Activity #1: Rocket Balloons

In this activity, you will learn about Newton’s Third Law of Motion: how do the actions and reactions in a moving system relate to forces and acceleration?

In this experiment you will create a balloon and straw rocket! You will figure out how to shoot the balloon from the back of your classroom and hit the blackboard with it at the front of the room. You will do this using the fishing line as a “track” for the balloon to follow.

Materials:
- balloons (one for each team)
- plastic straws (one for each team)
- tape (cellophane or masking)
- fishing line, 10 meters in length
- stopwatch
- measuring tape
- white board

Procedure: A Day at the Races

This is a race. The race will be timed and a winner determined.

1. Attach one end of the fishing line to the blackboard with tape. Have one teammate hold the other end of the fishing line so that it is taut and roughly horizontal. The line must be held steady and may not be moved up or down during the experiment.

2. Have one teammate blow up a balloon and hold it shut with his or her fingers. Have another teammate tape the straw along the side of the balloon. Thread the fishing line through the straw and hold the balloon at the far end of the line.

3. Assign one teammate to time the event. The balloon should be let go when the timekeeper yells “Go!” Observe how your rocket moves toward the blackboard.

4. Have another teammate stand right next to the blackboard and yell “Stop!” when the rocket hits its target. If the balloon does not make it all the way to the blackboard, “Stop!” should be called when the balloon stops moving. The timekeeper should record the flight time.
5. Measure the exact distance the rocket traveled. Calculate the average speed at which the balloon traveled. To do this, divide the distance traveled by the time the balloon was “in flight.” Fill in your results for Trial 1 in the table below.

6. Each team should conduct two more trials and complete the sections in the table for Trials 2 and 3.

7. Calculate the average speed for the three trials to determine your team’s race entry time. The winner of this race is the team with the fastest average balloon speed.

**Discuss and record your group answers to the following questions on the white board:**

1. What made your rocket move?

2. How is Newton’s Third Law of Motion demonstrated by this activity? What is accelerating? What provided the force?

3. Draw pictures using labeled arrows to show the action and reaction forces acting on the balloon before it was released and after it was released.

**Your TA will lead a class discussion at the end of this activity.**

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<th>Distance (m)</th>
<th>Times (sec)</th>
<th>Speed (m/sec)</th>
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<td>Trial 1</td>
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<td>Average:</td>
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**Activity #2 – Measuring Newton 3rd law forces**

You may have learned this statement of Newton’s third law: “To every action there is an equal and opposite reaction.” What does this sentence mean?

Unlike Newton’s first two laws of motion, which concern only individual objects, the third law describes an interaction between two bodies. For example, what if you pull on your partner’s hand with your hand? To study this interaction, you can use two Force Sensors. As one object (your hand) pushes or pulls on another object (your partner’s hand) the Force Sensors will record those pushes and pulls. They will be related in a very simple way as predicted by Newton’s third law.

The *action* referred to in the phrase above is the force applied by your hand, and the *reaction* is the force that is applied by your partner’s hand. Together, they are known as a *force pair*. This short experiment will show how the forces are related.
OBJECTIVES
• Observe the directional relationship between force pairs.
• Observe the time variation of force pairs.
• Explain Newton’s third law in simple language.

MATERIALS
- computer
- 500 g mass and hanger
- Vernier computer interface
- string
- Logger Pro
- rubber band
- two Vernier Force Sensors
- Wood block

PRELIMINARY QUESTIONS
1. You are driving down the highway and a bug splatters on your windshield. Which is greater: the force of the bug on the windshield, or the force of the windshield on the bug?

2. Hold a rubber band between your right and left hands. Pull with your left hand. Does your right hand experience a force? Does your right hand apply a force to the rubber band? What direction is that force compared to the force applied by the left hand?

3. Pull harder with your left hand. Does this change any force applied by the right hand?

4. How is the force of your left hand, transmitted by the rubber band, related to the force applied by your right hand? Write a rule, in words, for the force relationship.

