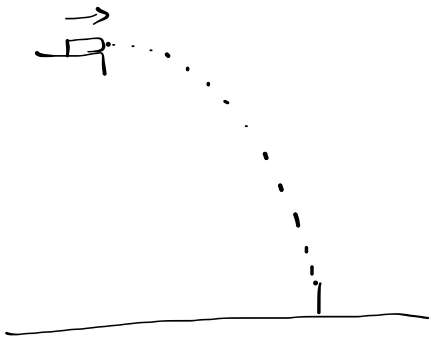
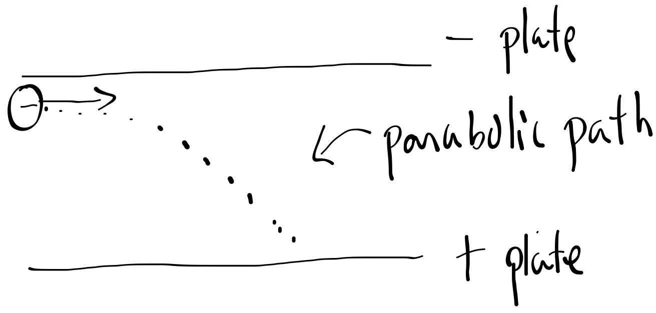
Projectile Motion

A projectile is any body that is given an initial velocity and follows a path determined by the effect of a gravitational field and by air resistance.

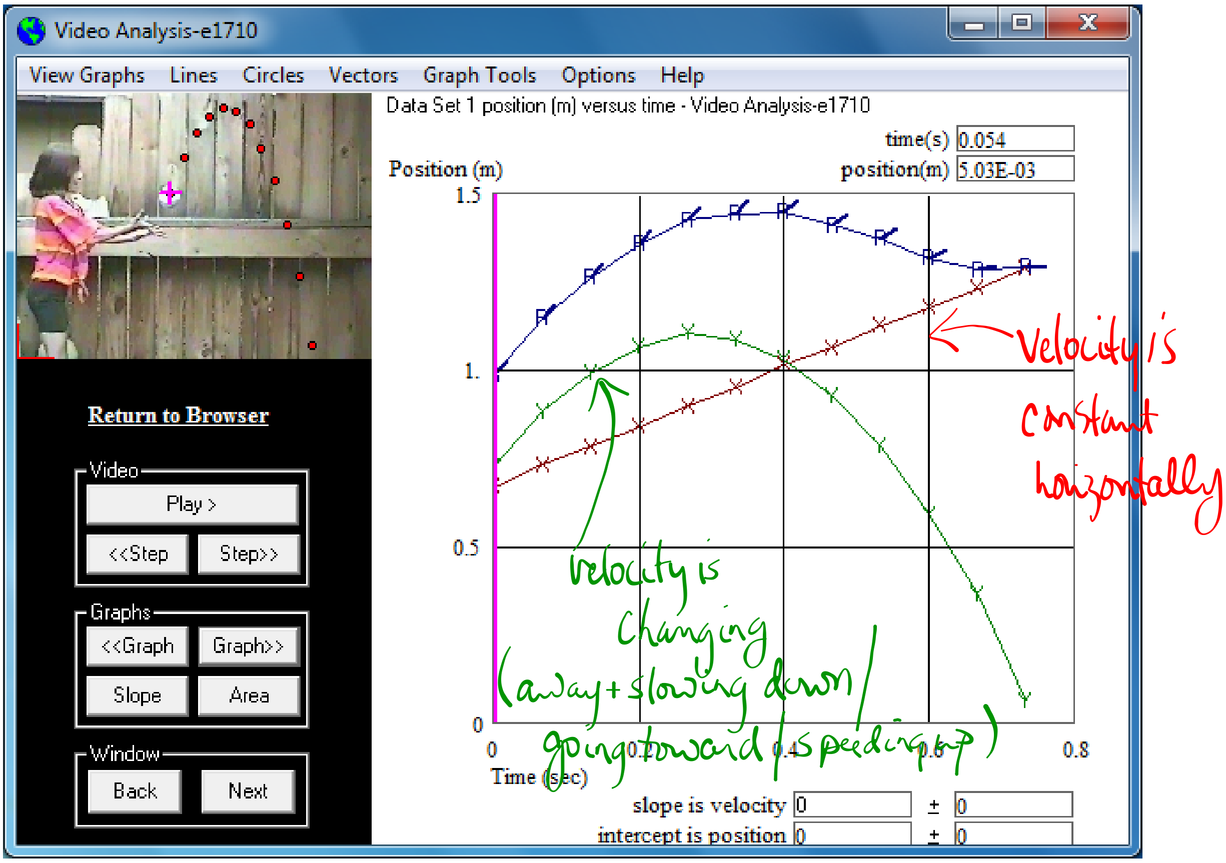
In the absence of air resistance, the path of the projectile is parabolic.

