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 (m s ⁻²) | 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 $\frac{1}{2}(27.5 + 27.5 - X) \times X = 100$ OR $27.5X - \frac{1}{2}X^2 = 100$ | A1ft | 1.1b |
| | X = 3.92 to 3sf | A1 | 1.1b |
| | | (4) | 1 |

| Not | es: | |
|-----|------|--|
| 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 ½ 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 S graph, with the correct structure, i.e. (triangle + rectangle) OR trapezium OR (rectangle – triangle), must see use of ½ where appropriate, to their answer for (c) to give a <u>quadratic equation in X only</u> N.B. they may use suvat to find the distance covered by S in one or more of the sections. N.B. M0 for use of a single suvat formula for the whole motion |
| | A1ft | Correct unsimplified quadratic equation in X only with at most one error, follow their answer for (c) |
| | A1ft | Correct unsimplified quadratic equation in X only, follow their answer for (c) |
| | A1 | cao |

| Question | Scheme | Marks | AOs | Notes |
|----------|---|-------|----------|---|
| (a) | $V = 30 \text{ (m s}^{-1})$ | B1 | 3.4 | cao |
| | | (1) | | |
| | 30♠ shape | 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 |
| (b) | 0 3 5 T | 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 <i>T</i>) |

| | $\frac{1}{2} \times 3 \times 30 + \frac{(30+6)}{2} \times 2 + 6(T-5) = 550$ OR: $\frac{1}{2} \times 3 \times 30 + \frac{1}{2} \times 2 \times 24 + 6(T-3) = 550$ OR: $\frac{1}{2} \times 3 \times 30 + \frac{1}{2} \times 2 \times 24 + (2 \times 6) + 6(T-5) = 550$ f | 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 | Attempt to solve for <i>T</i> provided they have tried to find the area using at least 3 sections. (M0 if they only solve for their unknown and never try to find <i>T</i>) |
| | 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 the value of T Allow 'it would increase, get larger etc' 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 acceleration not constant); smooth changes in a; B0 for: moves horizontally; mass/weight of parachutist; upthrust; air pressure; air resistance; terminal velocity | В1 | 3.5 c | Any appropriate refinement of the model. B0 if incorrect (or irrelevant) extras |
| | | (1) | | |
| | N // | | - C | |

| 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 |
| | | A1 | 1.1b |
| | $5t^2 - 5t - 1.2 = 0$ | M(A)1 | 1.1b |
| | t = 1.2 (s) | A1 | 1.1b |
| | | (4) | |

| → <i>t</i> 4, –19) | B1 shape | 1.18 |
|-----------------------------------|-------------|------|
| es. | B1ft | 1.18 |
| | (2) | |
| low the ball down. | B1 | 3.5a |
| | (1) | |
| cts, use a more accurate value of | B1 | 3.50 |
| | (1) | |
| | 8 | (1) |

| 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 | |

| Question | Scheme | Marks | AOs |
|----------|--|-------|--------|
| (a) (i) | 24 (m s ⁻¹) | B1 | 1.1b |
| (ii) | 48 (s) | B1 | 1.1b |
| (iii) | shape | В1 | 1.1b |
| | | (3) | |
| (b) | Equating area under graph to 4800 to give equation in one unknown | M1 | 3.1b |
| | $\frac{1}{2}(T+T+80+48) \longleftrightarrow 24 = 4800 \text{OR}$ $(\frac{1}{2} \times 80 \times 24) + 24T + (\frac{1}{2} \times 48 \times 24) = 4800 \text{oe}$ | Alft | 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. B0 if either an incorrect extra is included or an incorrect reason for a valid improvement is included. N.B. Variable acceleration due to air resistance is B0 BUT Variable acceleration due to variable air resistance is B1 | B1 | 3.5c |
| | | (1) | |
| | | (7 n | narks) |

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

| Question | Scheme | Marks | AOs |
|----------|--|-------|------|
| (a) | (25) shape (700) | В1 | 1.1b |
| - | | (1) | |
| (b) | Using total area = 15000 to set up an equation in one unknown Or they may use suvat on one or more sections (but must still be considering all sections) Allow an attempt at a clear explicit verification using $t = 40$ e.g. the following would score M1A1A1*: $4 \times 40 = 160 \text{ then } 700 - 40 - 160 = 500$ $\frac{(700 + 500)}{2} \times 25 = 15000 = 15 \text{ km}$ Withhold A1* if they don't include = 15 km N.B. M0 if a single suvat 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 (s)* | A1* | 1.1b |
| | | (3) | |

| (c) | 0.63 or 0.625 or $\frac{5}{8}$ oe (m s ⁻²) isw | В1 | 1.1b/ (2.2a |
|-----|--|-----|----------------|
| | | (1) | |
| (d) | Complete method to find the speed or velocity at $t = 572$ e.g $\pm \left(25 - (32 \times \frac{5}{32})\right)$ 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 | 3.56 |
| | 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) | |
| | (d) (d) | (8 | marks) |

| Not | es: | |
|-----|-----|--|
| а | B1 | Overall shape of graph, starting at the origin, with deceleration phase <i>longer</i> than the acceleration phase if nothing on the <i>t</i> -axis but ignore the relative lengths and allow if <i>t</i> (or 40) and 4 <i>t</i> (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 all sections to be included, with <u>correct structure for each section</u> , with $\frac{1}{2}$'s where appropriate. Allow = 15 or 150 or 1500 etc instead of 15000 |
| | 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 of the model. B0 if any incorrect extra answers. |

Q6.

