

Name: _____
Partners: _____

PHYSICS 220 LAB #3: NEWTON'S LAWS



When a golf club strikes a golf ball, it exerts such a large force that the ball is actually deformed. The force has to be large because the club is not in contact with the ball for very long. In order to get the ball to a high speed in a short time the acceleration (and therefore the force) must be large. This is an example of Newton's Second Law.

(equipment: PC, Lab Pro, cart, force probe, motion detector, string, masses, pulley, stand)

OBJECTIVES

1. To learn how to use a force probe to measure forces.
2. To get practice drawing *free-body diagrams* and applying Newton's Laws.
3. To compare the observed motion of a system to the predictions of Newton's Laws.

OVERVIEW

Newton's Laws are:

1. An object will maintain a constant velocity (perhaps zero) if there is no net force on it.
2. The net force on an object is equal to its mass time the resulting acceleration ($\vec{F}_{\text{net}} = \sum \vec{F} = m\vec{a}$).
3. If object A exerts a force on object B, then object B exerts a force of the same size but in the opposite direction on object A.

In order to apply the Newton's Second Law, a free-body diagram showing all of the forces on an object is needed. The second law is usually used in component form:

$$F_{\text{net},x} = \sum F_x = ma_x \quad \text{and} \quad F_{\text{net},y} = \sum F_y = ma_y$$

The size of the force of gravity on an object near Earth (its weight) is given by

$$W = mg$$

where m is the mass of the object and g is the gravitational acceleration (9.80 m/s^2). This is the only force that will be studied this semester that does not require contact with another object. In the SI system of units, mass has units of kg , acceleration has units of m/s^2 , so you can see that force has units of $\text{kg}\cdot\text{m/s}^2$, which is defined as a Newton (abbreviated “N”).

According to your textbook (in a footnote on p. 85), if “the pulley is both massless and frictionless”, then “the tension in the rope is the same on both sides of the pulley.” In other words, an ideal pulley just redirects a force, but does not change its size.

PRE-LAB (to be completed before coming to lab)

Prior to coming to lab, read through this write-up and perform all the exercises labeled “**Pre-Lab**”. You will also want to copy this work onto the back pages of the lab, which I will collect during the first 5 minutes of lab.

PART ONE: Calibrating and Testing the Force Probe

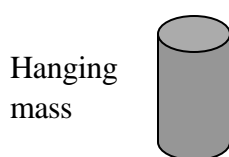
1. By suspending known masses with your force probe, you will be able to calibrate your force probe so that the reported value is in units of Newtons. Be sure a force probe is plugged into CHANNEL 1 of the Lab Pro and a motion detector is plugged into the DIG/SONIC 1 port.
2. Open the file called **Force and Motion** (in Physics Experiments / Physics 220 – 221/ Newton’s Laws) folder on the computer desktop to start with a set up to measure velocity, acceleration, and force.
3. To calibrate the force probe, select **Calibrate** from the *Experiment* menu, select CH1: Dual Range Force (N), and click **Calibrate Now**. For Reading One, leave the probe unloaded, enter 0 N and hit **Keep**. For Reading Two, hang a 100-g mass from the probe and enter its *weight*: 0.98 N, then click **Keep**. Finally, hit **Done**.
4. Check the calibration. *Before each measurement with the force probe*, “zero” it by removing any mass from it and hit the Zero button (top right of the window) and select just CH1, then Zero. Hang each of the four masses listed below from the hook for several seconds. You’ll notice at the very bottom of the screen, in a grey bar, “Force =” From this you can read off the force that the probe is measuring for each hanging mass.

hanging mass	0.05 kg	0.10 kg	0.20 kg	0.50 kg
measured force	N	N	N	N
calculated weight	N	N	N	N

Pre-Lab: Enter the calculated weight values in the above table.

Questions: Do your force probe readings correspond to your calculated weights for the whole range tested? Does it work better for small or large weights?

Pre-Lab: Draw a free-body diagram for a hanging mass while it is being weighed (the lengths of your force vectors should accurately represent their relative sizes). See figures in Ch. 4 of the text for examples of “free-body diagrams.” Explain the relative sizes of the forces using one of Newton’s Laws.



