Projectile Motion Mark Scheme

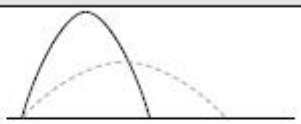
Q1.

Question Number	Answer	Mark
	C $vt \sin 35°$	1
	Incorrect Answers: A – correct formula but initial vertical velocity and not horizontal velocity used B – incorrect formula used with initial vertical velocity D – incorrect formula used with initial horizontal velocity	

Q2.

Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is D *A is not correct because the acceleration in the vertical plane is g* *B is not correct because the horizontal component of velocity is constant* *C is not correct because of $v = 0$ – at gives $t = v / g$*		1

Q3.

Question Number	Answer	Mark
	B 	1
	Incorrect Answers: A – this is the trajectory for a ball kicked at an angle greater than θ, at a greater speed C – this is the trajectory for a ball kicked at an angle greater than θ, at a greater speed D – this is the trajectory for a ball kicked at an angle lower than θ, at a lower speed	

Q4.

Question Number	Answer	Mark
	The only correct answer is C $\sqrt{(2 \times 9.81 \times 0.83) + 1.72^2}$ **from combining the vertical velocity (from** $v^2 = u^2 + 2as$**) and horizontal velocity of the ball** **A** *is not correct because the first part of the expression represents the (vertical velocity)^2 and so should not be squared.* **B** *is not correct because the first part of the expression represents the (vertical velocity)^2 and so should not be squared.* **D** *is not correct because this should be square rooted, as Pythagoras theorem is being used.*	1

Q5.

Question Number	Answer	Mark
	C	1

Q6.

Question Number	Acceptable answers	Additional guidance	Mark
	• Use of $v = s/t$ for the horizontal motion (1) **Or** see $u_h = 25$ m s^{-1} • Use of $s = ut + ½ at^2$ with $s = 0$ (1) **Or** $v = u + at$ with $t = 1.0$ s **Or** see $u_v = 9.81$ m s^{-1} (1) • Combining of horizontal velocity and vertical velocity expressions (1) **Or** see $\tan\theta = \left(\frac{9.81}{25}\right)$ • $\theta = 21°$	<u>Example of calculation</u> horizontal motion: $u_h = \frac{50 \text{ m}}{2.0 \text{ s}} = 25 \text{ m s}^{-1}$ vertical motion: $0 = (u_v)\ (2.0 \text{ s}) + ½(-9.81 \text{ m s}^{-2})(2.0 \text{ s})^2$ $u_v = 9.81 \text{ m s}^{-1}$ $\tan\theta = \frac{u_v}{u_h} = \frac{9.81 \text{ m s}^{-1}}{25 \text{ m s}^{-1}}$ $\theta = 21.4°$	4

Q7.

Question Number	Acceptable Answers	Mark
(a)	Use of an equation of motion involving $a = g$ *or* $-g$ **(1)** $v = u + at$ with v or $u = 0$ and double t **Or** Use of $s = ut + \frac{1}{2}at^2$ with $s = 0$ **Or** Use of $a = \frac{v-u}{t}$ with $v = -u$ **Or** Find max $s = 0.40$ m then use $s = \frac{1}{2}(v+u)\,t$ and double t **(1)** (do not award MP2 if 8 m s^{-1} used) Time = 0.57 or 0.58(s) **(1)** (Do not award 3rd mark if negatives have been ignored.) Example of calculation: using $a = \frac{v-u}{t}$ $t = \frac{0 - 2.8\,\text{m s}^{-1}}{-9.81\,\text{m s}^{-2}} = 0.285\,\text{s}$ to reach top of jump $t = 0.57$ (s)	**3**

Question Number	Acceptable Answers	Mark
(b)	Use of distance = 8 m s^{-1} × time (either their time or 0.6 s) **(1)** Distance = 4.6 m (ecf (a)) **(1)** (If show that value of 0.6 s used then $d = 4.8$ m) Example of calculation Distance = 8.0 m s^{-1} × 0.57 s Distance = 4.6 m	**2**

