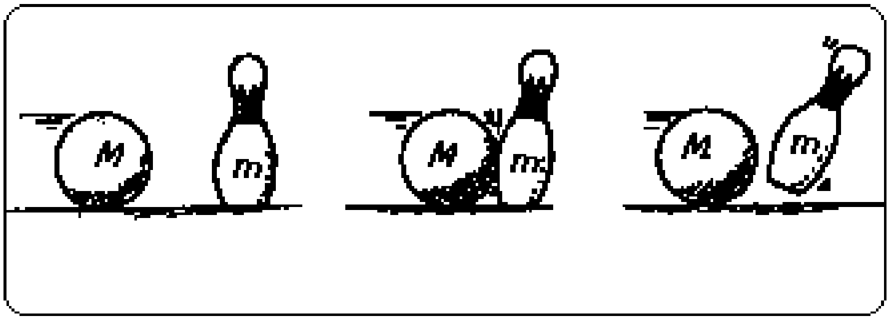
Experiment 7 : Newton's Third Law



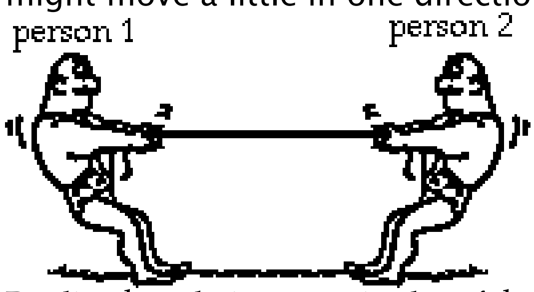
To every action there is always opposed an equal reaction, or the mutual actions of two bodies upon each other are always equal, and directed to contrary parts.
If you press a stone with your finger, the finger is also pressed by the stone. If a horse draws a stone tied to a rope, the horse (if I may say so) will be equally drawn back towards the stone . . . .

Isaac Newton
Principia (1686)

OBJECTIVES
To examine the consequences of *Newton's Third Law* as applied to interaction forces between objects.

OVERVIEW
Since interactions like collisions and explosions never involve just one object, we would like to turn our attention to the mutual forces of interaction between two or more objects. This will lead us to a very general law known as *Newton's Third Law* which relates the forces of interaction exerted by two objects on each other.
As usual you will be asked to make some predictions about interaction forces and then be given the opportunity to test these predictions.
Note: This is a lab, but you do not have to do a write-up. Just do the lab and respond to the questions.

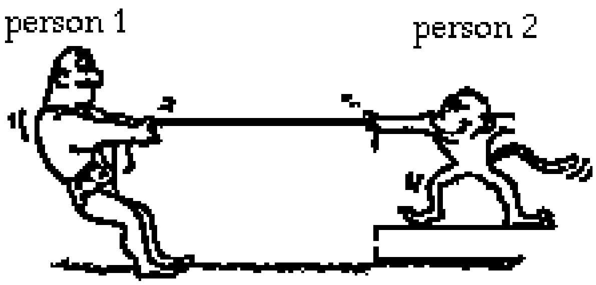
Investigation 1: Newton's Third Law
There are many situations where objects interact with each other. In this investigation we want to compare the forces exerted by the objects on each other. What factors might determine the forces between the objects? Is there some general law which relates these forces?
We will begin our study of interaction forces by examining the forces each person exerts on the other in a tug-of-war. Let's start with a couple of predictions.
Prediction 1-1: Suppose that you have a tug-of-war with someone who is the same size and weight as you. You both pull as hard as you can, and it is a stand-off. One of you might move a little in one direction or the other, but mostly you are both at rest.



Predict the relative magnitudes of the forces between person 1 and person 2. Circle your prediction!

______person 1 exerts a larger force on person 2
______the people exert the same force on each other
______person 2 exerts a larger force on person 1

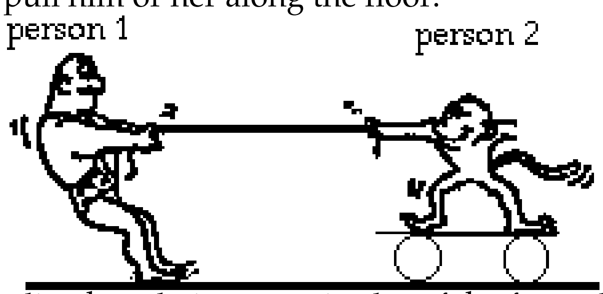
Prediction 1-2: Suppose now that you have a tug-of-war with someone who is much smaller and lighter than you. As before, you both pull as hard as you can, and it is a stand-off. One of you might move a little in one direction or the other, but mostly you are both at rest.



Predict the relative magnitudes of the forces between person 1 and person 2. Circle your prediction!

