000s$ $s = 0.316$ or 0.32	M1 A1 A1 (3) M1 A1 DM1 A1 A1 (5) M1 A1 M1 A1 (4) [12] M1 A1 M1 A1

(a)
First M1 for a complete method for finding u e.g.
 $28^2 = u^2 + 2g \times 17.5$
or $282 = u^2 + 2(-g) \times (-17.5)$
or $282 = 2gs \Rightarrow s = 40$ then $0^2 = u^2 + 2(-g) \times (22.5)$
condone sign errors
First A1 for a correct equation(s) with $g = 9.8$
Second A1 for " $u = 21$ " PRINTED ANSWER
N.B. Allow a verification method, but they must state, as a conclusion, that " $u = 21$ ", to score the final A1.

(b)
First M1 for a complete method for finding at least one t value i.e. for producing an equation in t only.
(condone sign errors but not missing terms)
First A1 for a correct quadratic equation in t only or TWO correct linear equations in t only.
Second DM1, dependent on first M1, for attempt to solve the quadratic or one of the linear equations.
Second A1 for 3.0 or 3 or 2.99
Third A1 for 1.3 or 1.30

(c)
First M1 for resolving vertically with usual rules.
First A1 for a correct equation
Second M1 for use of $v^2 = u^2 + 2as$, with $v = 0$, $u = 28$ or $u = 0$ and $v = 28$ and their a , (or any other complete method which produces an equation in s , which could be negative)
M0 if they haven't calculated a value of a .
Second A1 for 0.32 or 0.316. (must be positive since it's a distance)

Q14.

Question Number	Scheme	Marks
(a)	For crate, $55g - 473 = 55a$ $a = 1.2 \text{ m s}^{-2}$	M1 A1 A1 (3)
(b)	For system, $55g + 200g \pm T - 150 = 255a$ Magnitude = 2040 N or 2000 N OR For lift, $200g + 473 - 150 \pm T = 200a$ Magnitude = 2040 N or 2000 N	M1 A2 A1 M1 A2 A1 (4)
7		
	Notes	
(a)	M1 for an equation in a only, with usual rules. First A1 for a correct equation Second A1 for $1.2 \text{ (m s}^{-2}\text{)}$. Allow $-1.2 \text{ (m s}^{-2}\text{)}$ if appropriate	
(b)	M1 for an equation, in T and a , for the system or the lift only, with usual rules. (a does not need to be a numerical value) A2 (-1 each error) for a correct equation (Allow $\pm T$). We do not need to see a numerical value for a . Third A1 for 2040 (N) or 2000 (N) N.B. In both parts of this question use the mass which is being used to guide you as to which part of the system is being considered.	

Q15.

Question Number	Scheme	Marks
(a)	For system, $(\uparrow), T - 950g - 50g = 1000 \times -2$	M1 A1
	$T = 7800 \text{ N}$	A1
		(3)
(b)	For woman, $(\uparrow), R - 50g = 50 \times -2$	M1 A1
	$R = 390 \text{ N}$	A1
		(3)
		[6]
Notes for Question		
Q (a)	(In both parts, use the <i>mass</i> to decide which part of the system is being considered and M marks can only be scored if an equation contains only forces acting on that part of the system) M1 is for a complete method for finding T i.e. for an equation in T only, dimensionally correct, with the correct number of terms. First A1 for a correct equation. Second A1 for 7800 (N).	
Q (b)	M1 is for a complete method for finding R i.e. for an equation in R only, dimensionally correct, with the correct number of terms. First A1 for a correct equation. Second A1 for 390 (N). N.B. Equation for lift only is: $T - 950g - R = 950 \times (-2)$	

Q16.

Question Number	Scheme	Marks
(a)	$T - 0.5g - 1.5g = 2 \times 0.5$ $T = 20.6 \text{ (N) or } 21 \text{ (N)}$	M1 A1 A1 (3)
(b)	$R - 1.5g = 1.5 \leftrightarrow 0.5$ $\text{Force} = 15.5 \text{ (N) or } 15 \text{ (N)}$ OR: $T - R - 0.5g = 0.5 \leftrightarrow 0.5$ $\text{Force} = 15.5 \text{ (N) or } 15 \text{ (N)}$	M1 A1 A1 (3) OR M1 A1 A1 (3) 6
	Notes	
(a)	N.B. In both parts of this question use the mass which is being used to guide you as to which part of the system is being considered M1 is for an equation for whole system in T only, with usual rules First A1 for a correct equation Second A1 for 20.6 or 21	
(b)	First M1 is for an equation for the brick only (1st alternative) or for the scale pan only (2nd alternative) with usual rules. First A1 for a correct equation (in the second alternative T does not need to be substituted) Second A1 for 15.5 or 15	
	N.B. If R is replaced by $-R$ in either equation, can score M1A1. This would lead to $R = -15.5$ or -15. The second A1 can then only be scored if the candidate explains why the $-ve$ sign is being ignored.	

Q17.

Question	Scheme	Marks	AOs
	N.B. Use the mass in the ' ma ' term of an equation to determine which part of the system (cage and block, cage or block) it applies to.		
(a)	Translate situation into the model and set up the equation of motion for the <u>cage and the block</u> to obtain an equation in T only.	M1	3.3
	$T - 40g - 10g = 50 \times 0.2$	A1	1.1b
	500 (N) Must be positive	A1	1.1b
	Some examples: $T - 50 = 50 \times 0.2$ and $T - 40g - 10g = 50g \times 0.2$ both score M1A0A0		
		(3)	
(b)	Use the model to set up the equation of motion for the <u>block</u> to obtain an equation in R only.	M1	3.4
	$R - 10g = 10 \times 0.2$ Allow $-R$ instead of R	A1	1.1b
	100 (N) Must be positive.	A1	1.1b
	OR: Use the model to set up the equation of motion for the <u>cage</u> to obtain an equation in R only.	M1	3.4
	$T - 40g - R = 40 \times 0.2$ with their T substituted	A1	1.1b
	100 (N) Must be positive	A1	1.1b
		(3)	
(6 marks)			

Notes:

N.B. Only penalise the use of an incorrect value of g ONCE for the whole question, so max (a) M1A1A0 (b) M1A1A1

a	M1	Correct number of terms, condone sign errors
	A1	Correct equation in T only
	A1	cao
b	M1	Correct number of terms, condone sign errors
	A1	Correct equation in R only
	A1	cao

Q18.

Question	Scheme	Marks	AOs
(a)	(i) Equation of motion for P	M1	3.3
	$T - 2mg = 2ma$	A1	1.1b
	(ii) Equation of motion for Q	M1	3.3
	$5mg - T = 5ma$	A1	1.1b
	N.B. (allow $(-a)$ in both equations)	(4)	
(b)	Solve equations for a or use whole system equation and solve for a	M1	3.4
	$a = \frac{3g}{7} = 4.2$	A1	1.1b
	$v = \sqrt{2 \times \frac{3g}{7} \times h} = \sqrt{8.4h}$ or $v^2 = 2 \times \frac{3g}{7} \times h (= 8.4h)$	M1	1.1b
	$0 = \frac{6gh}{7} - 2gH$	M1	1.1b
	$H = \frac{3h}{7}$	A1	1.1b
	Total height = $2h + h + H$	M1	2.1
	Total height = $\frac{24h}{7}$	A1	1.1b
		(7)	
(c)	e.g. The distance that Q falls to the ground would not be exactly h oe	B1	3.5b
		(1)	
(d)	e.g. The accelerations of the balls would not have equal magnitude (allow 'wouldn't be the same' oe) B0 if they say 'inextensible => acceleration same'	B1	3.5a
		(1)	
(13 marks)			

Notes:		
a	M1	Translate situation into the model and set up the equation of motion for P (must contain T and a)
	A1	Correct equation
	M1	Translate situation into the model and set up the equation of motion for Q (must contain T and a)
	A1	Correct equation
		N.B. Allow the above 4 marks if the equations appear in (b).
		If m 's are omitted consistently, max (a) M1A0M1A0 (b)M1A0M1M1A1M1A0
b	M1	Solve for a
	A1	Allow $4.2 \text{ (m s}^{-2}\text{)}$ or must be in terms of g only.
		N.B. Allow the above 2 marks if they appear in (a).
	M1	Complete method to produce an expression for v or v^2 in terms h , using their a
	M1	Complete method to produce an expression for H in terms of h , using $a = -g$ and $v = 0$
	A1	Correct expression for H
	M1	Complete method to find the total distance
	A1	cao but allow $3.4h$ or better
c	B1	B0 if any incorrect extras are given
d	B1	B0 if any incorrect extras are given or for an incorrect statement e.g. tension is not constant so accelerations will be different

Q19.

