Physics 231: General Physics I **Names:**______________________
Lab 3 – Feb. 5, 2004 ______________________

Newton's Laws

Goals:

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.

Part I: Calibrating and Testing the Force Probe

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 setup to measure velocity, acceleration, and force.

To calibrate the force probe, select **Calibrate** from the *Experiment* menu, click on the CH1 / Force icon, and click **Perform 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 **OK**.

1. Check the calibration. Before each measurement with the force probe, "zero" it by removing any mass from it and hit the Zero button, then Zero Force. Click Collect to record data, then hang each of the four masses listed below from the hook for several second. In order to take data for the table below, on the plot of interest, select the region you'd like by holding the mouse button and dragging across the region, then hit the STAT button just below the menu bar. Record the mean value of the force as your measurement and calculate the weight for each 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

2. **Pre-Lab** Draw a free-body diagram for a mass hanging from the force probe. Explain the relative sizes of the forces using one of Newton's Laws.

Part II: The effect of a horizontal force on the cart

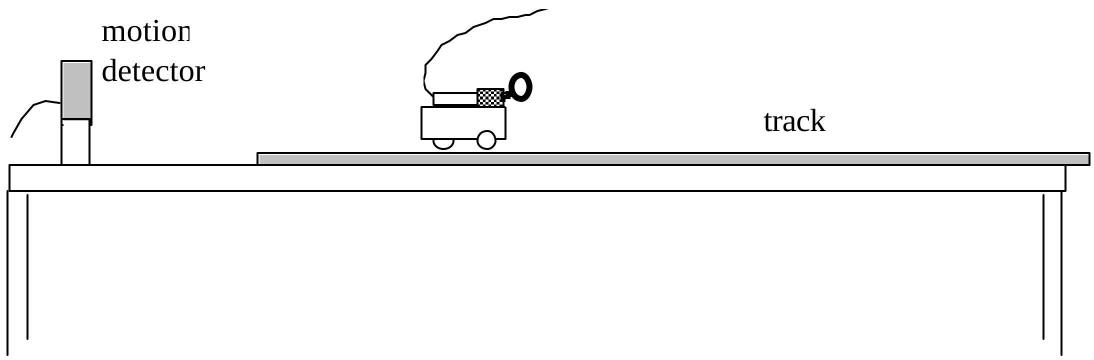
Screw the force probe securely into the mount on the top of a cart.

3. Measure the weight of the probe and cart together by hanging them from the probe.

   Weight of Cart + Probe: ______________________________ N

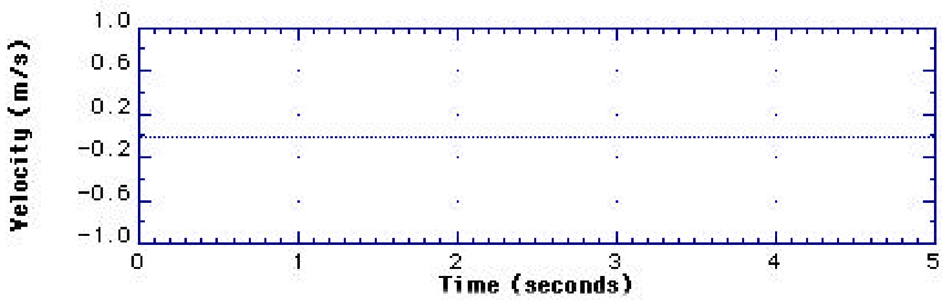
   Mass of Cart + Probe ______________________________ kg

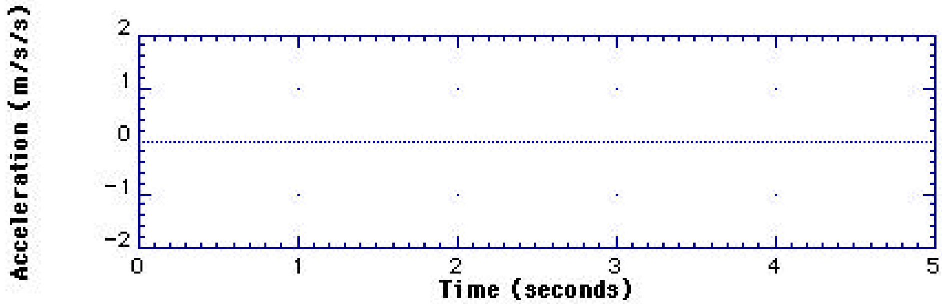
Set up the track so the end without the bumper is near the edge of the table. Place the motion detector near the other end of the track as shown below. Level the track so that the car won't roll when set on the track. Set the cart on the track as shown so a positive force (a pull on the hook) will correspond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

