Newton's Third Law

INTRODUCTION

In your discussion of the force concept you may have heard that a force is a push or pull exerted by one object on another. You may also have heard a popular expression of Newton's third law: "For every action, there is an equal, but opposite reaction." Unfortunately, this expression leads to some naïve conceptions about forces. Unlike Newton's first two laws, which deal with the effects of forces on a single object, the third law describes the interaction between two objects. In this experiment, you will examine this interaction in a variety of situations so that you might develop a better understanding of the forces involved when two objects interact.

OBJECTIVES

In this experiment, you will

- Observe the magnitude and direction of forces exerted by interacting objects.
- Observe the time variation of these forces.
- Develop a more robust expression of Newton's third law.

MATERIALS

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Vernier data-collection interface	string
Logger *Pro* or LabQuest App	rubber band
two Vernier Dual-Range Force Sensors, **or**	(optional) two magnetic bumpers **or**
two Wireless Dynamic Sensor Systems (WDSS)	two hoop springs from the
Vernier Dynamics Track	Bumper and Launcher Kit
two standard carts	

PRE-LAB INVESTIGATION

Before you begin your experiment, consider the following situations involving an interaction between two objects. Sketch a graph of the forces exerted by the objects as a function of time. Recall that force is a vector–it has direction as well as magnitude.

1. You and your little brother are engaged in a tug of war. You are bigger and stronger, but you choose to not pull your brother over during the contest. Assume that your force is in the positive direction. Graph both forces on one set of axes during the contest.
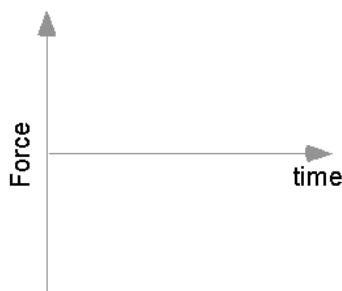
2. You are pushing on a wall. Graph the forces exerted by you and by the wall (if any). Assume that your force is in the positive direction.
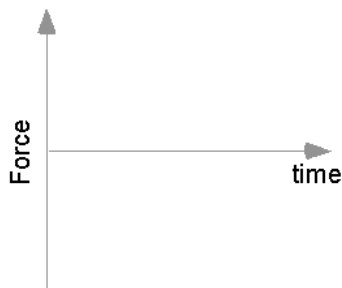
PROCEDURE

In this experiment, you will collect force-time data in a number of ways. In your lab notebook, record details about the way you collected the data for each trial.

1. Set the range switch on both sensors to 10 N. Connect both Force Sensors to the interface and start the data-collection program. The default data-collection mode works well for this experiment.

2. Make a loop with the string so that you can connect the hook ends of the two sensors. See Figure 1.
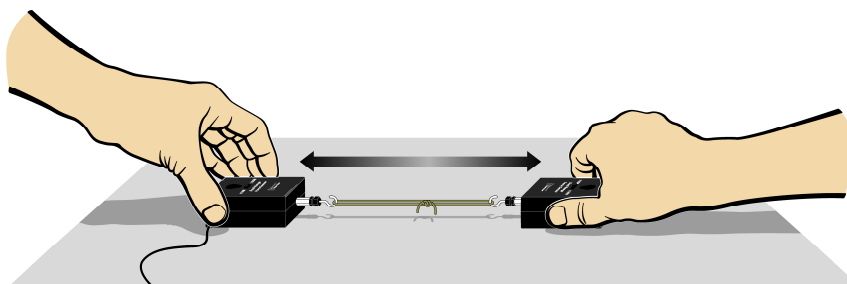
Figure 1

3. Since force is a vector quantity, you must reverse the direction of one of the sensors in the software. Decide which one you should adjust.

4. Before any force is applied to the force sensors, zero both sensors. Be sure to re-zero the sensors after each change you make in the configuration of the apparatus.

5. Begin data collection, wait a second, then you and your partner should pull on your sensor, being careful not to exceed the 10 N limit for data collection. During the 10 s data collection interval, vary the amount of force each of you applies to the other.