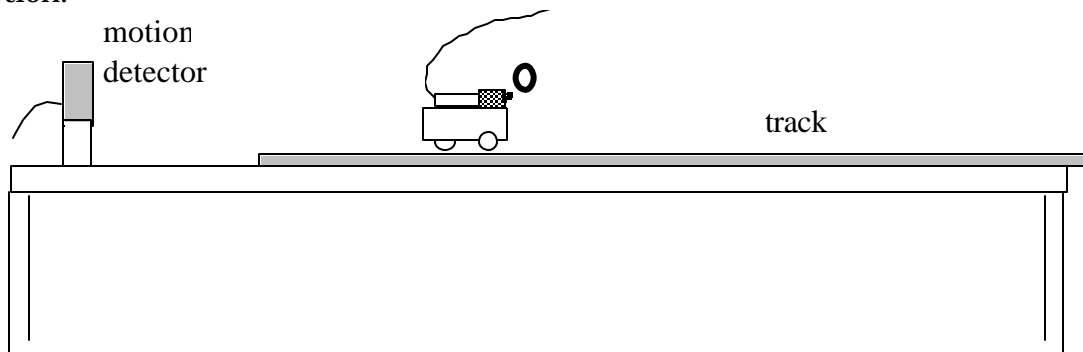
PART TWO: The Effect of a Horizontal Force on the Cart

1. Screw the force probe securely into the mount on top of a cart.
2. Hang the probe – cart system from the probe’s hook and thus measure their combined weight and calculate their combined mass. (You will use these measurements in Part 4)

Weight of Cart + Probe: $w_{c+p} =$ _____ N

Mass of Cart + Probe: $m_{c+p} =$ _____ kg

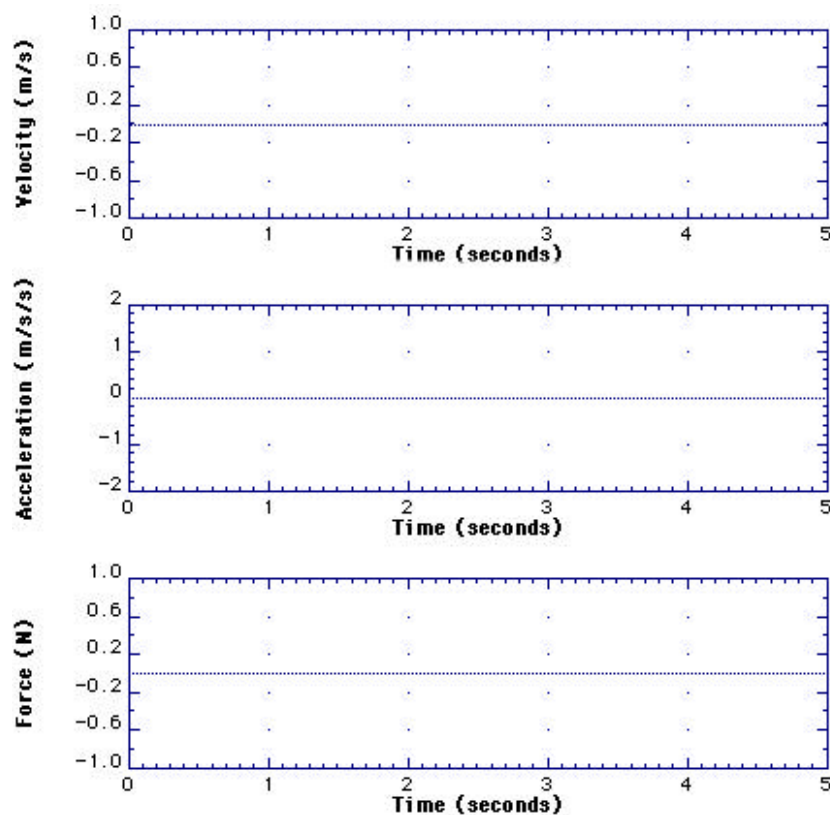
3. Set up the track so the end without the bumper is near the edge of the table. Place the motion detector near the other end of the track as shown below. Level the track so that the car won’t roll when set on the track. Set the cart on the track as shown so a positive force (a pull on the hook) will correspond with a positive direction of motion.