PROCEDURE
1. Connect the two Dual-Range Force Sensors to Channels 1 and 2 of the interface. Set the range switch to 50 N.

2. Open the file “11 Newton’s Third Law” in the Physics with Vernier folder.

3. Force Sensors measure force only along one direction; if you apply a force along another direction, your measurements will not be meaningful. The Dual Range Force Sensor responds to force directed parallel to the long axis of the sensor.
4. Since you will be comparing the readings of two different Force Sensors, it is important that they both read force accurately. In other words, it is set to calibrate them. To calibrate the first sensor:
   a. Choose Calibrate from the Experiment menu. Select CH1: Dual Range Force. Click on the **Calibrate Now** button.
   b. Remove all force from the first sensor and hold it vertically with the hook pointed down. Enter a 0 (zero) in the Value 1 field, and after the reading shown for Reading 1 is stable, click **Keep**. This defines the zero force condition.
   c. Hang the 500 g mass from the sensor. This applies a force of 4.9 N. Enter 4.9 in the Value 2 field, and after the reading shown for Reading 2 is stable, then click **Keep**.
   d. Click **Done** to complete the calibration of the first Force Sensor.
   e. Repeat the process for the second Force Sensor.

5. You will be using the sensors in a different orientation than that in which they were calibrated. Zero the Force Sensors to account for this. Hold the sensors horizontally with no force applied, and click **Zero**. Make sure both sensors are highlighted in the Zero Sensor Calibrations box and click **OK** to zero both sensors. This step makes both sensors read exactly zero when no force is applied.

6. Click **Collect** to take a trial run of data. Pull on each Force Sensor and note the sign of the reading. Use this to establish the positive direction for each sensor. Then adjust the sensor setting (ask your TA) so one sensor reads positive and the other negative force.

7. Make a short loop of string with a circumference of about 30 cm. Use it to attach the hooks of the Force Sensors. Hold one Force Sensor in your hand and have your partner hold the other so you can pull on each other using the string as an intermediary.

8. Click **Collect** to begin collecting data. Gently tug on your partner’s Force Sensor (while they hold theirs still) with your Force Sensor, making sure the graph does not go off scale. Do a second data run where your partner tugs on your sensor. You will have 10 seconds to try different pulls. Is there any way to pull on your partner’s Force Sensor without your partner’s Force Sensor pulling back? Try it. You may want to do a couple of trials to get a reasonable graph of the forces. Choose Store Latest Run from the Experiment menu when you have a good graph and copy the data to your jump drive or record it on paper.

9. What would happen if you used the rubber band instead of the string? Would some of the force get “used up” in stretching the band? Use the prediction tool to sketch a prediction graph, and repeat Steps 7–8 using the rubber band instead of the string.
10. Using a block of wood, push your Force Sensors on opposite ends of the wood and experiment with mutual pushes instead of pulls. Repeat the experiments above. Does the “push” on the block change the way the force pairs are related?

Refer to the P150A Lab Syllabus for information on the general guidelines for writing an Experimental Lab report.

This week’s Lab report must include the following:

Theory section - Write a description in your own words of Newton’s 3rd law and use it to explain how a bird flies, a passenger car accelerates and a rocket accelerates in space, making sure to identify the “action – reaction” pairs.

Data section –
- The data from Logger Pro for the 2 force sensors connected with a string and the associated graph done using Excel. Annotate your graph (handwritten on your graphs is ok) the areas that match Newton’s 3rd law predictions (equal, but opposite forces).

Observation Questions:

1. For Activity #1, describe how the acceleration of the balloon “rocket” is based on Newton’s 3rd law.

The following questions are for Activity #2

2. Examine the two data runs. What can you conclude about the two forces (your pull on your partner and your partner’s pull on you)? How are the magnitudes related – when you pulled harder was the force on your partner’s sensor lower than yours? How are the signs related?

3. How does the rubber band and the wood block change the results—or does it change them at all?

4. Reread the statement of the third law given at the beginning of this activity. Based on your observations during this lab, restate Newton’s third law in your own words, not using the words “action,” “reaction,” or “equal and opposite.”