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

Q20.

Question Number	Scheme	Marks
(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)	$v^2 = u^2 + 2as = 2 \times \frac{g}{7} \times 0.7 = 1.96$, $v = 1.4 \text{ ms}^{-1}$	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
	$s = \frac{5 \times 1.96}{2g} = 0.5 \text{ (m)}$	A1
	Total height = $0.7 + 0.5 = 1.2 \text{ (m)}$	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
	$s = \frac{2.5 \times 1.96^2}{g} = 0.5 \text{ (m)}$	A1
	Total height = $0.7 + 0.5 = 1.2 \text{ (m)}$	A1 ft (3)
		[16]

Notes for Question

Question (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 (b)

M1 for an equation in v only (usually $v^2 = u^2 + 2as$)

A1 for $1.4 \text{ (ms}^{-1}\text{)}$ allow $\sqrt{(g/5)}$ oe.

Question (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 $2.0 \text{ (ms}^{-2}\text{)}$ (allow a negative answer)

Question (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 $s = 0.5 \text{ (m)}$ correctly obtained

Second A1 ft for their $0.5 + 0.7 = 1.2 \text{ (m)}$

Alternative using conservation of energy

M1 for an equation in s only, with correct number of terms, using their v from (b):-

$(3mgs - 2mgs) = \frac{1}{2} 3m (1.4)^2 + \frac{1}{2} 2m (1.4)^2$

First A1 for $s = 0.5 \text{ (m)}$ correctly obtained

Second A1 ft for their $0.5 + 0.7 = 1.2 \text{ (m)}$

Q21.

Question	Scheme	Marks	AOs
(a)	Equation of motion for P with usual rules	M1	3.3
	$4mg - T = 4ma$	A1	1.1b
	Equation of motion for Q with usual rules	M1	3.3
	$T - 3mg = 3ma$	A1	1.1b
	Solve these equations for T (does not need to be in terms of mg)	M1	1.1b
	$T = \frac{24mg}{7}$ in any form (does not need to be a single term)	A1	1.1b
	Force on pulley = $2T$	M1	3.4
	$\frac{48mg}{7}$ Accept $6.9mg$ or better	A1	1.1b
		(8)	
(b)	Weight of the rope or extensibility of rope Or: pulley may not be smooth	B1	3.5b
		(1)	
(9 marks)			

Notes:

(a)	M1	Translate situation into the model and set up the equation of motion for P M0 if they omit m 's i.e. $4g - T = 4a$
	A1	Correct equation
	M1	Translate situation into the model and set up the equation of motion for Q M0 if they omit m 's i.e. $T - 3g = 3a$
	A1	Correct equation
		N.B. Condone either of the above equations being replaced by the 'whole system equation': $4mg - 3mg = 7ma$ (N.B. $a = g/7$) N.B. a replaced by $-a$ consistently can score all the marks
	M1	Solve equations for T
	A1	$T = \frac{24mg}{7}$ oe
	M1	T does not need to be substituted.
	A1	$\frac{48mg}{7}$ oe <u>Must be in terms of m and g and be a single term</u>
(b)	B1	B0 if any incorrect extras are given

Q22.

Question	Scheme	Marks	AOs
(a)	Equation of motion for P	M1	3.3
	$2mg - T = 2m \leftrightarrow \frac{5g}{7}$	A1	1.1b
	$T = \frac{4mg}{7}$	A1	1.1b
		(3)	
(b)	Since the string is modelled as being inextensible	B1	3.4
		(1)	
(c)	Equation of motion for Q OR for whole system	M1	3.3
	$T - kmg = km \leftrightarrow \frac{5g}{7}$ OR $2mg - kmg = (km + 2m) \frac{5g}{7}$	A1	1.1b
	$\frac{4mg}{7} - kmg = km \leftrightarrow \frac{5g}{7}$ oe and <u>solve for k</u>	DM1	1.1b
	$k = \frac{1}{3}$ or 0.333 or better	A1	1.1b
		(4)	
(d)	e.g The model does not take account of the mass of the string (see notes below for alternatives)	B1	3.5b
		(1)	
(9 marks)			

Notes: Condone both equations of motion appearing in (a) if used in (c)

(a)

M1: Resolving vertically for P with usual rules, correct no. of terms but condone sign errors and a does not need to be substituted (N.B. inconsistent omission of m is M0). Allow ma on RHS for M1

A1: A correct equation (allow if they use 7 instead of $\frac{5g}{7}$)

A1: A correct answer of form cmg , where $c = \frac{4}{7}$ oe or 0.57 or better

(b)

B1: String is inextensible. N.B. B0 if any extras (wrong or irrelevant) given

(c)

M1: Resolving vertically for Q or for a whole system equation, with usual rules, correct no. of terms but condone sign errors and neither T nor a does need to be substituted

(N.B. inconsistent omission of m is M0 and M0 if k is omitted from LHS or RHS or both.)

A1: A correct equation (allow if they use 7 instead of $\frac{5g}{7}$)

DM1: Sub for T using their answer from (a), if necessary, and solve to give a numerical value of k (i.e. m 's must cancel)

A1: $k = \frac{1}{3}$ or 0.333 or better.

(d)

B1: e.g. Pulley may not be smooth

Pulley may not be light

Particles may not be moving freely e.g. air resistance

Balls may not be particles

String may not be light

String may not be inextensible

(but allow converses in all cases e.g. 'pulley smooth')

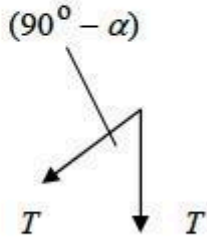
N.B. B0 if any extra incorrect answer is given BUT ignore incorrect consequence of a correct answer.

Also note: B0 : Use of a more accurate value of g

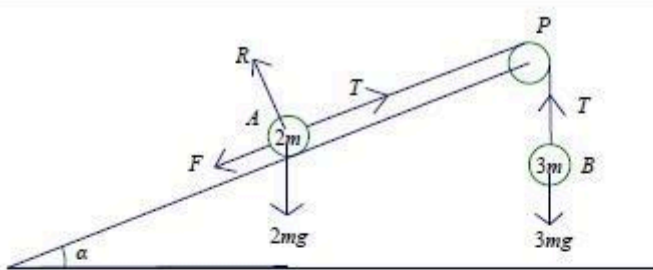
Q23.

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

Q24.

Question Number	Scheme	Marks
(a)	$T - 5g \sin \alpha = 5a$ $15g - T = 15a$ solving for a $a = 0.6g$ solving for T $T = 6g$	M1 A1 M1 A1 M1 A1 M1 A1 (8)
(b)	For Q : $5g - N = 5a$ $N = 2g$	M1 A1 A1 f.t. (3)
(c)	 $F = 2T \cos\left(\frac{90^\circ - \alpha}{2}\right)$ $= 12g \cos 26.56^\circ$ $= 105 \text{ N}$	M1 A2 A1 f.t. A1 (5) [16]

Q25.