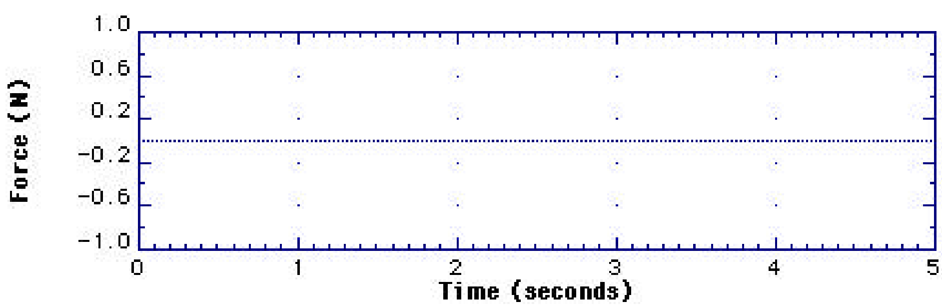


4. **Pre-Lab** Suppose you held the hook on the force probe and moved the cart back and forth in front of the motion detector. Do you think that either the velocity or the acceleration graph will look like the force graph? If so, which? Why?

5. 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 smoothly pull the cart away form the motion detector, stop it, push it back towards the motion detector, and stop it. Sketch the resulting graphs on the axes on the next page.



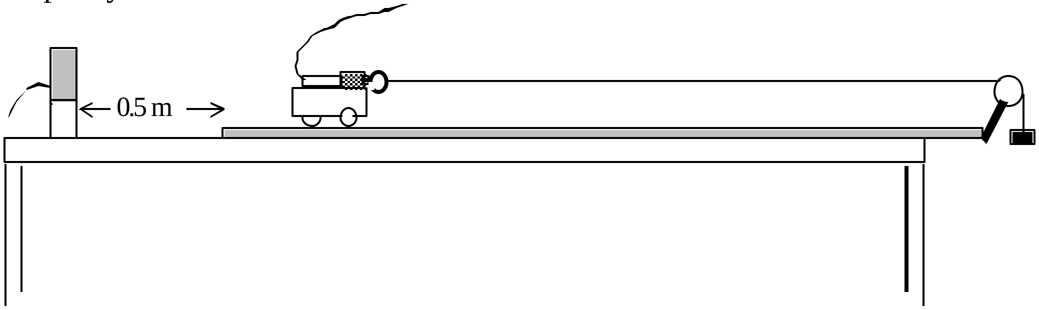




6. Was your answer to number 4 correct? If not, explain why.

Part III: Accelerating the cart with the hanging mass

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.



Hang a 50 or 100 g mass on the string so that the cart moves across the ramp in about 2 seconds or so after the mass is released.

