

VANDERBILT STUDENT VOLUNTEERS FOR SCIENCE

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# Straw Rockets

Spring 2012

**Goal:** To explain the concepts of angle of trajectory vs. distance and the horizontal/vertical components of projectile motion. To apply basic graphing and data interpretation skills to the physics of projectile motion.

## Lesson Outline

### I. Introduction

Discuss the general concepts behind projectile motion: angle vs. distance and horizontal/vertical components of force.

### II. Setup and Demonstration

Demonstrate how the launcher should be setup and used to determine the angle for maximum distance.

### III. Identifying the Best Angle for Maximum Distance of the Projectile

Students will use the launcher to conduct a series of trials to determine the angle that yields maximum distance.

### IV. Discussion of Student's Results

Students will plot their data on a graph and then be asked to interpret this information. Briefly discuss some problems encountered during testing that may have lead to the incorrect angle being identified.

## Materials (for 32 students in 8 groups of 4 students)

- 2 Straw launchers
- 10 meter measuring tapes
- Colored discs for marking the landing position of rocket
- Student Handouts
- Student Observation/Graph sheets
- Safety goggles for everyone**

Students may do experiment in pairs, groups, or individuals

- 1 full-length (20cm) straw rocket for each student (premade, with clay inserted, no fins)
- 1 shorter (10cm) straw rocket for each student (premade, with clay inserted, no fins)

## Pre-lesson Setup

Split the students into eight groups (each group should have 4 students) for the hands-on-activity, later in the lesson.

The VSVS volunteers can accomplish the following items, while one volunteer gives the introduction portion of the lesson.

- a. Identify the best location to conduct the testing. Inside a large tiled cafeteria floor works best, or passageway. The launchers will need approximately 25 feet of flight path. Begin to setup the launchers and all needed material at this location

## I. Introduction

This lesson is designed to help the students gain an understanding of projectile motion and the concept that the angle of trajectory can vary the distance traveled by the projectile.

### **Background (Advanced)**

Projectile motion is defined as the curved path an object follows when propelled by an external force. Examples of projectile motion include throwing a football, hitting a golf ball with a golf club, or launching a model rocket. The object is initially propelled forward by a force with a certain angle between the path of the object and the ground. This angle is called the launch angle. Together, the launch angle and launch force define the trajectory that an object will follow. The object then travels upward in a downward-shaped arc until it reaches a high point. After the maximum height, the object continues to travel downward in a downward-shaped arc until it reaches the ground.

This path (downward-shaped arc) is composed of two independent components. One portion of the curved path is the horizontal component or the part that is parallel to the ground. The force that causes the horizontal component leads to the distance that the object will travel and is only affected by drag (air resistance). The other portion of the curved path is the vertical component or the part that is perpendicular to the ground. Gravity affects the vertically component by causing the object to decelerate on its upward path until it reaches maximum height. After this point is reached, gravity causes the object to accelerate downwards until it hits the ground. Both the horizontal and vertical components of force act to form the curved trajectory of the object.

## II. Demonstrating the Launch and Path of a Rocket

Newton's 3<sup>rd</sup> Law of Motion states that for every action there is an equal and opposite reaction. The launch rod provides the launch force. When the rod is dropped, it compresses the air underneath it and rapidly forces air into the launch tube. The straw rocket covers the end of the launch tube and traps the air. Pressure builds up in the sealed straw and launches the rocket. The action is the air blowing into the straw. The reaction is the straw blasting off the launcher. Gravity pulls the rocket "back to earth".

### **Safety Concerns:**

**Make sure everyone has safety goggles on throughout the entire lesson.**

All students must be behind the launchers.

No student should enter the 'flying zone' to mark the landing location of their rocket until all the groups have conducted the first test.

One VSVS member should be the "spotter" to mark the place the rocket touches down (discs can be used to mark the spot).

Measurements using the tape measures should be done at the same time for all students, at the end of each trial.

Tell students to watch the path of the rocket as it flies through the air.

Set the angle at 45 degrees and launch a rocket using “10cm” rod height.  
Ask students to draw what they saw.

They should be able to draw a curved path.

Tell students they are going to investigate what affects the flight path and the distance travelled.  
They will need to change one variable at a time.

Pass out the Student Handouts, Student Observation/Graph sheets, and make sure that all students know that they will need to have a pencil with them to record their results.