6. Observe the plots of force *vs.* time for both sensors, then store this run.

7. Collect data again, but this time, one of you should simply hold onto your force sensor while the other applies the force. Observe the plots of force *vs.* time for both sensors, then store this run.

8. Replace the loop of string with a rubber band. Collect force-time data as you did in Step 5. Observe the plots of force *vs.* time for both sensors, then store this run.

9. Replace the hooks on the force sensors with bumpers (see Figure 2). Before any force is applied to the force sensors, zero both sensors.
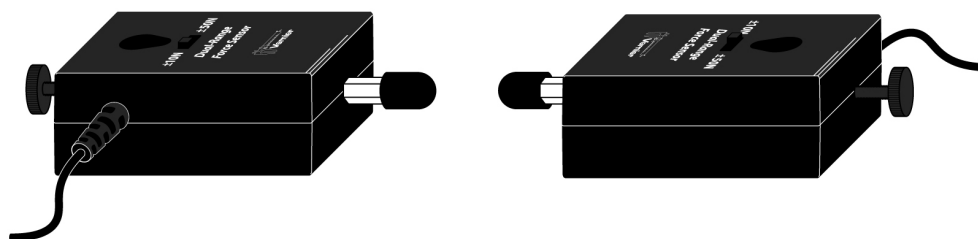

Figure 2

10. Collect force-time data while both of you push on your force sensor. Observe the plots of force *vs.* time for both sensors, then store this run.

11. To help you test your prediction posed in the second situation in the pre-lab, attach one force sensor to a support rod that is clamped to the table so that it cannot move. Position the other sensor so that the bumpers on the two sensors line up. Begin collecting data, then push on the free sensor so that both sensors are in contact. Observe the plots of force *vs.* time for both sensors, then store this run.

12. Be sure to save your data file. You will refer to it for the Evaluation of Data.

EVALUATION OF DATA

1. Examine your data and graph for your first trial. Compare the magnitude and direction of the forces that you and your partner applied.

2. Were you able to observe any time delay between the appearance of either force; i.e., does Force 2 appear to be a *reaction* to Force 1, or vice-versa?

3. Could you tell from the graph whether you or your partner was pulling harder than the other at any time during the run?

4. Examine the data and graph for your second trial. From the graph, can you tell which of you pulled on your force sensor and which one simply held on?

5. Examine your data and graph for your third trial. What effect, if any, did replacing the string with the rubber band have on your results?

6. Examine the data and graph for your fourth trial. Did it make a difference if you were *pushing* on the sensors instead of pulling on them?

7. Examine the data and graph for your fifth trial. Is it true that only one object was applying a force? Explain.

8. Reflect on the graphs for your various trials. Can you tell, without the help of your lab notes, how the forces were applied?

9. Re-state Newton's third law in your own words without using the words "action" and "reaction." If you said in Step 1 that the forces were *both* equal *and* opposite, find a more precise way to state the relationship between the forces.

EXTENSION

If the accessories in a Bumper and Launcher Kit (magnetic bumpers, hoop springs) are available, replace the regular bumpers with these and repeat data collection.
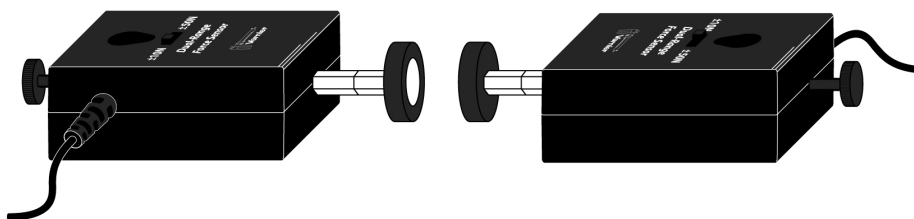

Figure 3

ANIMATED DISPLAY

If you're using Logger *Pro*, inserting an animated display allows you to represent both force vectors during the experiment. Your instructor will show you how to set up the point display options for such a display.