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

A.
$$1960 = (25 \times 20) + (30 \times 8) + (1/2 \times 30 \times 12) + (60 \times 8) + 8 \times t + 1/2 \times t \times 12$$
 M1 A3 ft $1960 = 500 + 240 + 180 + 480 + 14t$ M1 A1 $T = 115 + 40$ A1

B. $1960 = (25 \times 20) + 1/2 \times 30 \times (20 + 8) + (60 \times 8) + 1/2 \times t \times (20 + 8)$ M1 A3 ft $1960 = 500 + 420 + 480 + 14t$ M1 A1 $T = 115 + 40$ M1 A1 $T = 115 + 40$ M1 A1 $T = 115 + 40$ M1 A3 ft $1960 = 8T + 1/2 \times 12 \times (55 + 25) + 1/2 \times 12 \times (T - 115)$ M1 A3 ft $1960 = 14T - 210$ M1 A1 M1 A1

D. $1960 = 20T - 1/2 \times 12 \times (60 + T - 25)$ M1 A3 ft $1960 = 14T - 210$ M1 A1 M1 A1

E. $1960 = (55 \times 20) - 1/2 \times 30 \times 12 + (60 \times 8) + 1/2 \times t \times (20 + 8)$ M1 A3 ft $1960 = 1100 - 180 + 480 + 14t$ M1 A1 M1 A1

F. $1960 = (8 \times 115) + 1/2 \times 12 \times (55 + 25) + 1/2 \times 28 \times (T - 115)$ M1 A3 ft $1960 = 920 + 480 + 14t - 1610$ M1 A3 ft $1960 = 14T - 210$ M1 A1 M1 A1

| 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 |
| | $s_2 = \frac{1}{2} \times 9.8 \times 2.5^2 \qquad (30.625 \text{ or } \frac{245}{8})$ OR $s_3 = 14.7 \times 1 + \frac{1}{2} \times 9.8 \times 1^2 (19.6 \text{ or } \frac{98}{5})$ OR $-s_3 = 14.7 \times 4 - \frac{1}{2} \times 9.8 \times 4^2 (-19.6) (\text{allow omission of - on LHS})$ | 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) | |

If they use g = 9.81 or 10, penalise once for whole question. Notes: Complete method to find T, condone sign errors (M0 if they only find time to top) M1 T = 3 correctly obtained. A1 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 41.7 or 42 (after use of g = 9.8) A1 B0 if there are incorrect extra refinements but ignore extra incorrect statements. B1 c

| 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) | |

| Note | es: | Penalise explicit use of g = 9.81 or 10 once for the whole question the first time it occurs. | |
|------|-----|--|--|
| а | M1 | Complete method, using $s = ut + \frac{1}{2}at^2$ or possibly $s = vt - \frac{1}{2}at^2$ with the motion reversion or an 'up and down' method i.e an appropriate equation for the motion from O to the AND an appropriate equation from the top down to the ground AND combining to give 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 | |
| Ь | 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 D0 NOT ALLOW NEGATIVES OF THESE e.g there is no air resistance | |

| Ques | stion | Scheme | Marks | AOs |
|-------|-------|--|-------|--------|
| (| a) | 16 ($ m m~s^{-1}$) seen as the answer | B1 | 1.1b |
| | | | (1) | |
| (| b) | $s = \frac{1}{2} \times 3.2 \times 5^{2} \text{ OR } s = \frac{(0+16)}{2} \times 5 \text{ OR } s = (16 \times 5) - \frac{1}{2} \times 3.2 \times 5^{2}$ $OR 16^{2} = 2 \times 3.2 \times s OR \text{from a } v\text{-}t \text{ graph, } s = \frac{1}{2} \times 5 \times 16$ | M1 | 3.1b |
| | | s = 40 (m) | A1 | 1.1b |
| | | | (2) | |
| | | | (3 | marks) |
| Notes | i | | | |
| a | В1 | 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. | | |

| Question Number | Scheme | | S |
|--------------------|---|-------------------|-----|
| (a) | $0^2 = 19.6^2 - 2 \times gH$ | M1 | |
| | H = 19.6 m (20) | A1 | (2) |
| (b) | $14.7 = 19.6t - \frac{1}{2}gt^2$ | M1 A1 | |
| | $t^2 - 4t + 3 = 0$ | | |
| | (t-1)(t-3)=0 | DM1 | |
| | t = 1 or 3; Answer 2 s | A1; A1 | (5) |
| | | 001 | |
| (b) | (their $h - 14.7$) = ½ $g t^2$ OR $v^2 = 19.6^2 - 2g \times 14.7 \Rightarrow v = (\pm) 9.8$ $t = 1$ and $0.9.8 - 9.8 t \Rightarrow t = 1$ | M1 A1 | |
| ALT 1 | Total = 2 x their 1 $= 2 s$ | DM 1 A1 | |
| (b) | $v^2 = 19.6^2 - 2g \times 14.7$ $v = \pm 9.8$ | M1 A1 | |
| ALT 2/3 | EITHER: $-9.8 = 9.8 - gT$ T = 2 | DM 1 A1 A1 | |
| | OR: $0 = 9.8t - \frac{1}{2} \text{ g } t^2$ t = (0) or 2 | DM 1 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 t only (where t is time at 14.7 above O) First A1 for a correct equation Second DM1, dependent on first M1, for solving for t Second A1 for both values of t, 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 we see an attempt to substitute into a stated correct formula. Third A1 for 2 s N.B. Obtaining t = 1 at s = 14.7 (above O) only, can score max M1 A1 | | |

| 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 |
| | Symbol Masin | (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 0.9s + 0.9s + 0.2s))

