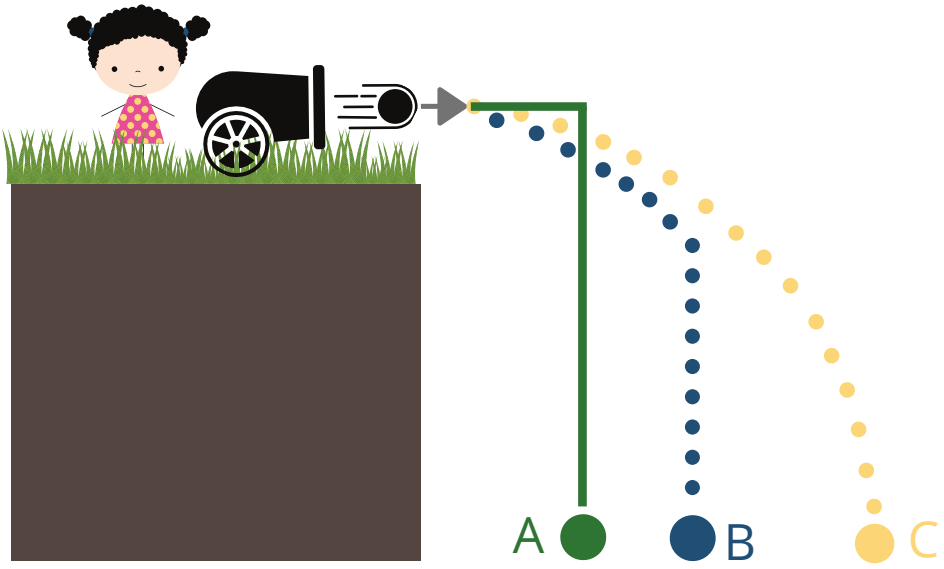
Projectile Motion

Imagine you are on the edge of a cliff, and you just happen to have a cannon. (Don't ask me where you got it.) You fire a cannonball, horizontally, off of the cliff. (Don't ask me why.) Which path will it follow? A, B, or C?



Most people guess either A or B. Researchers call this the Wile E Coyote effect, because this is what happens to Wile E Coyote when he runs off a cliff. He runs off the cliff, stops mid-air for a second, blinks, and then drops straight down. It's hilarious. But it's not how movement really works.

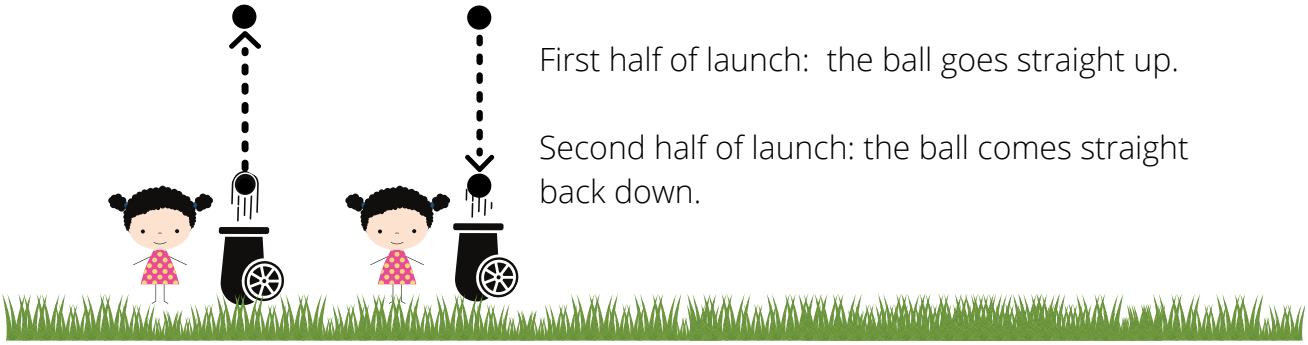
The cannonball would actually follow path C. When initially fired, the cannonball shoots straight out. Nothing stops it from moving forward, so it continues in this forward direction. But, as soon as the cannonball is released into the air, gravity starts pulling it down. The cannonball moves forward and down at the same time. This creates an arc. Objects that move with this pattern are called **projectiles**.