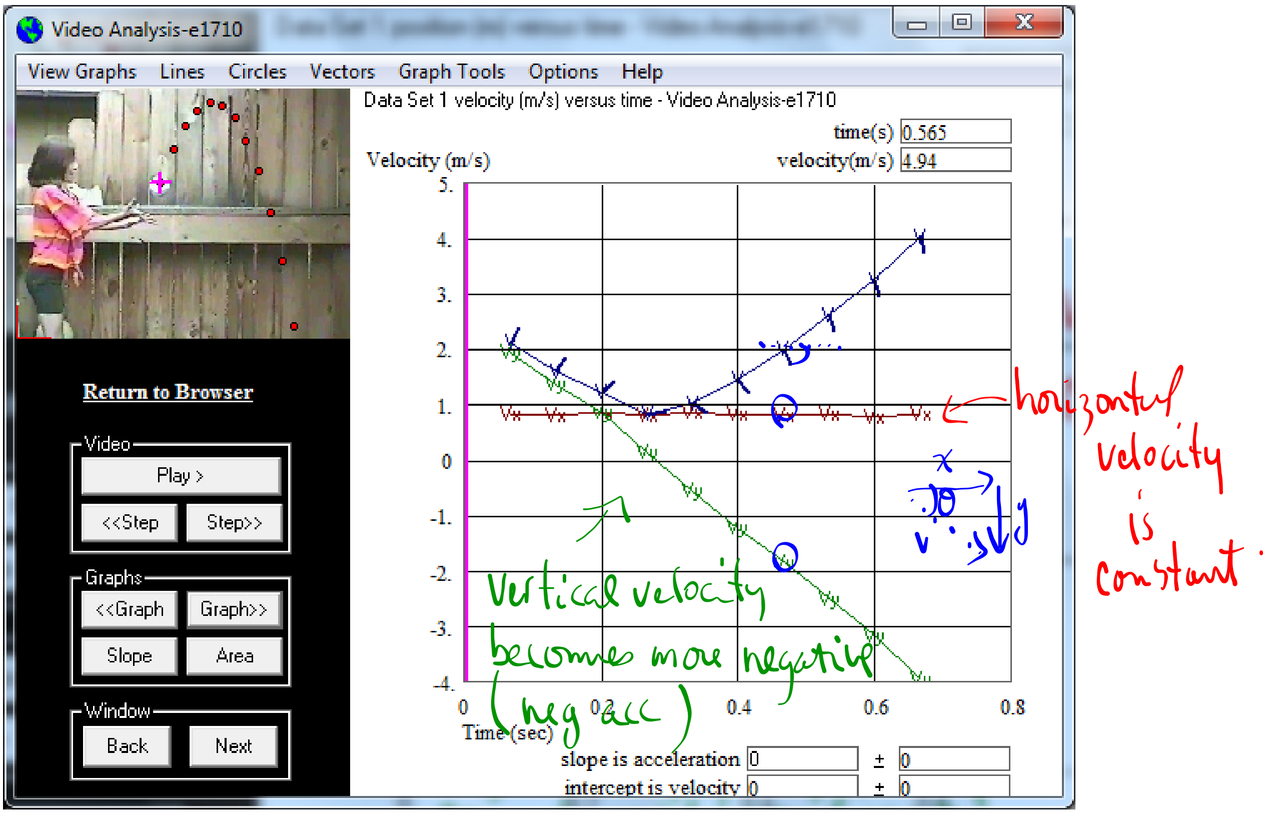


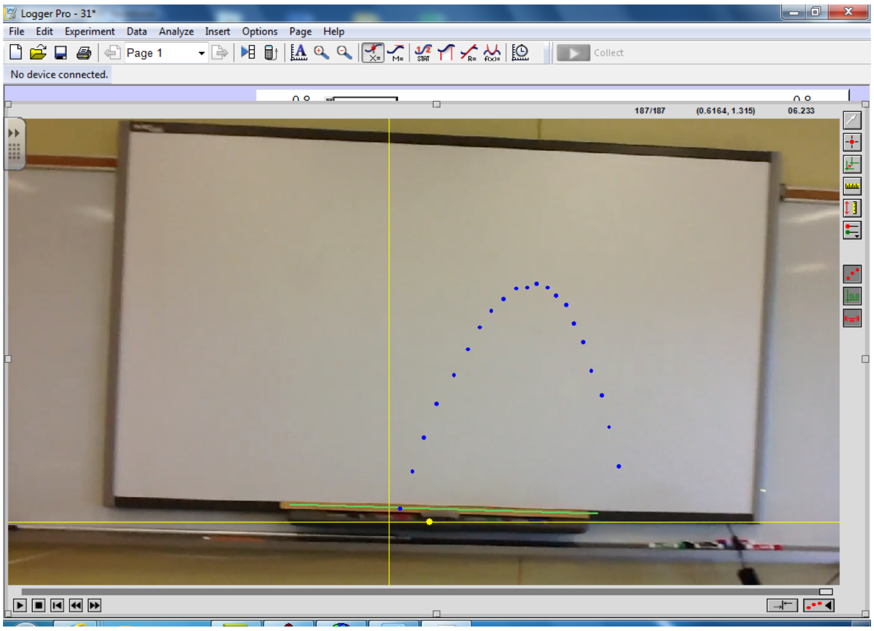
Parabolic motion results whenever an object is moving under the action of a force which is constant in both magnitude and direction. (i.e. force of gravity)