______person 1 exerts a larger force on person 2
______the people exert the same force on each other
______person 2 exerts a larger force on person 1

Prediction 1-3: Suppose now that you have a tug-of-war with someone who is much smaller and lighter than you. This time the lighter person is on a skateboard, and with some effort you are able to pull him or her along the floor.



Predict the relative magnitudes of the forces between person 1 and person 2. Circle your prediction!

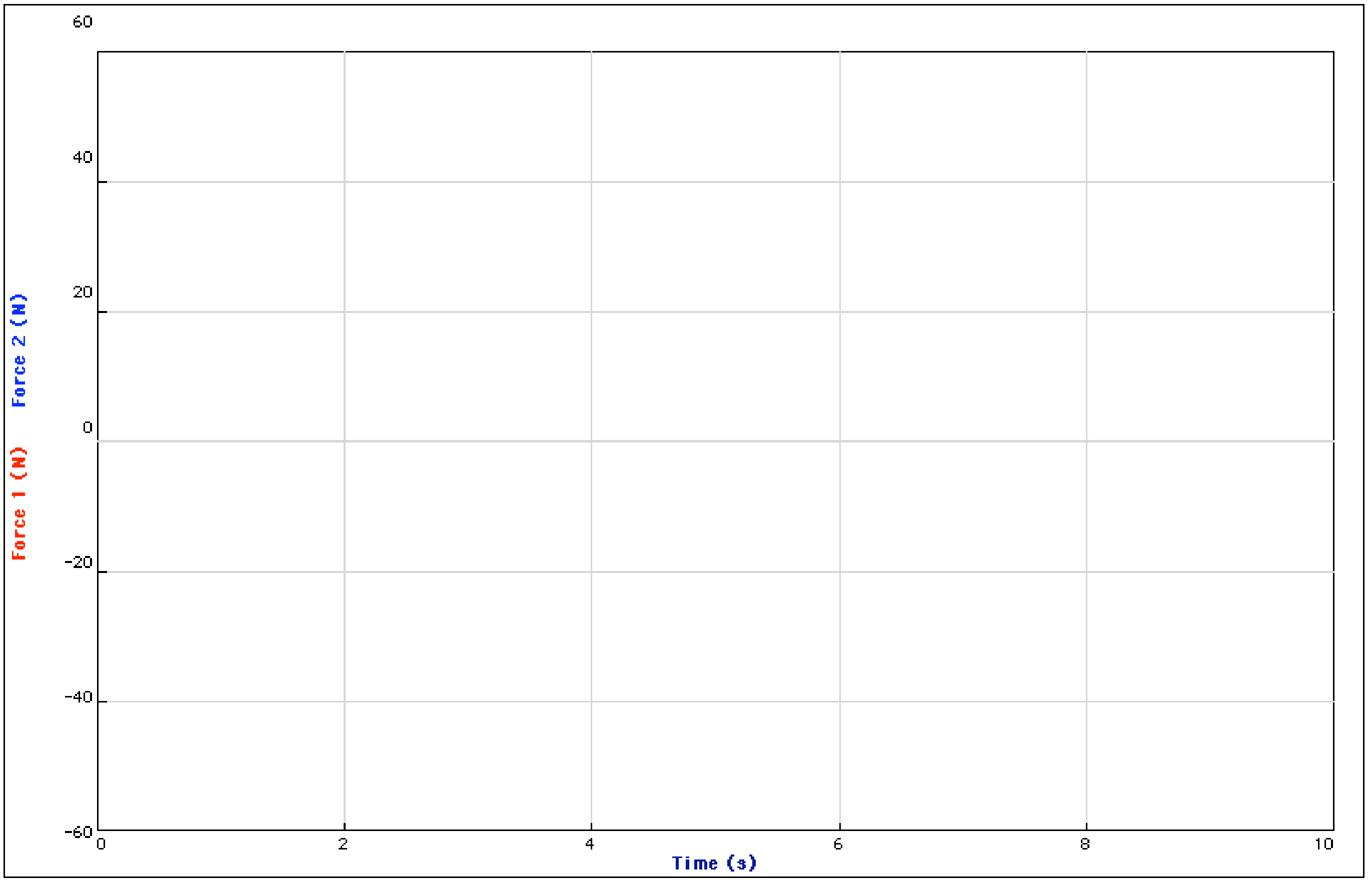
______person 1 exerts a larger force on person 2
______the people exert the same force on each other
______person 2 exerts a larger force on person 1

To test your predictions you will need the following:

- Two force probes and a LabPro
- *Logger Pro*
- A skateboard(use the round red skateboard) and string
- Two Spring Scales
- Two Pasco Carts with force probe holders attached
- Masses to place on the carts to increase mass

Activity 1-1: Interaction Forces in a Tug of War

1. Plug the two force probes into Channel 1 and 2 of the LabPro. Put the eyehooks (top of red box) on the force probes. Make sure both force probes are switched to the same range.
2. Open the **Logger Pro.** You should see two graphs on one coordinate axis, like the ones on the next page.



