Backyard Ballistics Teachers Guide

Lesson Plan: Exterior Ballistics

Objective:

This lesson plan introduces the student to the branch of physics known as ballistics. Ballistics is sometimes called the science of shooting. It is subdivided further into the sub areas of exterior ballistics, interior ballistics, and target or impact ballistics. This lesson plan deals with exterior ballistics. Interior ballistics quantifies what happens within the barrel of a gun, target ballistics deals with what happens when a projectile strikes an object. Exterior ballistics describes the motion and behavior of projectiles after they leave the gun barrel but before they enter the target.

Concepts:

Exterior Ballistics describes and predicts the motion of projectiles shot from guns. For example, when scientists use physics and engineering principles to predetermine the path of an artillery shell shot from a cannon or a rock thrown from a catapult, they are using exterior ballistics principles. Several basic equations have been derived by scientists to predict the motion of projectiles shot from guns. These equations require the use of trigonometry.

The velocity of a projectile at any point of its trajectory is a function of its initial velocity and the distance up or down it has traveled since firing*. The equation used to determine the velocity of the projectile is:

Equation 1: $$\text{Velocity} = \sqrt{v_i} - (2)gy,$$

Where:
V_i = initial velocity (sometimes called muzzle velocity)
g = acceleration due to gravity
y = vertical displacement from muzzle

The distance the projectile will travel horizontally after firing is a function of the muzzle velocity and the firing angle:

Equation 2: $$\text{Distance}_{horizontal} = (V_i \text{ cosine } \Phi)\, t,$$

Where:
Φ = the firing angle
t = time after launch

The distance the projectile will travel vertically is determined by equation 3:

Equation 3: $$\text{Distance}_{vertical} = (V_i \text{ sine } \Phi)\, t - \tfrac{1}{2} gt$$

*Equations describing the motion of projectiles during flight are derived from one and two dimension particle kinematics. This subject is normally introduced during high school physics. Consult appropriate textbooks if more detailed information is desired.

Field Work

Let's use the exterior ballistics equations to estimate muzzle velocity of the Backyard Ballistics spud gun. Build the spud gun in accordance with the instructions found in chapter 2 of the book Backyard Ballistics by William Gurstelle (Chicago Review Press, 2001).
Other materials required, besides those listed in chapter two of Backyard Ballistics:

- Stopwatch
- Football field with yardage marked or other method of measuring distances up to and beyond 100 yards.
- Angle measuring protractor.

To determine muzzle velocity:
1. Set up and fire the potato cannon. Measure and record the firing angle of the cannon
2. Measure and record the distance the potato traveled prior to impact.
3. Simultaneously, record the elapsed time between firing and ground impact.
4. Rearrange equation 2: $V_i = Distance_{horizontal} / (cosine\ \Phi)\ t$
5. Substitute values for distance and time and solve.

For example, if the spud gun was fired at a 45 degree angle, the time the potato was in the air was measured was 3 seconds, and the total distance from gun to impact was 80 yards (210 feet), then:

$$V_i = 210 \text{ feet} / .707*3 \text{ seconds} = 99 \text{ feet/second} = 67.5 \text{ miles per hour.}$$

The potato gun has an initial muzzle velocity of just more than 67 miles per hour. If desired, the instructor can then take this information and the weight of the potato and determine kinetic energy from $KE = 1/2mv^2$ as well illustrate other work-energy concepts.

Ideas for Further Field Work
Point the spud gun straight up. Record the time between firing and the time the potato impacts the ground. From this, and the muzzle velocity determined earlier, determine the maximum height to which the potato travels. WARNING! Protect everyone in the area from being hit by the potato as it comes down. Wear helmets and clear the landing area.

Empirically measure the velocity of the spud gun by firing the gun into a ballistic pendulum (see chapter 11 of Backyard Ballistics). Compare this figure to that determined in the exercise above.

Backyard Ballistics (ISBN: 1556523750) is available from most bookstores, online, and from the publisher
Sales: orders@ipgbook.com


Build potato cannons, paper match rockets, Cincinnati fire kites, tennis ball mortars, and more dynamite devices
BACKYARD BALLISTICS