Pre-Lab: Suppose you held the hook on the force probe and moved the cart back and forth in front of the motion detector. Do you think

that either the velocity or the acceleration graph will look like the force graph? If so, which?

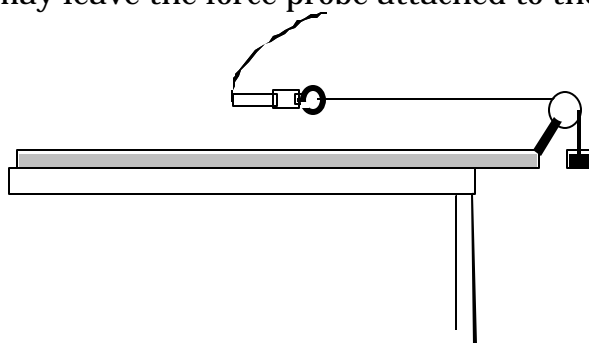
4. Be sure that the cable from the force probe doesn't extend beyond the cart so it won't be "seen" by the motion detector. Hold the hook on the force probe and click **Collect**. Wait a moment for the motion detector to start clicking, then move the cart around in front of the detector. Get in some sporadic motion (that really highlights the plots' similarities.) Sketch the resulting graphs on the axes below.



Questions: Does either graph (velocity or acceleration) resemble the force graph? Which one? Why?

PART THREE: The Effect of a Pulley

1. Attach the pulley to the end of the track hanging over the edge of the table. Hang a 0.05-kg mass from the force probe as shown below. You may leave the force probe attached to the cart.



2. Take measurements of the tension in the string for several masses hanging at rest (similar to what you did in Part One) and fill in the table below. The string should be approximately parallel to the track. *Don't forget to Zero the probe first (things shift when it gets tilted horizontal).*

hanging mass	0.05 kg	0.10 kg	0.20 kg	0.50 kg
measured tension	N	N	N	N
calculated weight	N	N	N	N

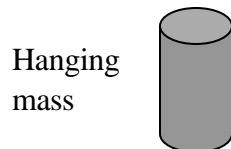
Pre-Lab: Enter the calculated weight values in the above table.

Question: Does the pulley have the effect that is expected? Explain.

3. With a 200-g mass hanging on the string, hit **Collect**. Hold the force probe still for about a second, then move the force probe suddenly toward the pulley allowing the mass to move downward. Carefully observe what happens to the force.

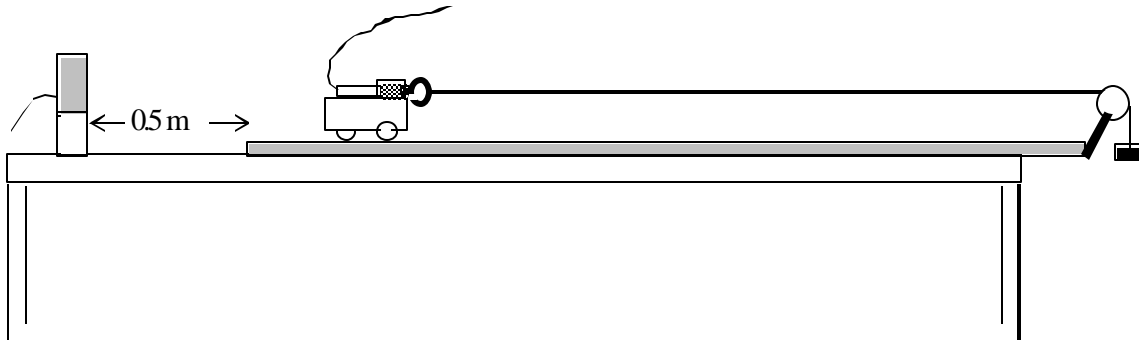
Question: What happens to the tension (measured by the force probe) when the mass is accelerating downward? (Just when you start to allow it to fall.)

Pre-Lab: Draw a free-body diagram for the mass when it is accelerating downward, i.e., an abstract sketch of the mass, with labeled arrows representing the forces applied to it (the lengths of your force vectors should accurately represent their relative sizes). By appealing to one of Newton's Laws, explain the relative sizes of the forces.