Question Number	Acceptable Answers	Mark
(c)	Attempt to calculate total / extra time using correct equations with correct vertical values **(1)** $t = 0.14$ s or 1/7 s extra time for additional drop assuming $u = 2.8\ m\ s^{-1}$ $t = 0.43$ s or 3/7 s time from calculation of maximum height using $u = 0$ $t = 0.71$ s or 5/7s time for whole trajectory using $s = -0.5$ m **(1)** Distance = $8.0\ m\ s^{-1} \times$ time **(1)** Extra horizontal distance travelled = 1.1m to 1.2m **(1)** Example of calculation $v^2 = (2.8\ m\ s^{-1})^2 + (2 \times 9.81\ m\ s^{-2} \times 0.50\ m)$ $v = 4.2\ m\ s^{-1}$ $t = \frac{4.2\ m\ s^{-1} - 2.8\ m\ s^{-1}}{9.81\ m\ s^{-2}}$ $t = 0.14$ s Distance = $8.0\ m\ s^{-1} \times 0.14$ s Distance = 1.1 m	**4**
	Total for question	**9**

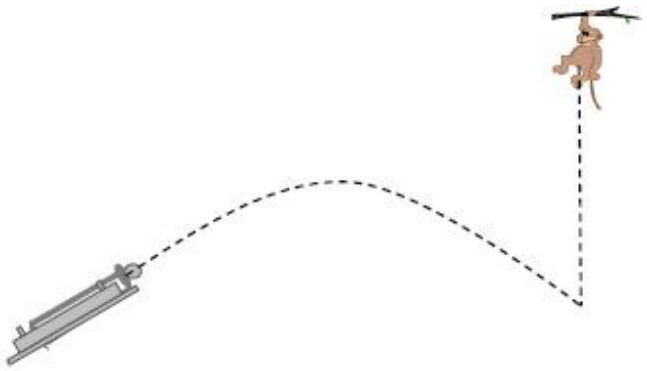
Q8.

Question Number		Mark
(a)	Use of suitable equation(s) of motion to find distance (1) Height = 7.4 (m) (1) (accept 9.8(1)/6 or 1.635 for acceleration but do not accept g/6 as a substitution if final answer is wrong and looking to award MP1 only) (a reverse argument leading to t = 2.9 s can score both marks) Example of calculation $s = ½ at^2$ $s = ½ \times (9.81 \text{ m s}^{-2} / 6) \times (3 \text{ s})^2$ $s = 7.4$ m	**2**
(b)(i)	Use of trig function appropriate to calculate vertical component of velocity **Or** 10.1 (m s^{-1}) seen (1) Use of suitable equation(s) of motion to find time (1) t = 12.4 (s) (1) (if v and u not consistent with sign of g max 2 marks. Calculation can be done for total time of 12.3 s with either total displacement =0 or u=-v) Example of calculation $u = 18 \text{ m s}^{-1} \times \sin 34° = 10.1 \text{ m s}^{-1}$ $v = u + at$ $0 = 10.1 \text{ m s}^{-1} - (9.81 \text{ m s}^{-2} / 6) \times t$ t = 6.2 s to max height time of flight = 12.4 s	**3**
(b)(ii)	Use of trig function appropriate to calculate horizontal component of velocity **Or** 14.9 (m s^{-1}) seen **Or** Use of Pythagoras (1) Use of suitable equation(s) of motion to find distance (1) Distance = 185 (m) (ecf time value from part (i)) (1) Example of calculation $v = 18 \text{ m s}^{-1} \times \cos 34° = 14.9 \text{ m s}^{-1}$ $s = vt = 14.9 \text{ m s}^{-1} \times 12.4$ s s = 185.0 m	**3**