5. When you are ready to start, **Zero** both of the force probes. (Click on **Zero** under the **Experiment** menu) Then hook a short loop of string between them, hit **Start** and begin a gentle tug-of-war. Pull back and forth while watching the graphs. **Do not pull too hard, since this might damage the force probes.** It may be more instructive to make one of the forces negative so you can see them both. If so, under the **Experiment** menu, go to **Setup Sensors**, **LabPro 1,Ch 1, Reverse Direction.**

6. Repeat with different people pulling on each side.

7. Sketch one set of graphs on the axes above, or print the graphs and affix them over the axes.

Question 1-1: (a) How did the two pulls compare to each other? (b) Was one significantly different from the other? (c) How did your observations compare to your predictions?

Activity 1-2: Interaction Forces Pulling Someone Along

In this activity you will test your prediction about the interaction forces when you are pulling someone on roller skates or a skateboard along the floor.

1. **You will use the Spring Scales** and the roller cart (or your own skates) for this part. **Do not use the Force Probes, you will damage them.** Make sure you zero the scales. Hook the two Spring Scales together and pull someone along on the board.

Question 1-2: (a) How did the two pulls compare to each other? (b) Was one significantly different from the other? (c) How did your observations compare to your predictions?

Comment: The fundamental law governing interaction forces between objects is *Newton's Third Law.* which can be stated: *If one object exerts a force on a second object, then the second object exerts a force back on the first object which is equal in magnitude and opposite in direction to that exerted on it by the first object.*

Question 1-3: Do your observations in Activities 1-1 and 1-2 support *Newton's Third Law* of motion?

Question 1-4: When you pull on 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?) Explain.

Comment: Newton actually formulated the third law by studying the interaction forces between objects when they collide. It is difficult to fully understand the significance of this law without first studying collisions.

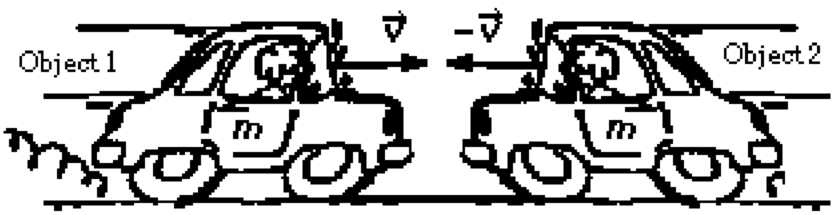
Investigation 2: Forces between interacting Objects

There are many situations where objects interact with each other, for example, during collisions. In this investigation we want to compare the forces exerted by the objects on each other. In a collision, both objects might have the same mass and be moving at the same speed, or one object might be much more massive, and they might be moving at very different speeds. What factors might determine the forces between the objects? Is there some general law which relates these forces?

Activity 2-1: Collision Interaction Forces

What can we say about the forces two objects exert on each other during a collision?

Prediction 2-1: Suppose the masses of two objects are the same and that the objects are moving toward each other at the same speed so that m1 = m2 and **v**1 = - **v**2 (same speed, opposite direction).



Predict the relative magnitudes of the forces between object 1 and object 2 during the collision. Circle your prediction!

______object 1 exerts a larger force on object 2

______the objects exert the same force on each other

______object 2 exerts a larger force on object 1

Prediction 2-2: Suppose the masses of two objects are the same and that object 1 is moving toward object 2, but object 2 is at rest.

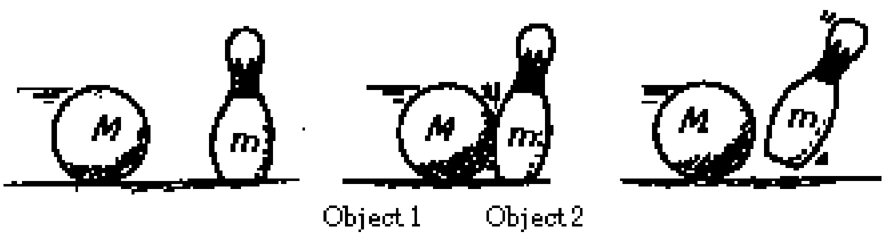
$m_1 = m_2$ and $\mathbf{v}_1 > 0$, $\mathbf{v}_2 = 0$

Predict the relative magnitudes of the forces between object 1 and object 2 during the collision. (Circle one)

______object 1 exerts a larger force on object 2
______the objects exert the same force on each other
______object 2 exerts a larger force on object 1

Prediction 2-3: Suppose the mass of object 1 is greater than that of object 2 and that it is moving toward object 2 which is at rest.

