SAN DIEGO MESA COLLEGE Name:________________________________

PHYSICS 195 LAB REPORT Date:___________________Time:________

TITLE: Newton's Second Law Partners:________________________________

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Objective:

To investigate the relationship of the variables 'force' and 'inertia' to the acceleration of an object. To determine whether Newton's Second Law is a valid description of these relationships.

Theory:

Acceleration has been defined as the rate of change of velocity, measured in meters per second per second.
Mass has been defined as the measure of inertia in standard units of the kilogram.
A force of 1 Newton has been defined as the push or pull necessary to cause the velocity of a one-kilogram mass to change at the rate of one meter per second per second.

Equipment:

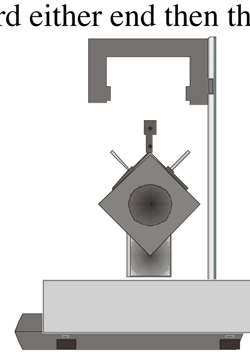
Air Track	Phototgate
Air Track Accessory Kit	Blower and Hose

Procedure:

1. Determine and record the mass of the glider/flag assembly using the electronic balance. Record this result in the data section.

2. Determine and record the length of the flag in the data section as the "Length of glider flag".

3. Carefully place the glider on the track at about the middle and turn on the blower. **Never move the glider along the track <u>without</u> the blower on!** If the glider moves toward either end then the track must be leveled.



4. Place the photogate so that the flag will pass under the photogate head without hitting it. The head may have to be raised or lowered (see diagram).

5. Place one of the glider masses on each of the two pegs on the sides of the glider. Each mass is approximately 50 grams. Measure the combined mass of this system and record this total.

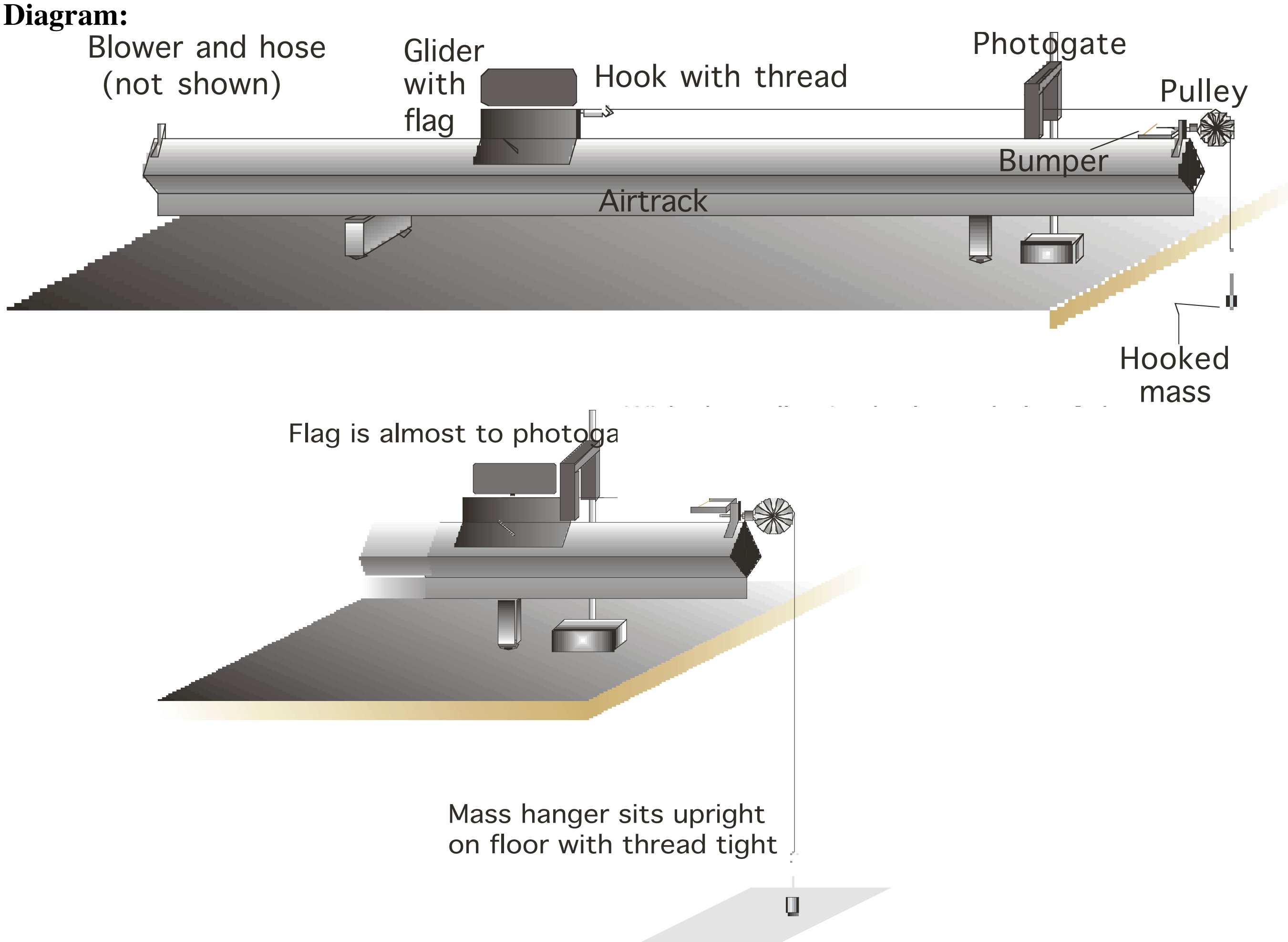
6. Remove the small mass hanger from your accessory box and record its mass in the data table.