A projectile is:

- An object that is set in motion and released
- Has only the force of gravity acting on it

Try it out. Roll a small nerf or wiffle ball off a kitchen table. If possible, work with a partner to record a slow motion video of the path the ball takes when it falls. You should see the arc pattern of movement. Or, try tossing a ball lightly, underhand, and observe its path. You'll see it arc up and then down. If you have a hard time seeing it, try using a wiffle ball, which will travel more slowly.

You can launch a projectile at any angle. You can launch it straight out, as in the cannon off the cliff. Or, you can launch it straight up in the air.



First half of launch: the ball goes straight up.

Second half of launch: the ball comes straight back down.

Usually, we launch projectiles at an angle somewhere in between. Think about throwing a ball to someone in a field. You throw the ball forward, but also slightly upward, to reach your target.

This canon fires at an angle that is partly up and partly across.

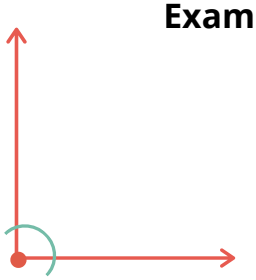
The angle that you use to launch a projectile impacts how long the projectile stays in the air, and how far the projectile goes. Can you guess which angles keeps the projectile in the air the longest?

On the next 2 pages, there is some math review on angles. If you already know how to measure and draw angles, you can skip these pages.

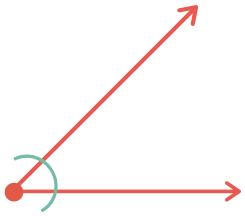
An ***angle*** is the space between two rays. Angles are measured in degrees. Degrees measure how far one ray is rotated from the other.

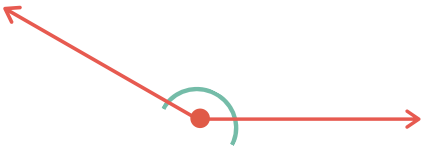
Using a protractor, measure each angle, and record its value on the line below it.

