

- 1
- (a) Vertical motion: $u = 25 \sin 40$, $v = 0$, $a = -9.8$ Using $v^2 = u^2 + 2as$: $0 = (25 \sin 40)^2 + 2(-9.8)s$ (M1) $s = \frac{(25 \sin 40)^2}{19.6} = 13.18... s = 13 \text{ m (2sf)}$ (A1)
- (b) Vertical motion for total time: $s = 0$, $u = 25 \sin 40$, $a = -9.8$ $0 = 25 \sin(40)t - 4.9t^2$ (M1) $t = 3.279... \text{ s}$ (A1) Horizontal motion: $s = ut$ $s = 25 \cos(40) \times 3.279... (M1) s = 62.8... = 63 \text{ m (2sf)}$ (A1)

(Total for question 1 is 7 marks)

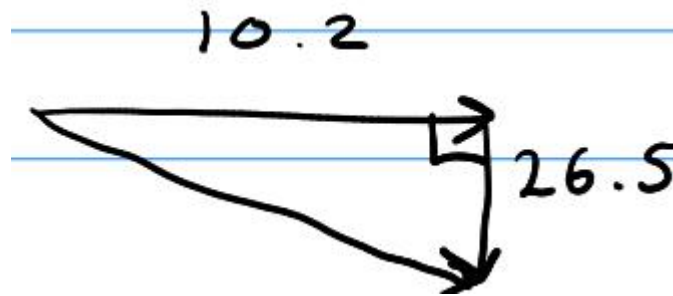
- 2
- (a) Horizontal velocity $v_x = 3$ (constant) (B1) Vertical velocity $v_y = u_y + at = 4 - 9.8(2) = -15.6$ (M1) Speed = $\sqrt{3^2 + (-15.6)^2}$ (M1) Speed = $15.88... = 16 \text{ ms}^{-1}$ (2sf) (A1)
- (b) Vertical motion to max height: $u = 4$, $v = 0$, $a = -9.8$ $v^2 = u^2 + 2as \Rightarrow 0 = 4^2 + 2(-9.8)s$ (M1) $s = 0.816... \text{ m}$ above projection point (A1) Total height = $20 + 0.816 = 20.8 \text{ m}$ (or 21 m) (A1)
- (c) Vertical motion to ground: $s = -20$, $u = 4$, $a = -9.8$ $-20 = 4t - 4.9t^2 \Rightarrow 4.9t^2 - 4t - 20 = 0$ (M1) $t = 2.47... \text{ s}$ (A1) Horizontal distance = $3 \times 2.47... (M1) = 7.4 \text{ m (2sf)}$ (A1)

(Total for question 2 is 11 marks)

- 3
- (a) Vertical motion: $s = 0$, $u = 25 \sin \theta$, $a = -9.8$, $t = 5$ $s = ut + \frac{1}{2}at^2 \Rightarrow 0 = (25 \sin \theta)(5) - 4.9(5^2)$ (M1) $125 \sin \theta = 122.5$ (M1) $\sin \theta = 0.98$ (A1) $\theta = 78.5^\circ$ (A1)
- (b) Horizontal motion: $s = (25 \cos \theta)t$ $s = 25 \cos(78.518...) \times 5$ (M1) $s = 24.9... = 25 \text{ m}$ (2sf) (A1)

(Total for question 3 is 8 marks)

- 4
- (a) Vertical motion to max height: $s = 16$, $u = U \sin 60$, $v = 0$, $a = -9.8$ $v^2 = u^2 + 2as \Rightarrow 0 = (U \sin 60)^2 - 2(9.8)(16)$ (M1) $0 = \frac{3}{4}U^2 - 313.6$ (M1) $U^2 = 418.13... \Rightarrow U = 20.44... = 20 \text{ ms}^{-1}$ (2sf) (A1)
- (b) Vertical motion to ground: $s = -20$, $u = 20.44 \sin 60$, $a = -9.8$ $-20 = 17.7t - 4.9t^2 \Rightarrow 4.9t^2 - 17.7t - 20 = 0$ (M1) $t = 4.50... \text{ s}$ (A1) Horizontal distance = $(20.44 \cos 60) \times 4.50$ (M1) $= 45.99... = 46 \text{ m}$ (2sf) (A1)
- (c) Vertical velocity: $v_y^2 = (20.44 \sin 60)^2 + 2(-9.8)(-20) = 705.6$ (M1) $v_y = 26.56...$
Horizontal velocity: $v_x = 20.44 \cos 60 = 10.22$ Speed = $\sqrt{26.56^2 + 10.22^2} = 28.4...$
(M1) $= 28 \text{ ms}^{-1}$ (2sf) (A1)



