Lesson Plan for Zip-Line Balloon Racer

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Background Info

Have you ever wondered why when you push a table it resists your pushing and doesn't collapse? Have you ever wondered how a space shuttle (Figure 1) changes its orbit in space? **Newton's Third Law of Motion** will tell you the answer. Today, a simpler model of space shuttle, a zip-line balloon racer, will help you understand the concept of force, why a force is a form of interaction, and the relationship between force and motion.

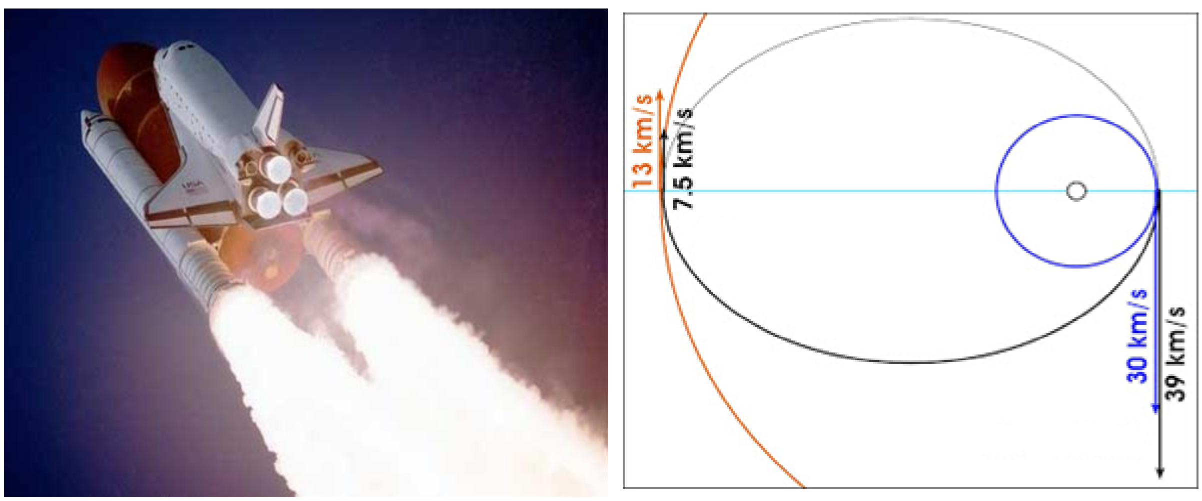


Figure 1. A space shuttle (left) and a diagram of a space shuttle changing orbits (right).

Force is the basic form of *interaction* between two objects. It is measured with the **SI unit** of **Newton (N)** and represented by the symbol **F**. There are different categories of forces (Figure 2), such as frictions, gravity, elastic force, etc. To explain the concept of force, mentors can utilize the **operational definition** (aka functional definition: one defines something in terms of the operations that count as measuring it). For example, suppose you have a specially designed spring, such as the spring scale. Exerting 1N of force on the spring scale stretches the spring a certain distance. Now 1N of force is characterized as that precise distance of stretch. There may be many possible operational definitions, but the goal is to make the concept more intuitive and to avoid throwing in more technical terms.

Here we are going to demonstrate force with the help of spring balance (Figure 3), which can show the magnitude and direction of forces. By connecting the hooks of two spring balances and pulling the rings to the opposite direction, we can test Newton's Third Law in a simple way. (A spring balance consists of a spring, a ring, a hook, a pointer, and a case with the graduated scale. It can tell people the magnitude and direction of the force, according to Hooke's Law.)

