	empty cart	cart+masses
trial 1		
trial 2		
trial 3		
trial 4		
AVERAGE		

7. Using Newton's 2nd Law and the measured values of the masses involved, predict what acceleration should have been observed in the two cases (empty cart, cart+masses).

8. Compare the measured and predicted values. Express the difference as a percentage.

Q3. Suggest some factors which could account for any discrepancy between the expected and actual values of the acceleration of the cart.

Part II. Newton's Second Law

1. Set up the Science Workshop software to read the data collected by the "smart pulley." Create a graph of velocity vs. time.

2. Make sure that the air track is perfectly level. To do this, turn on the air supply and make sure that the cart does not move when released from rest. Adjust the leveling by using the screws in the feet of the wide air track support. When you are finished, turn off the air supply.

3. Measure and record the mass of the empty air cart and banana plug using the balance. Remember to adjust the zero setting on the balance, if necessary. Record your measurement to the nearest 0.05 gram. Also measure and record the mass of the four metal weights which may be attached to the sides of the air cart. Finally, measure and record the mass of the small hanging mass which will supply the driving force accelerating the cart.

mass of hanging mass	
mass of cart	
mass of weights	
mass of cart+weights	

4. With the air track power supply OFF, attach the string to the (empty) cart by looping it over the banana plug. Thread the string over the pulley and attach the small hanging mass. Carefully align the pulley with the air track by sighting along the top of the pulley toward the cart. Check to see that the string is not catching on the ring stand etc. and that the cord for the "smart pulley" is out of the way.

5. While your partner holds the (empty) cart at rest, turn on the air supply. Click on the "Record" button in the Science Workshop control panel just before your partner releases the cart. Record through 5 or 6 cycles of the motion, and click the "Stop" button. Repeat after loading the cart with the four additional masses.

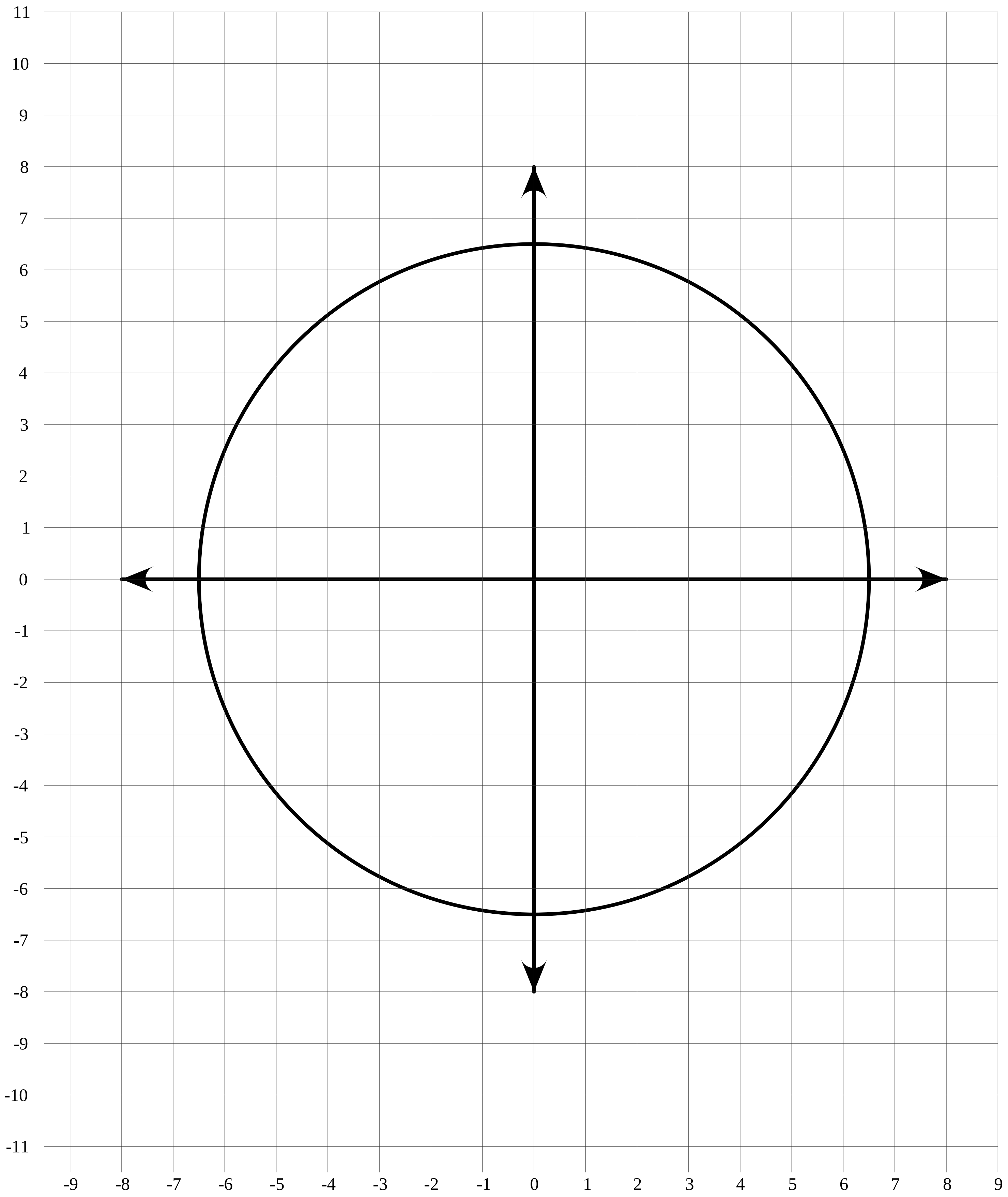
6. Adjust the axis scales on the graphing window to make the data easy to see. Determine the acceleration of the cart by using the slope of the linear sections of the plot. Do this for at least 4 suitable sections of each data set. Determine the average acceleration in each case. You should round your average slope values to three significant figures.