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	• distance between at least two pairs of images (1) • distances between images are the same in x direction (1) • distance between images varies in y direction showing a changing velocity (1) • velocity in the x direction is constant so x direction is independent of y direction (1)	MP1 and 2 could come from marks on the diagram	4
(ii)	• use of $v^2 = u^2 + 2as$ or $s = ut + \frac{1}{2}at^2$ (1) • initial vertical component velocity = 0.47 m s^{-1} (1) • use of $v_H = d/t$ in the horizontal (1) • Use of Pythagorus with v_H and u_V (1) • Resultant velocity = 1.1 m s^{-1} (1)	alt to MP2 : 0.5 m s^{-1} (allow 0.4 to 0.6) if using distance taken from first two images and $v_H = d/t$ Example of calculation: $0 = u^2 - 2 \times 9.81\ \text{m s}^{-2} \times 0.011\ \text{m}$ $u_V = 0.465\ \text{m s}^{-1}$ $v_H = \frac{0.08\ \text{m}}{0.08\ \text{s}}$ $v_H = 1.0\ \text{m s}^{-1}$ $v = \sqrt{(0.47^2 + 1.0^2)}$ Resultant velocity = 1.1 m s^{-1}	5

Q10.

Question Number	Answer		Mark
(a) (i)	Use of correct equation(s) of motion to be able to find t $t = 0.23$ (s) (no ue) Example of calculation $0.25\ \text{m} = (0 \times t) + ½ \times 9.81\ \text{m s}^{-2} \times t^2$ $t = 0.23$ s	(1) (1)	2
(a) (ii)	Use of $\text{speed} = \frac{\text{distance}}{\text{time}}$ Distance = 0.59 m - 0.60 m (ecf) (show that value gives $d = 0.52$ m) Example of calculation $d = 2.6\ \text{m s}^{-1} \times 0.23\text{s}$ $d = 0.60$ m	(1) (1)	2
(b)(i)	 Ball has a curved path with a decreasing gradient and the monkey' path is downwards Initial path of ball parallel to launcher and monkey approximately vertical with paths intersecting below initial position of monkey (Allow a small gap between the paths approximately the width of monkey)	(1) (1)	2

(b)(ii)	Use of speed $= \frac{\text{distance}}{\text{time}}$ with $\cos 20^\circ$ to find the time of the drop (1) Use of $s = ut + \frac{1}{2}at^2$ with $u = 0$ (1) Distance fallen = 0.15 m − 0.16 m (1) Example of calculation $t = \frac{0.50\text{ m}}{3\cos 20^\circ} = 0.177\text{ s}$ $s = \frac{1}{2} \times 9.81\text{ m s}^{-2} \times (0.177\text{ s})^2$ $s = 0.154\text{ m}$	3
	Total for question	**9**

Q11.

Question Number	Answer	Additional Guidance	Mark
(i)	• $v \sin\theta = 2.2\text{ (m s}^{-1}\text{)}$ (1)	Example of calculation $v \sin\theta = 2.6\text{ m s}^{-1} \times \sin 57^\circ$ $= 2.18\text{ m s}^{-1}$	1
(ii)	• Use of $v = u + at$ (1) • Use of $v \cos\theta$ (1) • Use of $s = ut + \frac{1}{2}at^2$ (1) • Number of body lengths = range/body length (1) • 12.7 body lengths, so not twenty lengths (1)	Example of calculation $t = \frac{(0 - 2.2)\text{m s}^{-1}}{-9.8\text{ m s}^{-2}} = 0.224\text{ s}$ $v \cos\theta = 2.6\text{ m s}^{-1} \times \cos 57^\circ$ $= 1.42\text{ m s}^{-1}$ $s = 1.42\text{ m s}^{-1} \times 2 \times 0.224\text{ s}$ $= 0.636\text{ m}$ $\text{number of lengths} = \frac{0.636\text{ m}}{0.05\text{ m}}$ $= 12.7$	5

Q12.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• Use of trig to determine the vertical or horizontal component of the initial velocity (1) • Use of equation(s) of motion to determine time the water in air (1) • Use of $s = vt$ (1) • $s = 4.8$ m (1) Allow ecf from (a) (Using show that value, $s = 5.0$ m)	Example of calculation $u_h = 7.8 \text{ m s}^{-1} \times \sin 25 = 3.30 \text{ m s}^{-1}$ $u_v = 7.8 \text{ m s}^{-1} \times \cos 25 = 7.07 \text{ m s}^{-1}$ $0 = (7.07 \text{ m s}^{-1})t + ½ (-9.81 \text{ N kg}^{-1})t^2$ $t = 1.44$ s $s = 1.44 \text{ s} \times 3.30 \text{ m s}^{-1} = 4.75$ m	4

Question Number	Acceptable answers	Additional guidance	Mark
(b)	• There is friction between the water and the pipes (1) • This will reduce the (initial) velocity of the water (1)	MP2 is dependent on MP1	2

Q13.

