1 **In this question take $g = 10$.**

A golf ball is hit from ground level over horizontal ground. The initial velocity of the ball is $40\,\mathrm{m\,s^{-1}}$ at an angle α to the horizontal, where $\sin\alpha = 0.6$ and $\cos\alpha = 0.8$. Air resistance may be neglected.

(i) Find an expression for the height of the ball above the ground t seconds after projection. [2]

(ii) Calculate the horizontal range of the ball. [4]

2 A ball is kicked from ground level over horizontal ground. It leaves the ground at a speed of $25\,\mathrm{m\,s}^{\ 1}$ and at an angle θ to the horizontal such that $\cos\theta = 0.96$ and $\sin\theta = 0.28$.

(i) Show that the height, y m, of the ball above the ground t seconds after projection is given by $y = 7t - 4.9t^2$. Show also that the horizontal distance, x m, travelled by this time is given by $x = 24t$. [3]

(ii) Calculate the maximum height reached by the ball. [2]

(iii) Calculate the times at which the ball is at half its maximum height.

Find the horizontal distance travelled by the ball between these times. [4]

(iv) Determine the following when $t = 1.25$.

(A) The vertical component of the velocity of the ball.

(B) Whether the ball is rising or falling. (You should give a reason for your answer.)

(C) The speed of the ball. [5]

(v) Show that the equation of the trajectory of the ball is

$$y = \frac{0.7x}{576}(240 - 7x).$$

Hence, or otherwise, find the range of the ball. [5]

3 A particle is thrown vertically upwards and returns to its point of projection after 6 seconds. Air resistance is negligible.

Calculate the speed of projection of the particle and also the maximum height it reaches. [4]

4 You should neglect air resistance in this question.

A small stone is projected from ground level. The maximum height of the stone above horizontal ground is 22.5 m.

(i) Show that the vertical component of the initial velocity of the stone is 21 m s ^{1}. [2]

The speed of projection is 28 m s ^{1}.

(ii) Find the angle of projection of the stone. [2]

(iii) Find the horizontal range of the stone. [4]

5 **In this question take the value of g to be $10\ \mathrm{m\,s^{-2}}$.**

A particle A is projected over horizontal ground from a point P which is 9 m above a point O on the ground. The initial velocity has horizontal and vertical components of $10\ \mathrm{m\,s^{-1}}$ and $12\ \mathrm{m\,s^{-1}}$ respectively, as shown in Fig. 7. The trajectory of the particle meets the ground at X. Air resistance may be neglected.

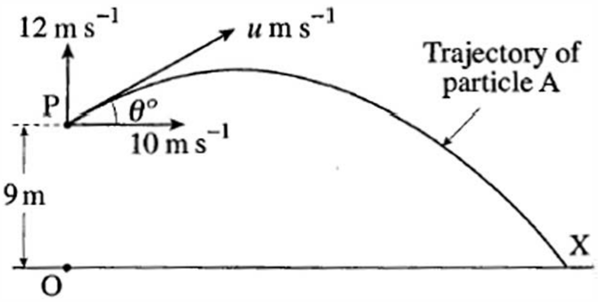

Fig. 7

(i) Calculate the speed of projection $u\ \mathrm{m\,s^{-1}}$ and the angle of projection $\theta°$. [3]

(ii) Show that, t seconds after projection, the height of particle A above the ground is $9 + 12t - 5t^2$. Write down an expression in terms of t for the horizontal distance of the particle from O at this time. [4]

(iii) Calculate the maximum height of particle A above the point of projection. [2]

(iv) Calculate the distance OX. [4]

A second particle, B, is projected from O with speed $20\ \mathrm{m\,s^{-1}}$ at 60° to the horizontal. The trajectories of A and B are in the same vertical plane. Particles A and B are projected at the same time.

(v) Show that the horizontal displacements of A and B are always equal. [2]

(vi) Show that, t seconds after projection, the height of particle B above the ground is $10\sqrt{3}t - 5t^2$. [1]

(vii) Show that the particles collide 1.7 seconds after projection (correct to two significant figures). [3]

6 Ali is throwing flat stones onto water, hoping that they will bounce, as illustrated in Fig. 5.

Ali throws one stone from a height of 1.225 m above the water with initial speed $20\,\mathrm{m\,s^{-1}}$ in a horizontal direction. Air resistance should be neglected.

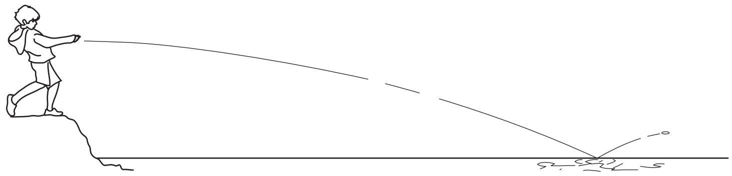

Fig. 5

(i) Find the time it takes for the stone to reach the water. **[2]**

(ii) Find the speed of the stone when it reaches the water and the angle its trajectory makes with the horizontal at this time. **[5]**

7 A projectile P travels in a vertical plane over level ground. Its position vector **r** at time t seconds after projection is modelled by

$$\mathbf{r} = \begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} 0 \\ 5 \end{pmatrix} + \begin{pmatrix} 30 \\ 40 \end{pmatrix} t - \begin{pmatrix} 0 \\ 5 \end{pmatrix} t^2 ,$$

where distances are in metres and the origin is a point on the level ground.

(i) Write down

(A) the height from which P is projected,

(B) the value of g in this model. **[2]**

(ii) Find the displacement of P from $t = 3$ to $t = 5$. **[2]**

(iii) Show that the equation of the trajectory is

$$y = 5 + \frac{4}{3} x - \frac{x^2}{180} .$$ **[4]**