	mass	weight	angle	W_x	W_y
mass #1					
mass #2					
mass #3					
resultant	●●●●●				

5. Compare the magnitude and direction of your resultant to the force exerted on the ring by the force probe. What do you notice?

Q1. Is it reasonable to conclude that Newton's First Law has been verified for an object (the ring) at rest? Explain.

Q2. Suggest some factors which could account for any discrepancy between the expected and actual values of the force exerted on the ring by the force probe.


11
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1
2
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4
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6
7
8
9

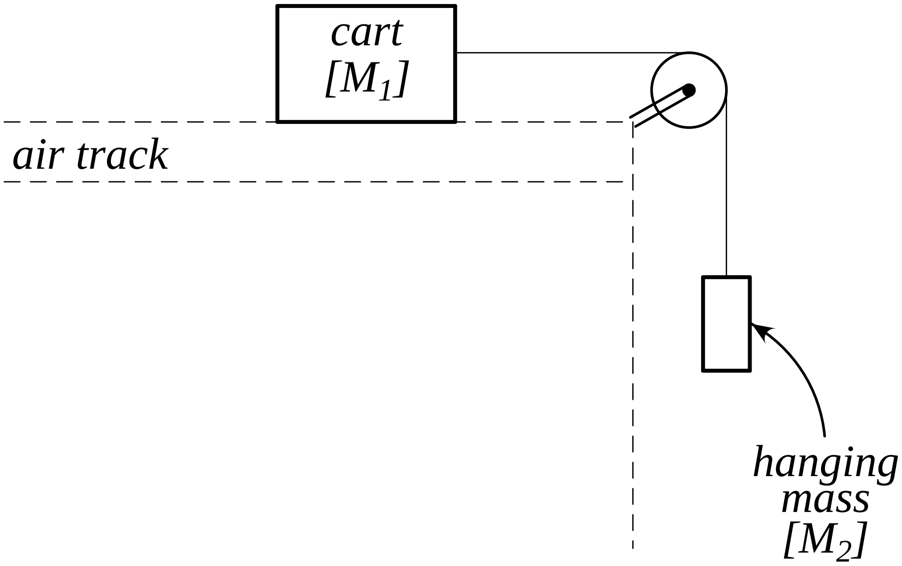
Part I. Newton's First Law

1. Set up the Science Workshop software to read the data collected by the force probe located on the force table. Do not graph the data. Instead, set up a Digits screen. Calibrate the force sensor as follows:
   - **a.** Mount the force sensor in a vertical position.
   - **b.** Bring up the calibration screen for the force sensor by double-clicking on the force sensor icon.
   - **c.** Press the TARE button. Replace the entry in the box labelled LOW VALUE with "0". Click on the READ button to automatically set the value in the VOLTS column.
   - **d.** Hang 1.000 kg on the hook. (Don't forget that the hook itself has a mass of 50 g!) Replace the entry in the HIGH VALUE box with "9.80". Click on the READ button to automatically set the value in the VOLTS column.
   - **e.** Your force sensor is now calibrated. Click on OK to accept the calibration and close the calibration window.