Question	Scheme	Marks	AO
(a)			
	$R = 2mg \cos \alpha$	B1	3.4
	$F = \frac{2}{3} R$	B1	1.2
	Equation of motion for A:	M1	3.3
	$T - F - 2mg \sin \alpha = 2ma$	A1	1.1b
	Equation of motion for B:	M1	3.3
	$3mg - T = 3ma$	A1	1.1b
	Complete strategy to find an equation in T , m and g only.	M1	3.1b
	$T = \frac{12mg}{5} \quad *$	A1*	2.2a
		(8)	
(b)	$(F_{\max} =) \frac{16mg}{13} > \frac{10mg}{13}$	M1	2.1
	 so A will not move.	A1	2.2a
		(2)	
(c)	• Extensible string • Weight of string • Friction at pulley e.g. rough pulley • Allow for the dimensions of the blocks e.g. "Do not model blocks as particles"; "(include) air resistance"; "include rotational effects of forces on blocks i.e. spin"	B1 B1	3.5c 3.5c
		(2)	
		(12)	

Marks		Notes
a	B1	Normal reaction between A and the plane seen or implied, $\cos \alpha$ does not need to be substituted.
	B1	$F = \frac{2}{3}R$ seen or implied anywhere, including part (b)
	M1	Form an equation of motion for A . Must include all relevant terms. Must be the correct mass but condone consistent missing m 's. Condone sign errors and sin/cos confusion
	A1	Correct unsimplified equation (F does not need to be substituted). Allow consistent use of $(-a)$ N.B. If $T - 2mg = 2ma$ is seen with no working, M0A0 unless both B1 marks have been scored.
	M1	Form an equation of motion for B . Must be the correct mass on RHS but condone consistent missing m 's. Condone sign errors and sin/cos confusion.
	A1	Correct unsimplified equation (F does not need to be substituted). Allow consistent use of $(-a)$
		N.B. Allow the 'whole system' equation to replace the equation for A or B . $3mg - F - 2mg \sin \alpha = 5ma$ Must be the correct mass on RHS but condone consistent missing m 's. Condone sign errors and sin/cos confusion.
	M1	Complete method to give an equation in T , m and g only. N.B. Allow θ in the equation if they have defined what θ is: e.g. $\theta = \tan^{-1}(\frac{5}{12})$ This is an <u>independent</u> mark but they must have two simultaneous equations in T and a unless one of the equations is the whole system equation in which case one equation will be in T and a and the other equation will be in a only.
	A1*	Obtain the given answer from correct working using EXACT trig ratios. (not available if using a decimal angle)

b	M1	Comparison of their $F_{\max} \left(\frac{2}{3}R \right)$ and their component of weight down the slope, must be comparing numerical values. oe e.g. if they consider the difference N.B. Allow comparison of μ and $\tan \alpha$ with numerical values
	A1	Correctly justified conclusion and no errors seen N.B. If they equate their difference to an 'ma' term then A0
c	B1 B1	Deduct 1 mark for each extra (more than 2) incorrect answer up to a maximum of 2 incorrect answers. Ignore extra correct answers. e.g. two correct, one incorrect B1 B0 one correct, one incorrect B1 B0 one correct, two incorrect B0 B0 Ignore incorrect reasons or consequences. Ignore any mention of wind or a general reference to friction.

Q26.

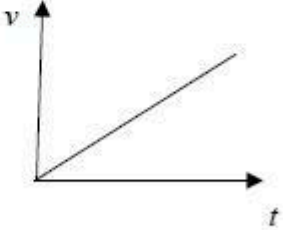
Question	Scheme	Marks	AOs	Notes
(a)	Equation of motion for Q	M1	3.3	Equation of motion for Q with correct no. of terms, condone sign errors.
	$0.6g - T = 0.6a$	A1	1.1 b	A correct equation
	Equation of motion for P	M1	3.3	Equation of motion for Q with correct no. of terms, condone sign errors.
	$T = 0.8a$	A1	1.1 b	A correct equation
	$a = 4.2 \text{ (m s}^{-2}\text{) } *$	A1*	2.2 a	<u>Given</u> acceleration obtained correctly. You must see an equation in a only before reaching $a = 4.2$
		(5)		N.B. if they just use the whole system equation: $0.6g = 1.4a$, can only score max M1A1M0A0A0 N.B. Use of $g = 9.81$ or 10 loses final A mark only. N.B. Complete verification, using both equations, can score full marks.

(b)	$0.4 = \frac{1}{2} \times 4.2 \times t_1^2$ or e.g. they may find v first and then use $v = 4.2 t_1$	M1	2.1	Complete method (they may use more than one <i>suvat</i> equation) to find time for Q to hit the floor (M0 if 0.4 not used as distance moved and/or if 4.2 is not used as acceleration <u>and this applies to finding v as well if they use v to find t_1</u>)
	$t_1 = 0.436(4357\dots)$ Allow 0.43, 0.44, 0.436, or better, or any surd form e.g. $\frac{2}{\sqrt{21}}$	A1	1.1 b	See alternatives
	$v = 4.2 \times t_1$ or $v = \sqrt{2 \times 4.2 \times 0.4}$ or $0.4 = \frac{(0+v)}{2} \times t_1$ ($v = 1.8330\dots$)	M1	3.4	Complete method to find speed of Q as it hits the floor (M0 if 0.4 not used as distance moved and/or if 4.2 is not used as acceleration <u>and this applies to finding t_1 as well if they use t_1 to find v</u>)
	$t_2 = \frac{1.5 - 0.4}{v}$	M1	1.1 b	Uses distance/speed to find time for P to hit the pulley after Q has hit the floor. N.B. This is <u>independent</u> of previous M mark.
	Complete strategy to solve the problem by finding the sum of the two times $t_1 + t_2$	DM 1	3.1 b	Complete method to solve the problem by finding and adding the two required times, <u>dependent on previous three M marks</u>
	1.0 (s) or 1.04 (s)	A1	1.1 b	
		(6)		
(c)	e.g. rope being light; rope being inextensible; pulley being smooth; pulley being small; balls being particles	B1	3.5 b	Clear statement. Allow negatives of these i.e. the rope may not be light, the rope may not be inextensible etc Must be a <u>limitation of the model stated in the question</u> <u>Penalise incorrect or irrelevant extras</u>
		(1)		B0 for: Air resistance, table being smooth
(12 marks)				

Q27.

Question Number	Scheme	Marks
(a)	$R = 0.3g \cos \alpha$ $= 0.24g = 2.35 \text{ (3sf)} = 2.4 \text{ (2sf)}$	M1 A1 (2)
(b)	$mg - T = 1.4m$ $T - 0.3g \sin \alpha - F = 0.3 \times 1.4$ $F = 0.5R$ Eliminating R and T $m = 0.4$	M1 A1 M1 A2 M1 DM1 A1 (8)
(c)	$v = 1.4 \times 0.5$ $-0.3g \sin \alpha - F = 0.3a$ $a = -9.8$ $0 = 0.7 - 9.8t$ $t = 0.071 \text{ s or } 0.0714 \text{ s (1/14 A0)}$	B1 M1 A1 A1 M1 A1 (6) 16

Q28.

Question	Scheme	Marks	AOs
	Mark parts (a) and (b) together		
(a)	Equation of motion for A	M1	3.3
	$3mg \sin \alpha - F - T = 3ma$	A1	1.1b
		(2)	
(b)	Resolve perpendicular to the plane	M1	3.4
	$R = 3mg \cos \alpha$	A1	1.1b
	$F = \frac{1}{6}R$	B1	1.2
	Equation of motion for B OR for whole system	M1	3.3
	$T - mg = ma$ OR $3mg \sin \alpha - F - mg = 3ma + ma$	A1	1.1b
	Complete method to solve for a	DM1	3.1b
	$a = \frac{1}{10}g$ *	A1*	2.2a
		(7)	
(c)		B1	1.1b
	e.g. acceleration (of B) is constant; dependent on first B1	DB1	2.4
		(2)	
(d)	e.g. the tensions in the two equations of motion would be different. Tension on A would be different to tension on B	B1	3.5a
		(1)	
(12 marks)			

Notes: N.B. If m's are consistently missing treat as a MR, so max
(a) M1A0 (b) M1A0B0M1A1M1A1 (c) B1B1 (d) B1

For (a) and (b), allow verification, but must see full equations of motion.

a	M1	Equation in T and a with correct no. of terms, condone sign errors and sin/cos confusion (If one of the 3's is missing, allow M1) N.B. Treat $\sin(3/5)$ etc as an A error but allow recovery
	A1	Correct equation (allow $(-a)$ instead of a in <u>both</u> equations)
b	M1	Correct no. of terms, condone sign errors and sin/cos confusion Allow if appears in (a)
	A1	Correct equation
	B1	Seen anywhere in (a) or (b), including on a diagram
	M1	Equation (for B) in T and a with correct no. of terms, condone sign errors and sin/cos confusion OR Whole system equation with correct no. of terms, condone sign errors and sin/cos confusion
	A1	Correct equation
	DM1	Complete method (trig may not be substituted), dependent on M1 in (a) and second M1 in (b) if they use two equations, or second M1 in (b) if they use one equation.
	A1*	Correct answer correctly obtained.
c	B1	Straight line starting at the origin (could be reflected in the t -axis). B0 if continuous vertical line at the end.
	DB1	Dependent on first B1, for any equivalent statement
d	B1	B0 if incorrect extras

Q29.