Question Number	Answer		Mark
(a)(i)	Convex curve drawn from the box to the drop zone	(1)	1
(a)(ii)	Use of $s = ut + \frac{1}{2} at^2$ t = 3.6 (s) Example of calculation 63 m = 0 + (½ × 9.81 m s^{-2} × t^2) t = 3.6 s	(1) (1)	2
(a)(iii)	Use of speed = $\frac{\text{distance}}{\text{time}}$ Distance = 270 m (ecf) [300 m using the show that value] Example of calculation 75 m s^{-1} = $\frac{\text{distance}}{3.6\ s}$ Distance = 270 m	(1) (1)	2

Q14.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• use of $v^2 = u^2 + 2as$ **(1) OR** use of ½ $mv^2 = mgh$ **(1)** • initial speed = 7.0 m s^{-1} **(1)**	Example of calculation: $v = 0$ $a = -9.81$ m s^{-1} $s = 2.5$ m $u^2 = -2as$ $u^2 = -(2 \times -9.81$ m $s^{-1} \times 2.5$ m$) = 49$ m^2 s^{-2} $u = 7.0$ m s^{-1} Alternative calculation: ½ $v^2 = gh$ v = √(2gh) = √(2 x 9.81 x 2.5) = = 7.0 m s^{-1}	**2**
(b)	• use of trig function to find v vertical **(1)** • use of trig function to find v horizontal **(1)** • use of equation of motion to find time of flight **(1)** • use of equation of motion to find distance **(1)** • horizontal distance = 2.7 m **(1)**	Example of calculation vertical velocity = 6.5 m s^{-1} sin 20 = 2.22 m s^{-1} time of flight using $v = u + at$ -2.22 m s^{-1} = 2.22 m s^{-1} + (-9.81 m $s^{-1} \times t$) $t = 0.45$ s horizontal velocity = 6.5 m s^{-1} cos 20 = 6.11 m s^{-1} horizontal distance using $s = ut$ $s = 6.11$ m $s^{-1} \times 0.45$ s $s = 2.7$ m	**5**

Q15.

Question Number	Answer		Mark
(a)(i)	The ball has bounced **Or** the ball would be below initial height **Or** the ball has landed before reaching the goal **Or** the ball has hit the ground	(1)	1
(a)(ii)	Correct shape of at least one trajectory, starting at the kick and ending at/beyond the goal	(1)	
	Range/position of the higher angle > range/position of lower angle ball seen with paths labelled	(1)	2
	Example of response scoring 2 marks 		
(b) (i)	Use of $(u_H) = u \cos 15$ **Or** $u \sin 75$ **Or** see 25(.1) m s^{-1}	(1)	
	Use of $u = s/t$ to calculate the time to the goal **Or** see 0.44 s	(1)	
	Use of $(u_V) = u \sin 15$ **Or** $u \cos 75$ **Or** see 6.7 m s^{-1}	(1)	
	Use of $s = ut + \frac{1}{2} at^2$ (a must be negative)	(1)	
	$s = 2.0$ m	(1)	
	Use of (value obtained + the 0.22 m (or 0.11 m)) to make a sensible statement as to whether or not the goal will be scored e.g. the top of the ball on reaching the goal 2.23 m. (This is less than 2.4 m and) the goal will be scored	(1)	6
	(Answer must be consistent with calculated distance. For calculated heights greater than 2.4 m, candidates do not need to refer to radius /diameter but a comparison of heights is needed.)		
	Example of calculation $t = \frac{11 \text{ m}}{26 \text{ ms}^{-1} \times \cos 15°} = 0.44$ s $s = (26 \text{ m s}^{-1} \times \sin 15°)(0.44 \text{ s}) + (\frac{1}{2})(-9.81 \text{ N kg}^{-1})(0.44 \text{ s})^2$ $s = 2.01$ m Height of the top of the ball on reaching the goal = 2.01 m + 0.22 m = 2.23 m		
(b) (ii)	Air resistance is in the opposite direction to the ball's motion **Or** air resistance adds a backwards force **Or** work is done against air resistance	(1)	
	The ball will decelerate (horizontally) **Or** the ball will have a decreasing velocity/speed **Or** the ball will not travel as far **Or** this reduces the maximum height the ball reaches **Or** the ball is in the air for less time **Or** the ball will take longer to reach the goal	(1)	2
	Total for question		11

