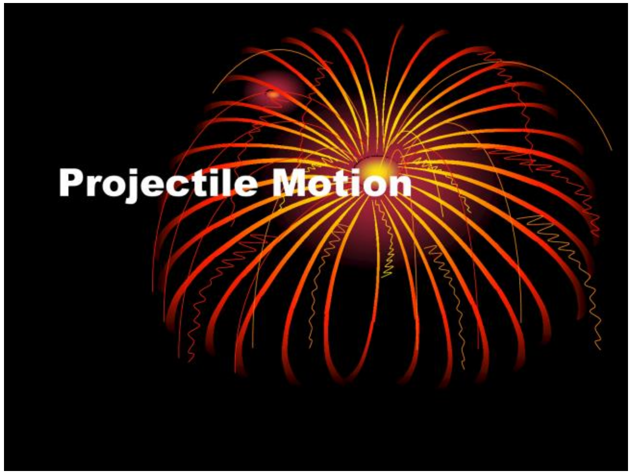
4.1 – Projectile Motion



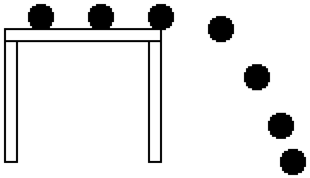
Please pick-up a new packet and worksheet!!!

Projectile Motion

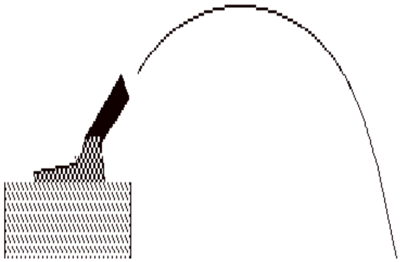
A projectile is any object that moves through the air or space, acted on only by gravity (and air resistance, if any).

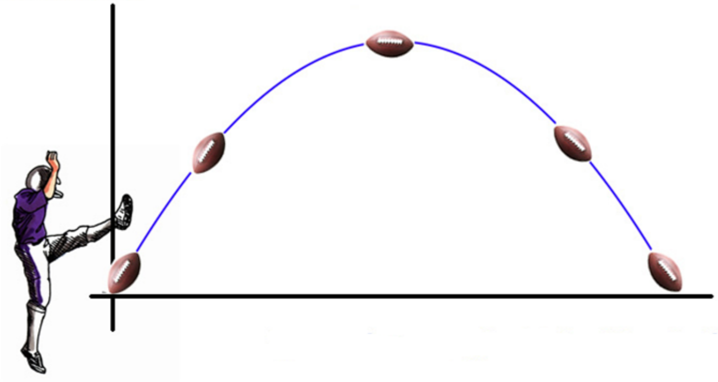
Projectile Motion

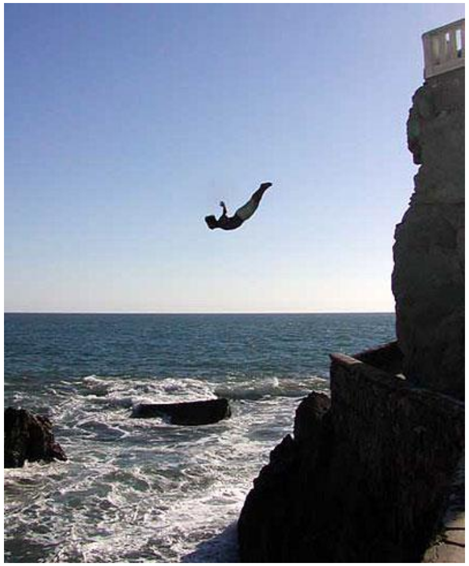
<u>Examples of projectiles:</u>



a. A cannonball shot from a cannon
b. A football that has been kicked
c. A ball rolling off the edge of a table
d. Diver jumping from a cliff