$$m_1 > m_2 \text{ and } \mathbf{v}_1 > 0, \mathbf{v}_2 = 0$$

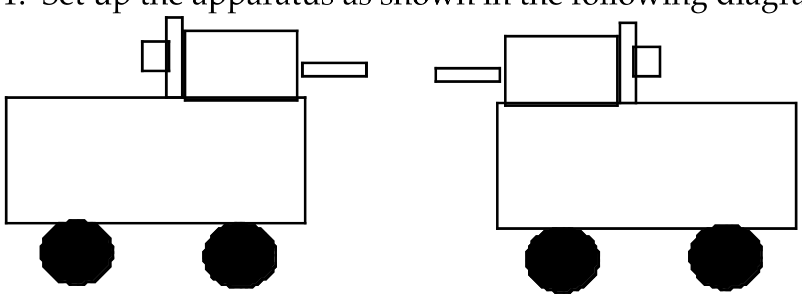


Predict the relative magnitudes of the forces between object 1 and object 2 during the collision. (Circle one)

______object 1 exerts a larger force on object 2
______the objects exert the same force on each other
______object 2 exerts a larger force on object 1

What are the circumstances under which you predict that one object will exert a greater force on the other object?

1. Set up the apparatus as shown in the following diagram.



The force probes should be securely fastened to the carts.
The hooks should be removed from the force probes and replaced by the brown tipped bumpers (also in top of red boxes) and should be *carefully aligned* so that they will collide head-on with each other.

2. Open a new file.

3. Under the Experiment menu go down to Zero, then Zero all sensors to zero the probes.

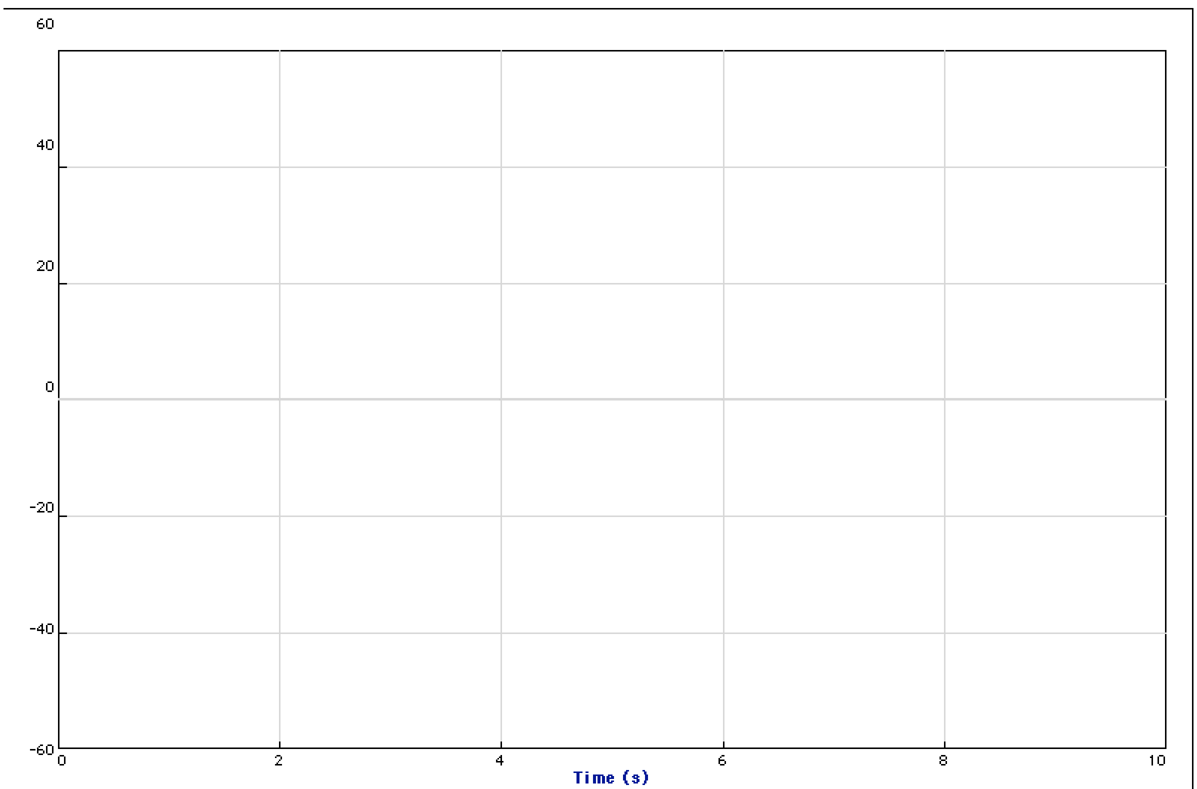
4. Use the two carts to explore various situations which correspond to the predictions you made about interaction forces. Sketch the graphs for each collision on the axes below. Be sure to label

your graphs. **Your goal is to find out under what circumstances one object exerts more force on another object so mark the points where one force is significantly larger than the other. You can examine the forces point by point by selecting Examine under the Analyze menu.**

Try collisions (a) - (c) listed below.
Also, if the top of your curves are flat horizontal lines, that means you applied a force too large for the force probes to read.

