# Projectiles AQA M1 2005-2010 (6 Questions)

Jan 05

**8** A football is placed on a horizontal surface. It is then kicked, so that it has an initial velocity of $12\ \text{m s}^{-1}$ at an angle of 40° above the horizontal.

(a) State two modelling assumptions that it would be appropriate to make when considering the motion of the football. *(2 marks)*

(b) (i) Find the time that it takes for the ball to reach its maximum height. *(4 marks)*

(ii) Hence show that the maximum height of the ball is 3.04 metres, correct to three significant figures. *(3 marks)*

(c) After the ball has reached its maximum height, it hits the bar of a goal at a height of 2.44 metres. Find the horizontal distance of the goal from the point where the ball was kicked. *(7 marks)*

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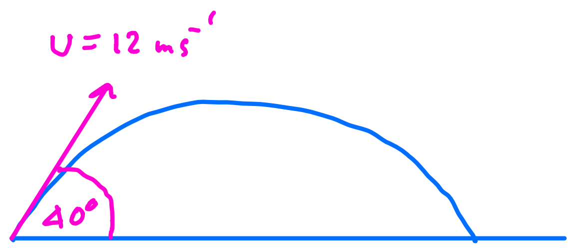
|---|---|---|
| **8(a)** | Ball is a particle<br>No air resistance | B1<br>B1 |

b) i)




**SUVAT Equations**

$v = u + at$

$v^2 = u^2 + 2as$

$s = ut + \frac{1}{2}at^2$

$s = vt - \frac{1}{2}at^2$

$s = \frac{1}{2}(u+v)t$

s – displacement
u – initial velocity
v – final velocity
a – acceleration
t - time

$$V_y = U_y - 9.8t$$

At max height $V_y = 0$

$$0 = 12\sin 40° - 9.8t$$

$$9.8t = 12\sin 40°$$

$$t = \frac{12\sin 40°}{9.8} = 0.78709\ \text{s}$$

$$t = 0.787\ \text{s}$$

ii) $y = u_y t - 4.9t^2$

$y = 12\sin 40^\circ \times 0.78709 - 4.9 \times 0.78709^2$

$y = 3.03558$

Max height $y = 3.04$ m to 3 s.f.

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c) $y = u_y t - 4.9t^2$

$2.44 = 12\sin 40^\circ \times t - 4.9t^2$

$4.9t^2 - 12\sin 40^\circ \times t + 2.44 = 0$

By calc $t = 1.136$s or ~~$t = 0.438$ s~~ before max height

$t = 1.136$s

At $t = 1.136$s $\quad x = U_x t$

$x = 12\cos 40^\circ \times 1.136$

$x = 10.44$

Horizontal distance $x = 10.4$ m

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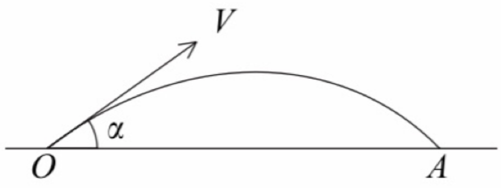
**5** A golf ball is projected from a point $O$ with initial velocity $V$ at an angle $\alpha$ to the horizontal. The ball first hits the ground at a point $A$ which is at the same horizontal level as $O$, as shown in the diagram.




It is given that $V\cos\alpha = 6u$ and $V\sin\alpha = 2.5u$.

(a) Show that the time taken for the ball to travel from $O$ to $A$ is $\dfrac{5u}{g}$. *(4 marks)*

(b) Find, in terms of $g$ and $u$, the distance $OA$. *(2 marks)*

(c) Find $V$, in terms of $u$. *(2 marks)*

(d) State, in terms of $u$, the least speed of the ball during its flight from $O$ to $A$. *(1 mark)*

a) Ball lands when $y = 0$

$$y = u_y t - \tfrac{1}{2}gt^2$$

$$0 = 2.5ut - \tfrac{1}{2}gt^2$$

$$\tfrac{1}{2}gt^2 - 2.5ut = 0$$

$$gt^2 - 5ut = 0$$

$$t(gt - 5u) = 0$$

$\Rightarrow$ ~~$t = 0$~~ (start) or $gt - 5u = 0$

$$gt = 5u$$

$$t = \frac{5u}{g}$$

**SUVAT Equations**

$v = u + at$

$v^2 = u^2 + 2as$

$s = ut + \frac{1}{2}at^2$

$s = vt - \frac{1}{2}at^2$

$s = \frac{1}{2}(u+v)t$

s – displacement
u – initial velocity
v – final velocity
a – acceleration
t - time

b)

$$x = V\cos\alpha \times t$$

$$x = 6ut$$

At A $\quad x = 6u \times \frac{5u}{g}$

$$OA = x = \frac{30u^2}{g}$$

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c)

