1 Forces and Motion

In the following experiments, you will investigate how the motion of an object is related to the forces acting on it. For our purposes, we'll use the everyday definition of a force as a push or a pull. *For all questions, you must explain your reasoning.*

1.1 Experiment

1. Clamp a ringstand to the table.
2. Place a rubber band over the ringstand. Using your right hand, pull horizontally on the rubber band until you've stretched the rubber band to about 3 times its original length.
3. Draw a side-view picture of the situation below, showing the ringstand, rubber band, and your hand when the rubber band is fully stretched.
4. Sketch an arrow on the picture above showing the direction of the force on the rubber band due to your hand.
5. Does the ringstand exert a force on the rubber band?
6. If the ringstand exerts a force on the rubber band, sketch an arrow on the picture above that shows the direction of the force on the rubber band due to the ringstand.
7. If the ringstand exerts a force on the rubber band, which pulls harder on the rubber band when the rubber band is fully stretched, you or the ringstand?
8. If the rubber band is only slightly stretched such that maybe it is only about 2 times its original length, which pulls harder on the rubber band, you or the ringstand?

9. When you pull on the rubber band, does the rubber band pull back on your finger? If so, then which one pulls harder?

Please ask your teacher to initial here before continuing.

1.2 Experiment

Now we will use force sensors and the LabPro data acquisition device to test your predictions.

1. You will use a force sensor and LabPro interface to measure forces. The switch on each probe should be set at 50 N. The LoggerPro software should already be open and should show two digital readouts that display the force on each of two force sensors.

2. With nothing pushing or pulling the hook of the force sensor, it should read zero. As a result, we must calibrate each force sensor. 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 the 500 g mass from the sensor. This applies a force of 4.9 newtons. Enter 4.9 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.

   Repeat the process for the second force sensor.

3. You will be using the sensors in a different orientation than that in which they were calibrated, so we have to zero the force sensors to account for this. Set the sensors on the tracks so that they are horizontal, and with no force applied to the sensors, 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. You will notice the initial reading vary a bit, but this variation is probably due to vibrations.

4. Pull on each force sensor and note the sign of the reading. What does the + sign and – sign indicate?

5. Make a short loop of string with a circumference of about 30 cm. Use it to attach the hooks of the force sensors. Set the force sensors flat on a level cart track. 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.

6. Gently tug on your partner's force sensor with your force sensor. Try pulling harder or softer. What do you observe?

7. Replace the string with a rubber band and repeat the experiment. What do you observe?

8. Replace the hooks on the sensors with the rubber-covered screws. Try pushing the force sensors together. What do you observe?

9. Put the screws back on the sensors, and attach one sensor to a secured ring stand. Place a rubber band between the force sensors and repeat the experiment.

10. In general, when one object pushes or pulls on another object, how hard and in what direction does the second object push or pull on the first object?

A rocket engine pushes exhaust out of the engine. Suppose a rocket is oriented as shown in the image below.

Figure 1:

In what direction is the force on the exhaust due to the rocket? On the picture, sketch an arrow showing the force of the rocket on the exhaust.

In what direction is the force on the rocket due to the exhaust? Sketch an arrow showing the force of the exhaust on the rocket.

Which one of these forces is larger? Use what you learned from the previous experiments in answering this question.

Please ask your teacher to initial here before continuing.

1.3 Experiment

We call the force of exhaust on a rocket, the *thrust* of the rocket. In the last experiment, you learned why the thrust of a rocket is due to the force of the exhaust on the rocket, and you learned that the direction of the thrust is in the opposite direction as the force on the exhaust. In other words, if the rocket pushes the exhaust downward, then the rocket pushes the rocket upward.

In the next experiment, you will study the effect of force on motion. A spaceship has four rocket engines, or thrusters, that can fire up, down, left, or right, respectively. Any of the thrusters can be turned off or on at any time.

A picture of the spaceship with all four thrusters firing simultaneously is shown below.

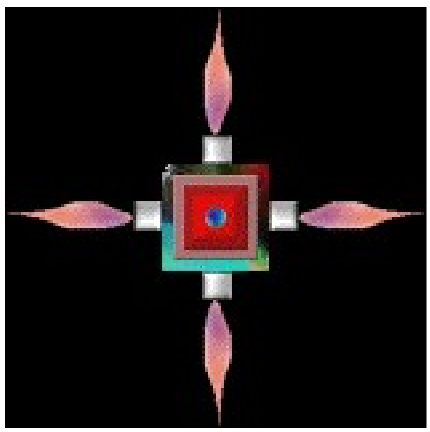

Figure 2:

What is the direction of the force of the left thruster on the ship?

