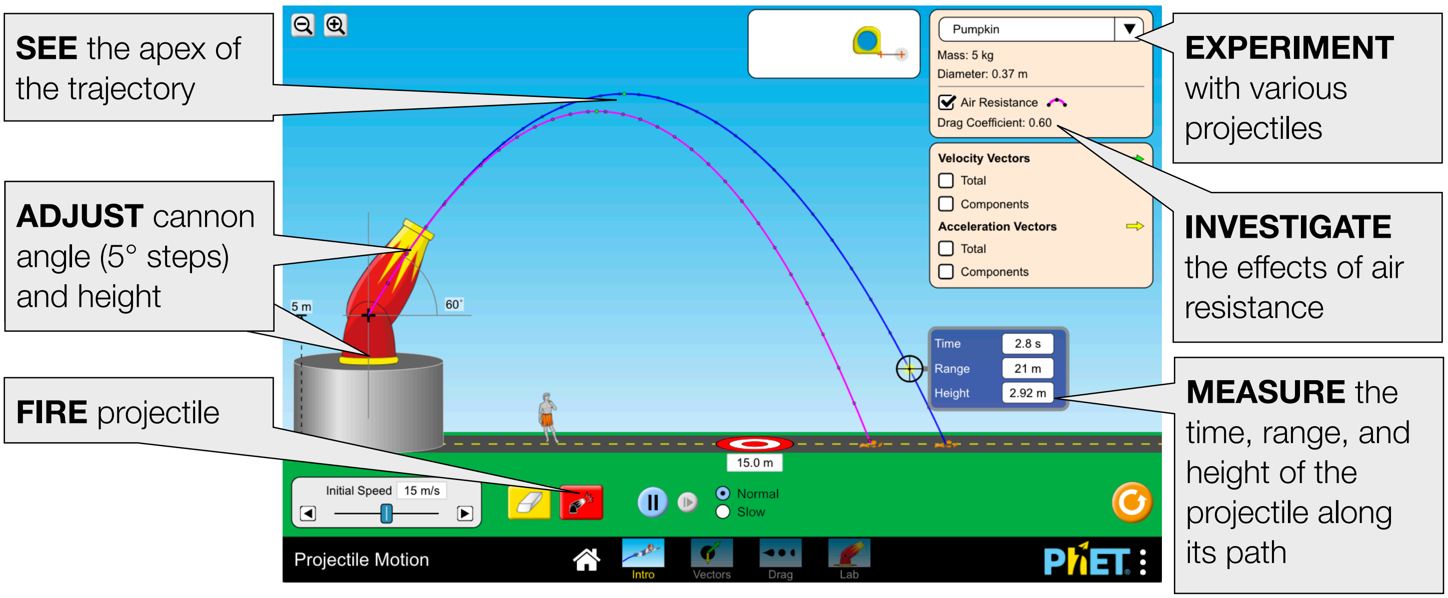
Projectile Motion

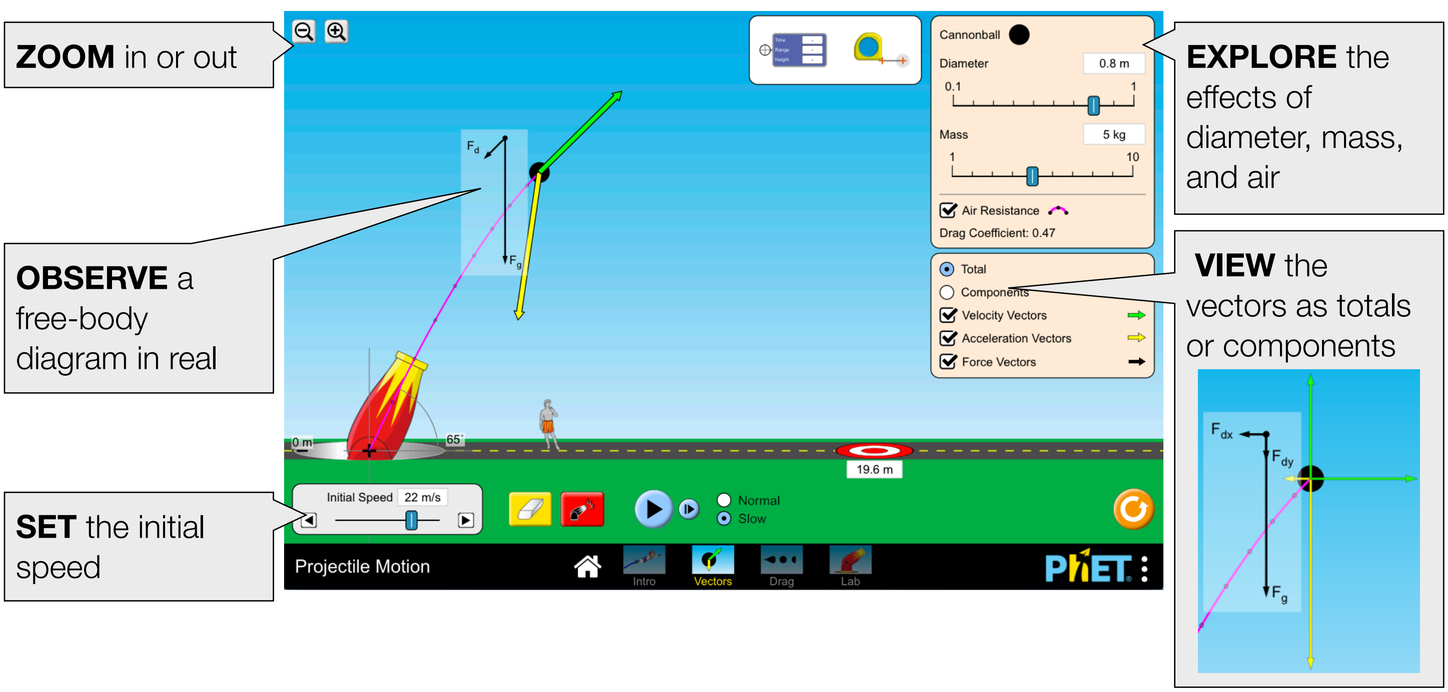
Intro Screen

Investigate the the factors that affect a projectile's trajectory, such as angle, height, initial speed, and air resistance.



