

Introduction

This lab investigates the forces two objects exert on each other when they interact. For example a falling ball feels a force from the earth, and the earth feels a force from the ball. A book resting on a desk pushes down on the desk, and the desk pushes up on the book. We would like to determine if we can find general factors that determine the sizes of the forces between two objects, and if there is a general law that relates these forces.

Before you begin work on this lab read sections 4.1 through 4.4 in Serway and Faughn.

Pre-lab homework:

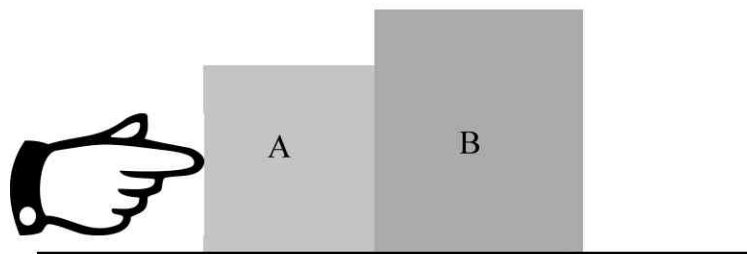
1. a.) *Suppose you have a tug of war with a friend who is the same size and weight as you are. You both pull as hard as you can, but neither of you seems to be winning. You move a little one way or the other, but mostly you are just at rest (although sweating some). Compare the magnitude of the force exerted by you on your friend, with the magnitude of the force exerted by your friend on you. Are they the same or different? If they are not the same, which is larger? Why or why not?*

b.) *Now you have a tug of war with your kid brother (who is much smaller and lighter than you). Again you both pull hard but end in a standoff with neither of you moving much. In this situation compare the magnitude of the force you exert on your brother with the magnitude of the force he exerts on you. Are they the same or different? If they are not the same, which is larger? Why or why not?*

c.) *The next tug of war is still with your kid brother but he is now standing on his skateboard. You can now make him roll across the floor (with a constant speed) when you pull hard. In this situation compare the magnitude of the force you exert on your brother with the magnitude of the force he exerts on you. Are they the same or different? If they are not the same, which is larger? Why or why not?*
2. *Due to the drivers not paying attention, a small car and a big truck collide, both are initially moving at 15 mph towards each other. Compare the magnitude of the force the truck exerts on the car to the magnitude of the force the car exerts on the truck. Which force is greater? Which vehicle would you rather ride in? Describe why you made your choice.*
3. *A small car is pushing a larger truck that has a dead battery. The mass of the truck is twice as large as the mass of the car. At one instant of time the car and truck both have an acceleration of 2.5 m/s^2 . Which of the following statements is true? Defend your choice with an **explanation** using concepts associated with Newton's Laws.*
 - a.) *The car exerts a force on the truck, but the truck doesn't exert a force on the car.*
 - b.) *The car exerts a larger force on the truck than the truck exerts on the car.*
 - c.) *The car exerts the same amount of force on the truck as the truck exerts on the car.*
 - d.) *The truck exerts a larger force on the car than the car exerts on the truck.*
 - e.) *The truck exerts a force on the car, but the car doesn't exert a force on the truck.*

Group Activity

Suppose you have two blocks A and B, and that block B is more massive than block A. They are on a frictionless surface and you are pushing on block A as shown. The blocks are speeding up.



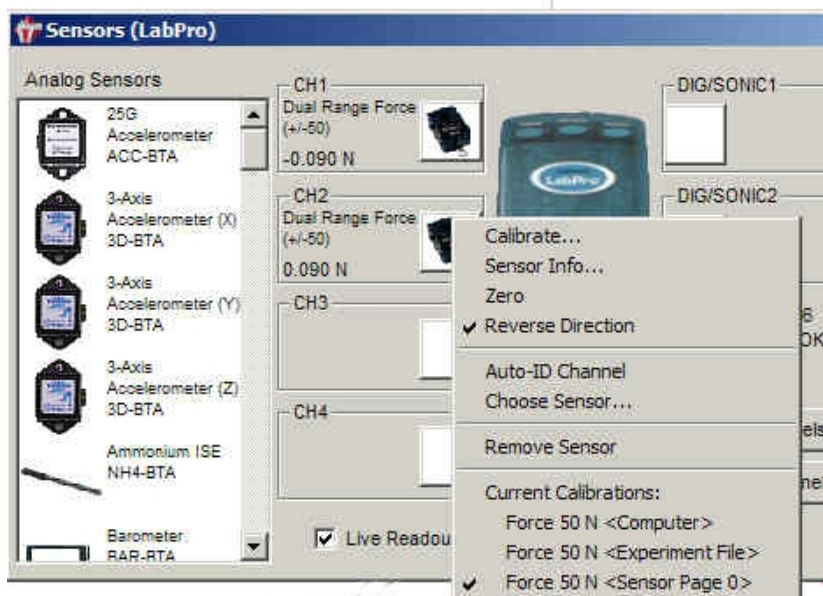
- Draw THREE separate free body diagrams for the hand, block A and block B. For this exercise, you should show only the horizontal forces. Label the forces in the form $F_{C \text{ on } D}$. Connect the action/reaction pairs with dotted lines.
- By applying the second law to each block, and the third law to each action/reaction pair, rank ALL of the horizontal forces, from largest to smallest. Explain your reasoning.
- Repeat both a) and b) for the case where there is friction (the blocks are still speeding up).