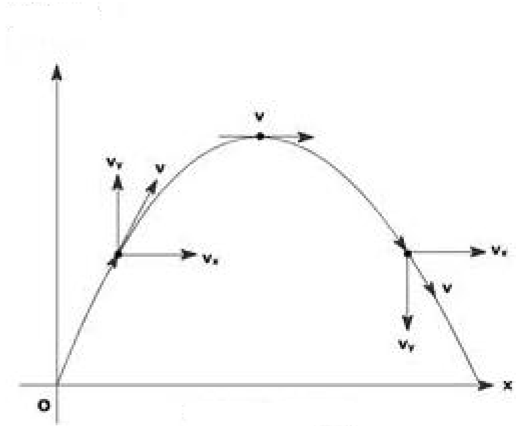
Projectile Motion

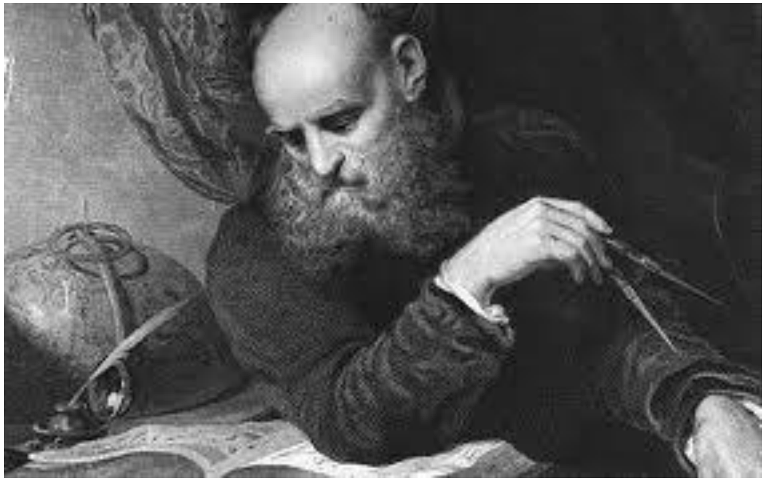
There are two general types of projectile motion situations:

1. Object launched horizontally
2. Object launched at an angle

Projectile Motion

Galileo, early in the 17th century, realized that the components of motion **are separate.**





Projectile Motion

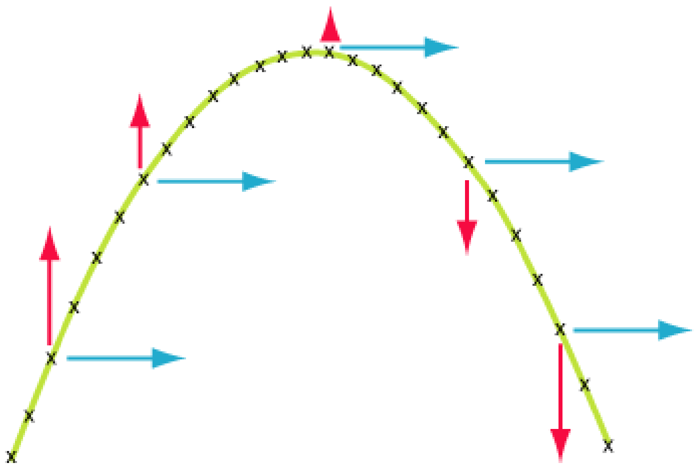
Projectiles near the surface of Earth follow a curved path that at first seems rather complicated.

These paths are surprisingly simple when we look at the horizontal and vertical components of motion separately.

Projectiles move in TWO dimensions

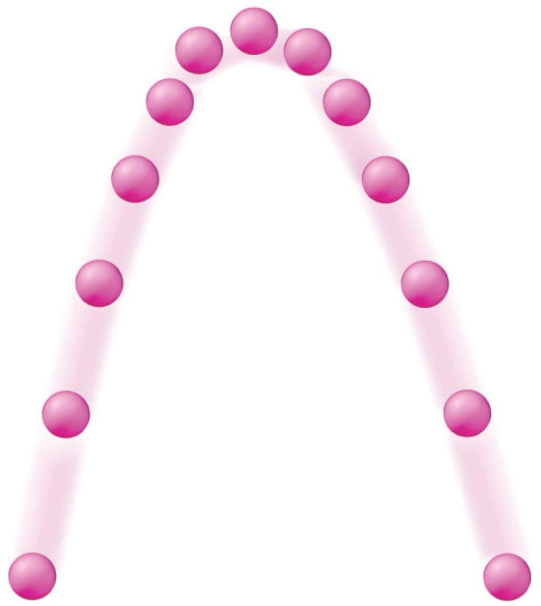
Since a projectile moves in 2-dimensions, it therefore has 2 components just like a resultant vector:

