Name: ____________________

Period: ____________________

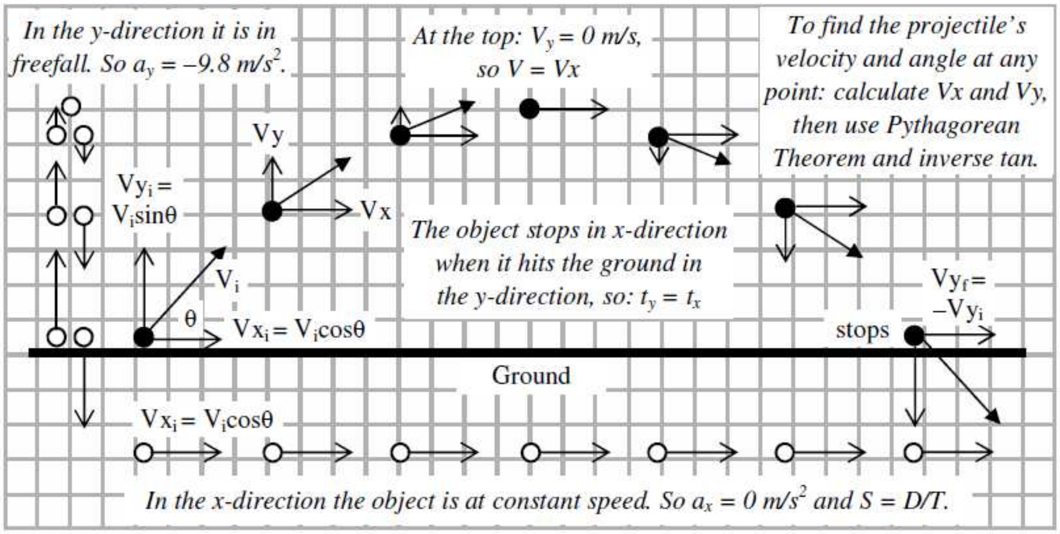
Projectile Motion

2.5

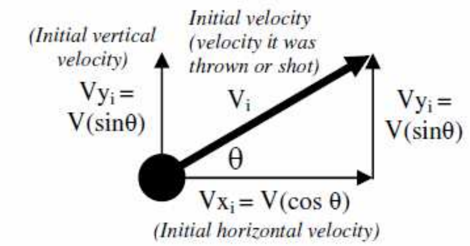
*A projectile is any thrown, shot, or launched object: a rock; a bullet; a volleyball; a person jumping. All projectiles follow a **parabolic path**. The distance a projectile travels in the x-direction is known as its **range**.*

If you took several quick pictures of a projectile in flight you would notice that in the y-direction it looks just like freefall—being pulled back to the earth by gravity.

In the x-direction you would see that the object is at constant speed, moving the same distance each second.

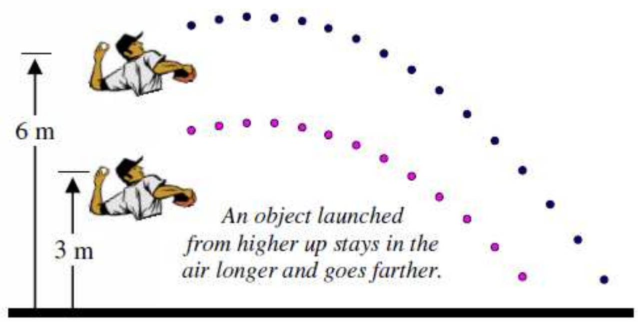


Just as with any vector, the x and y-components of the initial velocity can be found using sine and cosine.



If an object is launched horizontally, the initial vertical velocity is 0 m/s.

Time Comes From the Y-direction



You know that if you throw a rock from up on a cliff, it will go farther than if you were on the ground. This is because the higher up you are, the longer the rock is in the air. Flight time is dependent on the y-direction only!

Solving Projectile Motion Problems

Any projectile motion problem can be easily solved if you : 1) draw the situation; 2) write out what you know in the x and y-directions; 3) solve for unknowns.

Use your "Freefall" notes to help you assign the y-direction variables. Just as in all freefall problems, you will use one of the kinematic equations to calculate unknowns.

The accelerations will ALWAYS be $-9.8\ m/s^2$ and $0\ m/s^2$.

y–direction

$a_y = -9.8\ m/s^2$

$V_i = 0$ m/s

V_f = not used

$\Delta y = -8$ m

t = ?

$$\Delta y = (v_i t) + \left(\frac{1}{2}a(t)^2\right)$$

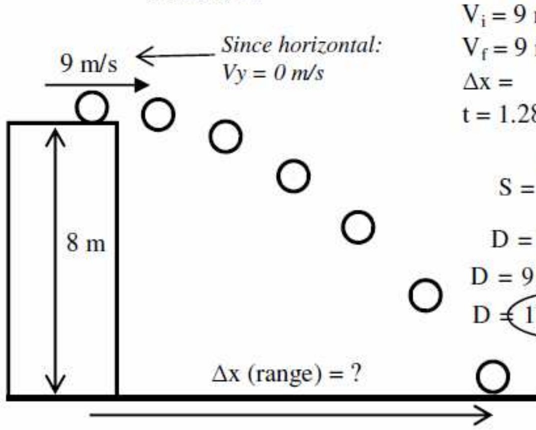
$$-8 = (0t) + \left(\frac{1}{2}(-9.8)(t)^2\right)$$

$$-8 = -4.9t^2$$

$$t^2 = \frac{-8}{-4.9} = 1.63$$

$$t = \sqrt{1.63} = 1.28 \text{ sec}$$

Often you will solve for time in the y-direction.



