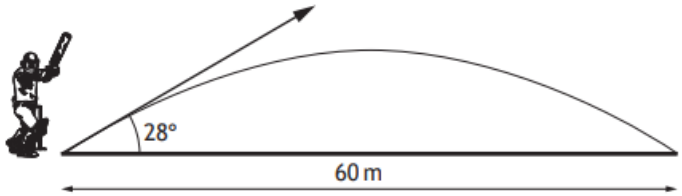
Y	Q	Projectiles
2024	8	A particle is launched from an origin on horizontal ground and moves freely under gravity. The particle is projected with speed u m s^{-1} at an angle θ to the horizontal. (a) Show that the subsequent motion of the projectile has the equation $$y = x\tan\theta - \frac{gx^2}{2u^2\cos^2\theta}$$ where x and y are measured in metres. **3** A particle is fired at 20 m s^{-1} and it needs to pass over a wall which is 9 metres high; the base of the wall is 30 metres horizontally from the launch point. (b) Calculate the range of angles of projection which will allow the particle to pass over the wall. Note that $\frac{1}{\cos^2\theta} = 1 + \tan^2\theta$. **4**
2023	3	A projectile is launched from a point on horizontal ground with speed U m s^{-1} at an angle θ to the horizontal. (a) Show that the maximum height, H metres, reached by the particle is given by $$H = \frac{U^2\sin^2\theta}{2g}$$ **2** (b) A particle is launched from a point h metres above horizontal ground with speed 40 m s^{-1} at an angle of 27° to the horizontal. Calculate the value of h if the particle reaches a maximum height of 50 metres. **2**
2022	3	A ball is kicked from horizontal ground with a speed of 25 m s^{-1} at an angle of 30° to the horizontal. (a) Calculate the maximum height of the ball. **2** As the ball falls it is caught at a height of 1 metre from the ground. (b) Calculate the total horizontal displacement of the ball during its motion. **3**
2019	15	A ball is kicked from floor level at an angle of θ with initial speed u m s^{-1} in a room of height 3 metres. (a) Show that, if the ball does not hit the ceiling, $\sin\theta < \frac{\sqrt{6g}}{u}$. **3** (b) The ball just touches the smooth ceiling at the highest point of its trajectory. (i) Show that the range of the ball is $12\sqrt{\frac{u^2-6g}{6g}}$ metres. **5** (ii) State the constraint that must be placed on the initial speed of the ball in this case. **1**

2018	9	A projectile is launched with speed $v\,\text{m s}^{-1}$, at an angle θ to the horizontal. (a) Show that the horizontal range R of the projectile is given in metres by $R=\dfrac{v^2\sin 2\theta}{g}$. **4** (b) A tennis training device fires balls at the same speed each time, but the angle of projection can vary. A ball is fired at 30° to the horizontal and has a range of R metres. Another ball is fired at 35° to the horizontal and has a range of $(R+5)$ metres. (i) Calculate the initial speed of the balls. **3** (ii) On a particular day, the tennis balls are assisted by a horizontal tailwind of $7\,\text{m s}^{-1}$. Find the new range of a ball fired at 35° to the horizontal. **3**
2017	7	A cricket batsman hits a ball from ground level. The ball lands on the boundary which is 60 metres away.  If the angle of flight to the horizontal ground is 28° at the instant the ball leaves the bat, calculate the initial speed of the ball. **5**
2016	16	A ball is projected from an origin on horizontal ground with speed $V\,\text{m s}^{-1}$ at an angle of elevation of θ and moves freely under gravity. It passes through a point which is x metres horizontally from the origin at a height y metres above the ground. (a) Show that the trajectory of the particle has equation $y=x\tan\theta-\dfrac{gx^2}{2V^2}\left(1+\tan^2\theta\right)$. (Note that $\sec^2\theta=1+\tan^2\theta$) **3** (b) The ball is at a vertical height of h metres when it has travelled $4h$ metres horizontally. It is again at a height of h metres when it has travelled a further h metres horizontally. Determine the angle of projection θ. **5**
2016 Spec	15	A golfer hits a ball from the point O with velocity $(P\mathbf{i}+Q\mathbf{j})\,\text{m s}^{-1}$. The ball first hits the ground a distance of 50 metres from O in the horizontal plane. (a) Show that $PQ=25g$. **4** (b) Given that the ball passes through $45\mathbf{i}+1{\cdot}6\mathbf{j}$ (i) Calculate P. **4** (ii) Calculate the initial angle of projection to the horizontal. **2**