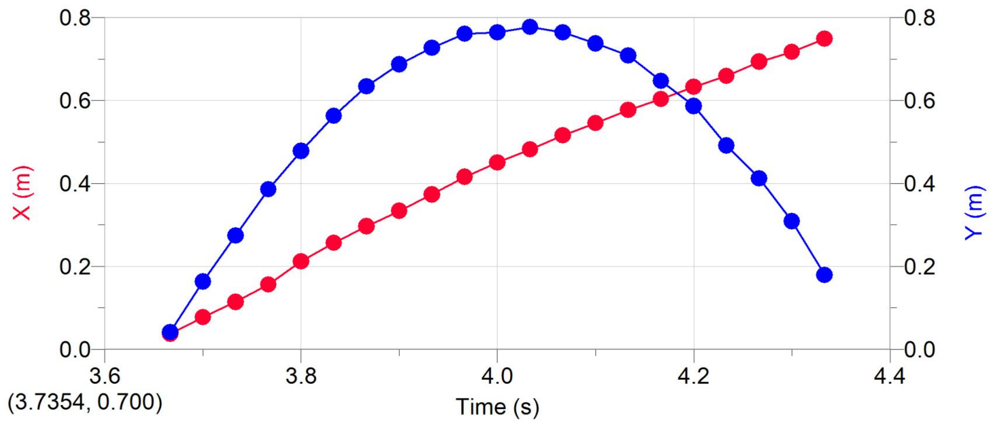


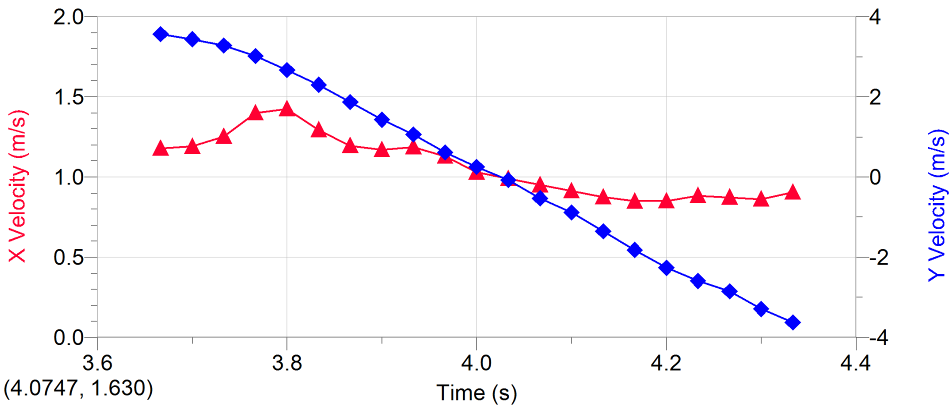
* In a uniform field, the horizontal and vertical components of velocity are independent.


Video Analysis-e1710
View Graphs Lines Circles Vectors Graph Tools Options Help
Data Set 1 position (m) versus time - Video Analysis-e1710
time(s) 0.054
position(m) 5.03E-03
Position (m)
Time (sec)
slope is velocity 0 ± 0
intercept is position 0 ± 0
Return to Browser
Video
Play >
<<Step Step>>
Graphs
<<Graph Graph>>
Slope Area
Window
Back Next
Velocity is constant horizontally
velocity is changing
(away + slowing down / going toward / speeding up)


Video Analysis-e1710
View Graphs Lines Circles Vectors Graph Tools Options Help
Data Set 1 velocity (m/s) versus time - Video Analysis-e1710
time(s) 0.565
velocity(m/s) 4.94
Velocity (m/s)
Time (sec)
slope is acceleration 0 ± 0
intercept is velocity 0 ± 0
Return to Browser
Video
Play >
<<Step Step>>
Graphs
<<Graph Graph>>
Slope Area
Window
Back Next
horizontal velocity is constant.
Vertical velocity becomes more negative
(neg acc)


Logger Pro - 31*
File Edit Experiment Data Analyze Insert Options Page Help
Page 1
Collect
No device connected.