Question	Scheme	Marks	AOs
(a)	Equation of motion for the car	M1	3.3
	$7400 - 2R - 2400 = 1200a$	A1	1.1b
	Equation of motion for the trailer	M1	3.4
	$2400 - R = 400a$	A1	1.1b
	$a = 0.5$	A1	1.1b
		(5)	
	N.B. Either equation could be replaced by: Equation of motion for the whole system $7400 - 3R = 1600a$		
(b)	The value of a_1 would be less than the value of a . Allow ' a_1 would be slower than a ', N.B. Allow 'it would be less than a '	B1	3.5a
		(1)	
(c)	The resistance won't be constant or just 'it won't be constant.' Allow the negative also: The resistance is constant or just 'it is constant' B0 for 'it doesn't take account of air resistance'	B1	3.5b
		(1)	
(7 marks)			

Notes:

a		N.B. When entering marks on ePEN for the two equations of motion, enter them in the order in which they appear on the script. For any equation of motion, use the mass in the ' ma ' term to determine to which part of the system it relates.
	M1	Correct no.of terms and condone sign errors, with the driving force as 7400 (when appropriate) and the tension as 2400.
	A1	Correct equation
	M1	Correct no.of terms and condone sign errors, with the driving force as 7400 (when appropriate) and the tension as 2400.
	A1	Correct equation
	A1	cao
b	B1	cao
c	B1	B0 if any incorrect extras are given or for an incorrect statement

Q30.

Question Number	Scheme	Marks
	$T - 0.5g = 0.5a$ $15 - T - 0.75g = 0.75a$ $(OR: 15 - 0.5g - 0.75g = 1.25a)$ $(a = 2.2 \text{ m s}^{-2})$ $T = 6 \text{ N}$	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.	

Q31.

Question Number	Scheme	Marks
(a)	$R = 4g \cos \alpha$ $T - 0.5g = 0.5a$ $4g \sin \alpha - T - F = 4a$ (OR: $4g \sin \alpha - F - 0.5g = 4.5a$) $F = \frac{1}{2}R; \quad \sin \alpha = \frac{4}{5} \quad \text{or} \quad \cos \alpha = \frac{3}{5}$ Eliminating a or finding a Solving for T (must have had an a) $T = \frac{2g}{3} \text{ N or } 6.5 \text{ N or } 6.53 \text{ N}$	M1 A1 M1 A1 M1 A1 B1; B1 M1 M1 A1 (11)
(b)	$\text{Magnitude} = 2T \cos \left(\frac{90 - \alpha}{2} \right)$ $= 2 \times \frac{2g}{3} \times \frac{3}{\sqrt{10}} \quad (0.94868\dots)$ $= 12 \text{ N or } 12.4 \text{ N} \quad \left(\frac{4g}{\sqrt{10}} \right)$	M1 A1 A1 ft on T A1 (4) 15

	Notes	
(a)	First M1 for resolving perp to plane, with usual criteria First A1 for a correct equation Second M1 for resolving vertically, with usual criteria Second A1 for a correct equation, in terms of a and T Third M1 for resolving parallel to the slope, with usual criteria. Third A1 for a correct equation, in terms of a, F and T <u>N.B. Their a could be UP the slope in which case all 4 marks for the 2 equations are available with $-a$ replacing a. provided they are consistent. If they are inconsistent, then assume the vertical resolution is the correct one and mark accordingly.</u> Either of the above two equations can be replaced by the 'whole system' equation N.B. If they use $a = 0$, in any of the above 3 equations, and they use the equation to find T, they lose both marks for that equation, and they lose the two M marks for eliminating and solving. First B1 for $F = \frac{1}{2}R$ seen or implied; Second B1 for $\sin \alpha = 0.8$ or $\cos \alpha = 0.6$ seen or implied. Allow close approximations if $\alpha = 53.1^\circ \dots$ used. Fourth M1 independent for eliminating a or finding a. Fifth M1 for solving for T but must have had an a. Fourth A1 for $2g/3$, 6.5 or 6.53.	

(b)

First M1 for a complete method for finding the magnitude of the resultant (N.B. M0 if same tensions used)

$$2T \cos\left(\frac{90^\circ - \alpha}{2}\right). \text{Allow sin/cos confusion and allow } 2T \cos\left(\frac{\alpha}{2}\right)$$

OR $\sqrt{(T + T \sin \alpha)^2 + (T \cos \alpha)^2}$. Allow sin/cos confusion and allow omission of $\sqrt{}$ sign, but only if $R^2 = \dots\dots\dots$ is included

OR $\sqrt{T^2 + T^2 - 2T^2 \cos(90^\circ + \alpha)}$. Allow $(90^\circ - \alpha)$ but must be cos and and allow omission of $\sqrt{}$ sign, but only if $R^2 = \dots\dots\dots$ is included

OR $\frac{T \sin(90 + \alpha)}{\sin\left(\frac{90^\circ - \alpha}{2}\right)}$. (Sine Rule) Allow sign errors in angles but must

be sin

First A1 for correct expression in terms of T and α

Second A1, ft on their T , for a 'correct' **single numerical** answer

Third A1 cao for 12 (N) or 12.4 (N)

Q32.

Question Number	Scheme	Marks
(a)	Use of $v^2 = u^2 + 2as$ $14^2 = 20^2 - 2a \times 100$ Deceleration is $1.02(\text{m s}^{-2})$	M1 A1 A1 (3)
(b)	Horizontal forces on the car: $\pm T \cos \theta - 300 = 750 \times -1.02 = -765$ $T = -1550/3$ The force in the tow-bar is $1550/3$, 520 (N) or better (allow -ve answer)	M1A2 f.t. A1 (4)
(c)	Horizontal forces on the truck: $\pm T \cos \theta - 500 - R = 1750 \times -1.02$ Braking force $R = 1750$ (N)	M1A2 f.t. A1 (4)
	ALT: Whole system: $800 + R = 2500 \times 1.02$ $R = 1750$	M1A2 f.t. A1 [11]

Notes for Question

Q (a)	M1 for a complete method to produce an equation in a only. First A1 for a correct equation. Second A1 for $1.02 (\text{ms}^{-2})$ oe. must be POSITIVE.	
Q (b)	M1 for considering <u>the car ONLY</u> horizontally to produce an equation in T only, with usual rules. i.e. correct no. of terms AND T resolved: $\pm T \cos \theta - 300 = 750 \times -1.02$ A2 ft on their a for a correct equation (<u>300 and a must have same sign</u>); -1 each error (treat $\cos 0.9$ as an A error) A1 for $1550/3$ oe, 520 or better (N) N.B. Allow a negative answer.	
Q (c)	M1 for considering <u>the truck ONLY</u> horizontally to produce an equation, with usual rules. i.e. correct no. of terms AND T resolved: $\pm T \cos \theta - 500 - R = 1750 \times -1.02$ A2 ft on their T and a for a correct equation (<u>500, a and R must have same sign</u>); -1 each error (treat $\cos 0.9$ as an A error) A1 for 1750 (N). OR M1 for considering <u>the whole system</u> to produce an equation in R only, with usual rules. i.e. correct no. of terms. A2 ft on their a for a correct equation (<u>a and R must have same sign</u>) -1 each error A1 for 1750 (N). N.B. If 300 and 500 are given separately, penalise any sign errors only ONCE.	

Q33.