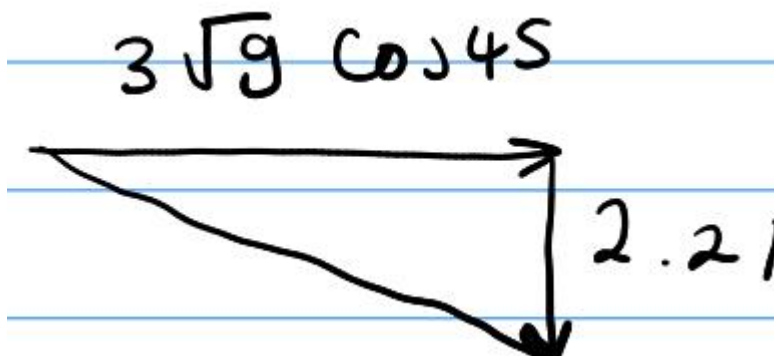
(Total for question 4 is 12 marks)

- 5
- (a) Vertical component $u_y = 4k$ At max height $v_y = 0$, $s = 24$, $a = -g$ $0 = (4k)^2 - 2g(24)$
(M1) $16k^2 = 48g \Rightarrow k^2 = 3g$ (M1) $k = \sqrt{3g}$ (A1)
- (b) Time of flight: $0 = (4\sqrt{3g})t - \frac{1}{2}gt^2 \Rightarrow t = \frac{8\sqrt{3g}}{g} = 8\sqrt{\frac{3}{g}}$ (M1) $t \approx 4.427 \text{ s}$ (A1)
Horizontal velocity $u_x = 3k = 3\sqrt{3g}$ (M1) Distance = $3\sqrt{3g} \times 8\sqrt{\frac{3}{g}}$ (M1) $= 24 \times 3 = 72 \text{ m}$ (A2)

(Total for question 5 is 9 marks)

6

- (a) Horizontal: $x = (U \cos \theta)t \Rightarrow t = \frac{x}{U \cos \theta}$ (M1) Vertical: $y = (U \sin \theta)t - \frac{1}{2}gt^2$ (M1)
 Substitute t : $y = U \sin \theta \left(\frac{x}{U \cos \theta} \right) - \frac{1}{2}g \left(\frac{x}{U \cos \theta} \right)^2$ (M1) $y = x \frac{\sin \theta}{\cos \theta} - \frac{gx^2}{2U^2 \cos^2 \theta} = x \tan \theta - \frac{gx^2}{2U^2 \cos^2 \theta}$ (A1)
- (b) Substitute values into trajectory equation: $2 = 6 \tan 45 - \frac{g(6^2)}{2U^2 \cos^2 45}$ (M1) $2 = 6 - \frac{36g}{2U^2(0.5)} \Rightarrow 2 = 6 - \frac{36g}{U^2}$ (M1) $4 = \frac{36g}{U^2} \Rightarrow U^2 = 9g \Rightarrow U = 3\sqrt{g}$ (A1) Horizontal velocity $v_x = 3\sqrt{g} \cos 45 = 6.62...$ Vertical velocity v_y : $v_y = u_y + at$ $t = \frac{6}{3\sqrt{g} \cos 45} = 0.904... \text{ s}$
 $v_y = 3\sqrt{g} \sin 45 - 9.8(0.904) = -2.21...$ (M1) Speed = $\sqrt{6.62^2 + (-2.21)^2} = 6.98...$ (M1) $= 7 \text{ ms}^{-1}$ (A1)



(Total for question 6 is 10 marks)