1. **Horizontal**
2. **Vertical**



Projectile Motion

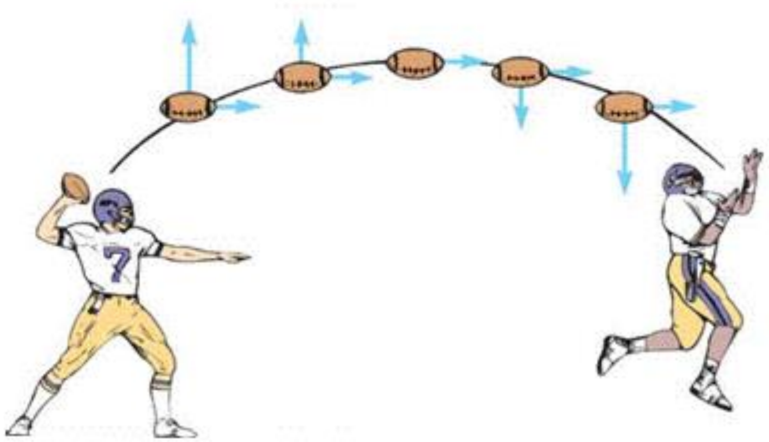
So far we have studied simple straight-line motion - linear motion. Now we extend these ideas to nonlinear motion - motion along a curved path.



Projectile Motion

Throw a football and the path it follows is a combination of:

a. constant-velocity horizontal motion (Gravity free)
b. accelerated vertical motion (Gravity)



Projectile Motion

Most important, the horizontal component of motion for a projectile is completely independent of the vertical component of motion.

Each component is independent of the other. Their combined effects produce the variety of curved paths that projectiles follow.

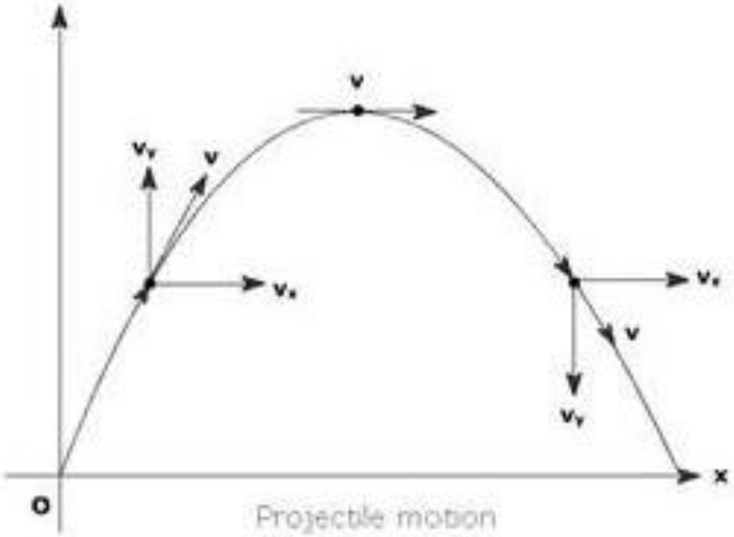
CONCEPT CHECK

Describe the components of projectile motion.

Horizontal: Constant velocity (Gravity Free)
Vertical: Accelerated motion (Gravity)

