Projectiles Questions

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1. ***A ball is thrown horizontally from the top of a vertical cliff. The cliff is 50 m high and the ball lands 60 m from the bottom of the cliff.***

   a) *How long does it take for the ball to reach the bottom of the cliff?*

$$
\begin{aligned}
s &= ut + \frac{1}{2}at^2 \\
-50 &= 0 \times t + \frac{1}{2} \times -9.81 \times t^2 \\
\frac{1}{2} \times -9.81t^2 &= -50 \\
\frac{1}{2} \times 9.81t^2 &= 50 \\
9.81t^2 &= 100 \\
t^2 &= 10.19... \\
t &= 3.19\,s \quad (3s.f.)
\end{aligned}
$$

   b) *What is the horizontal speed of the ball?*

$$
\begin{aligned}
v &= \frac{s}{t} \\
&= \frac{60}{3.19...} \\
&= 18.8\,ms^{-1} \quad (3s.f.)
\end{aligned}
$$

   c) *What is the vertical speed of the ball as it lands?*

$$s_v = -50 \quad u_v = 0 \quad v_v = v_v \quad a_v = -9.81 \quad t = 3.19$$

$$
\begin{aligned}
v^2 - u^2 &= 2as \\
v^2 &= u^2 + 2as \\
v &= \sqrt{u^2 + 2as} \\
&= \sqrt{0^2 + 2 \times -9.81 \times -50} \\
&= 31.3\,ms^{-1} \quad (3s.f.)
\end{aligned}
$$

2. ***A scientist wants to find out how fast he can throw a ball. He throws horizontally from a height of 2 m and it lands 20 m away from where he is standing. Calculate the initial velocity of the ball.***

$$s_v = -2 \quad u_v = 0 \quad v_v = ? \quad a_v = -9.81 \quad t_v = t_v$$

$$\begin{aligned} s &= ut + \frac{1}{2}at^2 \\ -2 &= 0 \times t \times \frac{1}{2} \times -9.81 \times t^2 \\ -2 &= \frac{1}{2} \times -9.81 \times t^2 \\ -4 &= -9.81t^2 \\ 9.81t^2 &= 4 \\ t^2 &= \frac{4}{9.81} \\ t &= \sqrt{\frac{4}{9.81}} \\ t &= 0.6385... \; s \end{aligned}$$

$$v_h = v_h \quad s_h = 20 \quad t = 0.6835...$$

$$\begin{aligned} v &= \frac{s}{t} \\ &= 31.3 \; ms^{-1} \quad (3s.f.) \end{aligned}$$

3. ***A tennis ball is hit horizontally from the top of a high building. It takes 4 seconds to reach the ground and it lands 80 m from the building.***

   a) *What is the height of the building?*

$$\begin{aligned} s &= u_v t + \frac{1}{2}at^2 \\ &= 0 \times 4 + \frac{1}{2} \times -9.81 \times 4^2 \\ &= -78.48 \; m \\ \text{height} &= 78.48 \; m \end{aligned}$$

   b) *At what vertical velocity does the ball hit the ground?*

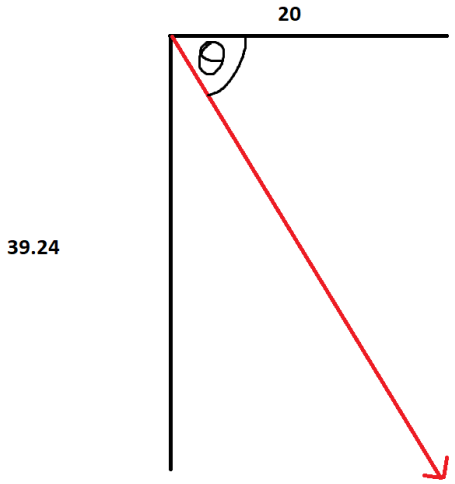
$$\begin{aligned} v &= u + at \\ &= 0 + -9.81 \times 4 \\ &= -39.24 \; ms^{-1} \end{aligned}$$

   c) *What is the horizontal velocity?*

$$\begin{aligned} v_h &= \frac{s_h}{t} \\ &= \frac{80}{4} \\ &= 20 \; ms^{-1} \end{aligned}$$

d) *What is its resultant velocity and at what angle does it hit the ground?*

$$\begin{aligned} v_v &= -39.24 \\ v_h &= 20 \\ v_R &= \sqrt{(-39.24)^2 + 20^2} \\ &= 44.04\, ms^{-1} \end{aligned}$$



$$\begin{aligned} \tan\theta &= \frac{39.24}{20} \\ &= 1.962 \\ \theta &= 63.0^\circ \quad (3s.f.) \end{aligned}$$

$v_R = 44.04\, ms^{-1}$, 63.0° from the horizontal (ground upon impact).

4. ***An object is projected horizontally at a speed of*** $16\, ms^{-1}$ ***into the sea from a cliff top of height 45.0 m. Calculate:***

a) *How long it takes to reach the sea.*

$$s_v = -45 \quad u_v = 0 \quad v_v = v_v \quad a_v = -9.81 \quad t = t$$

$$\begin{aligned} s_v &= u_v t + \frac{1}{2} a_v t^2 \\ -45 &= 0 \times t + \frac{1}{2} \times -9.81 \times t^2 \\ -45 &= \frac{1}{2} \times -9.81 \times t^2 \\ -90 &= -9.81 t^2 \\ 9.81 t^2 &= 90 \\ t^2 &= 9.17... \\ t &= 3.03\, s \quad (3s.f.) \end{aligned}$$

b) *How far it travels horizontally.*

$$\begin{aligned} v_h &= \frac{s_h}{t} \\ s_h &= v_h \times t \\ &= 16 \times 3.03... \\ &= 48.5\,m \quad (3s.f.) \end{aligned}$$

c) *Its impact vertical velocity.*

$$\begin{aligned} s_v = -45 \quad u_v = 0 \quad v_v = v_v \quad a_v = -9.81 \quad t = t \\ v_v^2 - u^2 &= 2as \\ v_v^2 &= u^2 + 2as \\ v_v &= \sqrt{u^2 + 2as} \\ &= \sqrt{0 + 2 \times -9.81 \times -45} \\ &= 29.7\,ms^{-1} \quad (3s.f.) \end{aligned}$$