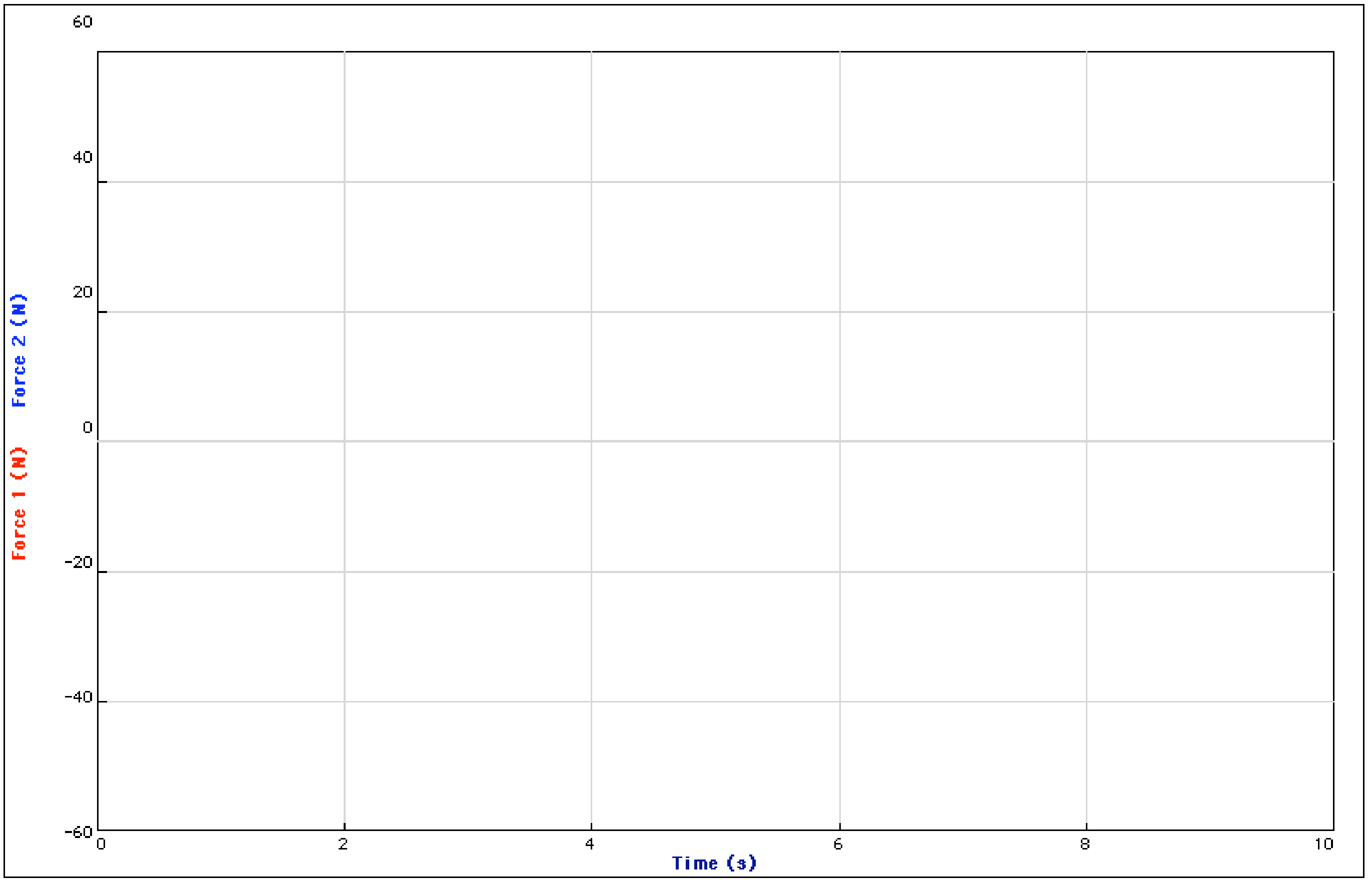
For each collision also find the values of the impulses exerted by each cart (**Impulse is the change in momentum of the object, which is also the integral or area under each force time graph**). You must first select the portion of the force-time graph for which you want to find the area or integral. This is done selecting **Examine** from the **Analyze** menu. To highlight the region of the force-time graph for the area, position the cursor line at the beginning of the desired region. Press and hold down the mouse button, and slide the mouse until the cursor line is at the end of the desired region. Release the mouse button. The region should remain darkened. Next select **Integral** (also under the **Analyze** menu and read the value of area or integral on the graph. Record these values below, and carefully describe what you did and what you observed.

) Two carts of the same mass moving towards each other at about the same speed.