Horizontal "Velocity" Component

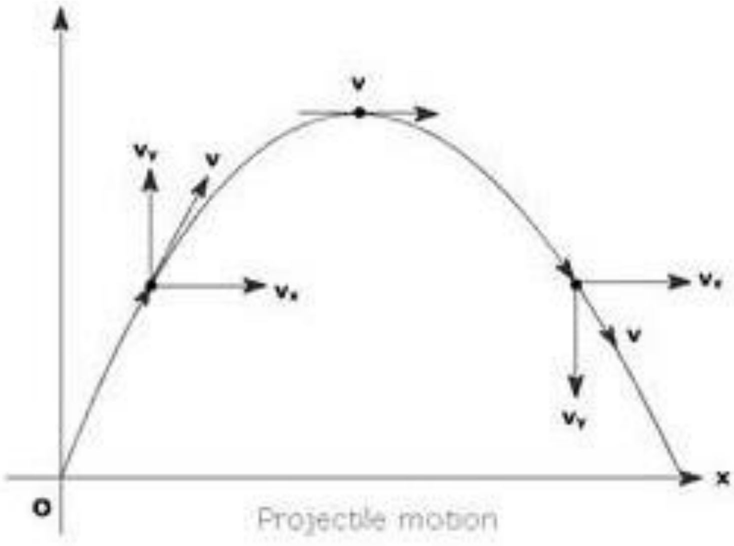
Horizontal Component



Horizontal "Velocity" Component

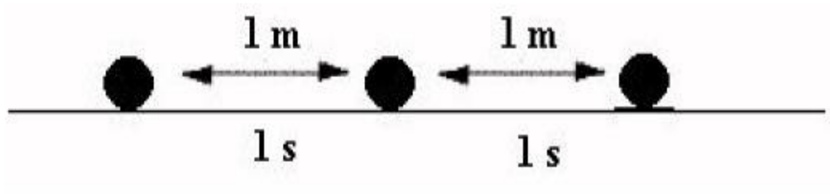
Horizontal Component

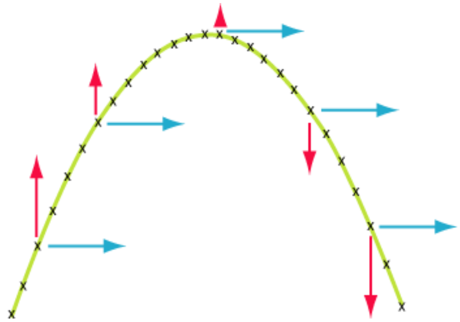
The horizontal component of motion for a projectile is just like the horizontal motion of a ball rolling freely along a level surface without friction.



Horizontal "Velocity" Component

The horizontal "velocity" component **NEVER** changes. This means the initial horizontal velocity (V_{ix}) equals the final horizontal velocity (V_{fx}) in the x-direction.



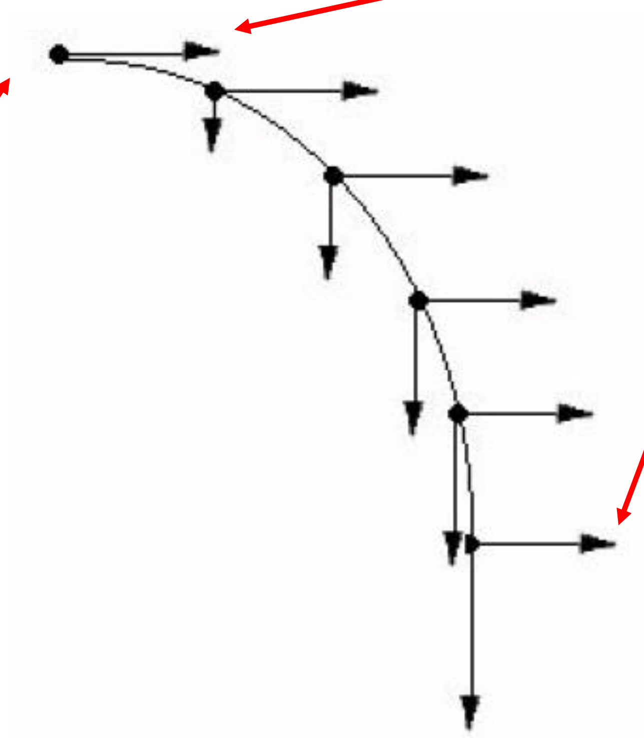


In other words, the horizontal velocity is always **constant**. But Why????

Gravity **does not** work horizontally to increase or decrease the velocity.

Horizontal “Velocity” Component

Projectiles which have NO upward trajectory and NO initial VERTICAL velocity.



$v_{ix} = v_{fx} = \text{constant}$

$v_{iy} = 0 \text{ m/s}$

Horizontal "Velocity" Component

To analyze a projectile in 2 dimensions we need 2 equations. One for the "horizontal" direction and one for the "vertical" direction. For the horizontal direction, we will only use one kinematic equation.

$$d_x = V_{ix}t + \tfrac{1}{2} a_x t^2$$

$d_x = V_{ix}t$	$a_x = 0$

Remember, the velocity is CONSTANT horizontally, so that means the acceleration is ZERO!