$V\sin\alpha = 2.5u \qquad V\cos\alpha = 6u$

$$V^2\sin^2\alpha + V^2\cos^2\alpha = 6.25u^2 + 36u^2$$

$$V^2(\sin^2\alpha + \cos^2\alpha) = 42.25u^2$$

$$V = 6.5u$$

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d) Horizontal speed component constant $= 6u$

Minimum speed occurs at max height

when vertical speed component $= 0$

Minimum Speed $= 6u$

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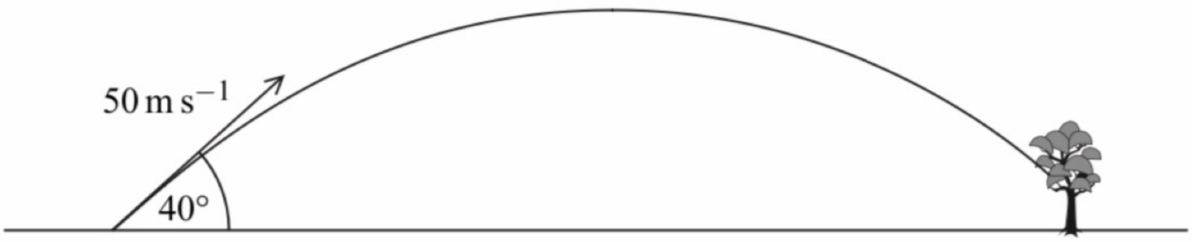
**7** A golf ball is struck from a point on horizontal ground so that it has an initial velocity of $50\,\mathrm{m\,s^{-1}}$ at an angle of 40° above the horizontal.

Assume that the golf ball is a particle and its weight is the only force that acts on it once it is moving.

(a) Find the maximum height of the golf ball. *(4 marks)*

(b) After it has reached its maximum height, the golf ball descends but hits a tree at a point which is at a height of 6 metres above ground level.




Find the time that it takes for the ball to travel from the point where it was struck to the tree. *(6 marks)*

a) Max height when $v_y = 0$

$$v_y^2 = u_y^2 - 19.6y$$

$$0 = (50\sin 40°)^2 - 19.6y$$

$$19.6y = (50\sin 40°)^2$$

$$y = \frac{(50\sin 40°)^2}{19.6}$$

Max height $= y = 52.7$ m

**SUVAT Equations**

$v = u + at$

$v^2 = u^2 + 2as$

$s = ut + \frac{1}{2}at^2$

$s = vt - \frac{1}{2}at^2$

$s = \frac{1}{2}(u+v)t$

s – displacement
u – initial velocity
v – final velocity
a – acceleration
t - time

b)

$$y = u_y t - 4.9t^2$$

$$6 = 50\sin 40° \times t - 4.9t^2$$

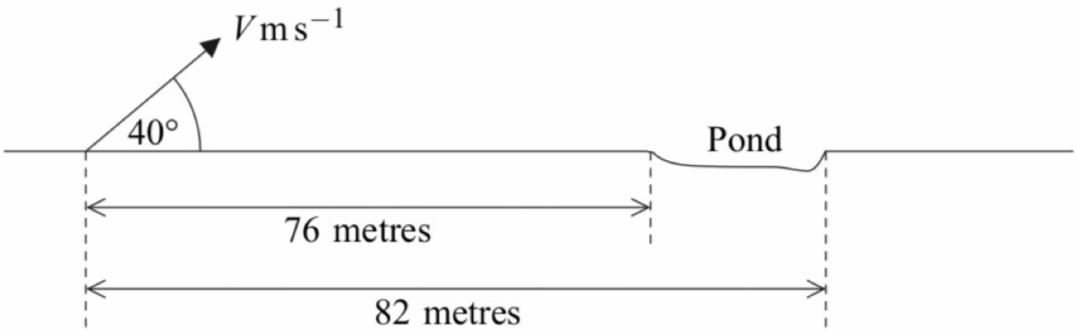
$$4.9t^2 - 50\sin 40° \times t + 6 = 0$$

By calc $t = 6.367\text{ s}$ or ~~$t = 0.192\text{ s}$~~ still rising

$t = 6.37\text{ s}$

Jan 08

**7** A golfer hits a ball which is on horizontal ground. The ball initially moves with speed $V\text{ m s}^{-1}$ at an angle of 40° above the horizontal. There is a pond further along the horizontal ground. The diagram below shows the initial position of the ball and the position of the pond.