x–direction

$a_x = 0\ m/s^2$

$V_i = 9$ m/s

$V_f = 9$ m/s

Because it's at constant velocity

Δx =

t = 1.28 sec ← *From the y-direction*

$$S = \frac{D}{T}$$

$$D = ST$$

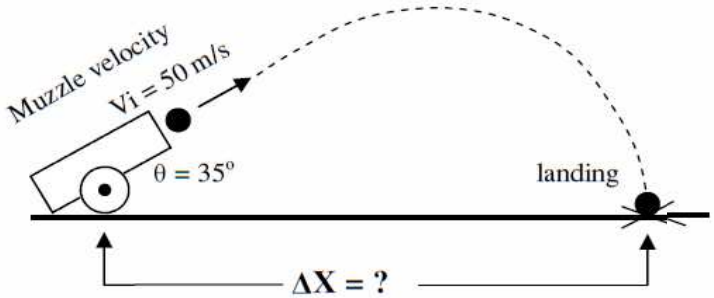
$$D = 9(1.28)$$

$$D = 11.5 \text{ m}$$

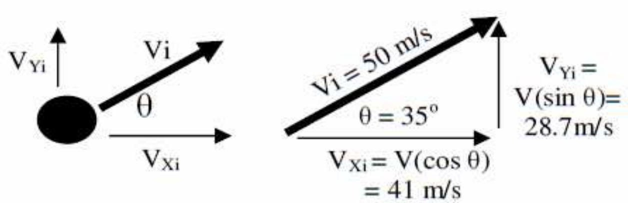
Since the x-direction is at constant speed, you can ALWAYS use S = D/T for your x-direction equation.

Projectile Motion Example

Problem: A cannon fires a cannonball. If the cannon's angle is 35° to the ground and the muzzle velocity is 50 m/s, what is the range of the cannonball?



Step 1: Resolve V into Vx and Vy



X-component
$V_X = V(\cos\theta)$
$V_X = 50m/s(\cos 35^\circ)$
$\mathbf{V_X = 41m/s}$

Y-component
$V_Y = V(\sin\theta)$
$V_Y = 50m/s(\sin 35^\circ)$
$\mathbf{V_Y = 28.7m/s}$

Step 2: Find time from the y-direction.

In the y-direction, the cannonball is in freefall.

Write the variables you know:

$\mathbf{a_y = -9.8\ m/s^2}$
$\mathbf{Vi = V_y = V\sin\theta = 28.7m/s}$ *(see step 1)*
$\mathbf{Vf = -Vi = -28.7m/s}$
$\mathbf{\Delta Y = 0m}$ *(from ground to ground)*
$\mathbf{\Delta t = ?}$

Choose one of the kinematic equations:

$$\Delta y = \frac{1}{2}(v_i + v_f)t \qquad \Delta y = v_f t - \left(\frac{1}{2}at^2\right)$$
$$v_f = v_i + (at)$$
$$\Delta y = v_i t + \left(\frac{1}{2}at^2\right) \qquad v_f^{\,2} = v_i^{\,2} + (2a\Delta y)$$

Since you have all of the variables, you can use any formula. So use the easiest one:

$\mathbf{v_f = v_i + (at)}$

Put in what you know:

$-28.7 = (28.7) + (-9.8t)$
$-28.7 \quad -28.7$

$-57.4 = -9.8t$
$\div$ by -9.8

$\mathbf{t = 5.8\ sec}$

Step 3: Find Δx from the x-direction.

In the x-direction, the cannonball travels at constant velocity: Vx, the x-component of the velocity. The time of flight we just found in the y-direction.

Write the variables you know:

$\mathbf{a_x = 0\ m/s^2}$
$\mathbf{V_i = V_f}$
$\mathbf{V_x = V\cos\theta = 41\ m/s}$ *(see step 1)*
$\mathbf{t = 5.8\ sec}$ (from y [*see step 2]*)
$\mathbf{\Delta x = ?}$

$$S = \frac{D}{T}$$

Since $a_x = 0\ m/s^2$

$$S = \frac{D}{T}$$
$$D = ST$$
$$D = 41(5.8)$$

RANGE → $\mathbf{\Delta x = 237.8\ m}$

By knowing only the launch velocity and angle, you can calculated that the cannon-ball traveled 237.8 meters in 5.8 seconds.

This is the most basic of all projectile motion problems: from the ground-to-the-ground (A to E). Steps 1 and 3 will ALWAYS be the same. Step 2 is just freefall and will change according to the situation.