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 and adding 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.

| Scheme | Marks | AOs |
|---|---|---|
| Complete method to produce an equation in $\it U$ 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 | | |
| A correct equation in U only. | | |
| U = 8 (only this answer) | A1 | 1.1b |
| | (3) | |
| Complete method to find an equation in T only: $10 = -8 + gT \text{or} 1.8 = 10T - \frac{1}{2}gT^2 \text{or} 1.8 = \frac{(-8+10)}{2}T$ or $1.8 = -8T + \frac{1}{2}gT^2$ | M1 | 3.4 |
| 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 | | |
| $0 = 8 - gt_{\text{UP}} (\Rightarrow t_{\text{UP}} = 0.8)$ | | |
| $h_{\rm UP} = \frac{(8+0)}{2} \times 0.8 \ (=3.2)$ | | |
| 120 | | |
| | | |
| e.g. $8 = -8 + gt_A (\Rightarrow t_A = 1.6)$ | | |
| | | |
| T = 1.8 oe e.g. 9/5 | A1 | 1.1b |
| | (2) | |
| 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. | B1 | 3.5c |
| | Complete method to produce an equation in U only e.g. $10^2 = U^2 + 2 \times g \times 1.8$ oe OR a complete method where they find T first and use it to find an equation in U only A1 A correct equation in U only. Complete method to find an equation in T only: $10 = -8 + gT \text{or} 1.8 = 10T - \frac{1}{2}gT^2 \text{or} 1.8 = \frac{(-8+10)}{2}T$ 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. $8 = -8 + gt_A (\Rightarrow t_A = 1.6)$ $1.8 = \frac{(8+10)}{2} \times t_{AG} (\Rightarrow t_{AG} = 0.2)$ $T = t_A + t_{AG}$ $T = 1.8 \text{ oe e.g. } 9/5$ 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 | Complete method to produce an equation in U only e.g. $10^2 = U^2 + 2 \times g \times 1.8$ oe A1 OR a complete method where they find T first and use it to find an equation in U only A correct equation in U only. A1 $U=8$ (only this answer) A1 Complete method to find an equation in T only: $10 = -8 + gT \text{or} 1.8 = 10T - \frac{1}{2}gT^2 \text{or} 1.8 = \frac{(-8+10)}{2}T$ 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. $8 = -8 + gt_A \ (\Rightarrow t_A = 1.6)$ $1.8 = \frac{(8+10)}{2} \times t_A \ (\Rightarrow t_A = 0.2)$ $T = t_A + t_A \ (\Rightarrow t_A = 0.2)$ |

| | | | (1) | |
|-----|-----|---|----------------|---------|
| | (d) | U would be greater. Allow without U , e.g it would be greater, or just 'greater' oe ISW | | 3.5a |
| | | | (1) | |
| | | | (7 | marks) |
| Not | es: | | | |
| a | M1 | Use the model to obtain an equation in U only, condone sign errors incorrect formula. | , but M0 if us | sing an |
| | A1 | A correct equation in U only, g does not need to be substituted (so 9.81) | allow g = 9.8 | or |
| | 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 allow $g = 9.8$ or 9.81) condone sign errors, but M0 if using an incomposition of their U where necessary | | - C |
| | 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 mentione | d | |
| d | B1 | cao | | |

| Question Number | | Scheme | | Mark | s |
|--------------------|--|--|---------|-------------|-------------|
| | The state of the s | $2as \implies 28^2 = u^2 + 2 \times 9.8 \times 17.5$ Leading to $u = 21$ | eso | M1 A1 A1 | (3) |
| | (b) $s = ut + \frac{1}{2}$ | $at^2 \implies 19 = 21t - 4.9t^2$ | Г | M1 A1 | |
| | | $4.9t^{2} - 21t + 19 = 0$ $t = \frac{21 \pm \sqrt{21^{2} - 4 \times 4.9 \times 19}}{1 + 21 + 21 + 21 + 21 + 21 + 21 + 21 + $ | | | |
| | | 9.8 $t = 2.99 \text{ or } 3.0$ | L | DM1 A1 | |
| | () | t = 1.30 or 1.3 | | | (5) |
| | (e) N2L | 4g - 5000 = 4a $(a = -1240.2)$ | | M1 A1 | |
| | $v^2 = u^2$ | $+2as \implies 0^2 = 28^2 - 2 \times 1240.2 \times s$ | | | |
| | | Leading to $s = 0.316$ (m) | or 0.32 | M1 A1 | (4) [12] |
| | OR \(\frac{1}{2}\) | $x 4 x 28^2 + 4gs = 5000s$ | | M1 A1 | |
| | Work-Energy: | s = 0.316 or 0.32 | | 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)

| Question Number | Scheme | Marks | |
|--------------------|---|-------|-----|
| (a) | For crate, $55g - 473 = 55a$ | M1 A1 | |
| | $a = 1.2 \text{m s}^{-2}$ | A1 | (3) |
| (b) | For system, $55g + 200g \pm T - 150 = 255a$ | M1 A2 | |
| | M agnitude = 2040 N or 2000 N | A1 | |
| | OR | | |
| | For lift, $200g + 473 - 150 \pm T = 200a$ | M1 A2 | |
| | M agnitude = 2040 N or 2000 N | A1 | (4) |
| | Notes | | |
| (a) | M1 for an equation in a only, with usual rules. | | |
| | First A1 for a correct equation | | |
| | Second A1 for 1.2 (m s ⁻²). Allow – 1.2 (m s ⁻²) 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. | | |

