1)

(a)		vertically down(wards) / vertically towards the ground	B1	**Not**: vertical / down
(b)		horizontal velocity = 24 × cos30 = 21 (m s^{-1}) vertical component = 24 × sin30 = 12 (m s^{-1})	B1 B1	**Note**: Answer to 3 sf is 20.8 (m s^{-1}) **Allow**: 12√3 **Allow**: 1 mark if the answers have been swapped. **Allow**: 1 mark for answers of '3.7 and -23.7' obtained using '30 rad'
(c)		The ball is (still) moving at **B** / has horizontal motion at **B** / has horizontal velocity (of 20.8 m s^{-1}) at **B** / has KE at **B**	B1	**Allow**: 'The ball has KE at the top / peak / maximum point'
(d)		$v^2 = u^2 + 2as$ Using the vertical component 12 (m s^1) 0 = 12^2 – 2 × 9.81 × h h = 7.3 (m)	C1 C1 A1	Possible ecf from **(b)** **Note**: Answer to 3sf is 7.34 (m) **Allow**: $mgh = \frac{1}{2}mv^2$ Using 12 (m s^1) C1 $h = 12^2/(2\times 9.81)$ C1 h = 7.3 (m) A1 **Allow**: m × 9.81 × h = ½ × m × 24^2 - ½ × m × 20.8^2 C1 h = (24^2 – 20.8^2)/2 × 9.81 C1 h = 7.3 (m) A1
		Total	**7**	

2)

(a)		Downward arrow at **P**	**B1**	Arrow must be close to or at point **P**
(b)		From gravitational potential (energy) to kinetic (energy) / KE / E $_k$ (wtte) Any further detail: KE maximum at bottom / Zero (G)PE at bottom / (G)PE is maximum at top / (G)PE and KE at top (wtte)	**B1** **B1**	The term gravitational to be included and spelled correctly in **(b)** to gain the first B1 mark **Not**: Heat / sound at ground
(c)		The acceleration / force / weight is at right angles to horizontal motion / velocity (wtte)	**B1**	**Allow**: 'In this direction the force / acceleration is zero'
(d)		time = $\frac{3.6}{7.0}$ (= 0.514 s)	**B1**	**Allow**: time = $\sqrt{(1.3\times 2)/9.81}$ (= 0.515 s) **Allow**: Use of 9.8 (m s^{-2})
(e)		u = 0 and $v = u + at$ or $v^2 = u^2 + 2as$ 'vertical' velocity = 9.81× 0.5(14) or 'vertical' velocity = $\sqrt{2\times 9.81\times 1.3}$ 'vertical' velocity = 5.0 (m s^{-1}) $v^2 = 7.0^2 + 5.0^2$ $v = 8.6$ (m s^{-1})	**C1** **C1** **C1** **A0**	**Watch out for**: '$v^2 = u^2 + 2as = 7^2 + (2\times 9.81\times 1.3) = 8.6$' – this scores **no** marks because of **wrong** physics. **Note**: Getting an answer 5.0 (m s^{-1}) scores the first 2 marks **Note**: Using t = 0.5 (s) gives 8.55 (m s^{-1}) **Note**: Bald answer scores zero marks – since this is a 'show' question (Allow full marks for correct analysis using the principle of conservation of energy.)
		Total	**8**	

3)

a	time = 1.2/8.0 time = 0.15 (s)	M1 A0	**Note**: The mark is for dividing the distance by the speed – hence must be seen
b	$s = ut + \frac{1}{2}at^2$ and $u = 0$ / $s = \frac{1}{2}at^2$ / $h = \frac{1}{2} \times 9.81 \times 0.15^2$ $h = 0.11$ (m)	C1 A1	
c	They both have same (vertical) acceleration / same acceleration of free fall / acceleration of 9.8 ms^{-2} (and zero initial vertical velocity)	B1	**Note**: Must have reference to both objects
	Total	**4**	

4)

Down	B1	**Allow** a downward arrow on Fig. 2.2

ii	Horizontal component of the velocity is constant There is no horizontal force	B1 B1	**Allow**: There is no horizontal acceleration **Allow**: Weight / g has no horizontal component or Weight / g is 90° to the horizontal or Weight / g is vertical or 'there is only a vertical force' (**Not** 'gravity' for 'weight'; allow 'force of gravity')
iii	Any two from: • It decreases from **X** to **Y** • It is zero at **Y** / It has the same magnitude at **X** and Z • It increases from **Y** to **Z** • It is positive from **X** to **Y** and negative from **Y** to **Z** (or vice versa)	B1 × 2	**Ignore** description in terms of acceleration or deceleration **Allow** it changes sign / direction from **X** to **Z**

5)