Vectors Screen

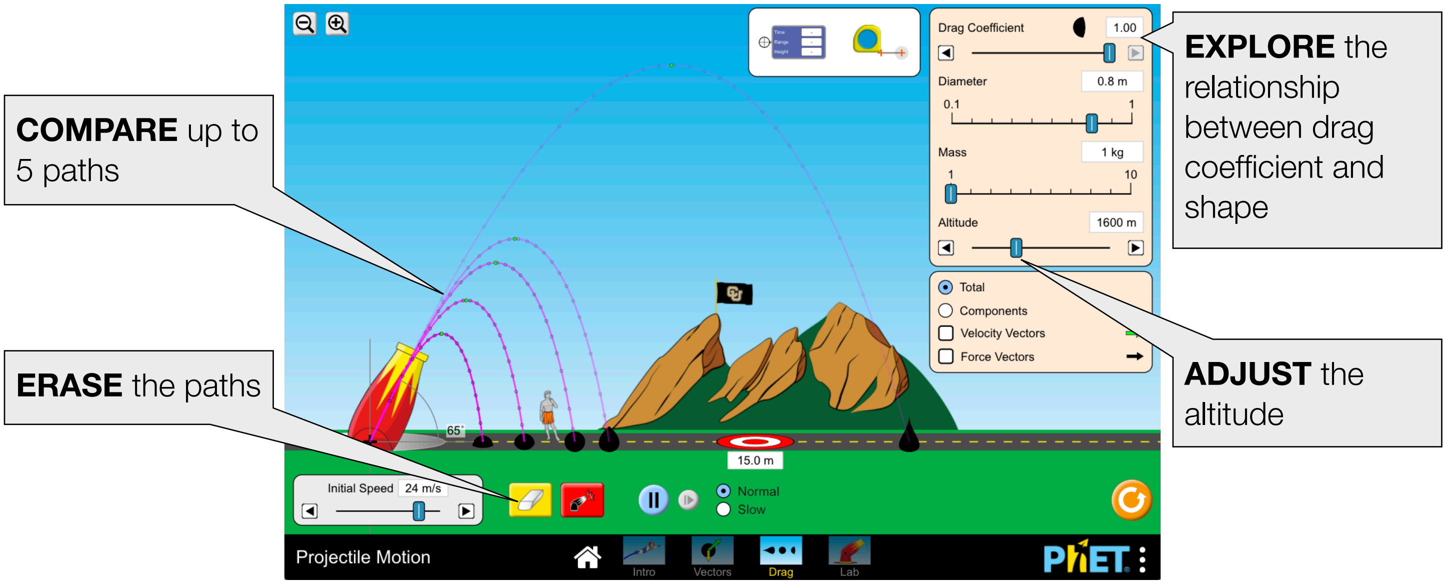
View the drag and gravitational forces in a free-body diagram, and explore how the velocity and acceleration are affected by air resistance.