Question	Scheme	Marks	AOs
(a)	Resolve perpendicular to the plane	M1	3.4
	$R = mg \cos \alpha = \frac{4}{5} mg$	A1	1.1b
		(2)	
(b)	Resolve parallel to the plane or horizontally or vertically	M1	3.4
	$F = mg \sin \alpha$ or $R \sin \alpha = F \cos \alpha$	A1	1.1b
	Use $F = \mu R$ and solve for μ	M1	2.1
	$\mu = \frac{3}{4} *$	A1*	2.2a
		(4)	
(c)	The forces acting on Q will still balance as the m 's cancel oe Other possibilities: e.g. the <u>friction</u> will increase <u>in the same proportion</u> as <u>the weight component or force down the plane</u> . The <u>force pulling the brick down the plane</u> increases <u>by the same amount</u> as the <u>friction</u> oe This mark can be scored if they do the calculation.	B1	2.4
		(1)	
(d)	Brick Q slides down the plane with constant speed.	B1	2.4
	No resultant force down the plane (so no acceleration) oe	B1	2.4
	These marks can be scored if they do the calculation.	(2)	
(9 marks)			

Notes:

a	M1	Correct no. of terms, condone sin/cos confusion
	A1	cao with no wrong working seen. $mg\cos 36.86$ is A0
b	M1	Correct no. of terms, condone sin/cos confusion
	A1	Correct equation
	M1	Must use $F = \mu R$ (not merely state it) to obtain a numerical value for μ . This is an independent M mark.
	A1*	Given answer correctly obtained
c	B1	Must have the 3 underlined phrases/word oe
d	B1	Must say constant speed.
	B1	Any appropriate equivalent statement

Q34.

Question Number	Scheme	Marks
(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)	$-\mu R = 2ma'$ $0^2 = \text{their } u^2 - 2a's$ $0 = \frac{2gh}{3}(1 - \frac{2}{3}) - 2(\frac{1}{3}g)s \text{ (or } s = (d - h))$ $s = \frac{1}{3}h$ $d = \frac{1}{3}h + h = \frac{4}{3}h$	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	
(a)(i)	First M1 for equation of motion for A with usual rules First A1 for a correct equation (allow $-T$ instead of T)	
(ii)	Second M1 for equation of motion for B with usual rules Second A1 for a correct equation (allow consistent $-T$ instead of T)	
(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)	
(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	
(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 $\mu = \frac{1}{3}$ Second A1 for $s = \frac{1}{3}h$ Third A1 for $d = \frac{4}{3}h$ ALTERNATIVE using work-energy principle: M2 for $\mu R s = \frac{1}{2} 2mu^2$ (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 $s = \frac{1}{3}h$ Third A1 for $d = \frac{4}{3}h$	
(e)	B1 for any one of the alternatives listed above.	

Q35.

Question	Scheme	Marks	AOs
(a)(i)	Resolve vertically	M1	3.1b
	F acting UP the plane: OR F acting DOWN the plane: $(\uparrow) F \sin \alpha + 68.6 \cos \alpha = 5g$ $-F \sin \alpha + 68.6 \cos \alpha = 5g$	A1	1.1b
	Other possible equations from which X would need to be eliminated to give an equation in F only to earn the M mark are shown below. The equation in F only must then be correct to earn the A mark. Possible equations: $(\nwarrow) 68.6 = X \sin \alpha + 5g \cos \alpha$ (leads to $X = 49$ with $g = 9.8$) F acting UP the plane: OR F acting DOWN the plane: $(\nearrow) F + X \cos \alpha = 5g \sin \alpha$ $-F + X \cos \alpha = 5g \sin \alpha$ $(\rightarrow) F \cos \alpha + X = 68.6 \sin \alpha$ $-F \cos \alpha + X = 68.6 \sin \alpha$		
	9.8 (N) (49/5 is A0) N.B. If sin and cos are interchanged in all equations, this leads to an answer of 9.8 in the wrong direction and can only score (a) (i)M1A0A0 (ii) A0	A1	1.1b
		(3)	

(a)(ii)	Down the plane (Allow down or downwards or an arrow ↙, but must appear as the answer to (a) (ii) not just on the diagram.)	A1	2.2a
		(1)	
(b)	N.B. If they use $R = 68.6$ in this part, the maximum they can score is M1A1M0A0M0A0 If they use $F = 9.8$ or their F from (a) in this part, the maximum they can score is M1A1M0A0M0A0		
	Equation of motion down the plane	M1	2.1
	$5g \sin \alpha - F = 5a$ Allow $(-a)$ instead of a	A1	1.1b
	Resolve perpendicular to the plane	M1	3.1b
	$R = 5g \cos \alpha$	A1	1.1b
	$F = 0.5R$ seen	M1	3.4
	$a = 1.96$ or 2.0 or $2 \text{ (m s}^{-2}\text{)}$ or $\frac{1}{5}g$	A1	1.1b
		(6)	
(10 marks)			

Notes:		
a (i)	M1	Complete method to obtain an equation in F only. For each equation used, correct no. of terms, dimensionally correct, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved.
	A1	Correct equation in F only, trig does not need to be substituted
	A1	cao (must be positive)
a (ii)	A1	cao. Note that this mark is dependent on an answer of 9.8 or -9.8 for (a)(i) <u>from a fully correct solution</u> unless they have used $g = 9.81$, in which case the answer will be 9.7 or -9.7 (2sf) see SC2 below. N.B. Allow this mark, if their answer to (a)(i) is fully correct apart from a small error due to use of inaccurate trig i.e using an angle 36.9°
		SC 1: If they use μR at any point (with an unknown μ) for F in part (a), can score (a)(i) max M1A1A0 (a) (ii) A1, where they must have obtained $\mu R = 9.8$ or -9.8 , from correct working. SC 2: If $g = 9.81$ is used consistently throughout (a), (leading to $X = 48.9\dots$ and $F = 9.7$ (2sf)) can score max (a)(i) M1A1A0 (a)(ii) A1
b	M1	Correct no.of terms, dimensionally correct, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved.
	A1	Correct equation for their F .
	M1	Correct no. of terms, dimensionally correct, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved. (N.B. M0 if $R = 68.6$ (N) is used in this equation)
	A1	Correct equation
	M1	Could be seen on a diagram (N.B. M0 if $R = 68.6$ (N) is used)
	A1	Cao. Must be positive.

Q36.

Question	Scheme	Marks	AOs
(a)	Using the model and vertical motion: $0^2 = (U \sin \alpha)^2 - 2g \leftrightarrow (3-2)$	M1	3.3
	$U^2 = \frac{2g}{\sin^2 \alpha}$ * GIVEN ANSWER	A1*	2.2a
		(2)	
(b)	Using the model and horizontal motion: $s = ut$	M1	3.4
	$20 = Ut \cos \alpha$	A1	1.1b
	Using the model and vertical motion: $s = ut + \frac{1}{2}at^2$	M1	3.4
	$-\frac{5}{4} = Ut \sin \alpha - \frac{1}{2}gt^2$	A1	1.1b
	sub for t : $-\frac{5}{4} = U \sin \alpha \left(\frac{20}{U \cos \alpha} \right) - \frac{1}{2}g \left(\frac{20}{U \cos \alpha} \right)^2$	M1 (I)	3.1b
	sub for U^2	M1(II)	3.1b
	$-\frac{5}{4} = 20 \tan \alpha - 100 \tan^2 \alpha$	A1(I)	1.1b
	$(4 \tan \alpha - 1)(100 \tan \alpha + 5) = 0$	M1(III)	1.1b
	$\tan \alpha = \frac{1}{4} \Rightarrow \alpha = 14^\circ$ or better	A1(II)	2.2a
		(9)	
	N.B. For the last 5 marks, they may set up a quadratic in t , by substituting for $U \sin \alpha$ first, then solve the quadratic to find the value of t , then use $20 = Ut \cos \alpha$ to find α . The marks are the same but earned in a different order. Enter on ePen in the corresponding M and A boxes above, as indicated below.		

