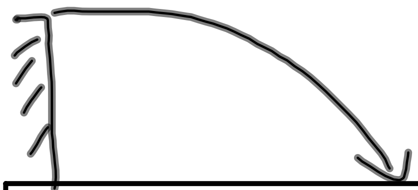
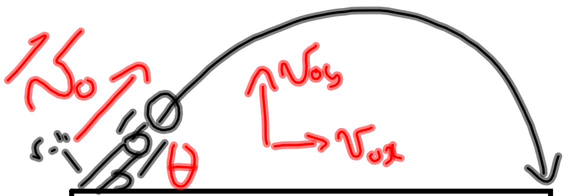
Projectile Motion

An object that is launched into the air and then comes under the influence of gravity moves in two dimensions (up/down and forward) and is called a projectile. The path taken by the projectile is called a trajectory.



Horizontally Launched Projectile



Projectile Launched At An Angle

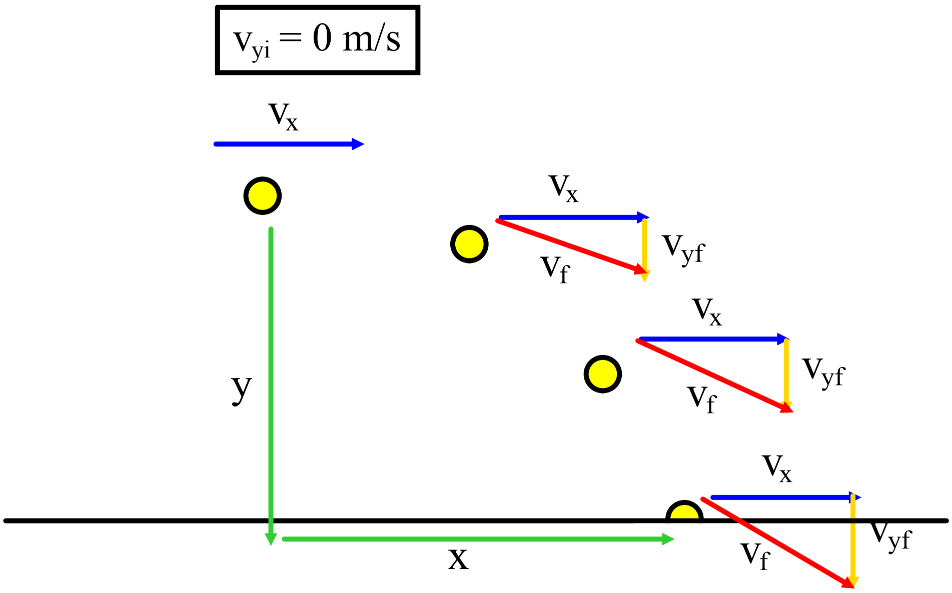
The vertical and horizontal motion of a projectile are independent of one another.

Horizontal Motion -> The horizontal velocity of a projectile is constant (ignoring air resistance).

Vertical Motion-> The vertical velocity of a projectile is constantly changing due to gravity.

Projectile Fired Horizontally

Imagine the trajectory of a ball launched horizontally from the top of a cliff.



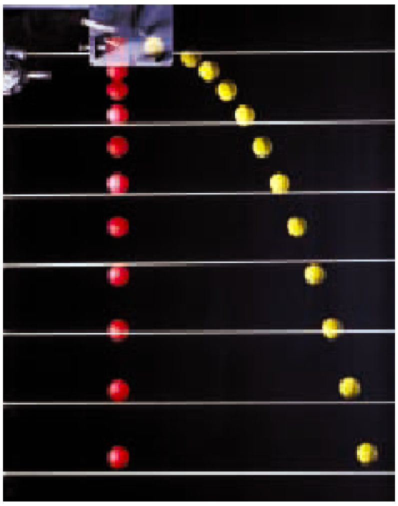
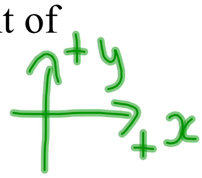


Figure 11.2 You can see that the balls are accelerating downward, because the distances they have travelled between flashes of the strobe light are increasing. If you inspected the horizontal motion of the ball on the right, you would find that it travelled the same horizontal distance between each flash of the strobe light.

<u>Example</u>: A projectile is fired horizontally from a height of 44.1 m at a speed of 50.0 m/s.



a) How long after it was fired, did the projectile hit the ground? (3.00 s)

b) How far forward did the projectile travel? (150 m)

a) $\vec{d}_0 = 44.1\text{m}$

$\vec{v}_0 = 50.0\text{m/s}$ ← all velocity is x-dir.

$d_{fy} = d_{oy} + v_{oy}t + \frac{1}{2}a_y t^2$ ($v_{oy} \to 0$)

$0 = 44.1 + 0 + \frac{1}{2}(-9.81)t^2$

$0 = 44.1 - 4.905t^2$

$-44.1 = -4.905t^2$

$\frac{-44.1}{-4.905} = t^2$

$9 = t^2$ → $\sqrt{9} = \sqrt{t^2}$

$\boxed{3.0 = t}$

b) $\vec{d}_x = ?$ $\quad \vec{v}_x = \frac{\vec{d}_x}{t}$ $\left\{ \vec{v}_{avg} = \frac{\vec{d}}{t} \right.$

$d_{ox} = 0, d_{fx} = ?$

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$50\text{ m/s} = \frac{d_x}{3.0\text{s}}$

$\boxed{150\text{m} = d_x}$

Example: A stone is thrown horizontally at a speed of 5.0 m/s from the top of a cliff that is 78.4 m high.

a) How long does it take the stone to reach the bottom of the cliff? (4.0 s)
b) How far from the bottom of the cliff does the stone land? (20 m)
c) What is the velocity of the stone as it hits the ground? (40 m/s, E 83° S)

~~Text: Page 536, PP #1-8~~

a) $d_{fy} = d_{oy} + v_{oy}t + \frac{1}{2}gt^2$

$0 = 78.4 + \frac{1}{2}(-9.81)t^2$

$-78.4 = -4.905\,t^2$

$16 = t^2$

$\boxed{4.0\,s = t}$

b) $d_x = ?$ $\quad v_x = \frac{d_x}{t} \Rightarrow 5 = \frac{d_x}{4s}$

$\boxed{d_x = 20\,m}$

c) find $v_{fy} = ?$

$t = 4.0\,s \quad g = -9.81\,m/s^2$

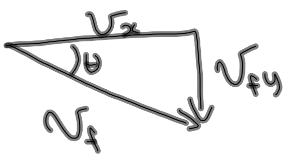
$v_{oy} = 0\,m/s$

$a = \frac{v_{fy} - v_{oy}}{t}$

$-9.81 = \frac{v_{fy} - 0}{4}$

$-9.81 \times 4 = v_{fy}$

$-39.24\,m/s = v_{fy}$



$v_f = \sqrt{v_x^2 + v_{fy}^2}$

$v_f = \sqrt{(5)^2 + (-39.24)^2}$

$v_f = 39.3\,m/s$

$\theta = \tan^{-1}\left|\frac{v_{fy}}{v_x}\right|$

$\theta = \tan^{-1}(7.848)$

$\theta = 83^\circ$

$v_f = 39.3\,m/s\ [E\ 83^\circ S]$

or $v_f = 39.3\,m/s$, 83° below x-axis

Pg 20 #1-4