PART FOUR: Accelerating the Cart with the Hanging Mass

4. Set up the track, pulley, cart, string, motion detector, force probe, and a hooked mass as shown below. The string should be approximately horizontal and the hanging mass should be close to the pulley when the cart is near the other end of the track.



5. Hang about 50 g or 100 g on the string so that the cart moves across the ramp in about 1 to 2 seconds after the mass is released. Record the combined mass of the cart and probe (from Part 2) and the size of the other mass.

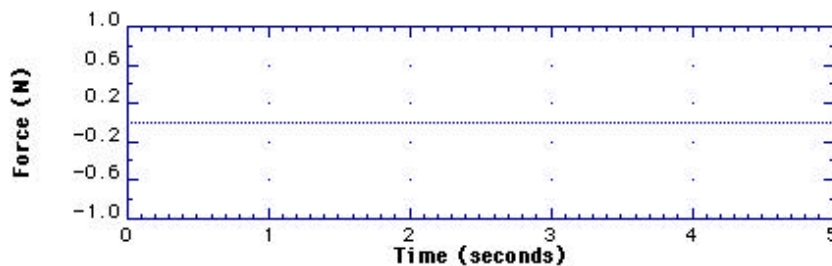
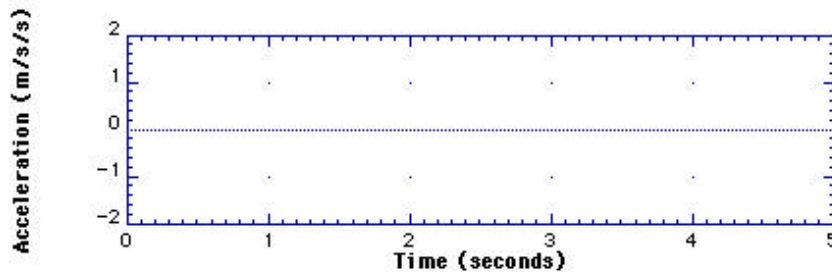
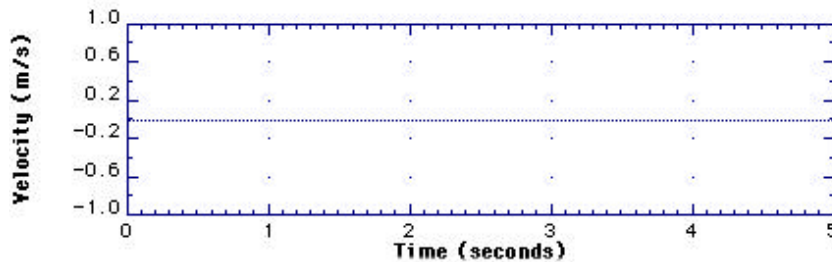
Mass of Cart & Probe: $m_{cp} = \underline{\hspace{2cm}} \text{ kg}$

Falling Mass: $m_f = \underline{\hspace{2cm}} \text{ kg}$

6. **Zero** the force probe without the string attached to the probe. Click **Collect** and release the cart after the motion detector starts clicking. Be sure that the cable from the force probe isn't seen by the motion detector and doesn't drag. Repeat until you get fairly smooth graphs of the motion.

7. Sketch the actual velocity, acceleration and force graphs on the axes below (don't worry about small bumps).

On the v vs. t graph mark the times **(A)** when the cart started moving and **(B)** when the falling mass hit the floor or you caught the cart.



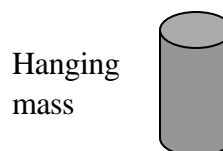
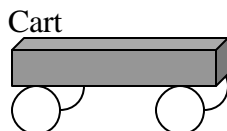
8. Analyze the data to determine the average acceleration of the cart and tension on the string during the motion, i.e., *after you release it and before you catch it.*

Acceleration of Cart: $a_c = \underline{\hspace{2cm}} \text{ m/s}^2$

Tension on String: $T = \underline{\hspace{2cm}} \text{ N}$

Note: *you will later compare these measurements with predicted values, so make sure you measure these quite carefully.*

Pre-Lab: Draw separate “free-body diagrams” for the cart and the hanging mass. Neglect friction and be sure to label all of the forces. Also, draw acceleration vectors next to or below each free-body diagram. Do not put the accelerations in the diagrams or you may mistake it for a force.