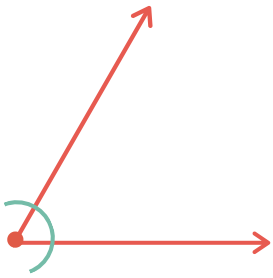
Example



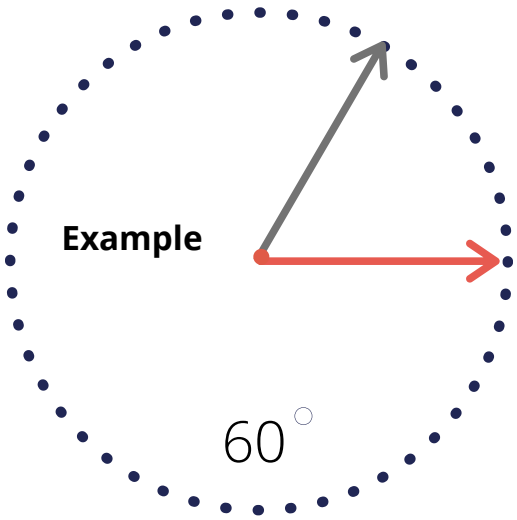
90°

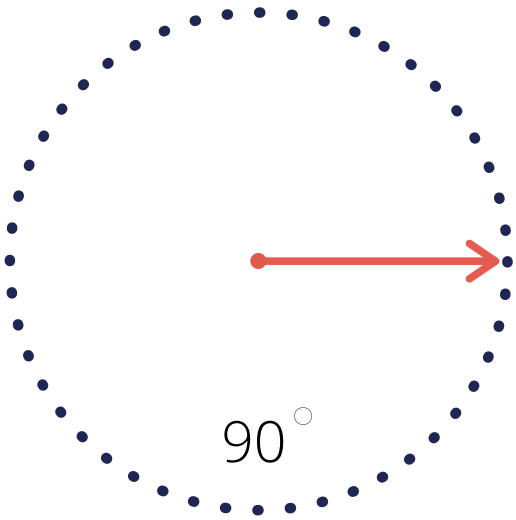


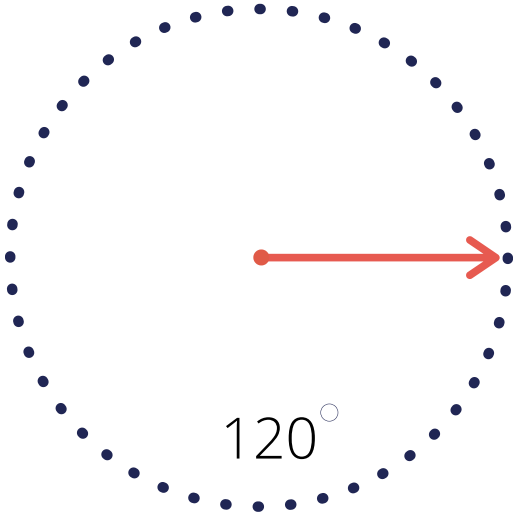


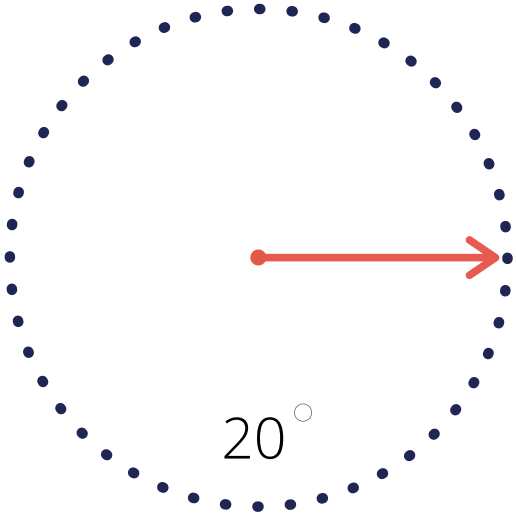


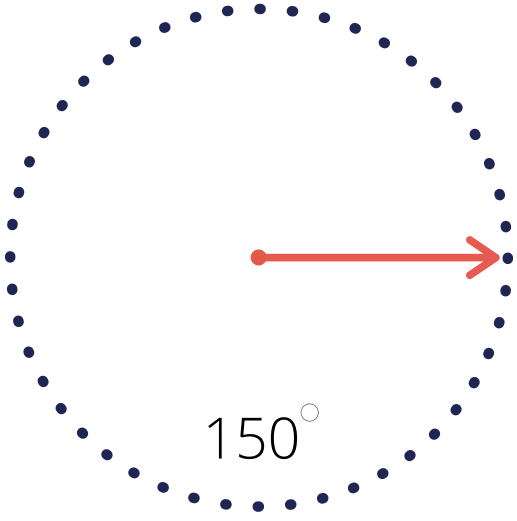
Using a protractor, complete the following angles, as shown in the example.

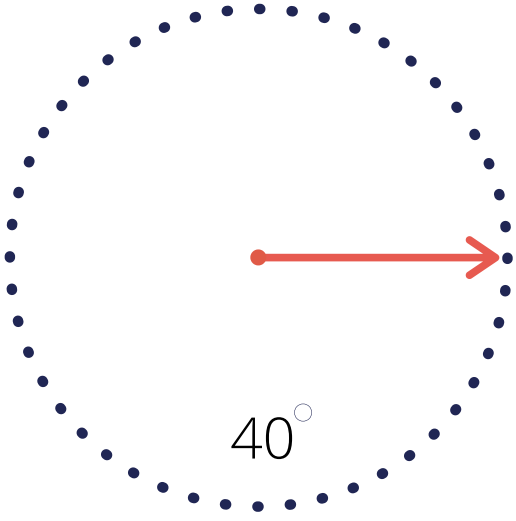












Speed Versus Velocity

To understand how projectiles move, you first need to understand the difference between speed and velocity.

Speed

You're probably used to thinking about how quickly something or someone moves in terms of speed. A car on the street, for example, might be traveling at 35 miles per hour. A Major League Baseball pitcher might throw a fastball at 100 miles per hour.

To calculate average speed, take the total distance traveled, divided by the total travel time. If a car travels 40 miles in the first hour and 60 miles in the second hour, you would calculate the average speed as:

$$\text{average speed} = \frac{\text{total distance}}{\text{total time}}$$

$$= \frac{40 + 60 \text{ miles}}{1 + 1 \text{ hours}} = \frac{100 \text{ miles}}{2 \text{ hours}}$$

$$= 50 \text{ miles/ hour}$$

With speed, it doesn't matter in what direction an object is moving. It doesn't matter what path the car took. All we care about is the total distance it went along that path, and how long the journey took.