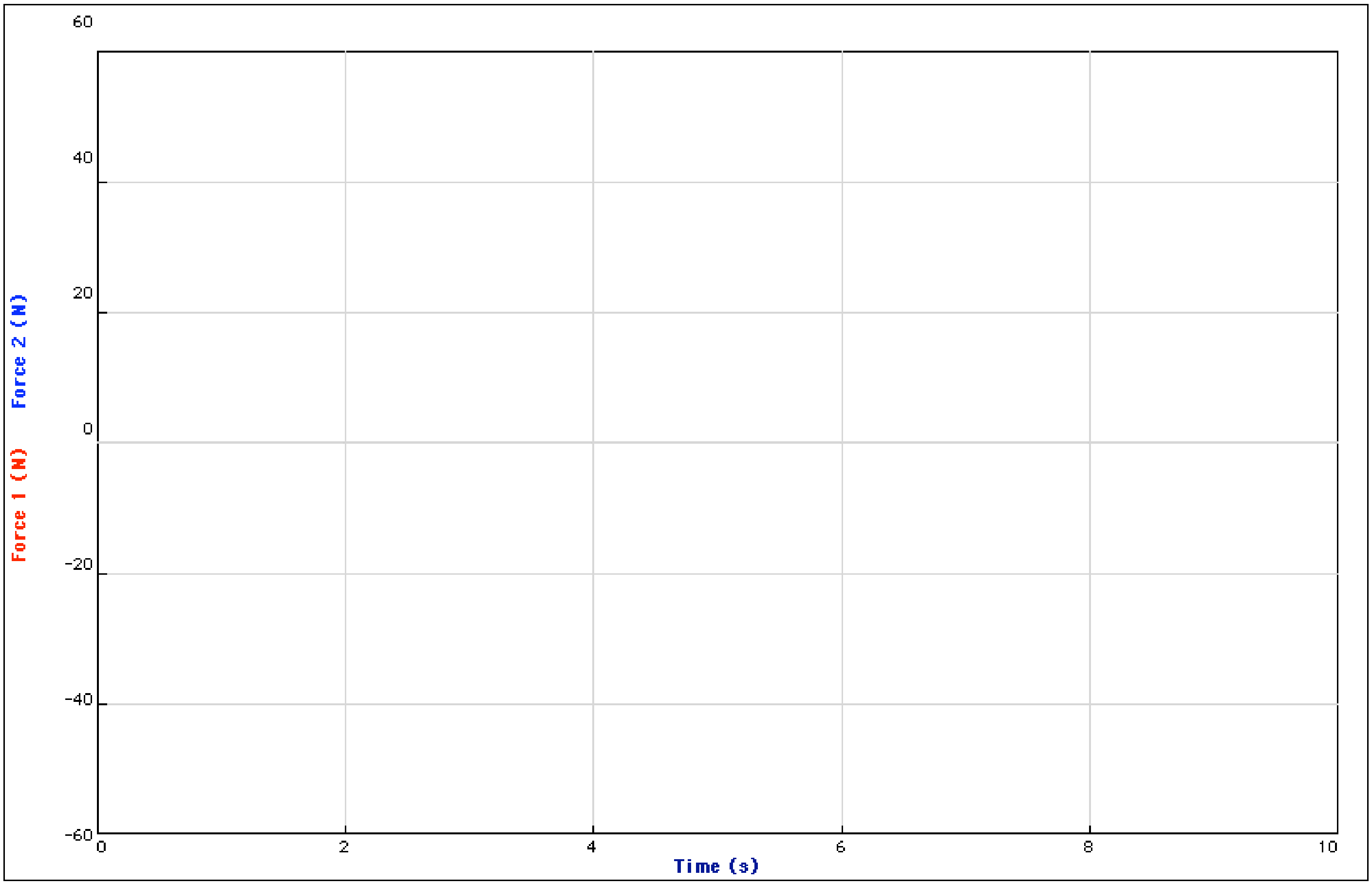
Impulse 1_______ Impulse 2____________

(b) Two carts of the same mass, one at rest and the other moving towards it.



mpulse 1_______ Impulse 2____________

(c) One cart twice or three times as massive as the other, moving toward the other cart which is at rest.

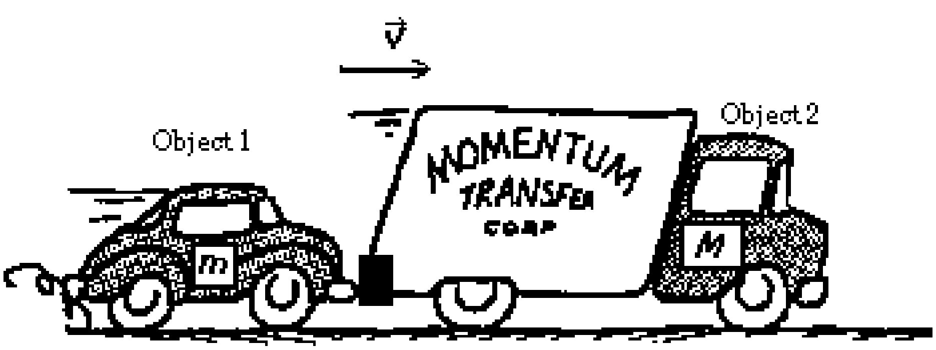


Impulse 1_______ Impulse 2____________

Question 2-1: Did your observations agree with your predictions? What can you conclude about forces of interaction during collisions? Under what circumstances does one object experience a different force than the other during a collision? How do forces compare on a moment by moment basis during each collision?