Rouinfar, August 2023

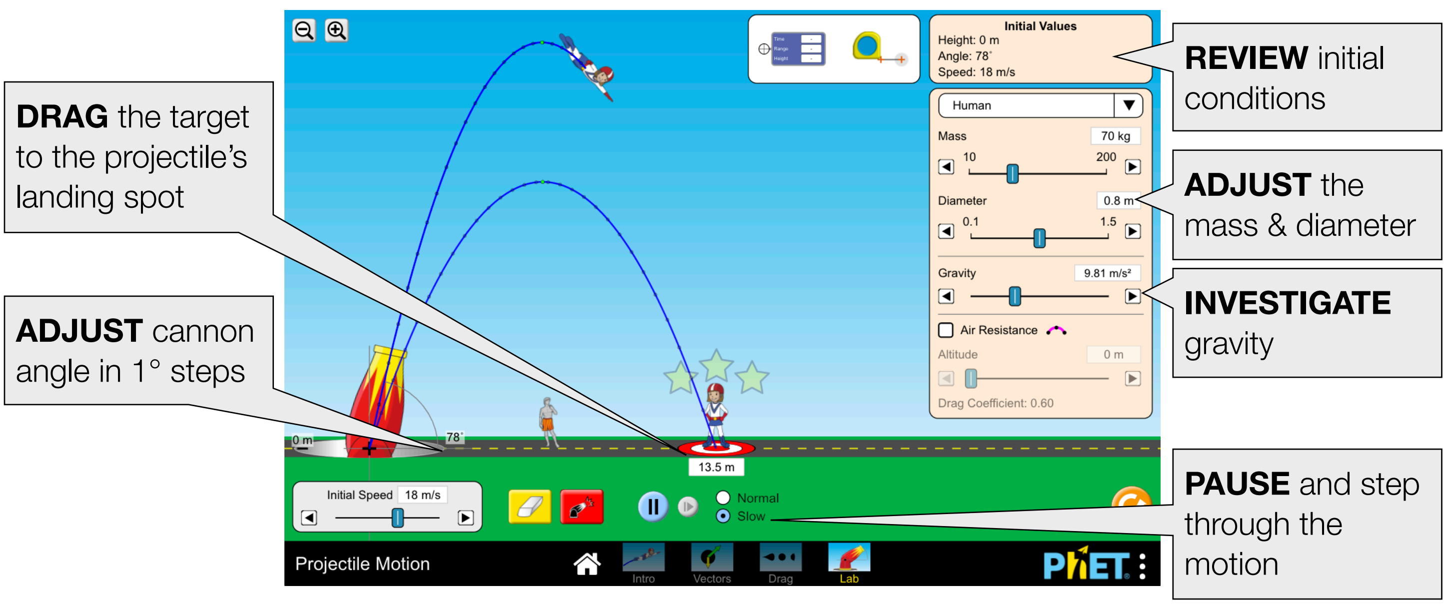
Drag Screen

Determine the factors that affect the drag force, and observe the relationship between the drag force and the velocity.



Lab Screen

Explore the effects of adjusting the projectile's parameters, and investigate the influence of gravity.



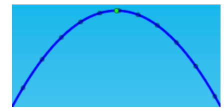
Model Simplifications

- The cannon has crosshairs to mark the initial location of the projectile.
- Changes in air resistance, altitude, and gravity apply immediately and will affect all projectiles mid-flight.
- Vectors are drawn from the center of the image, which may deviate slightly from the center of mass. For better visibility, the vectors do not scale with the zoom level.
- The drag force is modeled used quadratic drag ($F_{drag} \propto v^2$) which is valid in the high Reynold's number limit appropriate for macroscopic objects like baseballs. Linear drag (Stoke's Law) is only valid in the very low Reynold's number limit (like micron-sized droplets in air).
- The drag coefficient depends on the Reynolds number, which we have assumed to be a constant.

