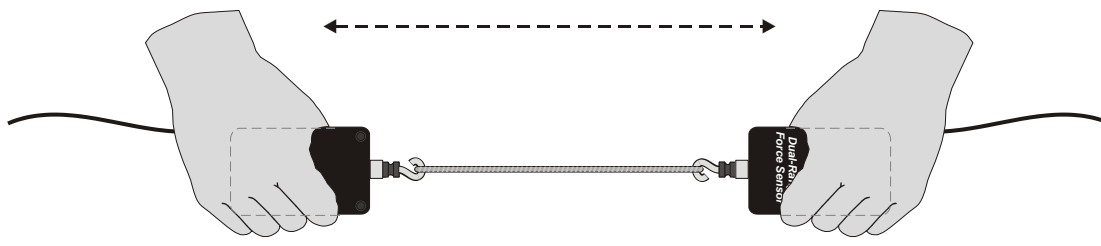# Newton's Third Law

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

- Calibrate two Force Sensors.
- Observe the directional relationship between force pairs.
- Observe the time variation of force pairs.
- Explain Newton's third law in simple language.

MATERIALS

LabQuest	0.5 kg mass
LabQuest App	string
two Vernier Force Sensors	rubber band

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. Set the range switch on both Force Sensors to 10 N. Connect the Force Sensors to LabQuest. Choose New from the File menu.

2. We need to calibrate both sensors to read the same magnitude under the same force, but with opposite signs. A pull on one sensor produces a positive reading while a pull on the other produces a negative reading. That way they will share the same coordinate system when the sensors are facing one another, so that the positive direction is left (or right, depending on perspective) for both sensors.

   a. Choose Reverse ► CH:2 Force from the Sensors menu to change the sign.

3. Next you will zero the sensors.

   a. Hold both sensors with the measurement axis horizontal and no force applied to the hooks.
   b. When the readings stabilize, choose Zero ► All Sensors from the Sensors menu. The readings for the sensors should be close to zero.

4. Use the string given to you by Mr. Duhrkopf 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. Be careful to apply force only along the sensitive direction of your particular Force Sensor.

5. Start data collection. *Gently* tug on your partner's Force Sensor with your Force Sensor. Also, have your partner tug on your sensor. You will have 5 seconds to try different pulls.

6. After data collection is complete, the graph of force *vs.* time will be displayed with data from both sensors. If either plot has force peaks with flat tops, you pulled too hard. Try again, pulling with less force. To take more data, start data collection again.

7. Print or sketch your graph.

8. What would happen if you used the rubber band instead of the string? Sketch a prediction graph of the two force readings, and repeat Steps 6–8 using the rubber band instead of the string. Print the resulting graph.

ANALYSIS

1. Examine the graph. To examine the data on the displayed graph, select any data point. As you move the tap each data point, the two force values for a given time are displayed to the right of the graph. 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? How are the signs related?

2. How does the rubber band change the results?

3. Is there any way to pull on your partner's Force Sensor without your partner's Force Sensor pulling back?

4. While you and your partner are pulling on each other's Force Sensors, do your Force Sensors have the same positive direction? What impact does your answer have on the analysis of the force pair?

5. Re-evaluate your answer to the bug-windshield question.

EXTENSIONS

1. Fasten one Force Sensor to your lab bench and repeat the experiments. Does the bench pull back as you pull on it? Does it matter that a *person* does not hold the second Force Sensor?

2. Use a rigid rod to connect your Force Sensors instead of a string and experiment with mutual pushes instead of pulls. Repeat the experiments. Does the rod change the way the force pairs are related?

3. Predict the shape of a plot of the reading of one Force Sensor *vs.* the reading of the other for your most recent run. Make such a plot and fit a line to it by fitting a straight line to channel 2 *vs.* channel 1.