(a) State **two** assumptions that you should make in order to model the motion of the ball. *(2 marks)*

(b) Show that the horizontal distance, in metres, travelled by the ball when it returns to ground level is

$$\frac{V^2 \sin 40° \cos 40°}{4.9}$$ *(6 marks)*

(c) Find the range of values of $V$ for which the ball lands in the pond. *(4 marks)*

| | | |
|---|---|---|
| **7(a)** | It is a particle /No air resistance / lift forces act on the ball. | B1<br>B1 |

b) First find time of flight

Lands when $y = 0$

$$y = u_y t - 4.9t^2$$

$$0 = V\sin 40° \times t - 4.9t^2$$

$$4.9t^2 - V\sin 40° \times t = 0$$

$$t(4.9t - V\sin 40°) = 0$$

$\cancel{t = 0}$ start or $4.9t - V\sin 40° = 0$

$$4.9t = V\sin 40°$$

$$t = \frac{V\sin 40°}{4.9}$$

| SUVAT Equations | |
|---|---|
| $v = u + at$ | s – displacement |
| $v^2 = u^2 + 2as$ | u – initial velocity |
| $s = ut + \frac{1}{2}at^2$ | v – final velocity |
| $s = vt - \frac{1}{2}at^2$ | a – acceleration |
| $s = \frac{1}{2}(u+v)t$ | t - time |

Now horizontal distance $x = V\cos 40° \times t$

$$\Rightarrow \quad x = V\cos 40° \times \frac{V\sin 40°}{4.9}$$

$$x = \frac{V^2 \sin 40° \cos 40°}{4.9}$$

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c) Lands in pond when

$$76\text{m} < \frac{V^2 \sin 40° \cos 40°}{4.9} < 82\text{m}$$

$$\frac{76 \times 4.9}{\sin 40^\circ \cos 40^\circ} < v^2 < \frac{82 \times 4.9}{\sin 40^\circ \cos 40^\circ}$$

$$\sqrt{\frac{76 \times 4.9}{\sin 40^\circ \cos 40^\circ}} < v < \sqrt{\frac{82 \times 4.9}{\sin 40^\circ \cos 40^\circ}}$$

$$27.5\ ms^{-1} < v < 28.6\ ms^{-1}$$

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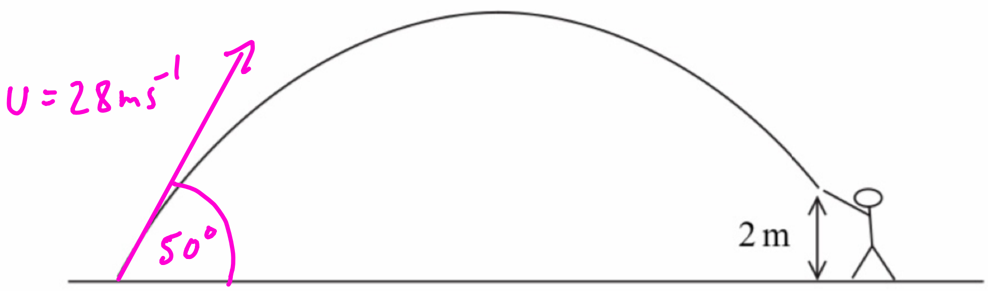
Jan 09

**8** A cricket ball is hit at ground level on a horizontal surface. It initially moves at $28\,\mathrm{m\,s^{-1}}$ at an angle of 50° above the horizontal.

(a) Find the maximum height of the ball during its flight. *(4 marks)*

(b) The ball is caught when it is at a height of 2 metres above ground level, as shown in the diagram.




Show that the time that it takes for the ball to travel from the point where it was hit to the point where it was caught is 4.28 seconds, correct to three significant figures. *(5 marks)*

(c) Find the speed of the ball when it is caught.

**SUVAT Equations**

$v = u + at$

$v^2 = u^2 + 2as$

$s = ut + \frac{1}{2}at^2$

$s = vt - \frac{1}{2}at^2$

$s = \frac{1}{2}(u+v)t$

s – displacement
u – initial velocity
v – final velocity
a – acceleration
t - time

a) Max height when $v_y = 0$

$v_y^2 = u_y^2 - 19.6y$

$0 = (28\sin 50^\circ)^2 - 19.6y$

$$19.6y = (28\sin 50°)^2$$

$$y = \frac{(28\sin 50°)^2}{19.6}$$

Max height $= y = 23.5\text{ m}$

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b) Caught when $y = 2\text{ m}$

$$y = u_y t - 4.9t^2$$

$$2 = 28\sin 50° \times t - 4.9t^2$$

$$4.9t^2 - 28\sin 50° \times t + 2 = 0$$

By calc $t = 4.282$ or ~~$t = 0.095$~~ still rising

$t = 4.28\text{ s}$ to 3 s.f.