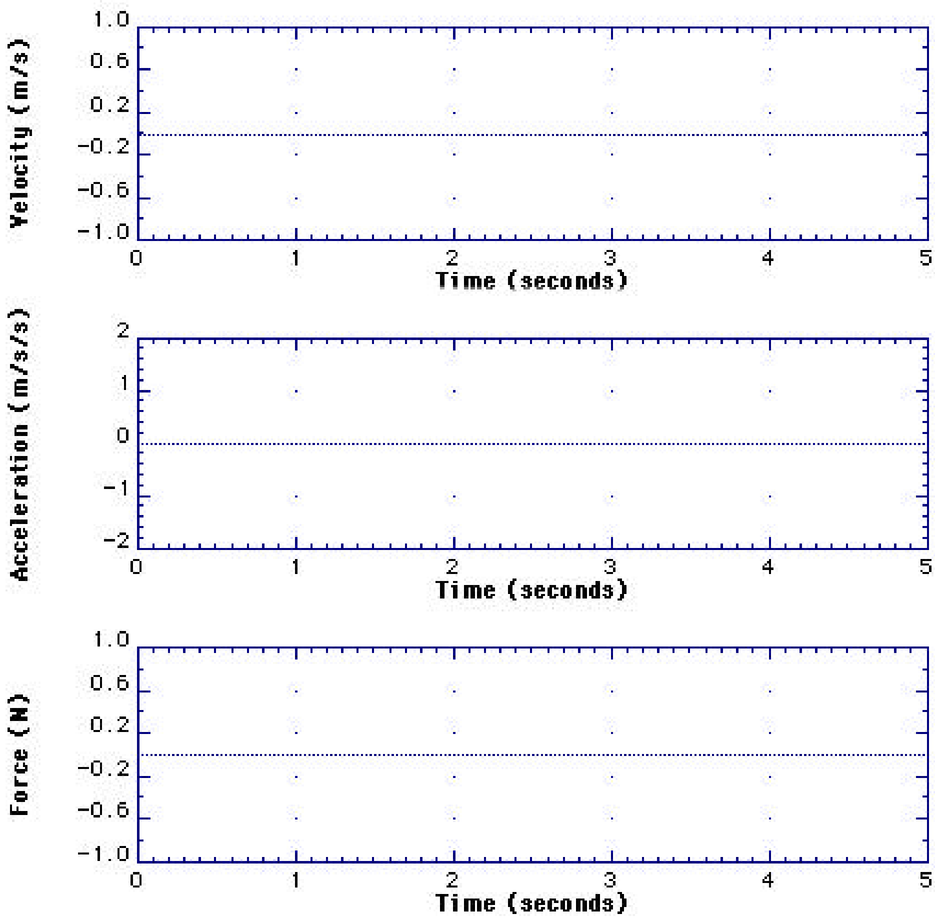
7. Record the combined mass of the cart and probe (from part II) and the mass of the hanging mass:

   Mass of the cart + probe: _________________________ kg

   hanging mass _________________________ kg

Zero the force probe without the string attached to the probe. Click **Collect** and release the cart after the motion detector start 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 motion.

8. Sketch the actual velocity, acceleration, and force graphs on the axes below.



9. 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.

10. 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 = _________________________ m/s^2

    Tension on string T = _________________________ N

11. **Pre-lab** Draw a separate free-body diagram 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 (not on) each free-body diagram.

12. **Pre-lab** How does the weight of the falling mass compare with the tension in the string, when the mass is falling? (is it greater, less than, or equal to?) Appeal to one of Newton's Laws to explain the relative sizes of the forces.

13. **Pre-lab** Using the free-body diagrams in step 11, 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. Be sure to label things differently in your equations.

14. **Pre-lab** How are the horizontal acceleration of the cart and the vertical acceleration of the falling mass related to each other?

15. **Pre-lab** Using your equations from #13, derive an expression for the acceleration purely in terms of the masses and g. (Tension should not be in your formula.)

16. Now that you have carried out the experiment, plug your numbers into the equation you derived in #15 to get the acceleration.

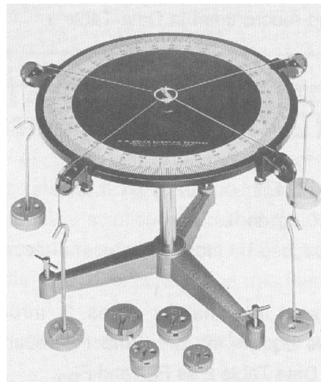
17. Compare the acceleration calculated in #16 to the acceleration measured in #10.

    Calculate the percentage difference: $\left|\frac{a_{measured} - a_{predicted}}{a_{measured}}\right| \cdot 100\%$.

18. What are some possible sources of error in this experiment?

Part IV: The Force Table

Carefully level the force table. Hang 200 grams from one string and 300 grams from another. Place these strings at an angle **other than** 90°.



Adjust the mass hanging from the third string and its angle so that the ring does not touch the pin in the middle of the table and each string points directly toward the pin (now the net force on the ring is zero and comes only from the 3 masses).

19. Record the masses and angles below. Don't forget to include the mass of the hanger if you use one.

    m_1 = ______________________ kg $?_1$ = ______________________ °

    m_2 = ______________________ kg $?_2$ = ______________________ °

    m_3 = ______________________ kg $?_3$ = ______________________ °

20. Draw the free body diagram for the ring. (Assume the tensions on the ring are approximately horizontal.)

21. Find the measured force on the ring using components. Show all of your work clearly.

22. How does the net force you calculated compare with what you expect it to be? Explain. (No need to calculate percent errors.)

Lab #3: Pre-lab

2. **Pre-Lab** Draw a free-body diagram for a mass hanging from the force probe. Explain the relative sizes of the forces using one of Newton's Laws.

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