| Question Number | Scheme | Marks |
|--------------------|---|-------|
| (a) | For system, (1), $T - 950g - 50g = 1000 \times -2$ | M1 A1 |
| - >-/- | T = 7800 N | A1 |
| | | (3 |
| (b) | For woman, (\uparrow) , $R-50g=50\times-2$ | M1 A1 |
| | R = 390 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: $T - 950g - R = 950 \times (-2)$ | |

| Question Number | Scheme | Marks | |
|--------------------|--|-------------|-----|
| (a) | $T - 0.5g - 1.5g = 2 \times 0.5$ | Ml Al | |
| | T = 20.6 (N) or 21 (N) | Al | (3) |
| (b) | $R - 1.5g = 1.5 \leftrightarrow 0.5$ | MI AI | (3) |
| | Force = 15.5 (N) or 15 (N) OR: $T - R - 0.5g = 0.5 \leftrightarrow 0.5$ Force = 15.5 (N) or 15 (N) | OR MI AI | (3) |
| | 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 <i>T</i> 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. | | |

| Question | Scheme | | 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: $T-50=50\times0.2$ and $T-40g-10g=50g\times0.2$ both score M1A0A0 | | |
| | | (3) | |
| (b) | Use the model to set up the equation of motion for the \underline{block} to obtain an equation in R only. | M1 | 3.4 |
| | $R-10g=10\times0.2$ 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) | |
| | | (5) (6 n | na |

| | Only | penalise the use of an incorrect value of g ONCE for the whole question, so M1A1A0 (b) M1A1A1 | | |
|----------|---|---|--|--|
| а | a M1 Correct number of terms, condone sign errors | | | |
| | A1 | Correct equation in T only | | |
| 0 | A1 | cao | | |
| b | M1 | Correct number of terms, condone sign errors | | |
|).2 V | A1 | Correct equation in R only | | |
| | A1 | cao | | |
| | | | | |

| Question | Scheme | | 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 n | narks | |

| Not | es: | |
|-----|-----|--|
| 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). |
| | 8 | If m's are omitted consistently, max (a) M1A0M1A0 (b)M1A0M1M1A1M1A0 |
| b | M1 | Solve for a |
| | A1 | Allow 4.2 (m s ⁻²) 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 | В1 | B0 if any incorrect extras are given or for an incorrect statement e.g. tension is not constant so accelerations will be different |

| Question Number | Scheme | Mar | ks |
|--------------------|--|-------|-------------|
| | (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 <i>B</i> under gravity $(0.3g)^2 = 2gs_2 \implies s_2 = \frac{(0.3)^2}{2}g \ (\approx 0.441)$ | M1 A1 | |
| | $S = 2s_1 + s_2 = 3.969 \approx 4.0$ (m) | A1 | (7) [14] |
| | | | |
| | | | |
| | | | |
| | | | |

| Question Number | Scheme | Marks |
|--------------------|--|------------------|
| (a) | 4mg - T = 4ma | M1A1 |
| 90,00 | 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 : $T = 3mg + 3\left(mg - \frac{T}{4}\right), T = 3mg + 3m\frac{g}{7}, \text{ or } T = 4mg - 4m\frac{g}{7}$ | M1 |
| | $T = \frac{24}{7} mg \text{ or equivalent, } 33.6m, 34m$ | A1 (* |
| (b) | $v^2 = u^2 + 2as = 2 \times \frac{g}{7} \times 0.7 = 1.96$, $v = 1.4$ ms ⁻¹ | M1A1 |
| (c) | $3mg - T = 3ma$ $T - 2mg = 2ma$ $a = \frac{g}{5}$ | M1A1 A1 A1 |
| (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 = $0.7 + 0.5 = 1.2$ (m) | A1 ft |
| 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 = $0.7 + 0.5 = 1.2$ (m) | A1 ft |
| | | [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 (ms⁻¹) 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 (ms⁻²) (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 (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):-

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

First A1 for s = 0.5 (m) correctly obtained

Second A1 ft for their 0.5 + 0.7 = 1.2 (m)

| 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 |
| | 48mg 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) | |

| Not | es: | |
|-----|-----|---|
| (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 | $T = \frac{24mg}{7} \text{ oe}$ |
| | M1 | T does not need to be substituted. |
| | A1 | $\frac{48mg}{7}$ oe Must be in terms of m and g and be a single term |
| (b) | B1 | B0 if any incorrect extras are given |

| 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 |
| | $\frac{4mg}{7} - kmg = km \leftrightarrow \frac{5g}{7} \text{ oe and solve for } k$ | 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) | |

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

Al: 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.)