X (m)
Y (m)
Time (s)
(3.7354, 0.700)


X Velocity (m/s)
Y Velocity (m/s)
Time (s)
(4.0747, 1.630)

For projectile motion:

horizontally, the velocity is constant : $v = \frac{\Delta d}{\Delta t}$

vertically, there is constant acceleration ($a = -9.81\,m/s^2$)

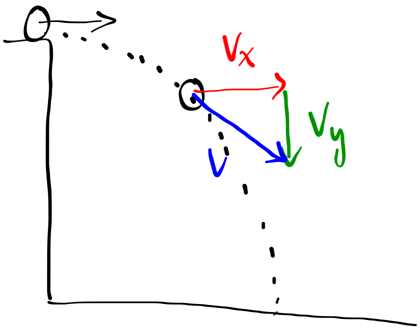
$a = \frac{\Delta v}{\Delta t}$ and "suvat" equations

* (1) $v = u + at$
* (2) $s = \left(\frac{u+v}{2}\right)t$
* (3) $v^2 = u^2 + 2as$
* (4) $s = ut + \frac{1}{2}at^2$

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

Example

An object is launched horizontally with a speed of $8.0 ms^{-1}$ from the edge of a cliff. What is the velocity of the object 1.2s after launch?



Horizontally, the velocity stays constant so

$$V_x = 8.0 ms^{-1}$$

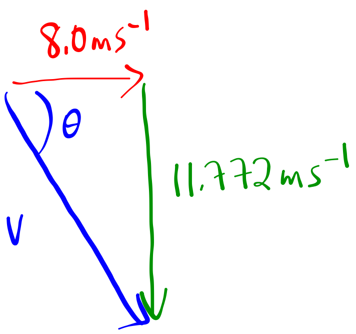
Vertically, there is constant acceleration:

$u = 0$

$a = -9.81 ms^{-2}$

$t = 1.2 s$

$v = ?$



$$v = u + at$$

$$v = 0 + (-9.81 ms^{-2})(1.2 s)$$

$$v = -11.772 ms^{-1}$$

$$v^2 = (8.0)^2 + (11.772)^2$$

$$v = 14 ms^{-1}$$

magnitude

$$\tan\theta = \frac{11.772}{8.0}$$

$$\theta = 56^\circ$$ ← direction

The velocity of the object is $14 ms^{-1}$, 56° below horizontal.