2. Carefully remount the force sensor in a horizontal position over the edge of the force table. While nothing is pulling on the force sensor, press the TARE button to zero it. Place three different masses on the other strings. Move the pulleys around the force table until the ring is held in equilibrium over the very center of the table. Make sure that all of the strings are "true." That is, all of the strings should be perpendicular to the ring which they are attached to. They should all leave the pulleys parallel to the groove in the pulley. When you look straight down on the pulley, the strings should line up with the markings on the pulley clamps. And, equally importantly, the string attached to the force sensor must be pulling directly outward from the sensor.

3. In the table provided, record the mass attached to each of the strings. Be sure to include the mass of the hook. Compute the weights. Record the angular position of each string. As an aid in determining the components of the forces acting on the ring, make a sketch of your force table. Label each weight and record the angular positions of each of the strings. You should draw the lengths of the vectors to scale (1 N = 1 cm works fairly well).

4. Determine the magnitude and direction of the resultant of the three force vectors created by the hanging masses. Clearly explain your method of vector addition. Add your information to the table.



In the second part of this week's lab, you will investigate Newton's 2nd Law, which relates the acceleration of a given object to the sum of the forces acting upon it:

$$M\boldsymbol{a} = \sum_{i=1}^{n} \boldsymbol{F}_i.$$

The geometry will be that of a mass on a (nearly) frictionless table (in the form of the air track) which is tied to a mass which is hanging over the edge of the table (see diagram).

The only forces acting on the hanging mass (M_2) are its weight $M_2 g$ and the tension in the string T. Both act along the vertical direction, so Newton's 2nd Law for the hanging mass reads

$$\sum F_y = M_2 a_{2y} = T - M_2 g.$$

A total of three forces act on the cart (M_1). Two of these forces are equal and opposite: the normal force and the weight of the cart. Thus, there is a single unbalanced force acting on the cart, the tension in the string:

$$\sum F_x = M_1 a_{1x} = T.$$

Therefore, the cart will be accelerated, *even if* $M_2 < M_1$*!!*

To compute the acceleration of the cart, note that since the two masses are tied together, they must have accelerations of equal magnitude. From the geometry of the setup, if we let $a_{1x} \equiv a$, then $a_{2y} = -a$. Replacing the tension T in the Newton's 2nd Law equation for the hanging mass with its value ($M_1 a$) allows us to determine the common acceleration:

$$a = \frac{M_2}{M_1 + M_2}\, g.$$

GDM 09/29/01

Experiment 4 – Newton's First and Second Laws

Objective

In Part I of this experiment you will test Newton's 1st Law on a stationary object which has several forces acting on it. In Part II you will test the prediction from Newton's 2nd Law for the acceleration of a system consisting of two masses tied together by a string threaded through a pulley.

Equipment

- Science Workshop 750 Computer Interface.
- Science Workshop Version 2.3.2 Data Acquisition Software for Windows.
- Pasco Scientific Force Sensor CI-6537.
- Force table with 3 pulleys.
- Small metal ring with 4 strings attached.
- 3 hooks.
- Assorted masses.
- Pasco Scientific Air Supply Model SF-9216.
- Pasco Scientific Air Track and Accessories
- Pasco Scientific Smart Pulley ME-9387
- Balance.
- Miscellaneous mounting hardware (large ring stand, clamps, etc.).

Theory

In the first part of the lab, you will investigate Newton's 1st Law in the intuitive case of an object at rest.

According to Newton's 1st Law, in order for an object to remain at rest, the net force acting on it must be zero. Recall that the net force is the sum of all of the forces acting on an object:

$$\boldsymbol{F}_{net} = \sum_{i=1}^{n} \boldsymbol{F}_i.$$

This is a vector equation: both the magnitudes and directions of the forces must be taken into account.

The situation you will set up will consists of three "known" forces (the weights of the masses hanging from the pulleys) and one "unknown" force. The unknown force will be measured with the force sensor, and compared to the value you predict by adding up the three forces exerted by the weights.