Al: 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 <u>numerical</u> 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

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

| Question Number | Scheme | Marks |
|--------------------|---|----------------------|
| (a) | $T - 5g\sin\alpha = 5a$ | M1 A1 |
| | $1 - 3g \sin \alpha = 3a$ $15g - T = 15a$ | MI AI |
| | | M1 A1 |
| | solving for a | M1 A1 |
| | a = 0.6g | 01 |
| | solving for T | M1 |
| | T=6g | A1 (8) |
| (b) | For $Q:$ $5g N=5a$ $N=2g$ | M1 A1 A1 f.t. (3) |
| (c) | | |
| | $F = 2T\cos(\frac{90^{\circ} - \alpha}{2})$ | M1 A2 |
| 0 | $= 12g\cos 26.56.^{\circ}$ | A1 f.t. |
| T | = 105 N | A1 (5) |
| | | [16] |

| Question | Scheme | Marks | AO |
|----------|---|----------|--------------|
| (a) | F 2mg 3mg B | | |
| | $R = 2mg\cos\alpha$ | 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 |
| 3 | Complete strategy to find an equation in T , m and g only. | M1 | 3.1b |
| | $T = \frac{12mg}{5} $ * | A1* | 2.2a |
| 9 | | (8) | |
| (b) | $(F_{\text{max}} =) \frac{16mg}{13} > \frac{10mg}{13}$ | M1 | 2.1 |
| | so A will not move. | A1 | 2.2a |
| | | (2) | 0 |
| (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 | 3.5e 3.5e |
| | | (2) | |
| 1 | | (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 signerrors 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} $(\frac{2}{3}R)$ 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. |

| 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 |
| | $a = 4.2 \text{ (m s}^{-2}) *$ | A1* | 2.2 a | Given acceleration obtained correctly. You must see an equation in a only before reaching a = 4.2 |
| | | | | N.B. if they just use the whole system equation: $0.6g = 1.4a$, can only score max M1A1M0A0A0 |
| | | (5) | | 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 <i>Q</i> to hit the floor |
|-----|---|-------------|----------|---|
| | | | | (M0 if 0.4 not used as distance moved and/or if 4.2 is not used as acceleration and this applies to finding v as well if they use v to find t_1) |
| | $t_1 = 0.436(4357)$ 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 $0.4 = \frac{(0+v)}{2} \times t_1$ $(v = 1.8330)$ | 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 and this applies to finding t_1 as well if they use t_1 to find v) |
| | $t_2 = \frac{1.5 - 0.4}{v}$ | M1 | 1.1 b | Uses distance/speed to find time for <i>P</i> to hit the pulley after <i>Q</i> 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, dependent on previous three M marks |
| | 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 | В1 | 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 limitation of the model stated in the question Penalise incorrect or irrelevant extras |
| | | (1) | | B0 for: Air resistance, table being smooth |
| | 30 | (12 m | arks) | |

| Question Number | Scheme | Marks |
|--------------------|---|---|
| (a) | $R = 0.3g \cos \alpha$ = 0.24g = 2.35 (3sf)=2.4 (2sf) | M1 A1 |
| (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 DM 1 A1 |
| (c) | $v = 1.4 \times 0.5$ $-0.3g \sin \alpha - F = 0.3a$ $a = -9.8$ $0 = 0.7 - 9.8t$ $t = 0.071 \text{ s or } 0.0714 \text{ s } (1/14 \text{ A0})$ | B1 M1 A1 A1 M1 A1 (6) |

| 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) | 8 |
| (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 |
| | $a = \frac{1}{10}g^{-\star}$ | A1* | 2.2a |
| | | (7) | |
| (c) | v • • • • • • • • • • • • • • • • • • • | 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) | |
| | 30 | (12 n | narks) |

| Not | es: N | (a) M1A0 (b) M1A0B0M1A1M1A1 (c) B1B1 (d) B1 |
|-----|-------|---|
| | F | 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 <i>t</i> -axis). B0 if continuous vertical line at the end. |
| | DB1 | Dependent on first B1, for any equivalent statement |
| d | B1 | B0 if incorrect extras |

| 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 |
| | <i>α</i> = 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) | |
| | <u> </u> | (7 | marks |

| lot | es: | |
|-----|-----|---|
| а | | 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 |
| С | B1 | B0 if any incorrect extras are given or for an incorrect statement |

| Question Number | Scheme | Marks |
|--------------------|---|---------|
| | T - 0.5g = 0.5a | M1 A1 |
| | 15 - T - 0.75g = 0.75a | M1 A1 |
| | (OR: $15 - 0.5g - 0.75g = 1.25a$) | |
| | $(a = 2.2 \text{ m s}^{-2})$ | M1 A1 6 |
| | T = 6 N | MI AI 0 |
| | 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 | 13 |
| | 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 . | |

| Question Number | Scheme | Marks |
|--------------------|---|----------------|
| (a) | $R = 4g\cos\alpha$ | M1 A1 |
| 0.0000-0 | $T - 0.5g = 0.5a$ $4g \sin \alpha - T - F = 4a$ (OR: $4g \sin \alpha - F - 0.5g = 4.5a$) | M1 A1 M1 A1 |
| | $F = \frac{1}{2}R$; $\sin \alpha = \frac{4}{5}$ or $\cos \alpha = \frac{3}{5}$ | B1; B1 |
| | Eliminating a or finding a Solving for T (must have had an a) | M1 M1 |
| | $T = \frac{2g}{3}$ N or 6.5N or 6.53N | A1 |
| (b) | Magnitude = $2T\cos\left(\frac{90-\alpha}{2}\right)$ | M1 A1 |
| | $= 2 \times \frac{2g}{3} \times \frac{3}{\sqrt{10}} (0.94868)$ | Al ft on T |
| | $= 12N \text{ or } 12.4N \left(\frac{4g}{\sqrt{10}}\right)$ | A1 (4) |

| | 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 | |
| | 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. | |
| | 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 $\alpha = 53.1^{\circ}$ 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. | |
| | 2 000 01 010 01 010 01 | |
| | | |
| | | |

(b)