Calculate the average speed for the following skateboard trips:

In one hour, the rider travels from point A to B.

A — 5 miles — B

average speed = _____

In the first hour, the rider travels from point A to B.
In the second hour the rider travels from point B to C.

A — 3 miles — B — 5 miles — C

average speed = _____

In the first hour, the rider travels from point A to B.

A — 4 miles — B

In the second hour, the rider goes back to where she started.
She rides from point B to point A.

A — 4 miles — B

average speed = _____

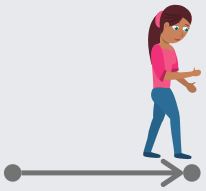
Velocity

In physics, there is an idea like speed, called **velocity**. The difference between speed and velocity is that ***velocity has direction***. When a baseball pitcher throws the ball, the pitcher sees the ball moving forward, away from him. To the pitcher, the ball has a forward (or positive) velocity. If the batter hits the ball, it changes the direction of the ball. The pitcher now sees the ball as having a backward (or negative) direction.

To calculate average velocity, we use displacement instead of distance. **Displacement** measures how far an object's position has changed from where it started.

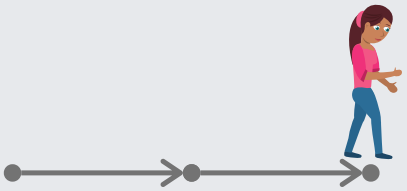
Try it Out

1) Stand in your room and take two steps forward. Your displacement is two steps.



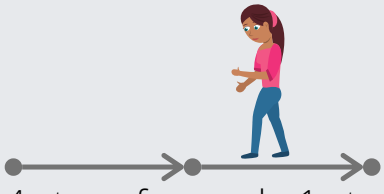
2 steps

2) Next, take another two steps forward. Your displacement is now four steps.



2 steps + 2 steps

3) Now take one step backward.



4 steps forward+ 1 step backward

You walked a total distance of 5 steps (4 forward + 1 backward). But you are only 3 steps from where you started. Your **displacement** is 3 steps.

Once we know an object's displacement, we can calculate its average velocity, just like we did for speed. We just use displacement instead of distance.

$$\text{average velocity} = \frac{\text{total displacement}}{\text{total time}}$$

Imagine a race car driving one lap around a track. Its average speed on the track was 200 miles per hour, and it finished the lap in 15 seconds. Since the car started and ended the lap in the exact same spot, its displacement is zero. So its average velocity for that lap is also zero.

$$\text{average velocity} = \frac{\text{total displacement}}{\text{total time}} = \frac{0 \text{ miles}}{15 \text{ seconds}} = 0 \text{ miles /hour}$$

Calculate the average velocity for the following skateboard trips:

In one hour, the rider travels from point A to B.

A — 5 miles → B

average velocity = _____

In the first hour, the rider travels from point A to B.

A — 4 miles → B

In the second hour, the rider goes back to where she started. She rides from point B to point A.

