Lab 7 – Forces: Newton's Second Law

Name ____

Partner's Name ____

I. Introduction

In this laboratory, you will investigate the changes in the motion of a cart on the air track that occur when different amounts of net force are applied.

Isaac Newton described the relationship of the net force applied to an object and the acceleration it experiences in the following way; the acceleration (a) of an object is directly proportional to and in the same direction as the net force (F_{net}), and inversely proportional to the mass (m) of the object.

$$a = \frac{F_{net}}{m}$$

II. Equipment

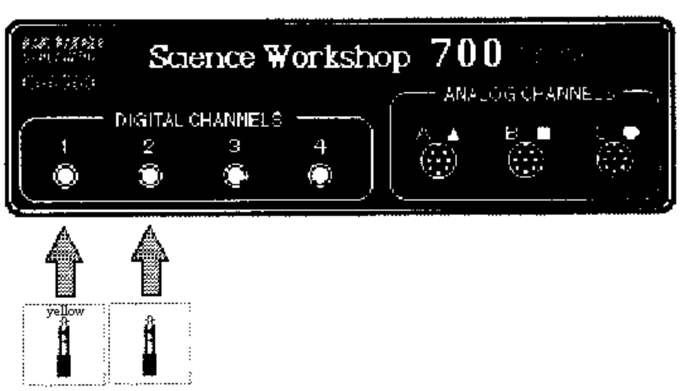
Computer with interface
Motion sensor
Air track with blower and pulley assembly
Air track cart, string, and air track mass/hanger set (20 g set)
Scale (for measuring mass)

III. Procedure/Data

For this activity, a motion sensor will measure the motion of a cart as it is pulled by a string that is attached to an object suspended over the pulley. The Science Workshop program calculates the changing speed of the cart as it moves. A graph of speed and time can give the experimental acceleration of the cart.

Part I: Computer Setup

1. Verify/Connect the motion sensor's stereo phone plugs to Digital Channels 1 and 2 on the interface. Connect the yellow-taped plug to Digital Channel 1 and the other plug to Digital Channel 2
2. Verify/Connect the *Science Workshop* interface to the computer, turn on the interface, and then turn on the computer.



3. Open the Science Workshop software for the Macintosh:

   <Macintosh HD>, <Science Workshop folder>, <Science Workshop>
   Drag the *plug* button to Digital Channel 1, choose motion sensor.
   Drag the *graph* button to Digital Channel 1, choose velocity.
   Setup the computer to display a graph of velocity vs. time.

