Range of an Angled Projectile — Teacher's Notes

Main Topic	Motion
Subtopic	Projectile Motion
Learning Level	High School
Technology Level	Low
Activity Type	Student

Description: Experimentally determine the launch velocity of the air powered projectile and predict its range for a given launch angle.

Required Equipment	Air Powered Projectile, Launch Pad, Angled Wooden Wedges, Air Pump, Stopwatch, Measuring tape or trundle wheel, Protractor, Safety Glasses
Optional Equipment	Altitude Finder

Educational Objectives

- Predict the range of a large-scale angled projectile using experimental data.

Concept Overview

An example used in many classrooms is to have students launch the projectile vertically and time how long it takes for the projectile to complete the trip up and down. This time is then divided in half to get a pretty good approximation for the time of the upward portion of the trip. Your students, knowing that the Air-Powered Projectile slows at the rate of 10 m/s^2, can now calculate the initial speed. (We have found using 10 m/s^2 instead of 9.8 m/s^2 allows the students to do the calculations in their heads.) Let's say it took the projectile 6 seconds total time in the air when launched vertically. Then the time spent on its upward trip would be 3 seconds, multiplied by the acceleration due to gravity-- the projectile's initial speed would be 30 m/s. Air resistance is not formally calculated but taken into consideration when calculating the initial velocity.

With this bit of information, your students can calculate the distance the projectile will travel at any angle the launch pad is placed! For example, if an angle of 60 degrees was assigned, a little trigonometry would yield both the vertical (y) and horizontal (x) components of velocity.

The initial velocity stays the same at 30 m/s. The equations would be v_y = 30 m/s (sin 60^o) = 26 m/s and the v_x = 30 m/s (cos 60^o) = 15 m/s. If the projectile starts out at 26 m/s in the y direction and gravity slows velocity by 10 m/s each second, it will take 2.6 seconds to reach the top and 2.6 seconds to fall to the ground, totaling 5.2 seconds in the air. Since the projectile travels in the air for 5.2 seconds at 15 m/s in the horizontal direction, it will go 78 meters before hitting the ground (5.2 seconds x 15 m/s = 78 m). Your students will be stunned by how accurate their calculations will be.

Lab Tips

The Air-Powered Projectile uses compressed air as fuel to power its launch. One of four thrust washers (sizes Low, Medium, High, and Super) is pressed onto the top of the launcher and the projectile slides down the launching tube. Air is pumped into the launcher with the air pump. When it reaches the pressure needed to launch the projectile, the thrust washer is forced off the launching tube, sending the projectile into the air.

A number of things can happen to generate error in the calculations of your students. The largest of these is in their ability to pace off the distance when estimating the expected range of the Air-Powered Projectile. To avoid this, have the experiment take place on the football field or prior to the experiment have distances measured with a meter tape.

Additionally, when doing the calculations the majority of your students will actually use the wrong angle of launch. For example, if the angled wedge used in the launch pad was the 55 degree wedge, the actual launch angle was its complementary angle or 35 degrees. A way to show why the correct range was calculated in spite of the error would be to introduce them to the projectile range equation, $R = (v_o^2/g) \sin 2\theta$. The fact that the sine of twice an angle and twice the complement of an angle yield the same result demonstrates the mathematical reason why your students still got the right answer. Be sure to measure the angle of the launch pad and not the wedge, because the wedge can move.

WARNING! Goggles should be worn and care taken in the launching of the Air-Powered Projectile as it launches at a high velocity! Do not lean over the launch pad when pumping the air pump.

For those who will be launching the Air-Powered Projectile in a cold climate, limit your outside launches to days above 50^{o} F to reduce the possibility of the projectile body cracking.

Please launch projectiles to land in large grassy areas, such as a football field. Repeated landings on hard surfaces such as concrete or asphalt may damage the red projectile body.

Range of an Angled Projectile Name: ____________________
Class: ______________________

Pre-Lab Questions:

1. If a projectile is launched straight up at a speed of 50 m/s and slows down at a rate of 10m/s every second, how long will it take to reach its high point (where the speed is zero)? _________________
2. If a projectile is launched straight up and reaches its high point in 2.0 seconds, what was its initial speed? (Approximate g=-10m/s^2.) _______________
3. A projectile is launched at 15m/s at an angle of 30º. Calculate its range (horizontal displacement).

Goal:

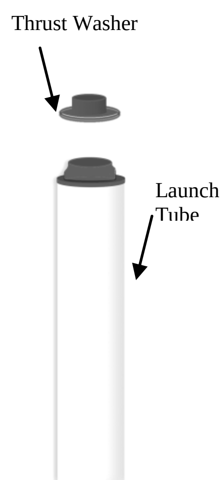
Predict the range of a large-scale angled projectile using experimental data.

Materials:

Air Powered Projectile, Launch Pad, Angled Wooden Wedges, Air Pump, Stopwatch, Measuring tape or trundle wheel, Protractor, Safety Glasses

Procedure:

1. Select a launching site clear of obstructions and preferably about 50 meters in diameter. Attach the air pump and adjust the launch pad to the desired angle. Set the rocket in launching position.
2. Select the super, high, medium or low thrust washer according to desired altitudes. Snap the thrust washer onto the launcher top (*be sure it snaps).*
3. Push the rocket completely onto the launcher and attach the nose cone. Push the cone on only about half an inch.
4. Stand sideways to pump and pump until the rocket launches automatically.
5. Use a stopwatch to measure the time of flight of the rocket. Record the time in seconds. ________________
6. How long did the rocket take to reach its high point? ________________
7. Approximating g=-10m/s^2 and the time above, calculate the rocket's initial velocity. ___________________
8. Use the wooden wedge provided to angle the launch pad. Measure the launch angle of the rocket and record it. ___________________
9. The rocket's initial velocity will remain constant as long as you use the same thrust washer as before. Use the initial velocity you found in #7 and the angle in #8 to predict the range (horizontal displacement) of your rocket before launching it.



Name: ____________________

Class: ____________________

10. Retrieve the rocket and nose cone. Push the thrust washer out of the end of the rocket with your thumb or finger and repeat steps 2 and 3 to prepare for the next launch.
11. If directed by your teacher, place a marker at your predicted distance.
12. Launch the rocket at an angle.
13. Record the rocket's actual range. ____________________
14. Calculate the percent error in your prediction.