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

$$2T\cos\left(\frac{90^{\circ}-\alpha}{2}\right)$$
. 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 $\sqrt{\text{sign}}$, but only if $R^2 = \dots$ 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 $\sqrt{\text{sign}}$, but only if $R^2 = \dots$ 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)

| uestion Number | Scheme | Marks |
|-------------------|---|-----------|
| (a) | Use of $v^2 = u^2 + 2as$ | M1 |
| | $14^2 = 20^2 - 2a \times 100$ | A1 |
| | Deceleration is 1.02(m s ⁻²) | A1 |
| | | (3 |
| (b) | Horizontal forces on the car: $\pm T \cos \theta - 300 = 750 \times -1.02 = -765$ T = -1550/3 | M1A2 f.t. |
| | The force in the tow-bar is 1550/3, 520 (N) or better (allow -ve answer) | A1 (4 |
| (c) | Horizontal forces on the truck: $\pm T \cos \theta - 500 - R = 1750 \times -1.02$ | M1A2 f.t. |
| | Braking force $R = 1750 \text{ (N)}$ | A1 |
| | | (4 |
| | | [11 |
| | ALT : Whole system: $800 + R = 2500 \times 1.02$ | M1A2 f.t. |
| | R = 1750 | A1 |
| | Notes for Question_ | \ |
| | M1 for a complete method to produce an equation in a only. | |
| Q (a) | First A1 for a correct equation. | |
| | Second A1 for 1.02 (ms ⁻²) oe. must be POSITIVE. | |
| | M1 for considering the car $ONLY$ horizontally to produce an equation in T | |
| | only, with usual rules. i.e. correct no. of terms AND T resolved: | |
| Q (b) | $\pm T\cos\theta - 300 = 750 \text{ x} - 1.02$ | |
| Q (0) | A2 ft on their a for a correct equation (300 and a must have same sign); -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. | |
| | M1 for considering the truck ONLY horizontally to produce an equation, with usual rules. i.e. correct no. of terms AND T resolved: $\pm T \cos \theta - 500 - R = 1750 \text{ x} - 1.02$ | |
| | A2 ft on their T and a for a correct equation (500, a and R must have same | |
| | sign); -1 each error (treat cos 0.9 as an A error) | |
| | A1 for 1750 (N). | |
| Q (c) | OR | |
| Q (c) | M1 for considering the whole system 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 (a and R must have same sign) -1 | |
| | each error | |
| | A1 for 1750 (N). | |
| | N.B. If 300 and 500 are given separately, penalise any sign errors only ONCE. | |
| | | |
| | | |
| | | |
| | | I |

| 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 n | narks) |

| Not | es: | |
|-----|-----|--|
| a | M1 | Correct no. of terms, condone sin/cos confusion |
| | A1 | cao with no wrong working seen. mgcos36.86 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 |

| Question Number | Scheme | Mar | ks |
|--------------------|---|---------------------------------|----------|
| (a) (i) (ii) | For $A: T-F=2ma$ For $B: mg-T=ma$ | 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 | В1 | (1) 1 |

| | 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 | |
| 10.5 | 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 $\mu Rs = \frac{1}{2} 2mu^2$ (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 $s = \frac{1}{3}h$ | |
| | Third A1 for $d = \frac{4}{3}h$ | |
| (e) | B1 for any one of the alternatives listed above. | |

| Question | Scheme | Marks | AOs |
|----------|---|-------|------|
| (a)(i) | Resolve vertically | M1 | 3.1b |
| | Facting UP the plane: OR Facting DOWN the plane: $(\uparrow) F \sin \alpha + 68.6 \cos \alpha = 5g$ 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: $(\land) 68.6 = X \sin \alpha + 5g \cos \alpha$ (leads to $X = 49$ with $g = 9.8$) Facting UP the plane: OR Facting DOWN the plane: $(\nearrow) F + X \cos \alpha = 5g \sin \alpha$ $-F + X \cos \alpha = 5g \sin \alpha$ $-F \cos \alpha + X = 68.6 \sin \alpha$ | A1 | 1.1b |
| | 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 \checkmark , 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 | 1,000 | |
| | Equation of motion down the plane | M1 | 2.1 |
| | $5g \sin \alpha - F = 5a$ Allow (-a) instead of a | A1 | 1.18 |
| | Resolve perpendicular to the plane | M1 | 3.18 |
| | $R = 5g\cos\alpha$ | A1 | 1.16 |
| | F = 0.5R seen | M1 | 3.4 |
| | $a = 1.96 \text{ or } 2.0 \text{ or } 2 \text{ (m s}^{-2}) \text{ or } \frac{1}{5} g$ | A1 | 1.1b |
| | | (6) | |

| Not | es: | |
|-----------|-----|--|
| 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) from a fully correct solution 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 $X = 48.9$ 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. |