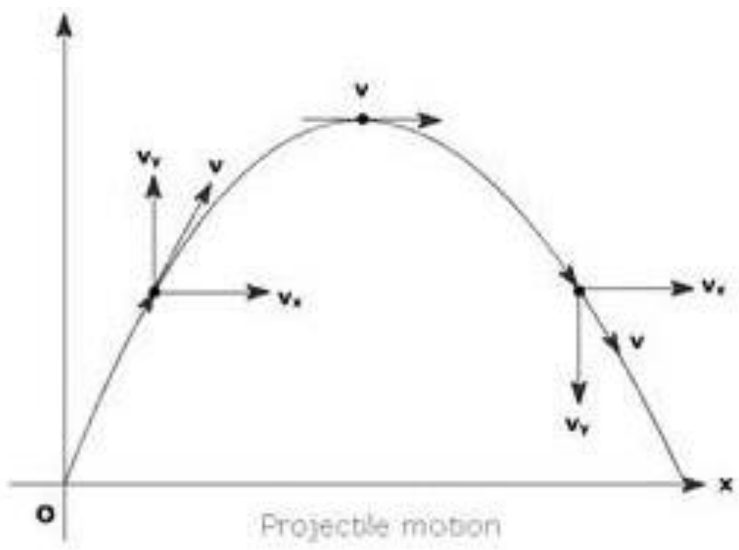
CONCEPT CHECK

Describe the horizontal motion of a horizontally launched projectile.