A ← 4 miles — B

average velocity = _____

x and y Velocity

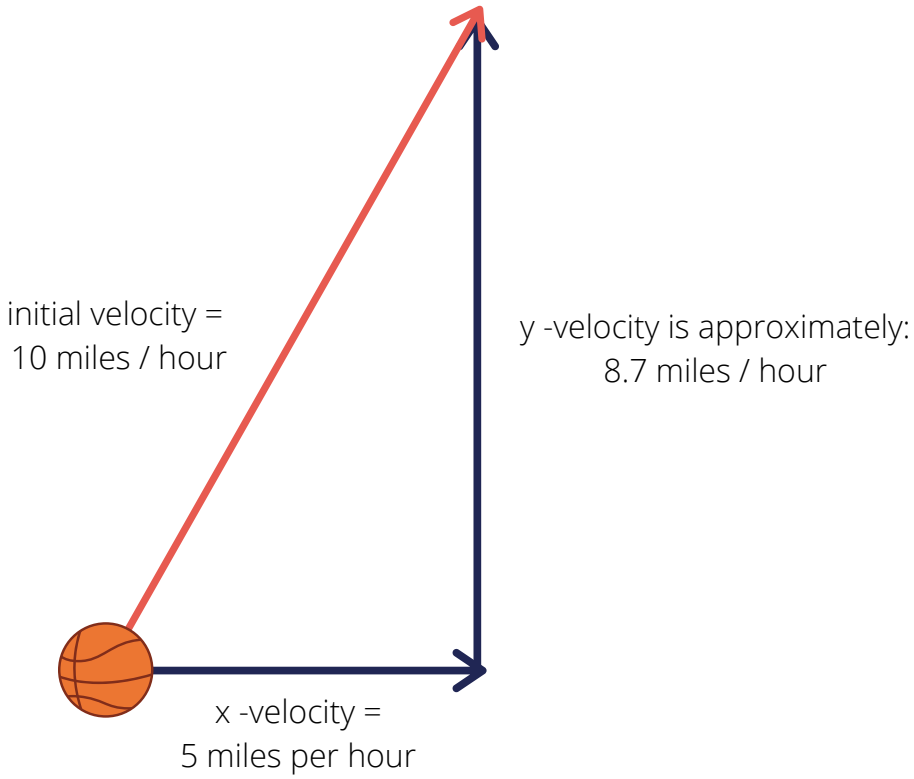
Velocity has a horizontal value (measuring forward and backward movement), and a vertical value (measuring upward and downward movement.) We call its horizontal value x-velocity and its vertical value y-velocity.

If I throw a ball straight up in the air, it only has a vertical (y) velocity. Its horizontal velocity (x) is 0, because it's not going across.

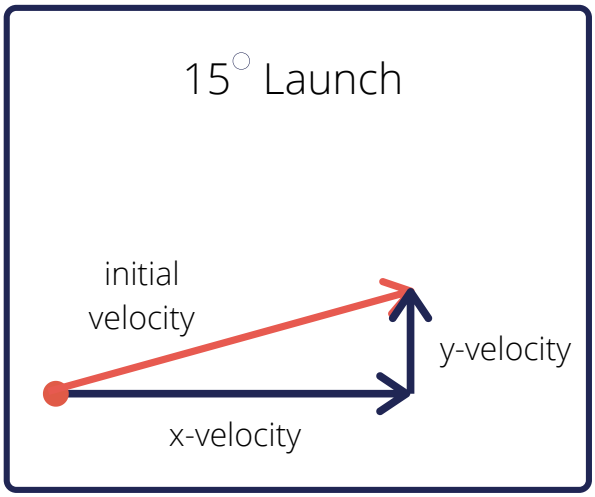
If I pass a basketball straight across to my teammate, then I give the ball a horizontal velocity. Its vertical velocity is 0, because it's not going up or down.

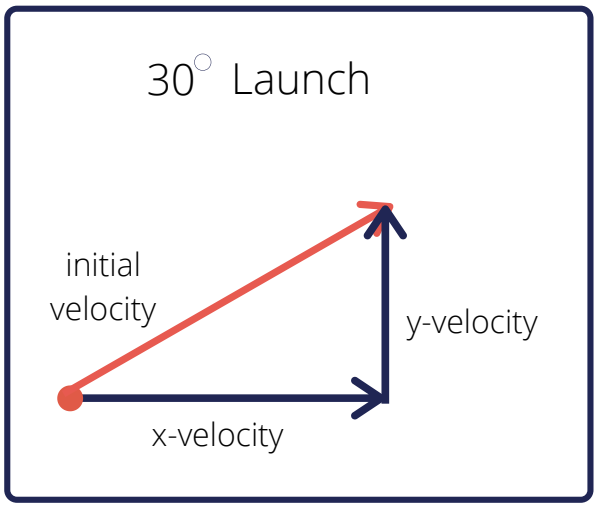
But what if I throw a ball somewhere in between? Then it will have both vertical and horizontal velocity.