### **III. Investigating the Effect of Length of the Rocket on the Distance Travelled.**

#### **Materials**

- 2 Straw launchers
- 10 meter measuring tapes
- Colored discs for marking the landing position of rocket
- Student Handouts
- Student Observation/Graph sheets
- Safety goggles for everyone**

Students may do experiment in pairs, groups, or individuals

- 2 full-length (20cm) straw rocket for each student (premade, with clay inserted, no fins)
- 2 shorter (10cm) straw rocket for each student (premade, with clay inserted, no fins)

Tell students that the amount of clay inserted into the straw was carefully weighed to be the same for all rockets.

Set the launcher angle at **45 degrees**.

Raise the launch rod to the calibration line labeled “**10 cm**”.

Each student or group will launch the 20 cm rocket (rocket A) and mark where the rocket first hits the floor with a disc (VSVS member will do this).

After all students have launched their Rocket A, measure and record the distance.

Repeat with the same rocket A and record the distance. Is the distance reproducible?

Repeat with shorter rocket (B).

How does the rocket body length affect the distance travelled?

### **IV. Investigating the Effect of Angle of Launch on Distance Travelled.**

#### **Materials**

- 1 straw rocket per group (20 cm, fixed nose weight, no fins)

Tell the students that now they will identify the best angle of launch to achieve the farthest distance from the launch point using angles of 15°, 30°, 45°, and 60° (all pointing forward).

All other variables are kept constant.

Use the longer straw rocket (20 cm) throughout the trials.

Set the launcher to the 15° angle.

Raise the launch rod to the calibration line labeled “**10 cm**” for each trial.

Repeat the steps above and record the distance after all groups have launched at this angle.

Change the launch angle to  $30^\circ$  and repeat. Repeat with the other angles.

## **V. Changing the Launching Force**

### **Materials**

1 straw rocket per group (20 cm, fixed nose weight, no fins)

**Keep the angle constant** ( $45^\circ$  or  $30^\circ$ , depending on the height of the ceiling in the room!).

Repeat the procedure, varying the height of the plunger. Use increments of 6 or 8 cm, depending on the amount of time left.

Data can be graphed at the end of each trial.

They may need some help accomplishing this task.

The distance is on the y-axis and the variable (Angle, Rocket length, plunger height) is on the x-axis.

After plotting the data, ask the students to draw a curve through their data points.

This curve will look like a hill with a gently slope on both sides. See the example curve.

## **VI. Shooting the Rocket into the Box**

1 straw rocket per group (20 cm, fixed nose weight, no fins)

1 Box which the launcher was inside

Set up the box that the launcher was inside, 5 meters from the launcher. Tell the students that they will now try to fire the straw rocket into the box. Set the launch angle to  $45^\circ$  and have the students vary the launching force to get the straw rocket inside the box. Give each student two tries to get the straw rocket inside the box. If the students miss on their first try, ask them if they should increase or decrease the launching force based on how far their rocket flew. Have the students collaborate with each other by telling others what launching force they used so that those who are firing next can adjust their launch force accordingly.

After each student has fired the rocket, ask the students approximately what amount of launching force is required to get the straw rocket inside the box.

Split the students up into teams and have the students compete to see who can get the rocket inside the box first. This time make the students use 2cm more of launching force than it required in the previous activity to get the rocket inside the box. Have them vary the launch angle instead to get the straw inside the box. Ask the students how they should vary the launch angle based on what they have learned so far.

*Optional:* If there is time remaining, have the students now replace the 20 cm rocket with the smaller rockets used earlier in the first launcher activity. Have the students try to get the rocket

inside the box. Ask them how should they vary the launch force based on what they learned so far.

## **VII. Discussion of Student's Results**

Ask each group what launch angle provided the maximum distance and how far the rocket flew on average from that launch angle?

Discuss any variations between the groups' results.

Angle:

Most groups should have found that  $45^\circ$  provided the best angle to achieve the farthest distance. An angle of  $30^\circ$  will produce a very close second maximum distance.

Ask the students if they can come up with any reasons why the distance varied between trials?

Why did  $45^\circ$  produce the maximum distance?

*An angle of  $45^\circ$  leads to neither a maximum vertical or horizontal component, but reaches a compromise between the two components to achieve the maximum distance. Only a set amount of force is available to launch the rocket. This force must be split in the best possible way between achieving distance through the horizontal component and allowing the rocket enough 'hang time' (vertical component) to use all the available force behind the horizontal component before hitting the ground.*

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