| 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) | 3 |
| (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) | 3.16 |
| | 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 |
| | $\tan \alpha = \frac{1}{4} \implies \alpha = 14^{\circ}$ 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) | |
|-----|--|---------|------|
| | $-\frac{5}{4} = \sqrt{2gt} - \frac{1}{2}gt^2$ | 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 | | TO. |
| | Using the model and horizontal motion: $s = ut$ | M1 | 3.4 |
| | $20 = Ut \cos \alpha$ | A1 | 1.1b |
| | A to top: $s = vt - \frac{1}{2}at^2$ and top to T: $s = ut + \frac{1}{2}at^2$ | | |
| | $1 = \frac{1}{2}gt_1^2 \implies t_1 = \sqrt{\frac{2}{g}} \qquad \text{and} \qquad \frac{9}{4} = \frac{1}{2}gt_2^2 \implies t_2 = \frac{3}{\sqrt{2g}}$ $\text{Total time} t = t_1 + t_2$ | M1 | 3.4 |
| | $= \sqrt{\frac{2}{g}} + \frac{3}{\sqrt{2g}} (=\frac{5}{\sqrt{2g}})$ | A1 | 1.1b |
| | $20 = U \frac{5}{\sqrt{2g}} \cos \alpha \qquad \text{(sub. for } t\text{)}$ | M1 | 3.1b |
| | $20 = \sqrt{\frac{2g}{\sin^2 \alpha}} \frac{5}{\sqrt{2g}} \cos \alpha \text{(sub. for } U\text{)}$ | 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 | 07029476 | 000000 |
| | Or The ball will have dimensions | B1 | 3.56 |
| | Or Wind effects | | |
| | Or Spin of the ball | | |
| | | (1) | |
| (d) | Find U using their α e.g. $U = \sqrt{\frac{2g}{\sin^2 \alpha}}$ | MI | 3.16 |
| | Use $20 = Ut \cos \alpha$ (or use vertical motion equation) | A1 M1 | 1.11 |
| | $t = \frac{5}{\sqrt{2g}}$ or 1.1 or 1.13 | B1 A1 | 1.11 |
| | | (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 | 3.11 |
| | $1 = \frac{1}{2}gt_1^2 \implies t_1 = \sqrt{\frac{2}{g}}$ and $\frac{9}{4} = \frac{1}{2}gt_2^2 \implies t_2 = \frac{3}{\sqrt{2g}}$ | A1 M1 | 1.11 |
| | Total time $t = t_1 + t_2$ | | |
| | 90000 | | |
| | $= \sqrt{\frac{2}{g}} + \frac{3}{\sqrt{2g}} \ (= \frac{5}{\sqrt{2g}}) = 1.1 \text{ or } 1.13 \text{ (s)}$ | B1 A1 | 1.10 |

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

Al: $\alpha = 14^{\circ}$ 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

Al: 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)

Al: 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

Al: 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)

| Question | Scheme | Marks | AOs |
|----------|--|-------|------|
| (a) | Using horizontal motion | M1 | 3.3 |
| | Whole Motion Half way | | |
| | $U\cos\alpha \times t = 120 \qquad U\cos\alpha \times t = 60$ | A1 | 1.1b |
| | Using vertical motion OR | M1 | 3.4 |
| | $U\sin\alpha \times t - \frac{1}{2}gt^2 = 0 \qquad 0 = U\sin\alpha - gt$ | 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 $10 = \frac{1}{2}gt^2$ oe $(t = \frac{10}{7})$ to obtain | | |
| | an equation in U and α only | | |
| | $U\sin\alpha = 14$ 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: | | |
| | $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. $U \sin \alpha = 14 \implies U \cos \alpha = 42$, 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 | | |
| | | DM1 | 3.16 |
| | $\tan \alpha = \frac{1}{3}$ then $\sin^2 \alpha = \frac{1}{10}$, hence result | | |
| | OR in ALTERNATIVE 2: sub for U ² using part (a), to give | | |
| | $\tan \alpha = \frac{1}{2}$ then $\sin^2 \alpha = \frac{1}{2}$, hence result | | |
| | 3 10 | | |

| | N.B. Just stating that $\sin^2 \alpha = \frac{1}{10}$, with no working is DM0A0. | | |
|-----|--|-----|------|
| | $U^2 = 1960 *$ | A1* | 2.2 |
| | 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 air resistance' isw | B1 | 3.5 |
| | | (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) | В1 | 3.50 |
| | | (1) | |
| | | (12 | mark |

| Not | es: | |
|-----|---------|--|
| 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, with no wrong working seen. 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*) |
| с | B1 | Clear statement isw |
| d | В1 | B0 if there is an incorrect extra e.g. mass or weight |

| 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 |
| | $-70 = 63 \sin \alpha \times t - \frac{1}{2} \times g \times t$ | 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) | Alft | 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) | |

| Not | es: | |
|-----|-------|--|
| 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 |
| ĺ | | 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 $(g = 9.8, 7.1 \text{ or } 7.11)$ $(g = 9.81, 7.1 \text{ or } 7.12)$ |
| 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 |
| 9 | M1 | Sub for trig and use Pythagoras |
| | A1 | Cao $(g = 9.8 \text{ or } 9.81, 75 \text{ or } 74.8)$ |
| c | B1 | B0 if incorrect extras |

| Question | Scheme | Marks | AOs |
|----------|---|-------|------|
| | N.B. In this question, allow misread of $lpha$ 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 $	au$ and $lpha$ 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 |
| | $\tan^2 \alpha - 4 \tan \alpha + 3 = 0 * \text{ (allow } 0 = \tan^2 \alpha - 4 \tan \alpha + 3)$ | 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. | B1 | 1.5 |
|-----|--|-----|------|
| V.5 | 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 | | 3.5b |
| | place in 3D not in 2D, g could be variable. | | 3.30 |
| | B0 if mass or weight are mentioned. | | |
| | B0 for ground may not be horizontal. | | .55 |
| | | (1) | |

| | | (11 marks) | | | | |
|-----|-----|---|--|--|--|--|
| Not | es: | | | | | |
| а | 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 $lpha$ (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 ${\it H}$ only, using <u>larger</u> 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 | | | | |