	Sub for $U \sin \alpha$ to give equation in t only	M1(II)	
	$-\frac{5}{4} = \sqrt{2g}t - \frac{1}{2}gt^2$	A1(I)	
	Solve for t	M1(III)	
	$t = \frac{5}{\sqrt{2g}}$ or 1.1 or 1.13 and use $20 = Ut \cos \alpha$	M1(I)	
	$\alpha = 14^\circ$ or better	A1(II)	
(b)	ALTERNATIVE		
	Using the model and horizontal motion: $s = ut$	M1	3.4
	$20 = Ut \cos \alpha$	A1	1.1b
	A to top: $s = vt - \frac{1}{2}at^2$ <u>and</u> top to T : $s = ut + \frac{1}{2}at^2$		
	$1 = \frac{1}{2}gt_1^2 \Rightarrow t_1 = \sqrt{\frac{2}{g}}$ <u>and</u> $\frac{9}{4} = \frac{1}{2}gt_2^2 \Rightarrow t_2 = \frac{3}{\sqrt{2g}}$ Total time $t = t_1 + t_2$	M1	3.4
	$= \sqrt{\frac{2}{g}} + \frac{3}{\sqrt{2g}} \quad (= \frac{5}{\sqrt{2g}})$	A1	1.1b
	$20 = U \frac{5}{\sqrt{2g}} \cos \alpha$ (sub. for t)	M1	3.1b
	$20 = \sqrt{\frac{2g}{\sin^2 \alpha}} \frac{5}{\sqrt{2g}} \cos \alpha$ (sub. for U)	M1	3.1b
	$\tan \alpha = \frac{1}{4}$	A1	1.1b
	Solve for α	M1	1.1b
	$\Rightarrow \alpha = 14^\circ$ or better	A1	2.2a
		(9)	

(c)	The target will have dimensions so in practice there would be a range of possible values of α Or There will be air resistance Or The ball will have dimensions Or Wind effects Or Spin of the ball	B1	3.5b
		(1)	
(d)	Find U using their α e.g. $U = \sqrt{\frac{2g}{\sin^2 \alpha}}$	M1	3.1b
	Use $20 = Ut \cos \alpha$ (or use vertical motion equation)	A1 M1	1.1b
	$t = \frac{5}{\sqrt{2g}}$ or 1.1 or 1.13	B1 A1	1.1b
		(3)	
(d)	ALTERNATIVE		
	A to top: $s = vt - \frac{1}{2}at^2$ and top to T: $s = ut + \frac{1}{2}at^2$	M1	3.1b
	$1 = \frac{1}{2}gt_1^2 \Rightarrow t_1 = \sqrt{\frac{2}{g}}$ and $\frac{9}{4} = \frac{1}{2}gt_2^2 \Rightarrow t_2 = \frac{3}{\sqrt{2g}}$ Total time $t = t_1 + t_2$	A1 M1	1.1b
	$= \sqrt{\frac{2}{g}} + \frac{3}{\sqrt{2g}} (= \frac{5}{\sqrt{2g}}) = 1.1 \text{ or } 1.13 \text{ (s)}$	B1 A1	1.1b
		(3)	
(15 marks)			

Notes:

(a)

M1: Or any other complete method to obtain an equation in U , g and α **only**

A1*: Correct GIVEN ANSWER

(b)

M1: Using horizontal motion

A1: Correct equation

M1: Using vertical motion . N.B. M0 if they use $s = \pm 2$ or ± 3 , but allow $s = \pm 1.25$ or ± 0.75 or ± 2.25 or ± 2.75

A1: Correct equation

M1: Using $20 = Ut \cos \alpha$ to sub. for t

M1: Substituting for U^2 using (a)

A1: Correct quadratic equation (in $\tan \alpha$ or $\cot \alpha$)

M1: Solve a 3 term quadratic, either by factorisation or formula (or by calculator (implied) if answer is correct) **and find α**

A1: $\alpha = 14^\circ$ or better (No restriction on accuracy since g 's cancel)

N.B. If answer is correct, previous M mark can be implied, but if answer is incorrect, an explicit attempt to solve must be seen to earn the previous M mark.

(b) ALTERNATIVE

M1: Using the model with the usual rules applying to the equation

A1: Correct equation

M1: Using the model to obtain the **total** time from A to T

A1: Correct **total** time t

M1: Substitute for t in $20 = Ut \cos \alpha$

M1: Substitute for U in $20 = Ut \cos \alpha$, using part (a)

A1: Correct equation in $\tan \alpha$ **only**

M1: Solve equation for α

A1: $\alpha = 14^\circ$ or better (No restriction on accuracy since g 's cancel)

N.B. If they quote the equation of the trajectory $y = x \tan \alpha - \frac{gx^2}{2U^2 \cos^2 \alpha}$ oe **AND** put in values for x and y , could score first 5 marks, M1A1M1A1M1 (nothing for the equation only); wrong x value loses first A mark and wrong y value loses second A mark

(c)

B1: Give one limitation of the model e.g. the ball will have dimensions, or there will be air resistance or wind effects or spin

N.B. B0 if any incorrect extra(s) but ignore extra consequences.

(d)

M1: Using their α to find a value for U

A1: Treat as M1: Using their U to find a value for t

B1: Treat as A1 : $t = 1.1$ or 1.10 (since depends on $g = 9.8$)

(d) **ALTERNATIVE**

M1: Using their α to find a value for U

A1: Treat as M1: Using their U to find a value for t

B1: Treat as A1 : $t = 1.1$ or 1.10 (since depends on $g = 9.8$)

Q37.

Question	Scheme	Marks	AOs
(a)	Using horizontal motion	M1	3.3
	Whole Motion Half way		
	$U \cos \alpha \times t = 120$ $U \cos \alpha \times t = 60$	A1	1.1b
	Using vertical motion OR	M1	3.4
	$U \sin \alpha \times t - \frac{1}{2}gt^2 = 0$ $0 = U \sin \alpha - gt$	A1	1.1b
	Attempt to solve problem by eliminating t	DM1	3.1b
	$U^2 \sin \alpha \cos \alpha = 588^*$	A1*	2.2a
		(6)	
	N.B. No credit given if they use the given answer from (b).		

(b)	Using vertical motion OR conservation of energy	M1	3.4
	$0^2 = (U \sin \alpha)^2 - 2g \times 10$ $\frac{1}{2} m U^2 - \frac{1}{2} m (U \cos \alpha)^2 = mg \times 10$	A1	1.1b
	ALTERNATIVE 1: If t is time to top: use of $10 = \frac{1}{2} g t^2$ or $(t = \frac{10}{7})$ to obtain an equation in U and α only M1 $U \sin \alpha = 14$ or $U \cos \alpha = 42$ A1 ALTERNATIVE 2: If t is time to top: use of: $10 = U \sin \alpha t - \frac{1}{2} g t^2$ with $t = \frac{60}{U \cos \alpha}$ substituted to obtain an equation in U and α only : M1 $10 = U \sin \alpha \times \frac{60}{U \cos \alpha} - \frac{1}{2} g \left(\frac{60}{U \cos \alpha} \right)^2$ A1		
	Attempt to solve problem by eliminating α : e.g. $U \sin \alpha = 14 \Rightarrow U \cos \alpha = 42$, from part (a) or from using $t = \frac{10}{7}$, then square and add to give result OR: $U^2 \sin^2 \alpha = 20g = 196$ and $U^2 \sin \alpha \cos \alpha = 588$, divide to give $\tan \alpha = \frac{1}{3}$ then $\sin^2 \alpha = \frac{1}{10}$, hence result OR in ALTERNATIVE 2: sub for U^2 using part (a), to give $\tan \alpha = \frac{1}{3}$ then $\sin^2 \alpha = \frac{1}{10}$, hence result	DM1	3.1b

	N.B. Just stating that $\sin^2 \alpha = \frac{1}{10}$, with no working is DM0A0.		
	$U^2 = 1960 *$	A1*	2.2a
	N.B. Verification (i.e. starting with $U^2 = 1960$ and trying to work backwards) is not an acceptable method for this question.		
		(4)	
(c)	V , since air resistance has to be overcome, or just 'because of <u>air resistance</u> ' isw	B1	3.5a
		(1)	
(d)	e.g. wind effects, more accurate value of g , spin of ball, size of ball, shape of ball, dimensions of ball, not a particle, variable acceleration, surface area of ball, humidity. Allow wind resistance and rotational resistance (Ignore any mention of air resistance or drag)	B1	3.5c
		(1)	
(12 marks)			

Notes:

a		N.B. Could score 2/6 for any one of the 4 given equations if there is no corresponding second equation or there is an attempt but it's incorrect.
	M1	Complete method to give equation in U , α and t only, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved
	A1	Correct equation
	M1	Complete method to give equation in U , α and t only, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved
	A1	Correct equation
	DM 1	Eliminate t , dependent on first and second M1's
	A1*	Given answer correctly obtained, <u>with no wrong working seen</u> . Allow $588 = U^2 \sin \alpha \cos \alpha$ but nothing else
b	M1	Complete method to give equation in U and α only with correct no. of terms, condone sin/cos confusion and sign errors, each term that needs to be resolved must be resolved
	A1	Correct equation
	DM 1	Eliminate α and rearrange, dependent on first M1
	A1*	Given answer correctly obtained with <u>no wrong working seen</u> (N.B. If they use a value for α (18.43.°) they lose the final A1*)
c	B1	Clear statement isw
d	B1	B0 if there is an incorrect extra e.g. mass or weight

Q38.