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c) When $t = 4.282$

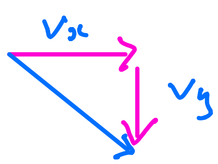
$$V_y = U_y - 9.8t$$

$$V_y = 28\sin 50° - 9.8 \times 4.282$$

$$V_y = -20.51 \text{ ms}^{-1}$$

$V_x = U_x = 28\cos 50° = 18.00\text{ ms}^{-1}$

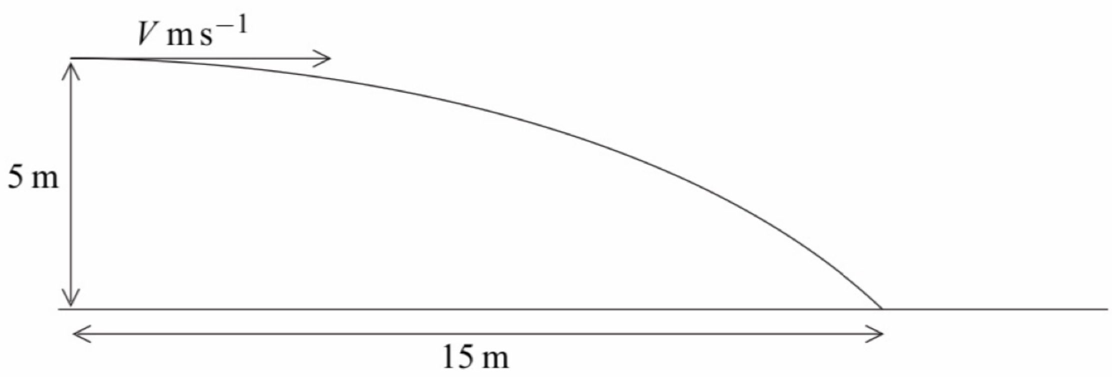
speed $= \sqrt{V_x^2 + V_y^2} = \sqrt{18.00^2 + (-20.51)^2}$




Speed $= 27.3\text{ ms}^{-1}$

Jan 10

**7** A ball is projected horizontally with speed $V \text{ m s}^{-1}$ at a height of 5 metres above horizontal ground. When the ball has travelled a horizontal distance of 15 metres, it hits the ground.




(a) Show that the time it takes for the ball to travel to the point where it hits the ground is 1.01 seconds, correct to three significant figures. *(3 marks)*

(b) Find $V$. *(2 marks)*

(c) Find the speed of the ball when it hits the ground. *(4 marks)*

(d) Find the angle between the velocity of the ball and the horizontal when the ball hits the ground. Give your answer to the nearest degree. *(3 marks)*

(e) State two assumptions that you have made about the ball while it is moving. *(2 marks)*

a) $y - y_0 = u_y t - 4.9t^2$

Hits ground when $y = 0$

Note $u_y = 0$ since projected in a horizontal direction

$0 - 5 = 0 - 4.9t^2$

$4.9t^2 = 5$

$t = \sqrt{\frac{5}{4.9}}$

$t = 1.01015$

**SUVAT Equations**

$v = u + at$

$v^2 = u^2 + 2as$

$s = ut + \frac{1}{2}at^2$

$s = vt - \frac{1}{2}at^2$

$s = \frac{1}{2}(u+v)t$

s – displacement
u – initial velocity
v – final velocity
a – acceleration
t - time

$t = 1.01\text{ s}$ to 3 s.f.

b) $U_x = V_x = V$

$x = U_x t$

On landing $\quad 15 = V \times 1.01015$

$$V = \frac{15}{1.01015} = 14.849$$

$$V = 14.8 \text{ ms}^{-1}$$

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c) $V_x = 14.849 \text{ ms}^{-1}$

$V_y = U_y - 9.8t$

$V_y = 0 - 9.8 \times 1.01015$

$V_y = -9.899 \text{ ms}^{-1}$

$$\text{Speed} = \sqrt{V_x^2 + V_y^2}$$

$$= \sqrt{14.849^2 + (-9.899)^2}$$

$$= 17.846$$

$$\text{Speed} = 17.8 \text{ ms}^{-1}$$

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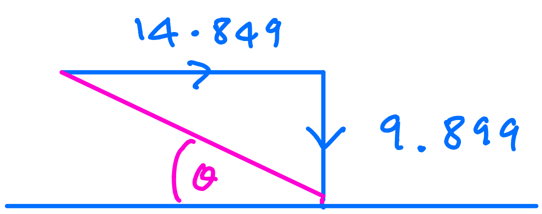
d)




$$\tan\theta = \frac{9.899}{14.849}$$

$$\theta = \tan^{-1}\left(\frac{9.899}{14.849}\right) = 33.69°$$

$\theta = 34°$ to nearest degree

e)

| | | | | |
|---|---|---|---|---|
| **(e)** | Particle<br>Experiences no air resistance **or** no wind **or** only gravity **or** no other forces acting **or** no spin. | B1<br>B1 | 2 | B1: Particle assumption<br>B1: Other assumption.<br>Ignore any other assumptions. |