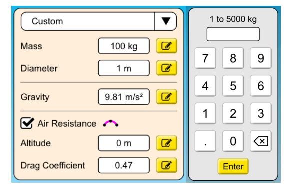
- The drag coefficient also depends on the geometry of the object, so benchmark projectiles (e.g. baseball, car) do not have an adjustable drag coefficient.
- The cross-sectional area of the projectiles is approximated to be a circle, and its area is determined by the diameter.
- Items that stay tangent to the trajectory while in motion (e.g. football, tank shell) are assumed to have the appropriate aerodynamics or weight distribution that leads to this behavior.

Complex Controls

- Up to three projectiles can be queued up if fired while paused.
- The tracer tool can measure the time, range, and height of the projectile at any dot along the path. The black dots are drawn in 0.1s intervals, and the green dot represents the apex.

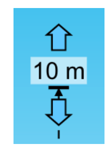


- The "Custom" projectile on Lab screen allows users to enter precise values for the mass, diameter, gravity, altitude, and drag coefficient. The acceptable range for these values will be displayed at the top of the keypad.



Insights into Student Use

- Students usually find all the available options in the sim without prompting, like adjusting cannon angle, moving the target, changing the projectile parameters, and turning on vectors.
- The cannon sits on a pedestal with an adjustable height. To cue this behavior, the cannon on the Intro screen starts at 10 m, and has arrows on the height label that will disappear once the cannon's height is adjusted.



Suggestions for Use

Sample Challenge Prompts

- Choose a variable, and design an experiment to determine how it affects the projectile's path.
- Predict how changing the initial conditions will affect the path of the projectile, and explain your reasoning.
- Determine which factors affect the range of the projectile when air resistance is turned on, but have no effect when air resistance is turned off.
- Describe how the behavior of the velocity and acceleration vectors over time, and how they are affected by air resistance.
- Explain why the black dots on the projectile's path are closer together near the top, but further apart when close to the ground.
- Create a situation in which the projectile reaches terminal velocity.

Customization Options

Query parameters allow for customization of the simulation, and can be added by appending a '`?`' to the sim URL, and separating each query parameter with a '`&`'. The general URL pattern is:
`…html?queryParameter1&queryParameter2&queryParameter3`

For example, in Projectile Motion, if you only want to include the 1st and 2nd screens (`screens=1,2`), with the 2nd screen open by default (`initialScreen=2`) use:
https://phet.colorado.edu/sims/html/projectile-motion/latest/projectile-motion_all.html?screens=1,2&initialScreen=2

To run this in Spanish (`locale=es`), the URL would become:
https://phet.colorado.edu/sims/html/projectile-motion/latest/projectile-motion_all.html?locale=es&screens=1,2&initialScreen=2

Rouinfar, August 2023

Query Parameter and Description	Example Links

`screens` - specifies which screens are included in the sim and their order. Each screen should be separated by a comma. For more information, visit the Help Center.	`screens=1`
	
	`screens=2,1`

`initialScreen` - opens the sim directly to the specified screen, bypassing the home screen.	`initialScreen=1` `initialScreen=3`
`locale` - specify the language of the simulation using ISO 639-1 codes. Available locales can be found on the simulation page on the Translations tab. Note: this only works if the simulation URL ends in "_all.html".	`locale=es` (Spanish) `locale=fr` (French)
`allowLinks` - when `false`, disables links that take students to an external URL. Default is `true`.	`allowLinks=false`

See all published activities for Projectile Motion here.
For more tips on using PhET sims with your students, see Tips for Using PhET.

Name ____

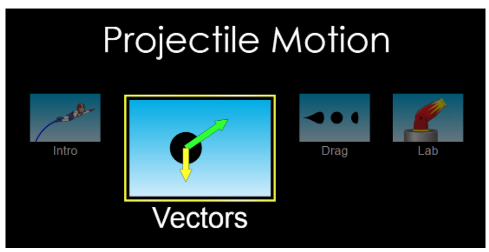
Date ____________________

PhET Vector and Projectile Motion Inquiry Activity

Introduction – You will use a computer simulation today to reinforce your ideas of vectors, acceleration and velocity. You will also start to investigate what projectile motion is. Since this is "inquiry based", you're not supposed to know everything going in, but learn as we walk through the lesson. **You must read all instructions carefully to get full credit.** Let's get started!