What is the direction of the force of the right thruster on the ship?

What is the direction of the force of the top thruster on the ship?

What is the direction of the force of the bottom thruster on the ship?

This spaceship is far from any stars or planets or anything else, so the only forces on the spaceship are the force due to its thrusters.

1. On the desktop of your computer, there is a file called *Canonical Spaceship*. If you cannot find it, you can always download it from `http://linus.highpoint.edu/~atitus/osp/`. Open this file by double-clicking its icon.

2. You will see two windows, the animation window and the control window. In the control window, click the `Initialize` button. Then, click the `Start` button. Then, click on the animation window so that it "has focus," meaning that the window has been selected and is the top-level window.

3. You are now ready to operate the ship. The ship has four engines that fire to the right, to the left, upward, and downward, respectively. At the beginning, the ship is at rest.
4. Make the ship speed up to the right by pressing and holding the `D` key for 5 seconds (just count to 5 by saying "one thousand 1, one thousand 2, ...").

   Describe the force on the ship and the motion of the ship as the engine was firing?

   Describe the force on the ship and the motion of the ship after the engine stopped firing.

   Predict what force is needed to make the ship slow down as it moves to the right?

5. Press the `F` key for 10 seconds.

   Describe the force on the ship and the motion of the ship as it was moving to the right?

   Describe the force on the ship and the motion of the ship as it was moving to the left?

6. Fire the appropriate engine to make the spaceship come to a stop and remain stopped.
7. Get the spaceship moving in any direction and fire all four engines simultaneously. What did you observe?

8. Write the most general statement possible that describes the motion of an object if there are no forces on the object. Your statement should be something like "If there are no forces on an object, ..."

9. Two students are discussing the so-called natural state of things.

   Student 1 "The natural state of things is to be at rest. If there are no forces on an object, then it will be at rest or at least eventually come to rest."

   Student 2 "The natural state of things is to have constant speed. If there are no forces on an object, then its speed is constant."

   Do you agree or disagree with each student? Explain.

Please ask your teacher to initial here before continuing.

1.4 Experiment

1. If you haven't done so already, click the `Stop` button in the control window. Then, click `New`, `Initialize` and `Start` to start over. Then, click once on the animation window to give it focus.
2. Let's get the spaceship moving upward at a constant speed. Press the `J` key for 5 seconds.
3. Predict what path the spaceship will have if we fire the left engine, and sketch the predicted path below.
4. When the spaceship is near the bottom of the window, press the `D` key until the spaceship is at the top of the window, and then release the key. Sketch the path taken by the spaceship.
5. Note that the path is not a straight line. Actually, the path is called a parabola. If the path of the spaceship looked straight to you, do the following exercise.
   (a) Using the control window, stop the animation.
   (b) Click `New`.
   (c) Change the value of the x variable to -20, the value of the y variable to -20, the value of the vy variable to 10, and the variable *thrusterW* to *true*.
   (d) Then, click `Initialize`.
   (e) Place a transparency over the computer screen. Place a mark at the location of the spaceship.
   (f) Click `Step` 5 times, and place another mark on the transparency.
   (g) Repeat this until you've mapped out the path of the spaceship.

6. In the previous example, the force on the spaceship is in a different direction than the direction in which the spaceship was initially moving. When this occurs, the path of the object is a parabola.

   There's an everyday example where this occurs. Toss a ball to a lab partner while the other lab partners observe the motion from a side view. What path do they observe?

Please ask your teacher to initial here before continuing.

1.5 Experiment

Using the program in the previous experiment, it's very difficult to get the spaceship to move in a circle. If you'd like to, go ahead and try it!

To get an object to move in a circle, the direction of the force on the object must change directions in just the right way. To study this, you will use a *vpython* simulation.

1. On the desktop of your computer is a file called newton.py. Double-click this file.

2. Two windows will appear. In the first window is a ball. Think of this as any object in space that is far from any other objects. Maybe it's a spaceship or something.

   In the second window, you will draw an arrow with your mouse. This represents the force on the ball. The ball in the other window will move according to the force.

3. Play around with it for a little while just to get used to it.

4. Now, see if you can get the ball to move along the circle shown in the window. You can close the window and restart it if you wish.

5. What did you notice about the direction of the force on the ball?