7

- (a) Horizontal: $80 = (U \cos 45)T \Rightarrow T = \frac{80}{U \cos 45}$ (M1) Vertical: $-20 = (U \sin 45)T - 4.9T^2$ (M1) Substitute T : $-20 = U \sin 45 \left(\frac{80}{U \cos 45} \right) - 4.9 \left(\frac{80}{U \cos 45} \right)^2$ (M1) $-20 = 80 - \frac{4.9 \times 6400}{U^2 \times 0.5}$ (M1) $100 = \frac{62720}{U^2} \Rightarrow U^2 = 627.2$ (M1) $U = 25.04... = 25 \text{ ms}^{-1}$ (2sf) (A1)
- (b) Vertical motion to max height: $u = 25 \sin 45$, $v = 0$, $a = -9.8$ $0 = (25 \sin 45)^2 - 19.6s \Rightarrow s = 15.94...$ (M1) Height above ground = $20 + 15.94 = 35.94...$ (M1) $= 36 \text{ m}$ (2sf) (A1)
- (c) U would have to be greater (to overcome air resistance and reach the same distance). (B1)

(Total for question 7 is 10 marks)

8

- (a) Max height is 1m above O . $v_y = 0$, $s = 1$, $a = -g$ $0 = (U \sin \alpha)^2 - 2g(1) \Rightarrow U^2 \sin^2 \alpha = 2g$ (Eq 1) (M1) At point A : $x = 10$, $y = -1.2 - 1.2 = 10 \tan \alpha - \frac{g(10^2)}{2U^2 \cos^2 \alpha}$ (M1) $-1.2 = 10 \tan \alpha - \frac{50g}{U^2 \cos^2 \alpha}$ (M1) From Eq 1: $U^2 = \frac{2g}{\sin^2 \alpha}$. Substitute into trajectory: $-1.2 = 10 \tan \alpha - \frac{50g \sin^2 \alpha}{2g \cos^2 \alpha} = 10 \tan \alpha - 25 \tan^2 \alpha$ (M1) $25 \tan^2 \alpha - 10 \tan \alpha - 1.2 = 0 \tan \alpha = 0.496... \Rightarrow \alpha = 26.4^\circ$ $U^2 = \frac{2g}{\sin^2(26.4)} = 99.4...$ (M1) $U = 10 \text{ ms}^{-1}$ (2sf) (A1)
- (b) From quadratic $25 \tan^2 \alpha - 10 \tan \alpha - 1.2 = 0$: $\tan \alpha = \frac{10 \pm \sqrt{100 - 4(25)(-1.2)}}{50} = \frac{10 \pm \sqrt{220}}{50}$ (M1) $\tan \alpha = 0.4966...$ (positive root) (A1) $\alpha = 26.4^\circ$ (A1)
- (c) Any one of:
- Air resistance was ignored.
 - The ball is not a particle (has dimensions/spin).
 - g is not exactly 9.8 ms^{-2} . (B1)

(Total for question 8 is 10 marks)

9

- (a) Horizontal velocity $v_x = 25 \cos 30 = \frac{25\sqrt{3}}{2} \approx 21.7$ (B1) Vertical velocity $v_y = 25 \sin 30 - 9.8(2) = 12.5 - 19.6 = -7.1$ (M1) Velocity vector = $(21.7\mathbf{i} - 7.1\mathbf{j}) \text{ ms}^{-1}$ (A1)
- (b) Collision at $t = 2$: P position: $x_P = (25 \cos 30) \times 2 = 25\sqrt{3} \approx 43.3$ $y_P = (25 \sin 30) \times 2 - 4.9(2^2) = 25 - 19.6 = 5.4$ Q position: $x_Q = 50 - (U \cos \theta) \times 2$ $y_Q = (U \sin \theta) \times 2 - 4.9(2^2)$ Equating y : $5.4 = 2U \sin \theta - 19.6 \Rightarrow 2U \sin \theta = 25 \Rightarrow U \sin \theta = 12.5$ (M1) Equating x : $25\sqrt{3} = 50 - 2U \cos \theta \Rightarrow 2U \cos \theta = 50 - 25\sqrt{3}$ (M1) $U \cos \theta = 25 - 12.5\sqrt{3} \approx 3.35$ (A1) $\tan \theta = \frac{12.5}{3.35} \Rightarrow \theta = 75^\circ$ (A1) $U = \frac{12.5}{\sin 75} = 12.94... = 13 \text{ ms}^{-1}$ (2sf) (A2)
- (c) Air resistance has not been taken into account. (B1)

(Total for question 9 is 13 marks)