**

Newton’s Third Law

LabQuest App 11

*From Physics with Vernier*

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? This experiment will help you investigate this question.

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.

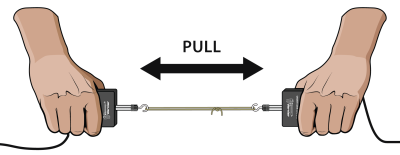


Figure 1

objectives

* Observe the directional relationship between force pairs.
* Observe the time variation of force pairs.
* Explain Newton’s third law in simple language.

Materials

LabQuest

LabQuest App

two Vernier Dual-Range Force Sensors or two Wireless Dynamics Sensor Systems (WDSS)

500 g mass

string

rubber band

Preliminary questions

Answer these questions as best you can. You will have a chance to revisit your answers after the activity.

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 switches of the Dual-Range Force Sensors to 50 N. Connect the two force sensors to LabQuest. Choose New from the File menu.

Force sensors measure force only along one direction; if you apply a force along another direction, your measurements will not be meaningful. The force sensor responds to force directed parallel to the long axis of the sensor.

1. (Optional) Because you will be comparing the readings of two different force sensors, it is important that they both read force accurately. To increase the accuracy of the sensors, you will calibrate them.
   1. Choose Calibrate ► CH:1 Force from the Sensors menu.
   2. Hold the sensor attached to Channel 1 so that you can hang a weight from it, but do not attach any weight now.
   3. Select Calibrate Now.
   4. Enter 0 (zero) as the known value for Reading 1, and then tap Keep.
   5. Hang a 4.9 N weight (500 g) from the sensor.
   6. Enter 4.9 as the known value for Reading 2 and tap Keep.
   7. Select OK.
   8. Now choose Calibrate ► CH:2 Force from the Sensors menu. Repeat Parts b–g for the second force sensor.
2. Set up the force sensors so they read the same magnitude under the same force, but with opposite signs. To do this, you will zero both sensors and then reverse the direction of one of them. When you are done, a pull on one sensor produces a positive reading while a pull on the other produces a negative reading.
   1. Place both sensors on a flat surface with the measurement axis horizontal and no force applied to the hooks.
   2. When the readings stabilize, choose Zero ► All Sensors from the Sensors menu. The readings for the sensors should be close to zero.
   3. Choose Reverse ► CH:2 Force from the Sensors menu to change the sign.
3. 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. Be careful to apply force only along the sensitive direction of your particular force sensor.
4. 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 10 seconds to try different pulls.
5. 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.
6. Print or sketch your graph. Store the run (Run 1) by tapping the File Cabinet.
7. 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? Sketch a prediction graph of the two force readings in your notes, and repeat Steps 5–7 using the rubber band instead of the string.

Analysis

1. Examine the string data.
   1. Choose Graph Options from the Graph menu and then select to graph only Run 1 on the y‑axis.
   2. 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. Examine the rubber band data.
   1. Choose Graph Options from the Graph menu and then select to graph only Run 2 on the y‑axis.
   2. Examine the data on the displayed graph. How does the rubber band change the results—or does it change them at all?
3. While you and your partner are pulling on each other’s force sensors, do your force sensors have the same positive direction? How does your answer affect the analysis of the force pair?
4. Is there any way to pull on your partner’s force sensor without your partner’s force sensor pulling back? Try it.
5. 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 () and opposite () then we must have ; 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.”
6. Re-evaluate your answers to the preliminary questions.

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 the second force sensor is not held by a person?
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?