Part II: Sensor Calibration and Equipment Setup

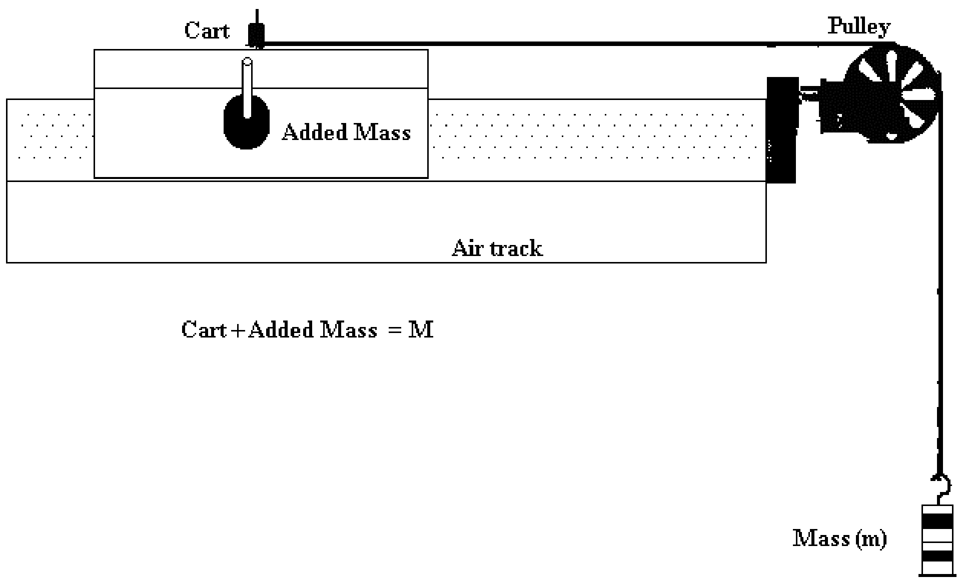


Figure 1

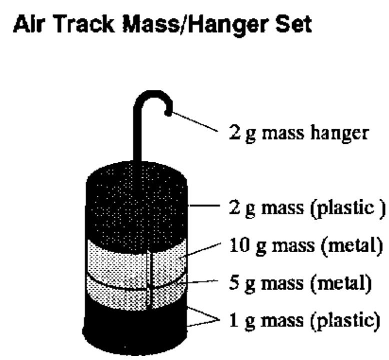


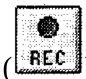
Figure 2

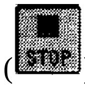
1. With the blower to the air track connected and turned on, place the cart on the track and level the track so the cart will not roll one way or the other on its own.
2. Verify/Mount the Pulley at the end of the track (and over the edge of the table). Verify/Mount a bumper on the cart such that the pulley and cart do not make direct contact. Verify/install the rubber band correctly on the bumper to absorb the shock of the cart on the Pulley.
3. Attach a string to the end of the cart as shown in Figure 1. Attach a mass hanger to the other end of the string.
4. Verify that the string is long enough so that when the cart's bumper is touching the pulley and the string is over the pulley, the string with mass hanger is short of reaching the ground by ~2 inches.
5. Put the string that connects the cart and the mass hanger over the pulley. Verify/Adjust the pulley so that the string from the cart is parallel to the level track or the top of the table as per Figure 1.
6. Place 20 grams of mass on the mass/hanger set, see Figure 2. The applied net force is the weight of the hanger and masses (m x acceleration due to gravity) minus friction forces.
7. Measure and record in Table 1, the total mass of the cart (M).
8. Measure and record in Table 1, the total mass of the mass/hanger set (m).

PART III: Data Recording

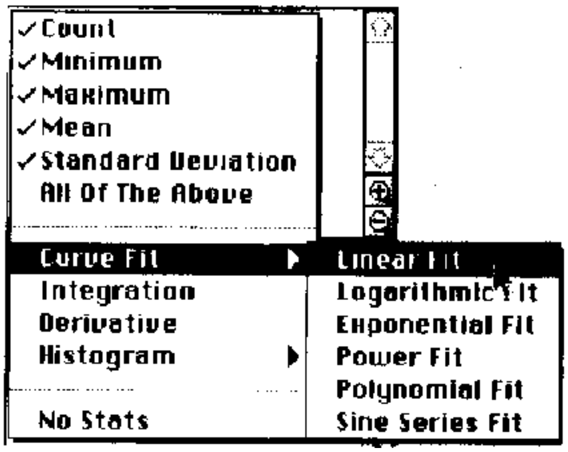
9. Verify/Install a bumper to prevent the cart from damaging the pulley when it reaches the pulley. Verify/install the rubber band correctly on the bumper to absorb the shock of the cart on the Pulley.

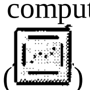
10. When you are ready to collect data, pull the cart away from the pulley until the mass hanger almost touches the pulley.

11. Click the REC button () to begin data recording and release the cart so it can be pulled by the falling mass/hanger set.