Activity 2-2: Other Interaction Forces

Interaction forces between two objects occur in many other situations besides collisions. For example, suppose that a small car pushes a truck with a stalled engine, as shown in the picture below. The mass of object 1 (the car) is much smaller than object 2 (the truck).



At first the car doesn't push hard enough to make the truck move. Then, as the driver pushes down harder on the gas pedal, the truck begins to accelerate. Finally the car and truck are moving along at the same constant speed.

Prediction 2-4: Place a check next to your predictions of the relative magnitudes of the forces between objects 1 and 2.

Before the truck starts moving:

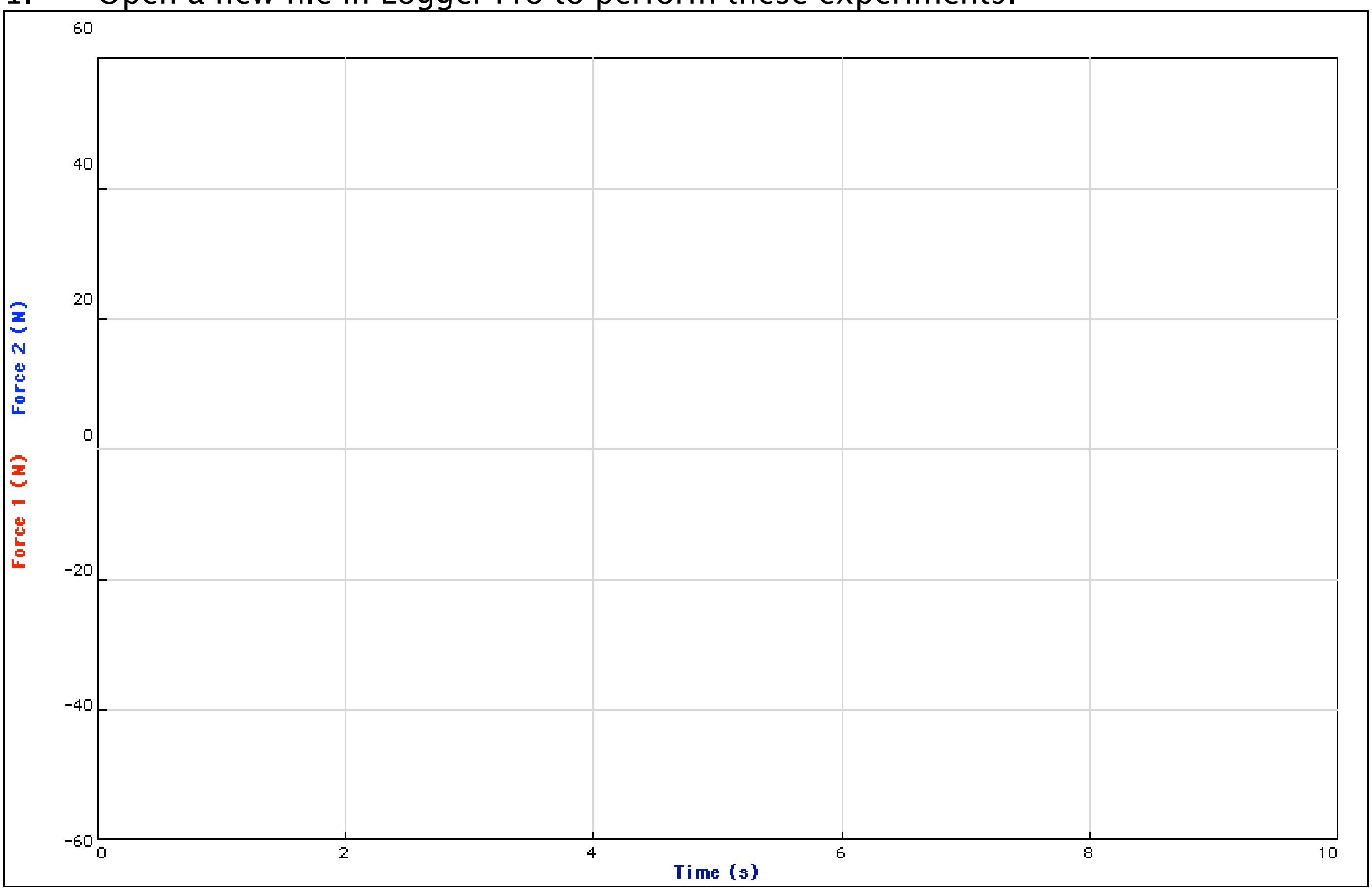
______the car exerts a larger force on the truck
______the car and truck exert the same force on each other
______the truck exerts a larger force on the car

While the truck is accelerating:
______the car exerts a larger force on the truck
______the car and truck exert the same force on each other
______the truck exerts a larger force on the car

After the car and truck are moving at a constant speed:
______the car exerts a larger force on the truck
______the car and truck exert the same force on each other
______the truck exerts a larger force on the car

Test your predictions.