Pre-Lab: How does the weight of the falling mass compare with the tension in the string, when the mass is falling (greater, less than, equal to)? Appeal to one of Newton’s Laws to explain the relative sizes of the forces.

- Pre-Lab:** Using the free-body diagrams in step 9, apply Newton’s Second law to the horizontal motion of the cart and to the vertical motion of the falling mass to write relationships between the forces, masses, and acceleration. These relations should be in terms of symbols like m , g , T , etc., without numbers. Make downward the direction positive for the falling mass. Be sure to label different things differently in your equations!

Pre-Lab: How are the horizontal acceleration of the cart and the vertical acceleration of the falling mass related to each other?

Pre-Lab: Assuming all you know are the masses of the cart and the falling mass, solve the equations in step 10 to predict the tension and acceleration. I.e., observing that you have *two equations and two unknowns* you can write an equation for tension, purely in terms of the two masses and g (not in terms of a); and write an equation for the acceleration purely in terms of the masses and g , (not in terms of the tension). These equations should be purely symbolic (no numbers – you'll get those and plug them in during the lab).

10. Plug the measured values of the *masses* and the accepted value for g into the above equations to find predicted values of Tension and Acceleration.

Question: How do your predictions compare to your measurements (calculate percentage differences of accelerations: $\left| \frac{a_{\text{measured}} - a_{\text{predicted}}}{a_{\text{measured}}} \right| \cdot 100\%$)? **Before turning in:** check with the instructor to make sure you have an acceptable % difference (<10%).

Explain any discrepancies.

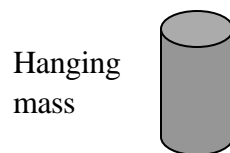
Pre-Lab#3

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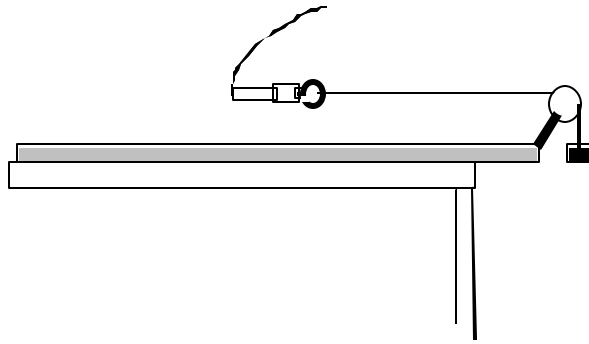
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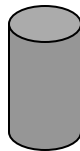


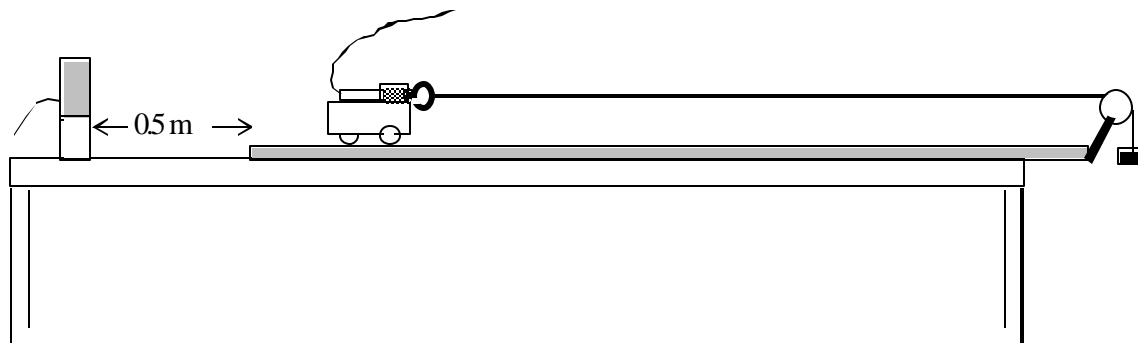
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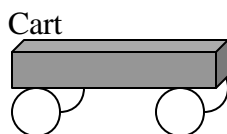
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Hanging
mass

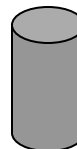




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