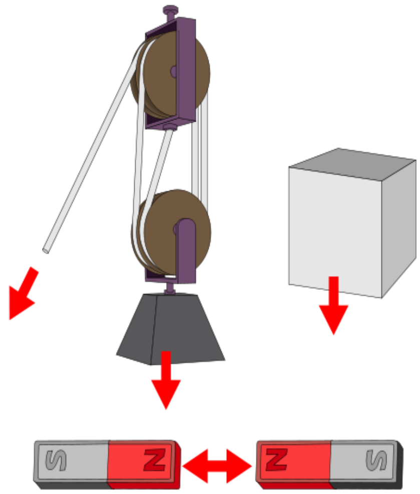


Figure 2. Different forms of forces

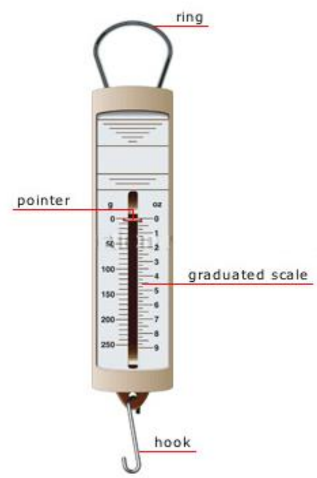


Figure 3. A spring balance

One application of Newton's Third Law is when a space shuttle changes its orbit. By expelling gas, the shuttle gains a propelling force. As the shuttle pushes the gas out, the gas also exerts an equal and opposite force on the shuttle, making it move forward. In this lesson, a balloon racer gains its propulsion in a similar way. By pushing air out, the racer gains a propelling force from the air and thus move forward on the string.

Student Objectives

- Develop an idea of **force**
- Understand basic usage of a **spring balance**
- Understand the basic idea of **Newton's Third Law**

Overview of Lesson Process

- Introducing the concept of force (5-10 mins)
- Introduce the Newton's Third Law (10 mins)
- Simple test on Newton's Third Law with spring balances, fill out the worksheet (5-10 mins)
- Making the zip-line balloon racer and test (20-30 mins)
- Conclusion—summarizing the concepts and probably mentioning the relationship between force and motion (10-15 mins)

Materials

Transparent tape	OfficeMax Item # : 09019117	$3.00
Drinking Straw	OfficeMax Item # : 22214854	$7.99
Ruler	OfficeMax Item # : 20594466	$4.19
String	Blick Item # : 77284-4865	$9.99
Scissors	OfficeMax Item # : 20856833	$3.89
Two chairs		
Two balloons	OfficeMax Item # : 22058185	$24.49
Spring balance	Fisher Item # : S04393A	$4.00
		Total: $57.55

Demonstration of Newton's Third Law

- Hook the top portion of one spring scale around your right thumb. Position your right hand on the right edge of a table.
- Hook a second spring scale to the first scale so the bottom portion of the second scale is hooked to the bottom portion of the first scale.
- With the two scales attached, hold your right hand steady so it does not move. With your left hand pull horizontally on the top portion of the second spring scale until the reading on the scale measures 5 Newtons (Figure 4).
- Look at the reading on the other spring scale. What does it read? Was the reading on both scales the same? Explain the reason for this. <u>(The same force was being exerted on both scales in the activity due to the third law of motion.)</u>