(a)	$E_p = 190 \times 9.81 \times 25$ $E_p = 4.7 \times 10^4$ (J)	B1	**Note**: Answer is 4.66×10^4 to 3sf
(b)	$E_k = ½ \times 190 \times 30^2$ $E_k = 8.6 \times 10^4$ (J)	B1	**Note:** Answer is 8.55×10^4 to 3sf
(c)	Work done by the motorbike / energy from the engine (AW)	B1	**Note**: There must be reference to work or energy **Allow:** chemical energy to kinetic energy / E_K
(d)	work done = change in energy force × 120 = $(8.55 - 4.66) \times 10^4$ force = 320 (N)	C1 A1	Possible ecf from **(a)** and **(b)**
(e)(i)	($s = ½ at^2$ – for the vertical fall) $9.5 = ½ \times 9.81 \times t^2$ (Any subject) $t = \sqrt{(2 \times 9.5)/9.81}$ or 1.39 time = 1.4 (s)	M1 M1 A0	
(e)(ii)	Horizontal velocity = 30 m s^{-1} distance = 1.4 × 30 or 42 (m) (number of cars =) 42/1.8 (number of cars =) 23	 C1 A1	 **Allow**: 23.3 cars **Allow:** 22 if height of last car is mentioned
	Total	**9**	

6)

(a)	(i)	There is only a vertical force / weight is vertical / no horizontal force(s) / acceleration is vertical	B1	**Not** 'horizontal acceleration is zero' – since horizontal velocity is constant is given in the question
	(ii)	1 Correct sketch of the rebound path. 2 The time is the same. For both, the height / vertical distance and (vertical) acceleration are the same.	B1 M1 A1	**Note**: The ball must hit the ground closer to wall. The rebound path should be curved and below the original path. **Allow** $s = \frac{1}{2}at^2$ with s and a are the same (for both)
(b)		Drop the ball from a given height **and** measure time of fall. $s = ut + ½ at^2$ **and** $u = 0$ or $s = ½ at^2$ (The acceleration of free fall is determined using) $a = 2s/t^2$	B1 B1 B1	 **Allow** $a \equiv g$ and $h \equiv s$ **Note:** a must be the subject to gain this B1 mark **Note**: $a = 2s/t^2$ will score the last two B1 marks **Allow** full credit for graphical approach: Drop ball from different heights & measure the times of fall (B1) ; plot a graph of s against t^2 (B1) ; $g = 2 \times$ gradient (B1)
(c)	(i)	Constant deceleration or uniform deceleration or constant negative acceleration or constant rate (of change) of velocity (Momentarily) stops at 1.5 (s) or reaches maximum height at 1.5 (s) Clear idea of returning back. (AW)	B1 B1 B1	**Allow** constant / uniform acceleration / acceleration is 2.66.. (m s^{-2}) **Allow** 'constant rate of deceleration or acceleration' **Not** 'slowing down' **Allow**: (The ball) goes up and (then) down (the ramp) **Not**: velocity changes sign or direction changes
	(ii)	distance = ½ × 4.0 × 1.5 distance = 3.0 (m)	C1 A1	**Note**: Speed in range 3.0 to 5.0 (m s^{-1}) and $v \neq 4.0$ (m s^{-1}), then possible ecf **Allow** 1 sf answer **Allow** full credit for correct use of equation(s) of motion **Special case:** total distance travelled is calculated; allow 1 mark for an answer of 6.0 (m)
		Total	**12**	

7)

(a)	(i)	9.8(1) m s^{-2} / g / acceleration of free fall The only force acting is weight / drag force is zero	B1 B1	
	(ii)	(The maximum velocity when) drag = weight	B1	
	(iii)	The golf ball experiences greater drag (at terminal velocity to equal its larger weight) (AW) Drag increases with speed or drag $\propto v^2$ or the golf ball takes longer time to reach its terminal velocity or the golf ball accelerates for longer time The golf ball (has greater terminal velocity)	B1 B1 B1	
(b)	(i)	drag = 2000 (N) from the graph net force = 3200 - 2000 (N) / net force = 1200 (N) acceleration = 1200/8000 acceleration = 0.15 (m s^{-2})	C1 C1 A1	 Possible ecf if reading off graph is incorrect No credit for 3200/8000 = 0.4(0 m s^{-2}) or 2000/8000 = 0.25 (m s^{-2})
	(ii)	The drag force will be greater than the (constant) forward force (which cannot be) or at 32 (m s^{-1} drag) force is 3200 ± 100 (N) or at 40 (m s^{-1} drag) force is 5100 ± 100 (N)	B1	**Allow** maximum speed is 32 (m s^{-1})
(c)		The time taken (for the driver) to stop is more or distance travelled (by the driver) is greater. $F = ma$ a decreases (hence F is smaller) or $Fx = KE$ KE is the same (hence F is smaller) or $F = \Delta p/\Delta t$ Δp is the same (hence F is smaller)	B1 B1 B1 B1 B1 B1 B1	**Allow** 'it takes longer to stop' or 'increases impact time' **Not** slower acceleration KE ≡ W (for work done)
		Total	**13**	