1. Open a new file in Logger Pro to perform these experiments.



2. Use the same setup as in the last activity with the two force probes mounted on carts. Add masses to cart 2 (the truck) to make it much more massive than cart 1 (the VW).

3. **Zero** both force probes .

4. Your hand will be the engine for cart 1. Move the carts so that the stoppers are touching, and then hit **Start**. When graphing begins, push cart 1 toward the right. At first hold cart 2 so it cannot move, but then allow the push of cart 1 to accelerate cart 2, so that both carts move toward the right.

5. Sketch your graphs on the axes on the previous page, or print them and affix them over the axes.

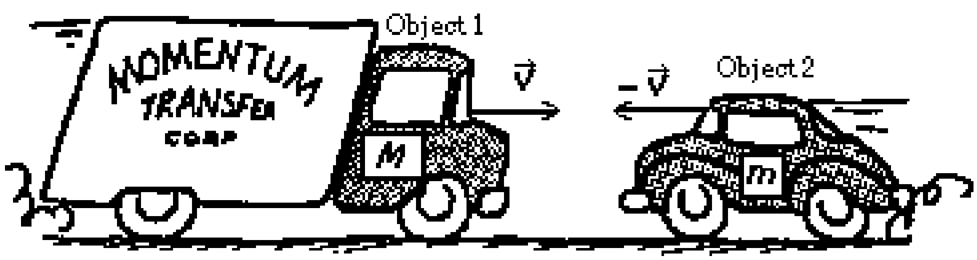
Question 2-4: (a) How do your results compare to your predictions? (b)Is the force exerted by cart 1 on cart 2 (reading of force probe 2) significantly different from the force exerted by cart 2 on cart 1 (reading of force probe 1) during any part of the motion?

Activity 3-1: More Collision Interactive Forces

Make predictions for the interaction forces in the following situations, and then use the apparatus to test your predictions if there is time left in lab. In each case describe your observations and how you made them. Include copies of any graphs you make. Compare your observations to your predictions.

Prediction 1: Suppose the mass of object 1 is greater than that of object 2 and that the objects are moving toward each other at the same speed so that

$m_1 > m_2$ and $\mathbf{v}_1 = -\mathbf{v}_2$

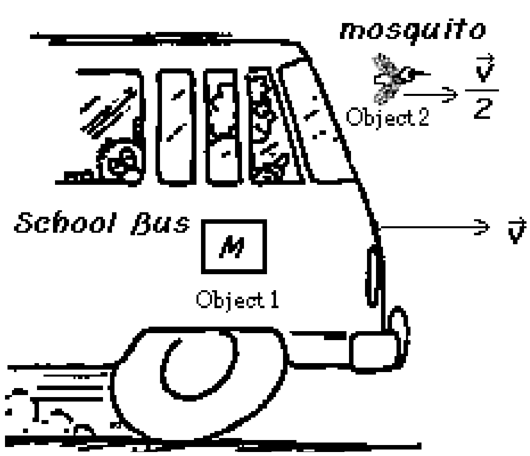


Predict the relative magnitudes of the forces between object 1 and object 2.

______object 1 exerts a larger force on object 2
______the objects exert the same force on each other
______object 2 exerts a larger force on object 1

Prediction 2: Suppose the mass of object 1 is much greater than that of object 2 and that object 2 is moving in the same direction as object 1 but not quite as fast so that

$m_1 >> m_2$ and $\mathbf{v}_1 > \mathbf{v}_2$



Predict the relative magnitudes of the forces between object 1 and object 2.

______object 1 exerts a larger force on object 2
______the objects exert the same force on each other
______object 2 exerts a larger force on object 1

Prediction 3: Suppose the mass of object 1 is much greater than that of object 2 and that both objects are a rest until an explosion occurs so that

$m_1 >> m_2$ and $\mathbf{v}_1 = \mathbf{v}_2 = 0$

Predict the relative magnitudes of the forces between object 1 and object 2. Place a check next to your prediction! Circle one.

object 1 exerts a larger force on object 2
the objects exert the same force on each other
object 2 exerts a larger force on object 1

What is your final conclusion about forces two exert on each other?