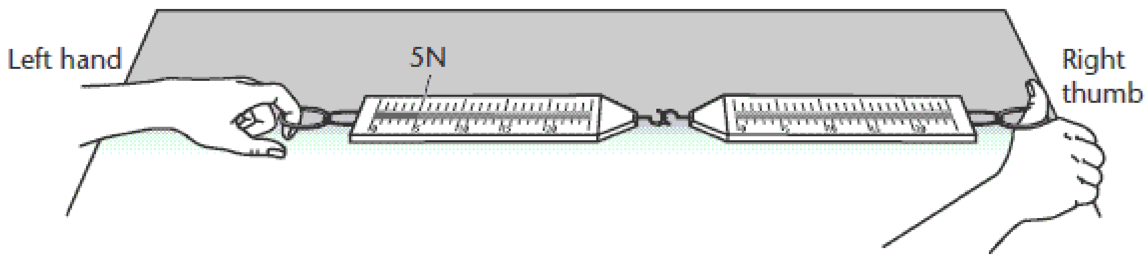


Figure 4. Experiment of Newton's Third Law of Motion

Procedures

➢ **Phase 1: Make the Balloon Racer**

- Cut a piece of tape that's 1 inch shorter than your deflated balloon. Fold the tape lengthwise, with the sticky side face out, to make a long, skinny tape loop (Figure 5A).
- Line up one end of the tape loop with one end of the straw, then press the tape along the length of the straw. Position the balloon over the tape and straw so that the end of the mouthpiece will hang over the end of the straw ad the body of the balloon will be attached to the straw. Press the balloon down to affix it (Figure 5B).
- Take a 2-inch piece of tape and affix it loosely around the straw and balloon near the mouthpiece. This tape does two things: (1) It helps hold the balloon in place and (2) it helps release the air more slowly when you're ready to make your balloon racer zip. Don't make the tape too tight, or you won't be able to blow up the balloon, but also, don't make it too loose, or you won't provide any resistance for the air when you let the racer go (Figure 5C).

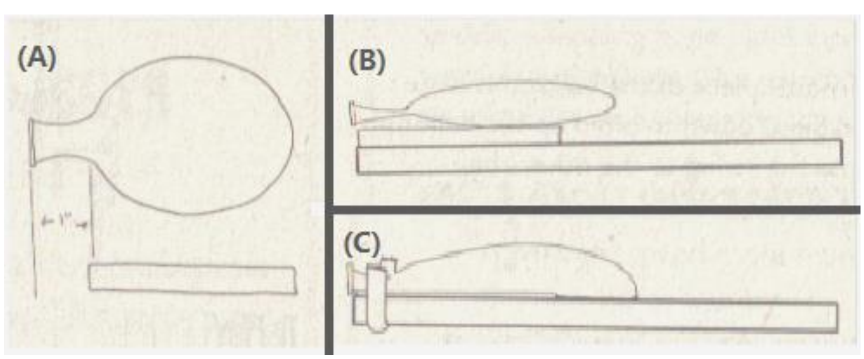


Figure 5. Phase 1 of making the balloon racer

- **Phase 2: Make the Zip Line**
    - Cut a 7-foot piece of string. Tie the string to the top of one chair, then slip the straw of the balloon racer over the loose end of string. Toe the loose end of the string to the other chair. Pull the chairs apart till the string is taut (Figure 6).

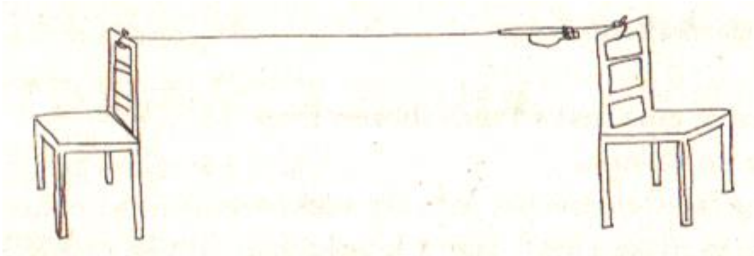


Figure 6. Phase 2 of making the balloon racer

- **Phase 3: Play**
    - Position the balloon racer so that the mouthpiece of the balloon is close to one chair. Hold the racer steady and bend down to blow up the balloon. Release the racer and watch it zip across the string to the other chair (Figure 7).

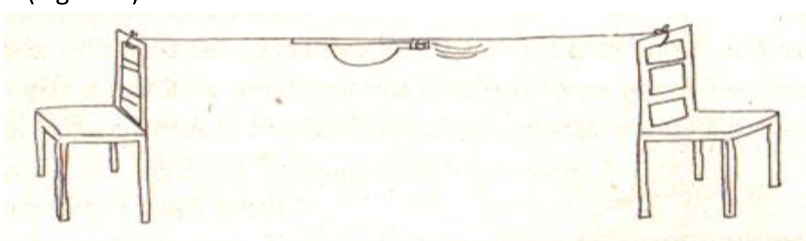


Figure 7. Phase 3 of making the balloon racer

Wrap-Up

In this lesson, we have explored the concept of force and the interactive essence of the force through Newton's Third Law. Recalling the two experiments we just did, we understood how a force can be measured by a spring balance, how to test Newton's Third Law with two springs, and how we can apply the physics law into reality (the balloon racer we just made).