Example

An object is thrown with a speed of 5.0 ms^{-1} at an angle of 30° upwards. Neglecting air resistance, calculate:

a) the maximum height reached

b) the time taken to reach max height

c) the time to return to the initial level

Find the horizontal (V_x) and vertical (V_y) components of the initial velocity.

$V_x = V\cos\theta = (5.0ms^{-1})(\cos 30°) = 4.3\ ms^{-1}$ ← constant

$V_y = V\sin\theta = (5.0ms^{-1})(\sin 30°) = 2.5\ ms^{-1}$ ← changing.

a) max height:

$u = 2.5ms^{-1}$

$v = 0$ (at max height)

$a = -9.81ms^{-2}$

$S = ?$

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

$v^2 - u^2 = 2as$

$s = \frac{\cancel{v^2}^{\,0} - u^2}{2a}$

$S = \frac{-u^2}{2a}$

$S = \frac{-(2.5)^2}{2(-9.81)}$

$S = 0.32\ m$

b) how long to reach max height?

$V = 0$

$u = 2.5ms^{-1}$

$S = 0.32m$

$a = -9.81ms^{-2}$

$t = ?$

$a = \frac{\Delta V}{t}$

$t = \frac{\Delta V}{a}$

$t = \frac{v-u}{a}$

$t = \frac{0 - 2.5ms^{-1}}{-9.81ms^{-2}}$

$t = 0.25\ s$

c) time to return to same level is double the time to reach max height due to the symmetry

$2(0.25s) = 0.51\ s$

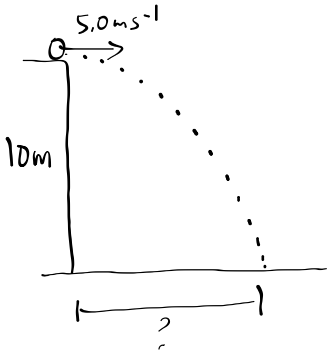
Example

A ball is thrown with a speed of $5.0\,ms^{-1}$ horizontally from a cliff 10 m high. Neglecting air resistance, determine:

a) the time for the ball to reach the ground.

b) the distance from the cliff where the ball lands.

c) the velocity just before it lands.



a) time to reach the ground (vertical motion is what's important)

$u = 0$

$s = -10\,m$

$a = -9.81\,ms^{-2}$

$t = ?$

$$s = \cancel{ut}^{\,0} + \frac{1}{2}at^2$$

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

$$t^2 = \frac{2s}{a}$$

$$t = \sqrt{\frac{2s}{a}}$$

$$t = \sqrt{\frac{2(-10\,m)}{-9.81\,ms^{-2}}}$$

$$t = 1.4\,s$$

b) how far horizontally?
(velocity is constant)

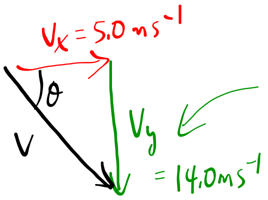
$$v = \frac{\Delta d}{t}$$

$$\Delta d = vt$$

$$\Delta d = (5.0\,ms^{-1})(1.4\,s)$$

$$\Delta d = 7.1\,m$$

c) velocity just before landing:



final vertical velocity

$u = 0$

$v = ?$

$t = 1.4\,s$

$a = -9.81\,ms^{-2}$

$$v = u + at$$

$$v = 0 + (-9.81\,ms^{-2})(1.4\,s)$$

$$v = -14.0\,ms^{-1}$$

$15\,ms^{-1}$ $70°$ below the horizontal