Experiment A: The Tug Of War

A1. Open the file *week5.xml*.

A2. Setup the force sensors:

- Check that cart #1 with force sensor #1 is connected to Lab-Pro input channel #1, and that cart #2 with sensor #2 goes to channel #2. Put both sensors into the 50N scale setting with the switches on top of the sensors. Zero both sensors when no load is attached. Set the carts on the track with the rubber bumpers facing each other.
- Check that the sign registered by the force sensor is positive for a “pull force” on sensor #1, and negative for a “pull force” on sensor #2. The forces are in opposite directions along the track, so they should have opposite signs. To achieve this, the sign of sensor #2 should be reversed, click “lab-pro”, then click on CH2, set “Reverse Direction”.



- c. Test your setup. Be sure a “pull” registers positive for #1 and negative for #2
- d. With nothing attached to the sensors re-zero them and slowly bump them into each other to obtain force measurements. Use the “autoscale” button to see the detail in the data. Are your force readings zero? Exactly zero? Explain the plot you just made. Note that you can see the numbers used in making the plot on “page 2” of your program. Copy a typical sequence of 5 readings of time, F_1 , and F_2 into your notes for later reference. Use a table like this:

Time (sec)	Force 1 (N)	Force 2 (N)

- A3.** Attach the two sensors to each other with a piece of string. Keep both carts on the track. Choose one person from your lab group to control one cart, and another person to control the other cart. Have a gentle tug of war with the two carts, recording data. Experiment with how hard you can tug while keeping the readings under the 50N maximum. How do the sizes of the forces compare to each other?
- A4.** Compare the details:
- When you can see the symmetry in the forces in A3, switch the sign of sensor #2 (click off the “reverse direction that you set in A2 above). Now the force curves should both have the same sign. This makes it easier to see exactly how well the forces compare.
 - Repeat A3 and check in detail how well the plots for the two sensors compare. Do this a few times to get a feel for the repeatability. Do these plots overlay as well as the measurements you made in A2 of zero force?
 - Are the outputs of the two sensors exactly the same? (i.e. are the *magnitudes* of the forces the same) Do the differences look like an incorrectly set zero point, or an incorrect calibration? What effect would these problems have on your data? Specify your experimental uncertainties and compare this to how well the two graphs agree. Record 5 sequential readings in a table as you did in experiment A2 and use this to justify your arguments.
- A5.** Now choose two people from your lab group who are approximately the same mass. Each person lifts a cart off the tracks. Take data during a gentle tug of war. Compare these data with data taken in A4. Are the forces still equal? Explain your observations. Compare with your answer to pre-lab question #1.
- A6.** Choose a large person and a small person, repeat experiment A5. How do the sizes of the forces compare to each other. Record 5 sequential readings in a table as you did in experiment A2, you should use this in your conclusion. Compare your results to the prediction you made for pre-lab question #2.
- A7.** Use the skate board or the “kinetic cart”. One person can sit on the cart – **BE SAFE**. The other person pulls gently so that the cart and person slowly begin to move. Measure the forces as the cart starts to move. You only need to move 2 or 3 feet. Be careful that the cord lengths to the LabPro are adequate to allow the motion you plan. How do the sizes of the forces compare to each other?

- A8. Are your observations consistent with Newton's Third Law of motion? Do the relative masses of the people matter? Is it important to know if the people are moving?
- A9. When you pull an object with a force probe, does the probe measure the force it exerts on the object, or the force exerted on the probe by the object? Does this distinction have any meaning?

Experiment B: Forces between colliding objects.

We will now attempt to measure the forces objects exert on each other when they collide, and the effects the forces have on the motion of the objects. This time we will use the same force sensors and carts as in experiment A and make gentle collisions (bumper to bumper) with the carts on the tracks. You need to remove the link you installed for experiment A and be sure the rubber stoppers are installed on the force sensors to act as bumpers.

- B1. Setup the sensors the same way you did in A2. The positive direction of the track is now from sensor #1 to sensor #2 as shown in the photo. Confirm for each of the sensors that a force in the positive direction registers as a positive force. Be sure you can recognize which graph belongs to which force sensor.



Carts 1 and 2 with force sensors and accelerometers. Positive direction is \rightarrow

- B2. Push the carts so they collide. Measure and compare the forces. (Slow speeds give cleaner data.)
- B3. Now load cart #1 with an extra mass. Weigh each cart. Try to avoid the wires attached to the sensor affecting the weights. Repeat B2, measure and compare the forces. Do the forces scale with the masses?
- B4. Using both accelerometers and force sensors:
- Attach an accelerometer on top of each force sensor with tape. Take care that the arrows on the accelerometers point in the positive direction as defined in B1.
 - To gain experience with the new acceleration sensors move one of the carts backwards and forwards repeatedly by pushing and pulling on its force sensor. Measure both the acceleration and force. Is there a relationship between them? What is the relationship? Have you seen it before?

B5. Repeat B2 (equal masses) measuring both forces and accelerations. Are the peak forces equal in magnitude? Are the peak accelerations equal in magnitude?

B6. Repeat B3 (cart #1 has 1 kg extra mass) measuring both forces and accelerations. Are the peak forces equal in magnitude? Are the peak accelerations equal in magnitude?

Review the answers to pre-lab questions and explain with reference to your data.

Conclusion:

1. Write a conclusion for the section of the lab that is assigned to you by the TA.