Website : https://phet.colorado.edu/en/simulation/projectile-motion

Click on the "play" icon, then double click on "Vectors"



Initial setup and explanation

You'll see a cannon on the left of your screen. To fire the cannon, click the red button at the bottom of the screen. To reset the cannon, click the yellow "erase" button at the bottom of the screen.

You can change the angle of the cannon, and adjust its initial speed. We'll get to this in a few minutes.

Initial setup and investigating gravity

1. Uncheck the "air resistance box". Set the following: diameter = 0.8m, mass 5 kg, initial speed = 18 m/s and the cannon angle = 45º. Click the "slow" button at the bottom to watch the simulation more carefully.

2. Click the box that says "acceleration vectors"

3. Fire the cannon. You will see the cannonball leave the cannon, with an acceleration vector.
4. What is the direction of the vector?
5. What does this vector represent?
6. What do you observe about the length of the vector throughout its flight?
7. What does this tell you about the **direction and magnitude** of the acceleration acting on the cannonball throughout its duration of flight?
8. What do you predict will happen to the acceleration vector if we change the angle of the cannon? Why do you think that?

Change the angle of the cannon to 65º. Fire the cannon at this new angle. Keep everything else the same. (Remember, click on the “slow” button to slow the simulation down)

9. What did you notice about the acceleration vector at this new angle?
10. What was different about the vector (if anything) compared to the 45º angle. Move the cannon back to 45º if you need to check or verify

11. Was your prediction correct about the acceleration vector at this new angle?

Change the angle of the cannon to 90º. Fire the cannon at this new angle. Keep everything else the same. (Remember, click on the "slow" button to slow the simulation down)

12. What did you notice about the acceleration vector at this new angle?

13. What was different about the vector (if anything) compared to the 45º or 60º angle? Move the cannon back to 45º or 60º if you need to check or verify anything.

14. Summary: What have you discovered about the acceleration due to gravity of an object in flight with regards to the angle of launch?

Change the angle of the cannon to 45º. Click the “slow” button. Fire the cannon and observe the acceleration vector. Now change the initial launch speed to 25 m/s. Fire the cannon again.

15. What did you observe about the acceleration vector when you fired it at the new speed? Was it any different from the initial speed?

Click the yellow erase button and unclick the acceleration vectors box. Click the “velocity vectors” box. Click on “components” just above it. This will track velocity in both the x and y directions.

Set the cannon to 60º and the initial velocity to 15 m/s. Click “slow” if you haven’t already. Fire the cannon. Click erase and fire multiple times if necessary.

16. What do you notice about the velocity vector in the y direction? Describe what happens to its length and direction throughout the flight? Be specific

17. At what point does it seem like there is no velocity vector in the y direction?

18. Describe in your own words what is happening to the velocity in the y direction as the cannonball leaves the cannon and flies through the air.

19. What do you notice about the velocity in the x direction?

20. Why do you think this isn't changing? (Hint: What is affecting the velocity in the y direction, but not the x direction?)

Predicting and calculating

Imagine a cannon was shooting at an initial velocity of 20 m/s at 75º above the horizontal. We are going to predict its range and check with the simulation.

Draw the scenario below:

Using the sin and cosine functions, calculate V_x and V_y. Show all work

We will use the following formula to calculate the time to the top of the flight path:

$v_f = v_y + at$

Since at the top of the flight, the $V_f = 0$, we have

$0 = v_y + at$

$-v_y = at$

$t = -(V_y / a)$ (Remember, $a = -9.81\ m/s^2$)

Using the bold formula above, acceleration due to gravity = $-9.81\ m/s^2$, and your v_y that you calculated above, solve for (t). Show all work.

The value you just solved for is *half* of the time the ball is in the air. (Remember, it's just to the top of the flight path). So take your time and **double** it. Show below:

Now, you solved for the total time in flight. Next, we'll solve for distance in the x direction. We'll use the following formula:

$v_x = d_x / t$

Rearranging for distance we get:

$d_x = v_x * t$

Using your v_x that you calculated above, and the TOTAL flight time (the one you doubled), calculate the distance in the x direction. Show work below:

Checking your prediction:

Set the cannon up to 20 m/s at 75º. Move the red and white target to your predicted distance in the x direction. Fire the cannon.

Did you hit the target?

Complete the calculations again using an initial launch speed of 30 m/s and an initial launch angle of 85º. Check your results with the simulation. Show all work below