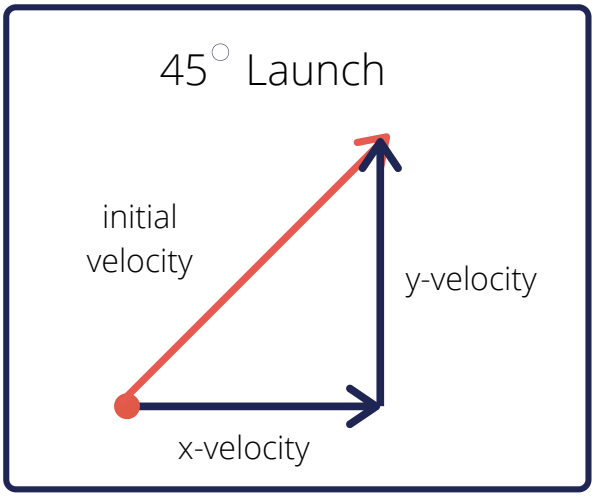
We can show the ball's starting velocity by drawing an arrow at the angle that we throw it. Then, we can break the velocity into horizontal velocity (x-velocity), and vertical velocity (y-velocity) by completing the triangle.

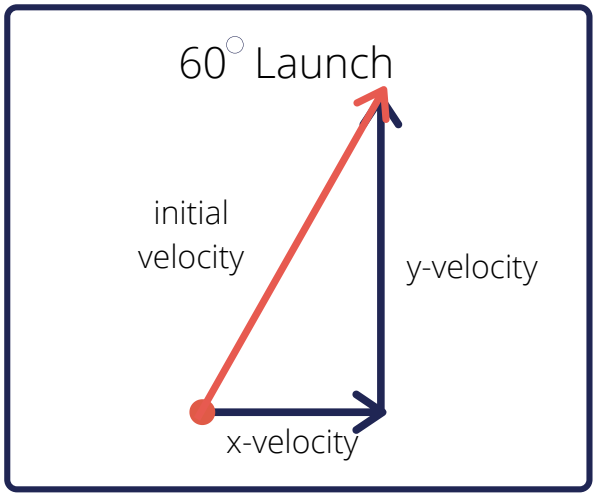


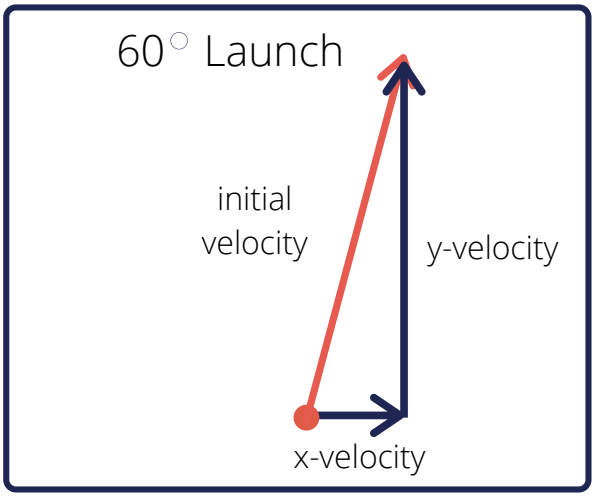
What happens to the x-value of an object's velocity, as we launch it at a higher and higher angle? As the angle gets bigger, does the x-value get bigger or smaller? Why is this? What about the y-value?

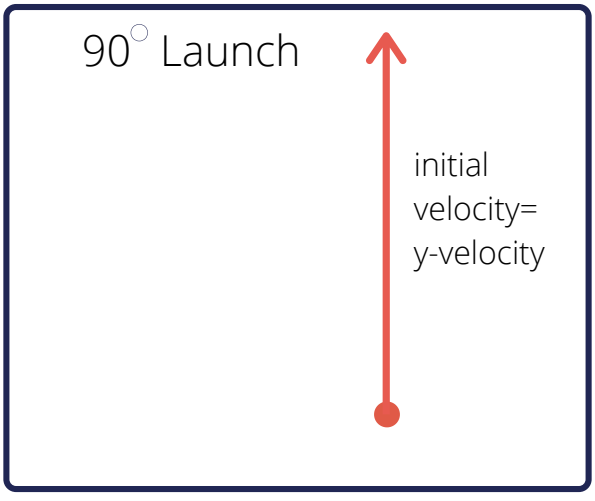












Practice drawing the angles you'll use in your projectile motion lab: