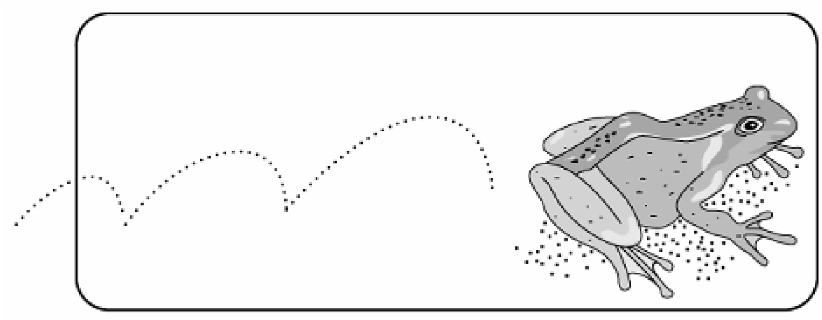
Name____________________________Date__________________Partners____________________________

LAB 6:
GRAVITATIONAL AND PASSIVE FORCES



And thus Nature will be very conformable to herself and very simple, performing all the great Motions of the heavenly Bodies by the attraction of gravity . . .
–Isaac Newton

OBJECTIVES

- To explore the nature of motion along a vertical line near the Earth's surface.
- To extend the explanatory power of *Newton's laws* by inventing an *invisible* force (the gravitational force) that correctly accounts for the falling motion of objects observed near the Earth's surface.
- To examine the magnitude of the acceleration of a falling object under the influence of the gravitational force near the Earth's surface.
- To examine the motion of an object along an inclined ramp under the influence of the gravitational force.
- To incorporate frictional forces into *Newton's first and second laws of motion*.
- To explore interaction forces between objects as described by *Newton's third law of motion*.
- To explore tension forces and understand their origin.
- To apply *Newton's laws of motion* to mechanical systems that include tension.

OVERVIEW

You started your study of *Newtonian dynamics* in Lab 4 by developing the concept of force. Initially, when asked to define forces, most people think of a *force* as *an obvious push or pull*, such as a punch to the jaw or the tug of a rubber band. By studying the acceleration that results from a force when little friction is present, we came up with a second definition of *force* as *that which causes acceleration*. These two alternative definitions of force do not always appear to be the same. Pushing on a wall doesn't seem to cause the wall to move. An object dropped close to the surface of the Earth accelerates and yet there is no visible push or pull on it.

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The genius of Newton was to recognize that he could define *net force or combined force* as that which causes acceleration, and that if the obvious applied forces did not account for the degree of acceleration then there must be other "invisible" forces present. A prime example of an invisible force is the gravitational force–the attraction of the Earth for objects.

When an object falls close to the surface of the Earth, there is no obvious force being applied to it. Whatever is causing the object to move is invisible. Most people rather casually refer to the cause of falling motions as the action of "gravity." What is gravity? Can we describe gravity as just another force? Can we describe its effects mathematically? Can *Newton's laws* be interpreted in such a way that they can be used for the mathematical prediction of motions that are influenced by gravity?

It almost seems that we have to "invent" an invisible gravitational force to save Newton's second law. Since objects near the surface of the Earth fall with a constant acceleration, we will use *Newton's second law* to show that there must be a constant (gravitational) force acting on the object.

Finding invisible forces (forces without an obvious agent to produce them) is often hard because some of them are not *active* forces. Rather, they are *passive* forces, such as *normal* forces, which crop up only in response to active ones. (In the case of normal forces, the active forces are ones like the push you exert on a wall or the gravitational pull on a book sitting on a table.)

Frictional and *tension* forces are other examples of passive forces. The passive nature of friction is obvious when you think of an object like a block being pulled along a rough surface. There is an applied force (active) in one direction and a frictional force in the other direction that opposes the motion. If the applied force is discontinued, the block will slow down to rest but it will not start moving in the opposite direction due to friction. This is because the frictional force is passive and stops acting as soon as the block comes to rest.

Likewise, tension forces, such as those exerted by a rope pulling on an object can exist only when there is an active force pulling on the other end of the rope.

In this lab you will first study vertical motion and the gravitational force. Then you will examine the motion of an object along an inclined ramp. You will use *Newton's laws of motion* as a working hypothesis to "invent" *frictional* and *tension* forces. Along the way you will examine *Newton's third law of motion.*

INVESTIGATION 1: MOTION AND GRAVITY

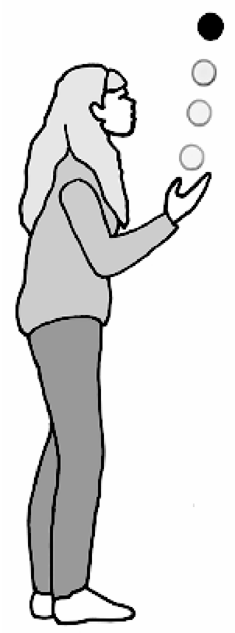
Let's begin the study of the phenomenon of gravity by examining the motion of an object such as a ball when it is allowed to fall vertically near the surface of the Earth. This study is not easy, because the motion happens very quickly! You can first predict what kind of motion the ball undergoes by tossing a ball in the laboratory several times and seeing what you think is going on.

A falling motion is too fast to observe carefully by eye. You will need the aid of the motion detector and computer to examine the motion quantitatively. Fortunately, the motion detector can do measurements just fast enough to graph this motion. To carry out your measurements you will need

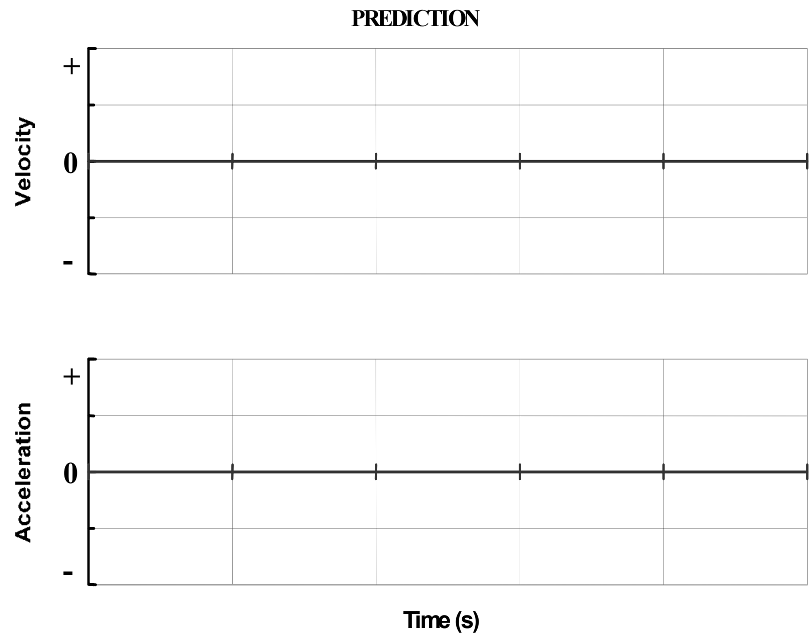
- motion detector
- basketball

- table clamps, rods, etc. to attach motion detector at least 2 m off floor.

Activity 1-1: Motion of a Falling Ball



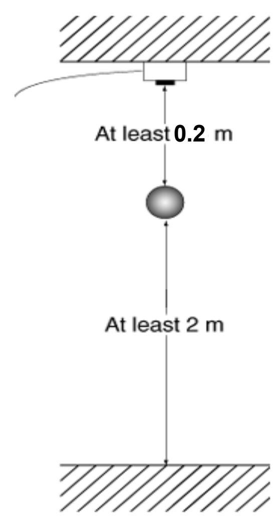
Prediction 1-1: Suppose that you drop the ball from height of about 2 m above the floor, releasing it from rest. On the axes that follow, sketch your predictions for the velocity—time and acceleration—time graphs of the ball's motion. Assume that the positive *y* direction is *upward*.



Test your predictions. You have previously used the motion detector to examine the motion of your body and of a cart. The motion of a falling ball takes place much faster. While you can use the motion detector to measure position, velocity, and acceleration, you will have to collect data at a faster rate than you have before.

The easiest way to examine the motion of the falling ball is to mount the motion detector as high up as you can and to use a large ball that is not too light (like a basketball rather than a beach ball). It is essential to keep your hands and the rest of your body out of the way of the motion detector after the ball is released. This will be difficult and may take a number of tries. It also will take some care to identify which portions of your graphs correspond to the actual downward motion of the ball and which portions are irrelevant.

1. Use the table clamps, rods, and right angle devices to attach the motion detector, about 2 m above the floor, with the detector looking straight downward, as shown on the right. Use the broad range on the motion detector.



2. Open the experiment file called **Falling Ball L6.1-1.** The axes will look similar to the ones on which you made your predictions. This experiment file will also set the data collection to a faster rate than has been used before (30 points/s). Because the motion detector is pointing downward in the negative *y* direction–the software has been set up to make **distance away from the detector negative.** Use the broad beam setting on the motion detector.

3. Hold the ball at least 0.2 m directly below the motion detector and at least 1.8 m above the floor. *Remember that your hands and body must be completely out of the path of the falling ball, so the detector will see the ball – and not*

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your hands or body–the whole way down.

4. When everything is ready, **begin graphing** and release the ball as soon as you hear the clicks from the motion detector.

5. **Adjust the axes** if necessary to display the velocity and acceleration as clearly as possible.

Do not erase the data so that the graphs can be later used for comparison.

Print one set of graphs for your group and include them with your report.

6. Use the mouse to highlight the time interval during which the ball was falling freely.

Question 1-1: What does the nature of the motion look like – constant velocity, constant acceleration, increasing acceleration, decreasing acceleration, or other (describe, if other)? How do your observations compare with the predictions you made?

Question 1-2: Is the acceleration of the ball positive or negative as it falls down? Does this sign agree with the way that the velocity appears to be changing on the velocity—time graph? Explain.

Activity 1-2: The Magnitude of Gravitational Acceleration

As you saw in Lab 3, you can find a value for the average acceleration in two ways. Method 1 is to read the average value from the acceleration—time graph. Method 2 is to find the slope of the velocity—time graph.

1. For Method 1, use the **statistics features** of the software to read the average value of the acceleration during the time interval from just after the ball began falling (beginning of uniform acceleration) to just before the ball stopped falling (end of uniform acceleration).

Average acceleration:___________m/s^2

2. For Method 2, use the **fit routine** to find the mathematical relationship between velocity and time during the same time interval as in (1).

Write below the equation you find from the fit that relates velocity (v) to time (t).

3. From the equation in step 2, what is the value of the acceleration?

Average acceleration:___________m/s^2

Question 1-3: Did the two values for the gravitational acceleration agree with each other? Should they agree with each other?

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Activity 1-3: Motion Up and Down

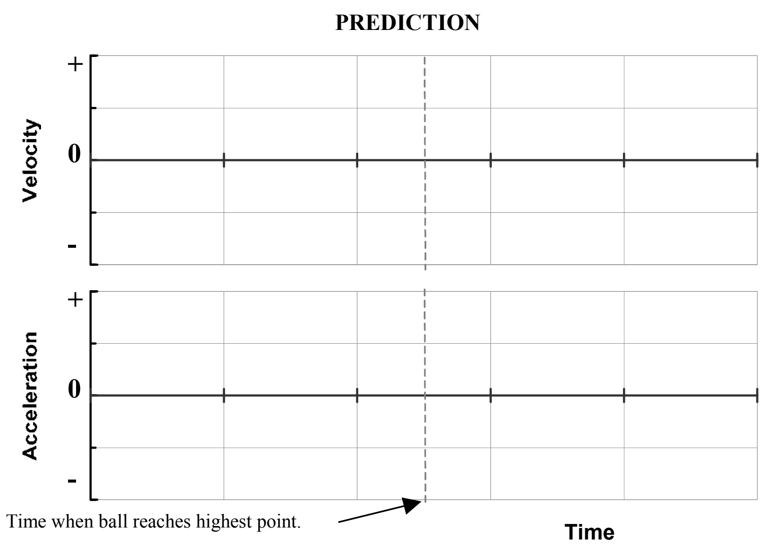
Prediction 1-2: Suppose that you toss a ball upward and analyze the motion as it moves up, reaches its highest point, and falls back down. Is the **acceleration** of the ball the same or different during the three parts of the motion – moving upward, momentarily at the highest point, and moving downward? Explain.

Moving upward:

Momentarily at highest point:

Moving downward:

Prediction 1-3: Sketch on the axes below your predictions of the velocity—time and acceleration—time graphs for the entire motion of the ball from the moment it leaves your hand going up until just before it returns to your hand. Assume that the positive direction is upward.



Throwing the ball upward and keeping it in the range of the motion detector is harder to do than dropping the ball. Try to throw the ball up directly under the motion detector. It may take a number of tries. *Again be sure that your body is not seen by the motion detector.*

1. The same experiment file **Falling Ball L6.1-1** used in Activity 1-1 should work in this activity as well. You can keep the graphs from Activity 1-1 on the screen if you desire. The new data will be in a different color. You can also click on the Data icon and choose not to display a particular data run. Use the broad range on the motion detector.

2. When everything is ready, **begin graphing**, and when you hear the clicking begin, toss the ball up toward the motion detector. Toss the ball as high as you can, but remember that it should never get closer than 0.2 m below the motion detector. A short quick throw will work best.

   Repeat until you get a throw where you are sure the ball went straight up and down directly below the detector. You can choose under Experiment to delete the last data run if you do not want to keep it. You can also "click" on a graph and use the DELETE key to remove it. You may need to make several tries before you decide to keep the data. Let all group members try, if you have

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time.

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When you obtain a good run, **print** one set of graphs for your group and include them in your report. Label the portions of the printed graphs that show the ball's up and down motion. Also label with an arrow the instant in time when the ball reached its highest point.

Question 1-4: Compare the experimental graphs to your predictions. In what ways do they differ, and in what ways are they the same?

Qualitatively compare the acceleration during the three parts of the motion – on the way up, at the highest point, and on the way down. Explain your observations based on the sign of the change in velocity.

On the way up:

At the highest point:

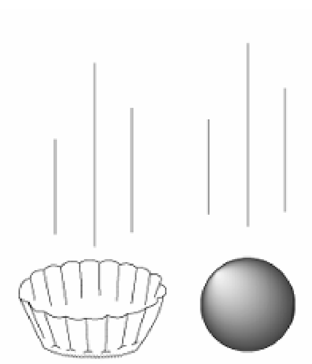
On the way down:

Question 1-5: There is a common misconception that the acceleration of the ball must be zero when it stops. If this were true, could the velocity of the ball change once it stopped? Explain.

Activity 1-4: Vertical Motion with Air Resistance

In this Activity you will use the motion detector to examine the motion of a paper coffee filter falling from rest. In addition to the setup in Activity 1-1 you will need

- flat-bottomed paper coffee filter–the type with folds along the sides



1. Use the experiment file **Falling Filter L6.1-4.** As usual, wait until you hear the motion detector click and then release the coffee filter with the flat bottom facing down as shown on the left. If necessary, increase the time range to record the complete motion of the filter and **adjust the velocity and acceleration axes** if necessary to display the graphs more clearly. It may take you several tries to obtain a good graph, because the coffee filter tends to float to the side out of range of the motion detector.

2. Be sure to keep your body out of the way of the motion detector.

3. **Print** out one set of graphs and include them with your report.

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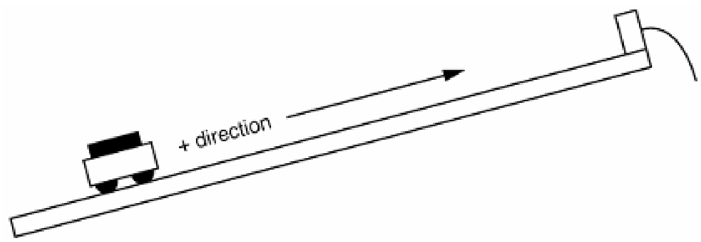
Question 1-6: Compare the graphs to those for the falling ball. Does the filter also appear to fall with a constant acceleration? If not, how would you describe the motion? Is the velocity changing as the filter falls. If so, how?

Question 1-7: Based on *Newton's laws of motion*, do you think that the gravitational force is the only force acting on the filter? If there is another force, what is its direction and how does its magnitude compare to the gravitational force? Explain.

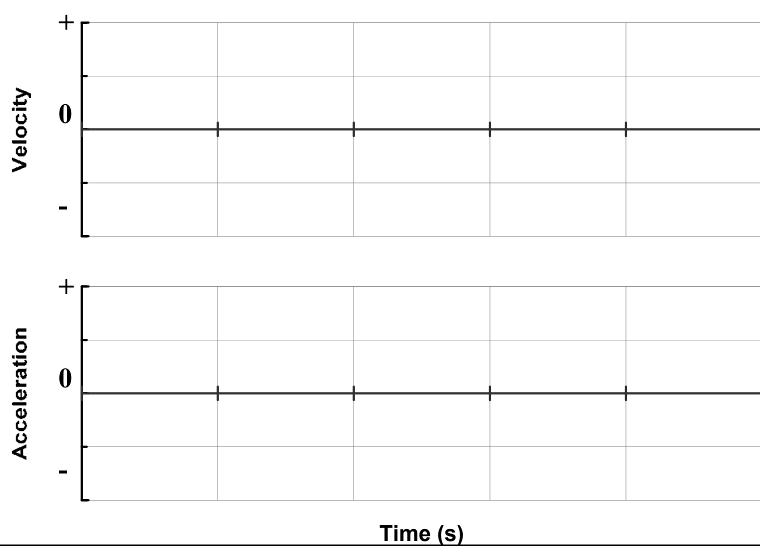
Activity 1-5: Motion Along an Inclined Ramp

Another common motion involving the gravitational force is that of an object along an inclined ramp.



Prediction 1-4: Consider a very low-friction cart moving along an inclined ramp, as shown above. The cart is given a push up the ramp and released, and its motion is graphed using the motion detector at the top of the ramp. (The direction *toward* the motion detector is positive.) Sketch on the axes below your predictions of the velocity—time and acceleration—time graphs for the motion of the cart.

Predictions



Prediction 1-5: How do you predict the magnitude of the acceleration of the cart will compare to the acceleration you determined in Activity 1-2 for a ball falling straight downward? Explain.

To test your predictions, you will need in addition to the equipment used above

- low-friction PASCO motion cart
- 2-m motion track and support to raise one end about 10 cm

1. Set up the ramp with the motion detector at the high end. Use the rods and table clamps to elevate one end of the ramp by 10 cm or so. Be sure that the motion detector sees the cart over the whole length of the ramp.

2. Open the experiment file called **Inclined Ramp L6.1-5** to display the velocity and acceleration time plots that were shown previously for Prediction 1-4. As before, the software has been set up to consider motion toward the detector positive so that *the positive direction of motion is up the ramp*.

3. If the cart has a friction pad, it should be raised out of contact with the ramp. Hold the cart at the bottom of the ramp and **begin graphing**. When you hear the clicks of the motion detector, give the cart a push up the ramp and release it. **DO NOT PUSH THE CART HARD ENOUGH FOR IT TO HIT THE MOTION DETECTOR OR FALL OFF THE TRACK!! PRACTICE A COUPLE OF TIMES!**

   The graph should include all three parts of the motion – up the ramp, at its highest point, and on its way down – and the cart should never get closer than 0.2 m from the motion detector. Repeat until you have good graphs. Only keep your good data.

4. **Print** out one set of graphs for your group and include them with your report.

5. Use an arrow to mark the instant when the cart was at its highest point along the track on both the velocity and acceleration graph.

6. Use the **statistics** features of the software to measure the average acceleration of the cart during the time interval after it was released and before it was stopped at the bottom of the ramp.

   Average acceleration: ___________m/s^2

Question 1-8: Did your graphs agree with your predictions? Does this motion appear to be with a constant acceleration?

Question 1-9: How did the magnitude of the acceleration compare with that for the ball falling which you determined in Activity 1-2? Is this what you predicted? Was this motion caused by the gravitational force? Why isn't the acceleration the same as for the ball falling?

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Question 1-10: What percentage of the falling-ball acceleration did the cart experience?

______ %

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INVESTIGATION 2: NEWTON'S LAWS WHEN FRICTION IS PRESENT

In previous labs we have been trying hard to create situations where we could ignore the effects of friction. We have concentrated on *applied* forces involving pushes and pulls that we can see and measure directly. The time has come to take friction into account. You can make observations by applying a force directly to your force probe mounted on a cart and comparing the cart's acceleration when no friction is present to the acceleration when a friction pad under the cart drags on the track.

To make observations on the effects of friction you will need

- force probe
- motion detector
- PASCO friction wood block
- PASCO motion cart with an adjustable friction pad under it
- 2-m motion track
- string

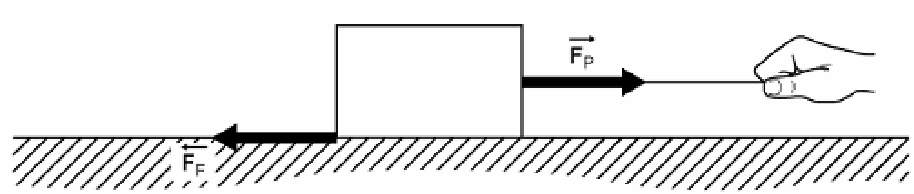
Activity 2-1: Static and Kinetic Frictional Forces

When the friction pad on the cart is lowered down to be in contact with the surface of the track, the track exerts a frictional force on the pad. If the frictional force is equal in magnitude to the applied force, then according to Newton's first law the cart must either remain at rest or move with a constant velocity.

The frictional forces when two objects are sliding along each other are called *kinetic* frictional forces. If the objects are not sliding along each other, then the frictional forces are called *static* frictional forces.

In this Activity you will examine whether the frictional force is different when an object is at rest (*static* friction) than when it is sliding along a track (*kinetic* friction).

Prediction 2-1: A block is sitting on a table, as shown below. You pull on a string attached to the block, and the block doesn't move because the frictional force opposes your pull. You pull harder, and eventually the block begins to slide along the table top. How does the frictional force *just before* the block started sliding compare to the frictional force when the block is actually sliding? Explain.



Prediction and explanation:

You can test your prediction by mounting the force probe on a wooden block and pulling the block along your ramp.

1. Set up the block, string, force probe, motion detector, and ramp as shown below. Set the force probe on top of the friction block. You will be adding 0.5 kg masses to the top tray of the force

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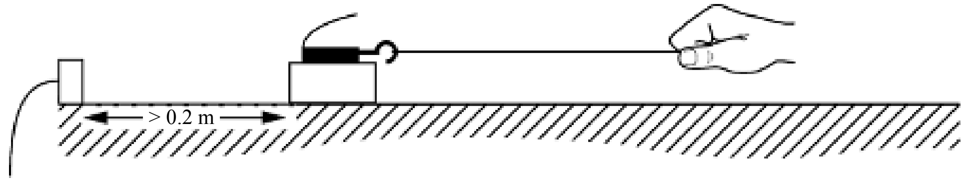
probe. Start with adding one 0.5 kg mass to the force probe to make the overall mass $M \approx$ 1 kg.



2. Measure the mass of the block and force probe: ___________kg. You may have to mass them separately on the digital mass scale and add them.

3. Prepare to graph velocity and force by opening the experiment file called **Static and Kinetic Friction L6.2-1**.

4. **Zero** the force probe with nothing pulling on it. Make sure 0.5 kg mass is on top of the force probe. **Begin graphing** with the string loose, then gradually pull *very gently* on the force probe with the string and increase the force very slowly. *Be sure that you pull horizontally – not at an angle up or down*. When the block begins to move, pull only hard enough to keep it moving with a small velocity, which is as constant (steady) as possible.

5. **Do not erase your data** so that you can use them for comparison with those in Activity 2-2. Do not yet print out the data.

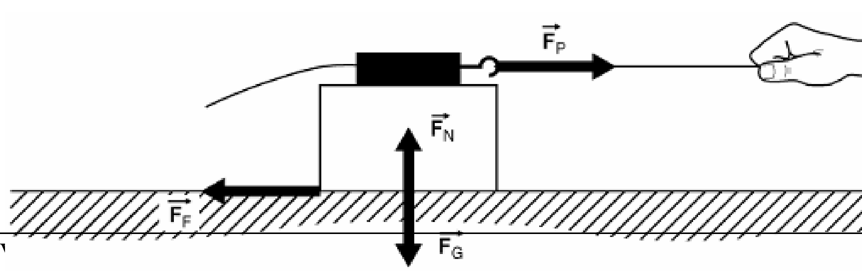
Question 2-1: Does the block feel a force on it due to the string, and yet not move? Why? What happens to the frictional force *just as* the block begins to slide? Does this agree with your prediction? Explain.

Activity 2-2: Frictional Force and Normal Force

The frictional force is nearly the same regardless of how fast the object moves, but there is usually a difference between *static* and *kinetic* frictional forces. Now you will examine if frictional forces depend on the force between the surface and the object – the *normal* force.

Comment: All of the forces exerted on a block being pulled on a table top or ramp are shown in the diagram below. As you know, surfaces like a wall or a table top can exert a force perpendicular to the surface called a *normal* force. In the case of the block on the table, the table exerts a *normal* force upward on the block, and the Earth exerts a *gravitational* force (the weight of the block) downward on the block.

Since you know that the block doesn't move up or down as it sits at rest or slides along the table's surface, the combined (net) vertical force must be zero according to *Newton's first law*. So the magnitude of the normal force must just equal the magnitude of the gravitational force.



Using the symbols in the diagram, we obtain

$$F_G = F_N = mg$$

where *m* is the total mass of the object, and g is the gravitational acceleration, 9.8 m/s^2.

Prediction 2-2: If you increase the normal force exerted by the table on the block (by adding extra masses to the force probe), what will happen to the frictional force? Explain.

1. Test your prediction. Use the same setup and experiment file, **Static and Kinetic Friction L6.2-1,** as in Activity 2-1.
2. Place another ½ kg mass on top of the force probe. The new total mass should be ~ 1.5 kg.
3. **Zero** the force probe with nothing pulling on it. The data from Activity 2-1 is still being displayed on the computer screen. As in Activity 2-1, **begin graphing** with the string loose, then gradually pull *very gently* on the force probe with the string, and increase the force very slowly. *Be sure that you pull horizontally–not at an angle up or down*. When the block begins to move, pull only hard enough to keep it moving with a small velocity that is as constant (steady) as possible.
4. Both sets of data with different masses should be displayed.

Question 2-2: Compare the two sets of graphs. In what ways are they similar, and in what ways are they different? Are the kinetic frictional forces the same or different? Explain.

5. Use the **statistics features** of the software to measure the average frictional forces during the time intervals when the block was moving with a constant velocity. You can choose which run # you are displaying by clicking on and off the Run # under the Data icon. Record the frictional forces in the first two rows of Table 2-1 along with the normal forces calculated from the masses.

Table 2-1

System: block, force probe and mass	Total Mass (kg)	Normal force (N)	Average kinetic frictional force (N)
1 - 0.5 kg mass			
2 – 0.5 kg masses			
3 – 0.5 kg masses			

6. Fasten an additional ½ kg mass on top and repeat the experiment. Be sure to **zero** the force

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probe before graphing. Once again pull so as to move the block with the same constant velocity. Record in Table 2-1 the total mass, the normal force, and the average frictional force.

7. **Print** out one set containing all these data for your group. Carefully mark on your graph the total mass for each set of data.

Question 2-3: Use an arrow to mark the time on your force graph when the block just began to slide. How do you know when this time is?

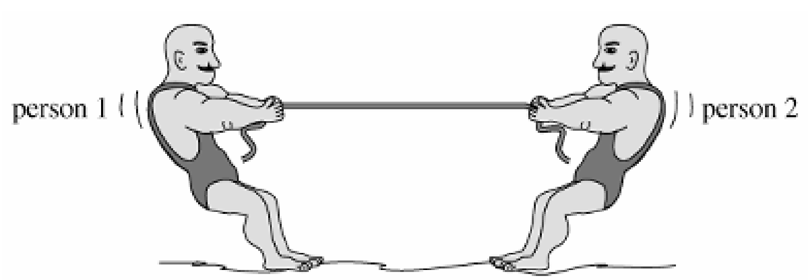
Question 2-4: How does the kinetic frictional force appear to vary as the normal force is increased? Try to state a mathematical relationship.

INVESTIGATION 3: NEWTON'S THIRD LAW

All individual forces on an object can be traced to an interaction between it and another object. For example, we believe that while the falling ball is experiencing a gravitational force exerted by the Earth on it, the ball is exerting a force back on the Earth. In this investigation we want to compare the forces exerted by interacting objects on each other. What factors might determine the forces between the objects? Is there a general law that 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 3-1: 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. Place a check next to your prediction.

______Person 1 exerts a larger force on person 2.

______The people exert the same size force on each other.

______Person 2 exerts a larger force on person 1.

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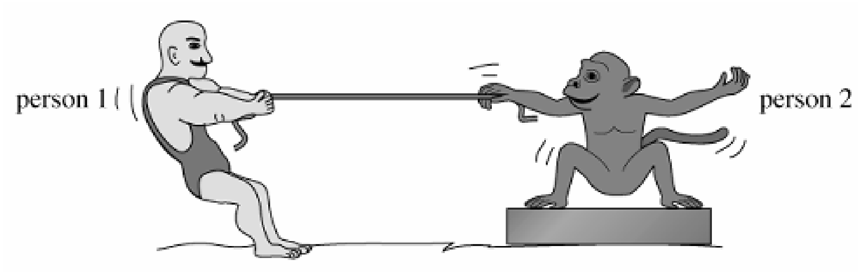
Prediction 3-2: Suppose now that you have a tug-of-war with someone who is much smaller and lighter than you. As before, you both pull as hard as you can, and it is a stand-off. One of you might move a little in one direction or the other, but mostly you are both at rest.



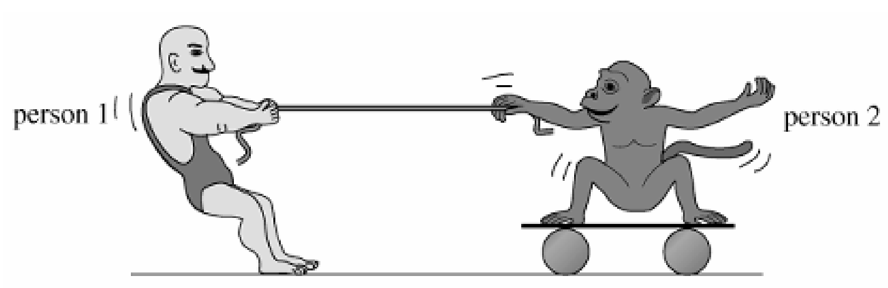
Predict the relative magnitudes of the forces between person 1 and person 2. Place a check next to your prediction.

______Person 1 exerts a larger force on person 2.

______The people exert the same size force on each other.

______Person 2 exerts a larger force on person 1.

Prediction 3-3: Again, suppose 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. Place a check next to your prediction.

______Person 1 exerts a larger force on person 2.

______The people exert the same size force on each other.

______Person 2 exerts a larger force on person 1.

To test your predictions you will need the following in addition to previously:

- another force probe (total of two)
- two 1-kg masses

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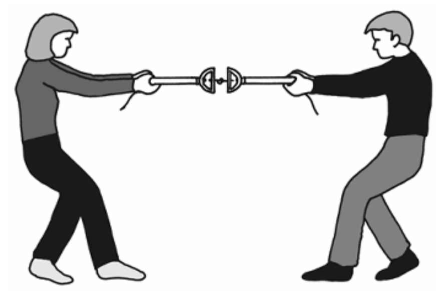
Activity 3-1: Interaction Forces in a Tug-of-War



1. Open the experiment file called **Tug-of-War L6.3-1**. The software will then be set up to measure the force applied to each probe with a data collection rate of 20 points per second.

2. Since the force probes will be pulling in opposite directions in the tug-of-war, you should **reverse the sign** of one of them. This should have already been done for you in the software.

3. When you are ready to start, **zero** both of the force probes. Then hook the force probes together, **begin graphing**, and begin *a gentle* tug-of-war. Pull back and forth while watching the graphs. Be sure not to exceed a force of 50 N. *Do not pull too hard, since this might damage the force probes.*

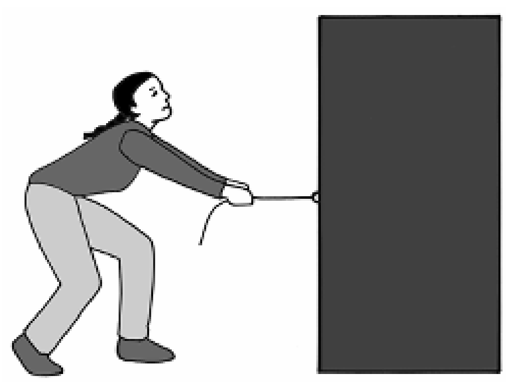
4. **Print** out one set of graphs for your group.

Question 3-1: How did the two pulls compare to each other? Was one significantly different from the other? How did your observations compare to your predictions?

INVESTIGATION 4: TENSION FORCES

When you pull on a rope attached to a crate, your pull is somehow transmitted down the rope to the crate. *Tension* is the name given to forces transmitted along stretched strings, ropes, rubber bands, springs, and wires.

Is the whole force you apply transmitted to the crate, or is the pull at the other end larger or smaller? Does it matter how long the rope is? *How* is the force "magically" transmitted along the rope? These are some of the questions you will examine in this investigation.



Obviously, the rope by itself is unable to exert a force on the crate if you are not pulling on the other end. Thus, tension forces are *passive* just like *frictional* and *normal* forces. They act only in response to an active force like your pull.

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Before you begin, examine your knowledge of tension forces by making the following predictions.

Prediction 4-1: If you apply a force to the end of a rope as in the picture above, is the whole force transmitted to the crate, or is the force at the crate smaller or larger than your pull?

To test your predictions you will need the following in addition to what you already have:

- heavy ring stand or table clamp and rod, clamp for force probe
- rubber band

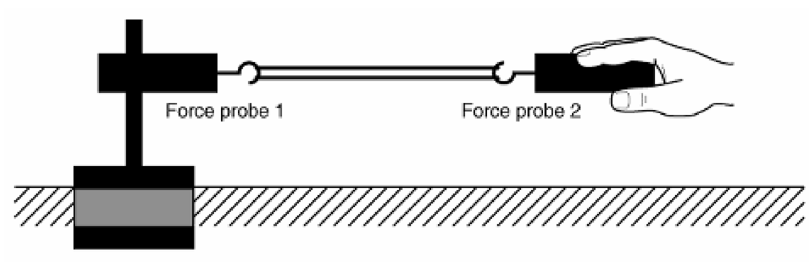
Activity 4-1: Mechanism of Tension Forces

1. Open the experiment file called **Tension Forces L6.4-1**.

2. Attach force probe 1 horizontally to the ring stand or table clamp and rod so that it won't move when pulled.

3. Place a rubber band between the force probes.

4. **Zero** both force probes with the rubber band hanging loosely. **Begin graphing**, and pull softly at first on force probe 2, then harder, and then vary the applied force. *Be sure not to exceed 50 N*.



5. **Print** out one set of graphs for your group.

Question 4-1: Based on the readings of the two force probes, when you pull on one end of the rubber band, is the force transmitted down to the other end? Explain.

6. Indicate with arrows on the diagram above the directions of the forces exerted by the rubber band on force probe 1 and on force probe 2.

Prediction 4-2: What happens when a string is hung around a pulley? Is the tension force still transmitted fully from one end of the string to the other?

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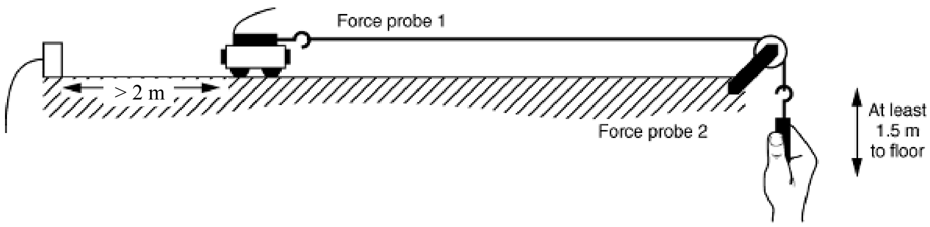
To test your prediction, in addition to the equipment listed above you will need

- low-friction pulley
- low-friction cart
- 2-m motion track
- long piece of string

Activity 4-2: Tension When a String Changes Direction

1. Attach force probe 1 securely to the cart, and set up the cart, track, pulley, string, and force probes.



2. The experiment file **Tension Forces L6.4-1** is also appropriate for this activity. You will have graphs of the two force probes versus time.

3. **Zero** both force probes with the string loose. Then **begin graphing** while pulling on force probe 2 and holding the cart to keep it from moving. Pull softly at first, then harder, and then alternately soft and hard. Do not exceed 10 N.

4. **Print** out one set of graphs for your group report.

Question 4-2: Based on your observations of the readings of the two force probes, was the pull you exerted on force probe 2 transmitted undiminished to force probe 1 even though it went through a right angle bend? How does this compare to your prediction? Explain.

Activity 4-3: Tension and Newton's Second Law

Prediction 4-3: Suppose that in place of force probe 2 you hang a 50-g mass from the end of the string. With the cart at rest, what value do you expect force probe 1 to read? Be quantitative. Explain.

Prediction 4-4: Suppose that you hang the same 50-g mass but release the cart and let it accelerate as the mass falls. Do you expect force probe 1 to read the same force or a larger or smaller force as the cart accelerates? Explain.

To test your predictions you will need the following in addition to the equipment for Activity 4-2:

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- various masses

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1. Use the same setup as for Activity 4-2, but replace force probe 2 with a hanging mass and set up the motion detector.
2. Determine the mass of the cart and force probe: __________kg
3. Open the experiment file called **Tension and N2 L6.4-3**.
4. Be sure that the motion detector can see the cart all the way to the end of the track.
5. Hang the 50-g mass from the end of the string, and hold the cart at rest at least 0.2 m away from the motion detector.
6. Just before you are ready to start **zero** the force probe with the string loose. Let the 50-g mass hang without swinging and then **begin graphing**. Hold the cart for the first second after you hear the clicks of the motion detector and then release it. *Be sure to stop the cart before it comes to the end of the track*.
7. **Print** out one set of graphs for your group. Use arrows on your force and acceleration graphs to indicate the time when the cart was released.
8. Use the **statistics features** of the software to measure the average value of the tension measured by the force probe before the cart was released and while it was accelerating. Also measure the average value of the acceleration during the time interval while the cart had a fairly constant acceleration.

   Average tension with cart at rest: ___________N

   Average tension with cart accelerating: ___________N

   Average acceleration: ___________m/s^2

Question 4-3: How did the tension *while the cart was at rest* compare to the weight of the hanging mass? (**Hint:** Remember that *weight* = mg.) Did this agree with your prediction? Was the force applied to the end of the string by the hanging mass transmitted undiminished to the cart, as you observed in the previous activity?

Question 4-4: Did anything happen to the tension after the cart was released? How did the value of the tension *as the cart was accelerating* compare to the weight of the hanging mass? Did this agree with your prediction?

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Comment: When the cart is released, both the cart and hanging mass must always move with the same velocity since they are connected by the string as a single system. Thus, the cart and mass must have the same acceleration.

According to *Newton's second law*, the combined (net) force on the cart must equal its mass times the acceleration, and the combined (net) force on the hanging mass must equal its mass times the same acceleration.

Question 4-5: Use *Newton's second law* to explain your answer to Question 4-4. Why must the tension in the string be smaller than the weight of the hanging mass if the hanging mass is to accelerate downward?

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