Computer
11

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.

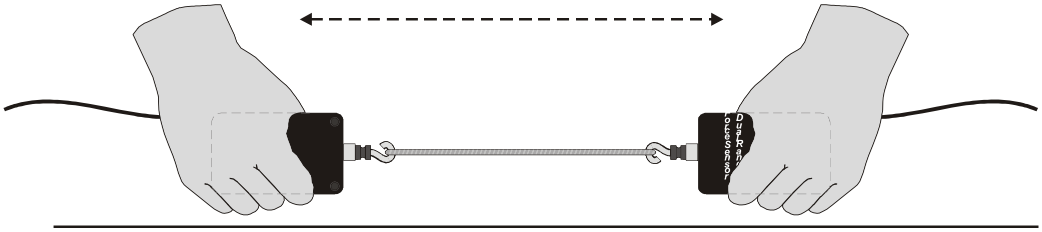

Figure 1

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
Vernier computer interface
Logger *Pro*
two Vernier Force Sensors
or two WDSS
500 g mass
string
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. 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. (Optional)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 400g of mass from the sensor. This applies a force of 3.92 N. Enter **3.92** 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. Enter **3.92** in the Value 2 field as you will be pulling with this sensor in the opposite direction.

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. 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.

7. Click ▶ Collect to begin collecting data. Gently tug on your partner's Force Sensor with your Force Sensor, making sure the graph does not go off scale. Also, have your partner tug on your sensor. You will have 10 seconds to try different pulls. Print your graph.

8. 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 Step 7 using the rubber band instead of the string.

ANALYSIS

1. 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? How are the signs related?

2. How does the rubber band change the results—or does it change them at all?

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

4. Reread the statement of the third law given at the beginning of this activity. The phrase *equal and opposite* must be interpreted carefully, since for two vectors to be equal ($\vec{\mathbf{A}} = \vec{\mathbf{B}}$) and opposite ($\vec{\mathbf{A}} = -\vec{\mathbf{B}}$) then we must have $\vec{\mathbf{A}} = \vec{\mathbf{B}} = 0$; that is, both forces are always zero. What is really meant by *equal and opposite*? Restate Newton's third law in your own words, not using the words "action," "reaction," or "equal and opposite."

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