Question	Scheme	Marks	AOs
	Note that $g = 10$; penalise once for whole question if $g = 9.8$		
(a)	Use $s = ut + \frac{1}{2}at^2$ vertically or any complete method to give an equation in t only	M1	3.4
	$-70 = 65 \sin \alpha \times t - \frac{1}{2} \times g \times t^2$	A1	1.1b
		M (A)1	1.1b
	$t = 7$ (s)	A1	1.1b
		(4)	
(b)	Horizontal velocity component at A = $65 \cos \alpha$ (60)	B1	3.4
	Complete method to find vertical velocity component at A	M1	3.4
	$65 \sin \alpha - g \times 7$ OR $\sqrt{(-25)^2 + 2g \times 70}$ (45)	A1ft	1.1b
	Sub for trig and square, add and square root : $\sqrt{60^2 + (-45)^2}$	M1	3.1b
	75 Accept 80 (m s^{-1})	A1	1.1b
		(5)	
(c)	e.g. an approximate value of g has been used, the dimensions of the stone could affect its motion, spin of the stone, $g = 10$ instead of 9.8 has been used, g has been assumed to be constant, wind effect, shape of the stone	B1	3.5b
		(1)	
(10 marks)			

Notes:		
a	M1	Complete method, correct no. of terms, condone sign errors and sin/cos confusion
	A1	Correct equation in t only with at most one error
	M(A)1	Correct equation in t only
		N.B. For 'up and down' methods etc, the two A marks are for all the equations that they use, lose a mark for each error.
	A1	Cao ($g = 9.8$, 7.1 or 7.11) ($g = 9.81$, 7.1 or 7.12)
b	B1	Seen, including on a diagram.
	M1	Condone sign errors and sin/cos confusion
	A1ft	Correct expression; accept negative of this, follow their t
	M1	Sub for trig and use Pythagoras
	A1	Cao ($g = 9.8$ or 9.81 , 75 or 74.8)
c	B1	B0 if incorrect extras

Q39.

Question	Scheme	Marks	AOs
	N.B. In this question, allow misread of α for a .		
(a)	Use horizontal motion to give an equation in T and α only: $28 \cos \alpha \times T = 40$	M1	3.4
	$T = \frac{10}{7 \cos \alpha} *$	A1*	1.1b
		(2)	
(b)	Use vertical motion to give an equation in T and α only	M1	3.3
	$20 = (28 \sin \alpha)T - \frac{1}{2}gT^2$	A1	1.1b
	Eliminate T to give an unsimplified equation in α only: $20 = (28 \sin \alpha) \times \frac{10}{7 \cos \alpha} - \frac{1}{2}g \left(\frac{10}{7 \cos \alpha} \right)^2$	M1	1.1b
	Use $\sec^2 \alpha = 1 + \tan^2 \alpha$ oe to give an unsimplified equation in $\tan \alpha$ only: $20 = 40 \tan \alpha - \frac{1}{2}g \times \frac{100}{49}(1 + \tan^2 \alpha)$	M1	3.1b
	$\tan^2 \alpha - 4 \tan \alpha + 3 = 0 *$ (allow $0 = \tan^2 \alpha - 4 \tan \alpha + 3$)	A1*	2.2a
		(5)	
(c)	Solve and use of $\tan \alpha = 3$ or $\sin \alpha = \frac{3}{\sqrt{10}}$ or $\alpha = 71.565..^\circ$ to find an equation in H only.	M1	3.1b
	$0 = (28 \sin \alpha)^2 - 2gH$ where $\tan \alpha = 3$ ($\alpha = 71.565..^\circ$)	M1	3.4
	$H = 36$ or 36.0 (m)	A1	1.1b
		(3)	

(d)	e.g. spin of the ball, the wind, the dimensions or shape of the ball, ball is modelled as a particle, uses an inaccurate value of g , motion takes place in 3D not in 2D, g could be variable. B0 if mass or weight are mentioned. B0 for ground may not be horizontal.	B1	3.5b
		(1)	

(11 marks)

Notes:

a	M1	Correct no. of terms, dim correct, condone sin/cos confusion and sign errors
	A1*	Correct printed answer correctly obtained. Allow $\frac{10}{7\cos\alpha} = T$ OR $T = \frac{40}{28\cos\alpha} = \frac{10}{7\cos\alpha}$ OR $\frac{40}{28\cos\alpha} = \frac{10}{7\cos\alpha} = T$ OR t instead of T
b	M1	Correct no. of terms, dim correct, condone sin/cos confusion and sign errors
	A1	Correct equation
	M1	Eliminate T , using either the given answer in (a) or their own T expression, from their equation to give an unsimplified equation in α only
	M1	Use $\sec^2 \alpha = 1 + \tan^2 \alpha$ to produce an equation in $\tan \alpha$ only
	A1*	Given answer correctly obtained. N.B. Must be α (or a) in the final answer but allow a different angle in the working.
c	M1	Solve given equation and select larger value of $\tan \alpha$ and use it to try to obtain an equation in H only.
	M1	Complete method to give an equation in H only , using larger value of α , correct no. of terms, dim correct, condone sin/cos confusion and sign errors.
	A1	cao. Must be positive, (allow a negative value, changed to a positive answer). N.B. This answer comes from use of $g = 9.8$, so must be rounded to 2 or 3 sf.
d	B1	B0 if any incorrect extras

Q40.

Question Number	Scheme	Marks	
a	After 4 seconds from O, horizontal speed $= u \cos \theta$	B1	
	Vertical component of speed at A $= u + at$	M1	Complete method using <i>suvat</i> to find <i>v</i> .
	$= u \sin \theta - 4g$	A1	
	At A, components are $15 \cos 20$ (horizontal) and $15 \sin 20$ (vertical)	B1	
	$u \cos \theta = 15 \cos 20$ $u \sin \theta = 15 \sin 20 + 4g$	DM1	Form simultaneous equations in <i>u</i> and θ and attempt to solve for <i>u</i> or θ . Depends on the previous M1
	$\theta = 72.4$ (72)	A1	Remember - A0 for the first overspecified answer
	$u = 46.5$ (47)	A1	
		[7]	
Alt a	After 4 seconds from O, horizontal speed $= u \cos \theta$	B1	
	At $t = 4$, $s = vt - \frac{1}{2}gt^2$	M1	Complete method to find the vertical height at A
	$= 98.9 \dots\dots$	A1	
	At A, components are $15 \cos 20$ (horizontal) and $15 \sin 20$ (vertical)	B1	
	$\frac{1}{2}mv^2 = \frac{1}{2}mu^2 - 2gh$	DM1	Conservation of energy. The equation needs to include all three terms but condone sign error(s).
	$u = 46.5$ (47)	A1	Remember - A0 for the first overspecified answer
	$\theta = 72.4$ (72)	A1	Beware inappropriate use of <i>suvat</i>

b	$-15 \sin 20 = 15 \sin 20 - gt$ or $0 = 15 \sin 20t - \frac{1}{2}gt^2$	M1	Complete method using <i>suvat</i> or otherwise to find the time to travel from <i>A</i> to <i>B</i>
	$t = 1.05 \text{ (s)}$ or 1.0 (s)	A1	
		[2]	
c	Total time = $4 + (1.05) + 4$	B1ft	Follow their t or $\frac{2u \sin \theta}{g}$ for their u, θ
	Range = $46.5 \times \cos 72.4 \times (8 + 1.05)$ (or $15 \cos 20 \times 9.05$)	M1	Correct method to find <i>OC</i> for their t, u and θ
	$= 128 \text{ (m)}$ or 127 (m) (130)	A1	
		[3]	
		(12)	

Q41.