Constant velocity – Never changes
Initial Velocity = Final Velocity

Horizontal "Velocity" Component

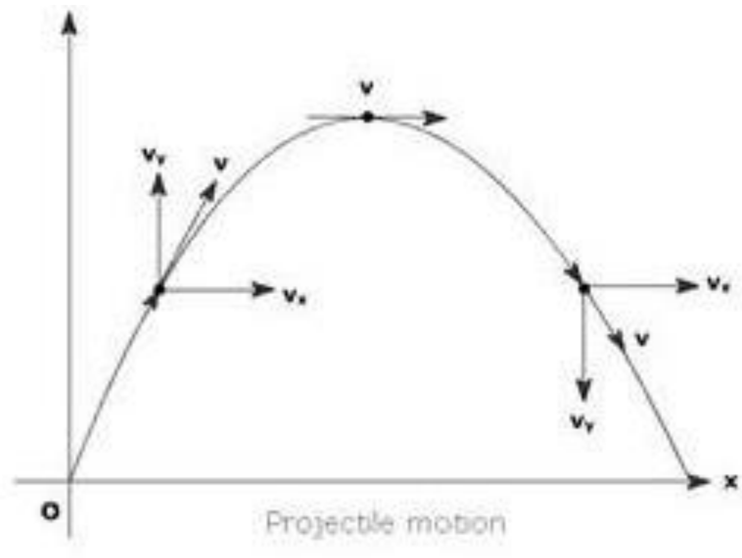
Vertical Component



Vertical "Velocity" Component

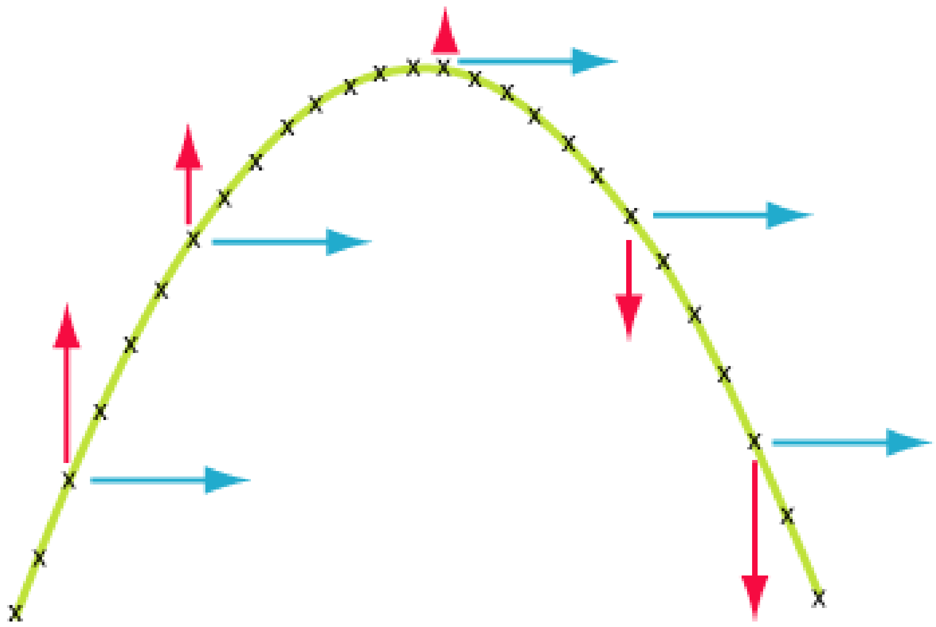
Vertical Component

The vertical component of a projectile's velocity is like the motion for a freely falling object.



Vertical "Velocity" Component

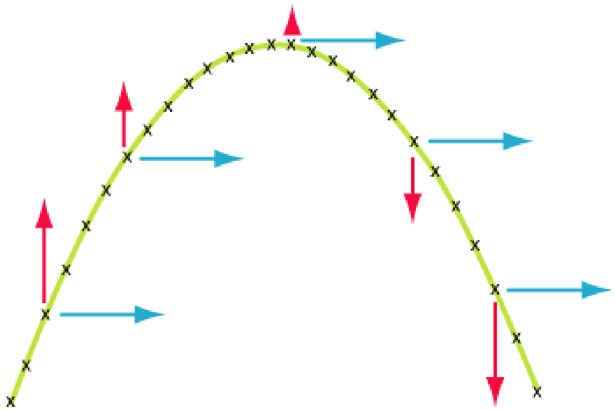
As with free fall, changes (due to gravity), does **NOT** cover equal displacements in equal time periods.



Vertical "Velocity" Component

Both the magnitude and direction change.

- As the projectile moves up the magnitude decreases and its direction is upward.
- As it moves down the magnitude increases and the direction is downward.



Vertical "Velocity" Component

For the "vertical" direction, we will use all the kinematic equations:

$$V_{fy} = V_{iy} + a_y \Delta t$$

$$\Delta d_y = V_{iy}\Delta t + \tfrac{1}{2} a_y \Delta t^2$$

$$\Delta d_y = \frac{1}{2}(V_{iy} + V_{fy})\Delta t$$

$$V_{fy}{}^2 = V_{iy}{}^2 + 2a_y \Delta d$$

$$\Delta d_y = V_{fy}\Delta t - \tfrac{1}{2} a_y \Delta t^2$$

Vertical “Velocity” Component

Note:

When using the kinematic equations for projectile motion problems, we need to use the horizontal and vertical solutions together. Typically you will needs to solve one and use this information to solve the information in the other.

Time is the same for both horizontal and vertical equations.

Projectile Motion – Assessment Questions

Question #1

When no air resistance acts on a projectile, its horizontal acceleration is:

a. "g"
b. at right angles to "g"
c. upward, "g"
d. zero

Projectile Motion – Assessment Questions

Question #1

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Projectile Motion – Assessment Questions

Question #2

A car runs off a 30 m cliff at 50 m/s.

a. How long it will take the car to hit the ground?
b. Where does the car land relative to the cliff?
c. What is the velocity when the car hits the ground?

a. $t = 2.47$ seconds
b. $d_x = 123.5$ meters
c. 55.58 m/s @ 25.88º below horizontal

Projectile Motion – Assessment Questions

Question #3

A ball is thrown horizontally at a speed of 24 m/s from the top of a cliff. If the ball hits the ground 4 seconds later, approximately how high is the cliff?

d_y = 78.48 meters

Projectile Motion – Assessment Questions

Question #4

A plane is flying horizontally with a speed of 340 m/s at a height of 7,200 m. If the plane drops a bomb, find the following:

a. **How long it will take the bomb to hit the ground?**
b. **How far the bomb will land relative to the release point?**
c. **What is the final velocity when the bomb hits the ground?**

a. **38.31 seconds**
b. **13,025.4 meters**
c. **506.82 m/s @ 47.87° below horizontal**