Q16.

Question Number	Acceptable answers	Additional guidance	Mark
	• Uses correct components of velocity **(1)** • Uses $v = d/t$ in the horizontal plane **Or** Uses any equation of motion in the horizontal plane **(1)** • Uses $s = ut + \frac{1}{2} at^2$ **(1)** • the ut term has the opposite sign to the term at^2 **(1)** • $s = 2.1$ m so fielder can catch the ball because it is less than 3 m **(1)** (allow rounding error in final answer)	Example of calculation Initial vertical component velocity = 23.8 sin50 = 18.23 m s^{-1} Horizontal component velocity = 23.8 cos50 = 15.30 m s^{-1} $t = 55.0 \text{ m} / 15.30 \text{ m s}^{-1} = 3.595 \text{ s}$ $s = 18.23 \text{m s}^{-1} \times 3.595 \text{ s} - \frac{9.81 \text{ m s}^{-2} \times 3.595^2 \text{ s}^2}{2}$ $s = 65.5 \text{ m} - 63.4 \text{ m} = 2.1 \text{ m}$ Or starts the same with v_H and v_V $3.0 \text{ m} = 18.23 \text{m s}^{-1} \times t - \frac{9.81 \text{ m s}^{-2} \times t^2}{2}$ $t = 3.54$ s s = 15.30 m s^{-1}×3.54 s = 54.2 m So at $s = 55$ m the ball will be below 3 m and can be caught	5

Q17.

Question Number	Acceptable answers		Additional guidance	Mark
(a)	• Use of $v\cos\theta$ where θ is angle between v and vertical or sin equivalent • Component = 8.55 (m s^{-1})	(1) (1)	Example of calculation Component = 14.2 cos53° Component = 8.546 m s^{-1}	2

Question Number	Acceptable answers		Additional guidance	Mark
(b)	• Use of $s = ut + ½ at^2$ (ecf value from (a)) • Using a = $-9.81\,\text{m s}^{-2}$ • h = 2.3 m above ground	(1) (1) (1)	If show that value used h = 2.2 m Example of calculation $s = 8.55\ \text{m s}^{-1} \times 1.98\,\text{s} + ½ \times (-9.81\,\text{m s}^{-2}) \times 1.98^2\,\text{s}^2$ s = 16.93 m - 19.23 m s = -2.3 m	3

Question Number	Acceptable answers		Additional guidance	Mark
(c)	• Horizontal component velocity = v cos37° • R = horizontal component x time • R = 22.5 m	(1) (1) (1)	Example of calculation $R = 14.2\cos 37° \times 1.98$ R = 22.5 m	3

Q18.

Question Number	Acceptable Answer		Additional guidance	Mark
	• Use of trig to determine the vertical or horizontal component of the initial velocity • Use of equation(s) of motion to determine the time of flight • Use of s=ut for horizontal motion • s = 150 m	(1) (1) (1) (1)	Example Calculation $u_v = 41.5\ \text{ms}^{-1} \sin 30 = 20.8\ \text{ms}^{-1}$ $u_H = 41.5\ \text{ms}^{-1} \cos 30 = 35.9\ \text{ms}^{-1}$ v = u + at $0\ \text{ms}^{-1} = 20.8\ \text{ms}^{-1} - 9.81\text{ms}^{-2}\,t$ t (to max height) = 2.12s s = 35.9 ms^{-1} × 2 x 2.12s s = 152 m	4