| 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 | 8 |
| | 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 u and θ and attempt to solve for u 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 | A1 | |
| | At A, components are 15cos 20 (horizontal) and 15sin 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 suvat |

| b | $-15\sin 20 = 15\sin 20 - gt$ or $0 = 15\sin 20t - \frac{1}{2}gt^2$ | M1 | Complete method using suvat or otherwise to find the time to travel from A to B |
|---|--|------|---|
| | t = 1.05 (s) or 1.0 (s) | A1 | |
| | 1.27. 1. | [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 OC for their t, u and θ |
| | =128 (m) or 127 (m) (130) | A1 | |
| | | [3] | |
| | | (12) | |

| Question Number | Scheme | Marks | |
|--------------------|--|-------|------|
| (a) | Vertical motion: $v^2 = u^2 + 2as$ | M1 | |
| | $(40 \sin \theta)^2 = 2 \times g \times 12$ $(\sin \theta)^2 = \frac{2 \times g \times 12}{40^2}$ | A1 | |
| | $\theta = 22.54 = 22.5^{\circ}$ (accept 23) | A1 | (3) |
| (b) | Vert motion $P \to R$: $s = ut + \frac{1}{2}at^2$ | | |
| | $-36 = 40 \sin \theta t - \frac{g}{2} t^2$ | M1 | |
| | $\frac{\theta}{2}t^2 - 40\sin\theta t - 36 = 0$ | A1 A1 | |
| | $t = \frac{40 \sin 22.54 \pm \sqrt{(40 \sin 22.54)^2 + 4 \times 4.9 \times 36}}{12.54 \times 4.9 \times 36}$ | | |
| | t = 4.694 9.8 | A1 | |
| | Horizontal P to R: s = 40 cos θt | M1 | |
| | =173 m (or 170 m) | A1 | (6) |
| (c) | Using Energy: | | |
| | $\frac{1}{2}mv^2 - \frac{1}{2}m \times 40^2 = m \times g \times 36$ | M1 A1 | |
| | $v^2 = 2(9.8 \times 36 + \frac{1}{2} \times 40^2)$ | | |
| | v = 48.0 | | |
| | $v = 48 \text{ m s}^{-1} \text{ (accept } 48.0)$ | A1 | (3) |
| | | | [12] |

| Question Number | Scheme | | | Marks | |
|--------------------|-----------------|--|---------------|-------------|--|
| (a) | (↓) | $u_y = 25 \sin 30^{\circ} \ (=12.5)$ | | B1 | |
| | | $12 = 12.5t + 4.9t^2$ | -1 each error | M1 A2, 1, 0 | |
| | | Leading to $t = 0.743$, 0.74 | | A1 (5) | |
| (b) | (\rightarrow) | $u_x = 25\cos 30^{\circ} \left(= \frac{25\sqrt{3}}{2} \approx 21.65 \right)$ | | В1 | |
| | | $OB = 25\cos 30^{\circ} \times t \ (\approx 16.09458)$ | ft their (a) | M1 A1f | |
| | | $TB \approx 1.1 \text{ (m)}$ | awrt 1.09 | A1 (4) | |
| (c) | (\rightarrow) | $15 = u_x \times t \Longrightarrow t = \frac{15}{u_x} (= \frac{2\sqrt{3}}{5} \approx 0.693 \text{ or}$ | 0.69) | M1 A1 | |
| | either | (\downarrow) $v_y = 12.5 + 9.8t \ (\approx 19.2896)$ | | M1 | |
| | | $V^2 = u_x^2 + v_y^2 \ (\approx 840.840)$ | | | |
| | | $V \approx 29 \text{ (ms}^{-1})$, 29.0 | | M1 A1 (5) | |
| | | | | (14 marks) | |

| Question | Scheme | Marks | AO |
|----------|---|-------|------|
| | In this question mark parts (a) and (b) together. | | |
| (a) | Horizontal speed = 20 cos 30° | 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 | 1.16 |
| | 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 |
| | θ = 52° 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 using $t = 2$ 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 control (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 | | | | |

| Q. | Scheme | Marks | Notes |
|-------|--|-------|---|
| a | 30 ms ⁴ \ p \ Q \ q ms ⁴ \ A \ 40 m \ B | | |
| | $30\cos 60 \times 2 + q\cos \theta \times 2 = 40$ | M1 | Equation for horizontal distance Need to be using the 40 m |
| ĵ | -72 | A1 | Correct unsimplified |
| | $30 \sin 60 \times 2 - 4.9 \times 4 = q \sin \theta \times 2 - 4.9 \times 4$ $30 \sin 60 = q \sin \theta$ | М1 | 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 |
| | $\theta = 79.1 (79)$ | 2 | (1.38 radians) or better |
| | q = 26.45 = 26.5 | A1 | (26 or better) (10√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) |
| | $30\sin 60 - 2g = 6.38$ | A1 | Correct unsimplified. Accept ± |
| | speed = $\sqrt{(30\cos 60)^2 + 6.38^2}$ | DM1 | Use Pythagoras. Dependent on previous M Follow their vertical component. |
| | 3.2 | A1ft | Correct unsimplified equation in v or v^2 . |
| | $=\sqrt{15^2+6.38^2}=16.3 \mathrm{(m\ s^{-1})}$ | A1 | or 16 2 or 3 sf only |
| | | (5) | D |
| 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 . |
| | $v = 16.3 \text{ (m s}^{-1}) (16)$ | A1 | 9 |
| | | (5) | |
| | | [11] | |