12. Stop the data recording after the mass/hanger set has reached the floor by clicking the STOP button ().

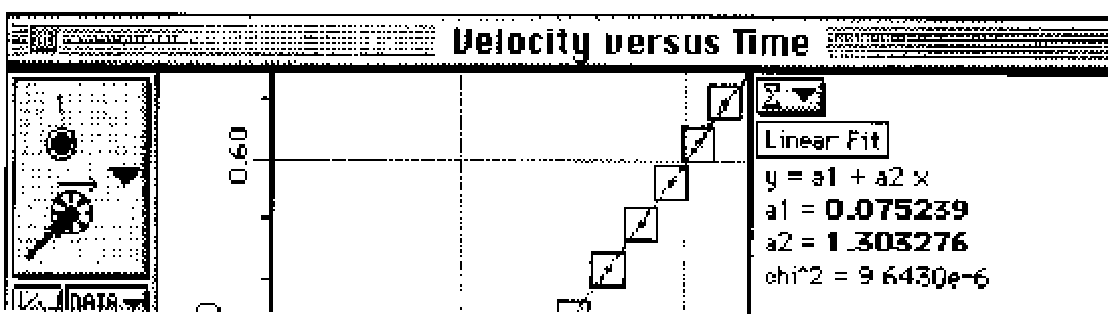
WARNING: Do not let the cart hit the Pulley, your bumper should be correctly installed to prevent this!



13. On the computer graph, click the Statistics button () to open the Statistics area. Click the Autoscale button () to resize the graph to fit the data. Click the Statistics Menu button (). select Curve Fit, Linear fit from the Statistics menu.

    The "Statistics" area will show the y-intercept (al), slope (a2), and the quality of the fit (chi^2). Make sure the analyzed data your statistics are a region of GOOD DATA!

14. Record in Table 1, the value of the slope of velocity versus time, which is the average experimental acceleration of the cart.



15. Change the applied force (F = mg) by removing one mass from the mass/hanger set and adding that mass to the cart. This changes the force without changing the total mass. Measure and record in Table 1, the new values for M (total mass, cart + added mass) and m (mass/hanger set).

16. Repeat the previous step until all the masses have been moved from the mass/hanger set to the cart. Each time, move one of the masses from the mass hanger to the cart. Measure and record in Table 1 the values for M (cart + added mass) and m (mass/hanger set). Record in Table 1 the value of the slope (i.e. experimental acceleration) for each trial.

IV. Analysis

1. Calculate and record in Table 1 the total mass (m + M) and the reduced mass {m/(m + M)} that is accelerated in each trial.
2. Calculate the applied net force (m+M)a acting on the cart for each trial in Table 1. The net force on the cart is the tension in the string minus the friction forces. If friction is neglected, the net force is:

$$\mathbf{F_{net}} = \text{Mass x } \mathbf{Acceleration = (}\text{M+m) x } \mathbf{a}$$

Theoretically, the acceleration is mg/(m+M) as shown previously.

3. Graph the applied net force (m+M)a vs. the reduced mass on Graph 1. Remember to label your axes and use an appropriate scale to display your data.
4. Calculate the theoretical force using Newton's Second Law ($\mathbf{F_{net}}$ = mass x **a**, mg). Record the theoretical force in Table 1.
5. From the data in Graph 1, estimate and record the uncertainty in the applied net force. Based on the scatter of the data points around a best fit line, estimate one uncertainty for all the forces.
6. Calculate the statistical difference between the actual and theoretical forces in Table1,
   Remember, statistical difference = |theory - actual| / uncert.
   statistical difference ≤ 2 for reasonable agreement.

Graph 1

Uncertainty in the force ______________________________

Trial	M(kg)	m(kg)	Exp.Accel a (m/s^2)	Total Mass m+M (kg)	Reduced Mass m/(m+M) (kg/kg)	Applied F_{net} (m+M)a (N)	Force, theory mg (N)	Statistical Difference

Table 1: Acceleration of a Cart

Questions

1. What relationships exist between the graphed variables?

2. Comment on how the applied force compares with the theoretical force?

3. Comment on the statistical difference between the actual and theoretical forces? What are some factors that could account for this difference?

V. Conclusions (include physical concepts and principles investigated in this lab, independent of your experiments success, and summarize without going into the details of the procedure.)

Addition comments for clarifying the lab procedures are always welcome.