The knowledge of Newton's Third Law can help to understand other phenomenon in reality. For example, when sitting on a chair, your body exerts a force on the chair and the chair exerts an equal force back if the chair didn't exert the same force you would fall on your butt.

An extending (but optional) discussion on the balloon racer model may focus on the relationship between force and motion. According to Newton's First and Second Law of Motion, we know that motion does not need a force to sustain, and a force causes changes in a motion. This may simply explain why the racer moves when it gains a force from expelled air. Mentors may not need to mention this, but if kids are curious and there is still plenty of time, it is proper to bring up this discussion.

Resources

Activity and Figures 5–7 adapted from:
Heather Swain, *Make These Toys: 101 Clever Creations Using Everyday Items*, A Perigee Book. Pp. 8-12.

3rd Law Demonstration and Figure 4 adapted from:
http://www.education.com/reference/article/newton-law-motion3/?page=2

Operational definition: http://en.wikipedia.org/wiki/Operational_definition

Worksheet for Zip-Line Balloon Racer

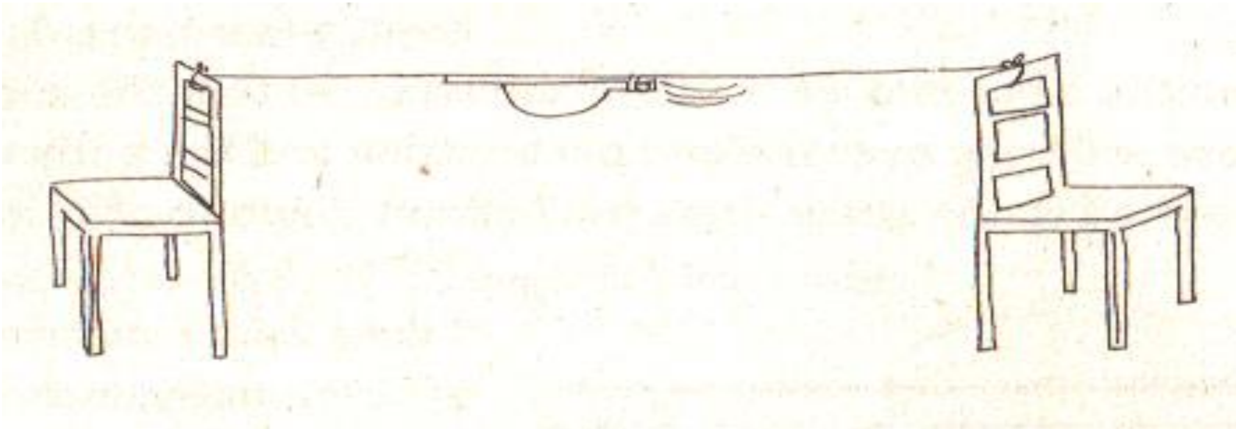
Demonstration of Newton's Third Law

After the two springs scales are hooked up, if one scale shows 5 Newtons, what will the other scale show? Are the two forces the same number? What about the direction?

Making a Balloon Racer

What propels the balloon racer forward when you release it? Is this an example of a force?

How does the balloon racer relate to Newton's Third Law? To answer this question, it might be helpful to draw the forces on the picture below.



Extra Questions to Test Understanding of Newton's Third Law

1. Gravity is a force that always pulls you down toward the ground. When you sit on a chair, gravity still pulls you down. What keeps you from falling through the chair?

2. You and your friend are each standing on a skateboard. If you push your friend, what will happen to you? Will you move? In what direction?