Question Number	Scheme	Marks
(a)	Vertical motion: $v^2 = u^2 + 2as$ $(40 \sin \theta)^2 = 2 \times g \times 12$ $(\sin \theta)^2 = \frac{2 \times g \times 12}{40^2}$ $\theta = 22.54 = 22.5^\circ$ (accept 23)	M1 A1 A1 (3)
(b)	Vert motion $P \rightarrow R$: $s = ut + \frac{1}{2}at^2$ $-36 = 40 \sin \theta t - \frac{g}{2}t^2$ $\frac{g}{2}t^2 - 40 \sin \theta t - 36 = 0$ $t = \frac{40 \sin 22.54 \pm \sqrt{(40 \sin 22.54)^2 + 4 \times 4.9 \times 36}}{9.8}$ $t = 4.694...$ Horizontal P to R: $s = 40 \cos \theta t$ $= 173 \text{ m}$ (or 170 m)	M1 A1 A1 A1 M1 A1 (6)
(c)	Using Energy: $\frac{1}{2}mv^2 - \frac{1}{2}m \times 40^2 = m \times g \times 36$ $v^2 = 2(9.8 \times 36 + \frac{1}{2} \times 40^2)$ $v = 48.0.....$ $v = 48 \text{ m s}^{-1}$ (accept 48.0)	M1 A1 A1 (3) [12]

Q42.

Question Number	Scheme	Marks
(a)	$(\downarrow) \quad u_y = 25 \sin 30^\circ (=12.5)$ $12 = 12.5t + 4.9t^2$ Leading to $t = 0.743$, 0.74 -1 each error	B1 M1 A2, 1, 0 A1 (5)
(b)	$(\rightarrow) \quad u_x = 25 \cos 30^\circ \left(= \frac{25\sqrt{3}}{2} \approx 21.65 \right)$ $OB = 25 \cos 30^\circ \times t \left(\approx 16.09458 \right)$ $TB \approx 1.1$ (m)	B1 ft their (a) M1 A1ft awrt 1.09 A1 (4)
(c)	$(\rightarrow) \quad 15 = u_x \times t \Rightarrow t = \frac{15}{u_x} (= \frac{2\sqrt{3}}{5} \approx 0.693 \text{ or } 0.69)$ either $(\downarrow) \quad v_y = 12.5 + 9.8t \left(\approx 19.2896 \right)$ $V^2 = u_x^2 + v_y^2 \left(\approx 840.840 \right)$ $V \approx 29 \left(\text{ms}^{-1} \right)$, 29.0	M1 A1 M1 M1 A1 (5) (14 marks)

Q43.

Question	Scheme	Marks	AO
	In this question mark parts (a) and (b) together.		
(a)	Horizontal speed = $20\cos 30^\circ$	B1	3.4
	Vertical velocity at $t = 2$	M1	3.4
	$= 20\sin 30^\circ - 2g$	A1	1.1b
	$\theta = \tan^{-1}\left(\pm \frac{9.6}{10\sqrt{3}}\right)$	M1	1.1b
	Speed = $\sqrt{100 \times 3 + 9.6^2}$ or e.g. speed = $\frac{9.6}{\sin \theta}$	M1	1.1b
	19.8 or 20 (m s^{-1}) at 29.0° or 29° to the horizontal oe	A1	2.2a
		(6)	
(b)	Using sum of horizontal distances = 50 at $t = 2$	M1	3.3
	$(u \cos \theta) \times 2 + (20 \cos 30^\circ) \times 2 = 50$ $(u \cos \theta = 25 - 20 \cos 30^\circ)$	A1	1.1b
	Vertical distances equal	M1	3.4
	$\Rightarrow (20 \sin 30^\circ) \times 2 - \frac{g}{2} \times 4 = (u \sin \theta) \times 2 - \frac{g}{2} \times 4$ $(20 \sin 30^\circ = u \sin \theta)$	A1	1.1b
	Solving for both θ and u	M1	3.1b
	$\theta = 52^\circ$ or better (52.47756849....°) $u = 13$ or better (12.6085128...)	A1	2.2a
		(6)	
(c)	It does not take account of the fact that they are not particles (moving freely under gravity) It does not take account of the size(s) of the balls It does not take account of the spin of the balls It does not take account of the wind g is not exactly 9.8 m s^{-2} N.B. If they refer to the mass or weight of the balls give B0	B1	3.5b
		(1)	
		(13)	

Marks		Notes
a	B1	Seen or implied, possibly on a diagram
	M1	Use of $v = u + at$ or any other complete method <u>using $t = 2$</u> Condone sign errors and sin/cos confusion.
	A1	Correct unsimplified equation in v or v^2
	M1	Correct use of trig to find a relevant angle for the direction. Must have found a horizontal and a vertical velocity component
	M1	Use Pythagoras or trig to find the magnitude Must have found a horizontal and a vertical velocity component
	A1	Or equivalent. Need magnitude and direction stated or implied in a diagram. (0.506 or 0.51 rads)
b	M1	First equation, in terms of u and θ (could be implied by subsequent working), using the horizontal motion with $t = 2$ used Condone sign errors and sin/cos confusion
	A1	Correct unsimplified equation – any equivalent form
	M1	Second equation, in terms of u and θ (could be implied by subsequent working), using the vertical motion – equating distances or just vertical components of velocities. Condone sign errors and sin/cos confusion
	A1	Correct unsimplified equation – any equivalent form
	M1	Complete strategy: all necessary equations formed and solve for u and θ N.B. This is an independent method mark but can only be earned if 50 m has been used in their solution.
	A1	Both values correct. (Here we accept 2SF or better, since the g 's cancel) Allow radians for θ : 0.92 or better (0.915906..) rads.
c	B1	Any factor related to the model as stated in the question. Penalise incorrect extras but ignore consequences e.g. ' AB (or the ground) is not horizontal' should be penalised or 'they do not move in a vertical plane' should be penalised

Q44.

Q.	Scheme	Marks	Notes
a			
	$30 \cos 60 \times 2 + q \cos \theta \times 2 = 40$	M1	Equation for horizontal distance Need to be using the 40 m
		A1	Correct unsimplified
	$30 \sin 60 \times 2 - 4.9 \times 4 = q \sin \theta \times 2 - 4.9 \times 4$ $30 \sin 60 = q \sin \theta$	M1	Equal vertical distance or initial vertical components of velocity
		A1	Correct unsimplified (no error seen)
	$q \cos \theta = \pm 5$ $q \sin \theta = 15\sqrt{3}$		
	$\tan \theta = 3\sqrt{3}$ $(\tan \theta = 6 \sin 60)$	DM1	Solve for q or θ Dependent on both preceding M marks
	$\theta = 79.1 \text{ (79)}$		(1.38 radians) or better
	$q = 26.45 \dots = 26.5$	A1	(26 or better) $(10\sqrt{7})$ Both correct and no error seen
		(6)	
b	Vertical component of speed =	M1	Must be working towards speed of P (or v^2) (condone if working on Q - they equal vertical components of velocity)
	$30 \sin 60 - 2g (= 6.38 \dots)$	A1	Correct unsimplified. Accept $\pm$
	speed = $\sqrt{(30 \cos 60)^2 + 6.38^2}$	DM1	Use Pythagoras. Dependent on previous M Follow their vertical component.
		A1ft	Correct unsimplified equation in v or v^2 .
	$= \sqrt{15^2 + 6.38^2} = 16.3 \text{ (m s}^{-1}\text{)}$	A1	or 16 2 or 3 sf only
		(5)	
b alt	Vertical distance =	M1	Must be working towards speed of P
	$30 \sin 60 \times 2 - 4.9 \times 4 = 32.36$	A1	Correct unsimplified
	Conservation of energy:	DM1	Dependent on previous M. Follow their vertical distance.
	$\frac{1}{2}mv^2 + mg \times 32.36 = \frac{1}{2}m \times 900$	A1ft	Correct unsimplified equation in v or v^2 .
	$v = 16.3 \text{ (m s}^{-1}\text{)} \text{ (16)}$	A1	
		(5)	
		[11]	