7. Tie one end of a thread to the "stem" of the flag so that it will clear the top of the glider and run the thread over the top of the pulley at the end of the track. The thread should run level between the glider and pulley.

8. Place the center of the glider on the air track about 60cm from the "pulley" end and (with the thread over the top of the pulley) cut the thread at the floor. Tie this thread to the mass hanger. Position the glider on the track such that the mass hanger just hits the floor. Write down the position of the *center* or *edge* of the glider using the scale on the side of the air track. Position the photogate so that the flag is just in front of the gate (see diagram). This position represents the location at which the glider will stop accelerating, and continue through the photogate at constant velocity.

9. Turn on the blower and pull the glider back toward the other end of the air track so that the mass hanger is just below the pulley, this will be your "start" position. Write down the position at the edge of the glider using the scale and subtract the number you obtained in step 8. This is the distance over which the glider is accelerated. Record this in your data.

Diagram:

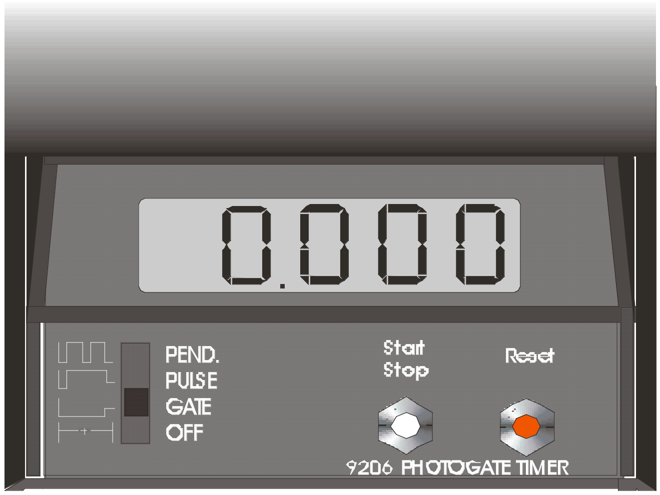


Part I:

Determine the acceleration of a **constant mass glider** under the influence of a **varying external force**.

Procedure:

Push the slider switch of the photogate to the "gate" position and press the "reset" button. The display should now read 0.000 (if it doesn't, let your instructor know).



There are four hanging masses you will use in this lab: two black plastic masses, and two metal masses. Measure and record their masses in your data table.

Turn the air blower on and allow the air to circulate for several seconds. Position the glider and the two, 50 gram masses attached to it at the 'start' position you have determined.

Remove everything but the mass hanger from the other end of the thread. Maker sure the mass hanger is not swinging back and forth.

Once everything is motionless, release the glider and have one of your partners catch it after it completely passes through the photogate. **Do not let it hit the bumper and bounce back through the gate!**

Record the number shown on the photogate display as t_1 in the data table, then push the "reset" button. Repeat this portion of the experiment and record the time as t_2. Take the average of these two times and record it in your data table.

Repeat these steps for different combinations of masses as indicated in your data table. Take two runs for each mass combination. Record the times for each run and the average time in the data table.

Data: Part I:

Length of glider flag(L):	________________ m
Distance glider moves(Δx):	________________ m
Mass of glider & flag:	________________ kg
Mass of glider, flag and two, '50 g' masses:	________________ kg
Mass of empty mass hanger:	________________ g
Mass of 'small black plastic' mass (A):	________________ g
Mass of 'large black plastic' mass (B):	________________ g
Mass of 'small metal' mass (C):	________________ g
Mass of 'large metal' mass (D):	________________ g

Hanging mass description:	Hanging mass (kg):	t_1(s):	t_2(s):	$t_{average}$(s):	v_o	$v_f = \frac{L}{t_{ave}}$	$a = \frac{v_f^2 - v_o^2}{2\Delta x}$
Empty hanger					0		
Hanger & B					0		
Hanger, B & A					0		
Hanger & C					0		
Hanger, C & B					0		
Hanger & D					0		

Show a sample calculation (with units) for average time, final velocity and average acceleration values in the space below:

Use the values for the hanging masses to calculate the tension in the string connected to the glider in each case.

T_H = ______________ N

T_{H+B} = ______________ N

T_{H+B+A} = ______________ N

T_{H+C} = ______________ N

T_{H+C+B} = ______________ N

T_{H+D} = ______________ N

Next, derive the expression for the net external force acting on the glider and show that this is equal to the tension in the string caused by the hanging mass. Start with a free body diagram for the glider and show that $F_{ext} = \frac{mMg}{(m+M)} = T$ and in the special case that m<<M, this reduces to T=mg.

Use the values for the masses of the glider, '50 g' masses and empty mass hanger that you measured and calculate the actual external force acting on the glider. Show your calculation, with units.

Compare this result to the value for T_H in the table above. Calculate the percent error between the actual external force and the approximation used in calculating T_H. Show your calculation, with units.

$$\% Error = \frac{|F_{external} - T_H|}{F_{external}} * 100\ \%$$

% Error:___________

Does the approximation T=mg seem valid? Explain your answer.

Part II:

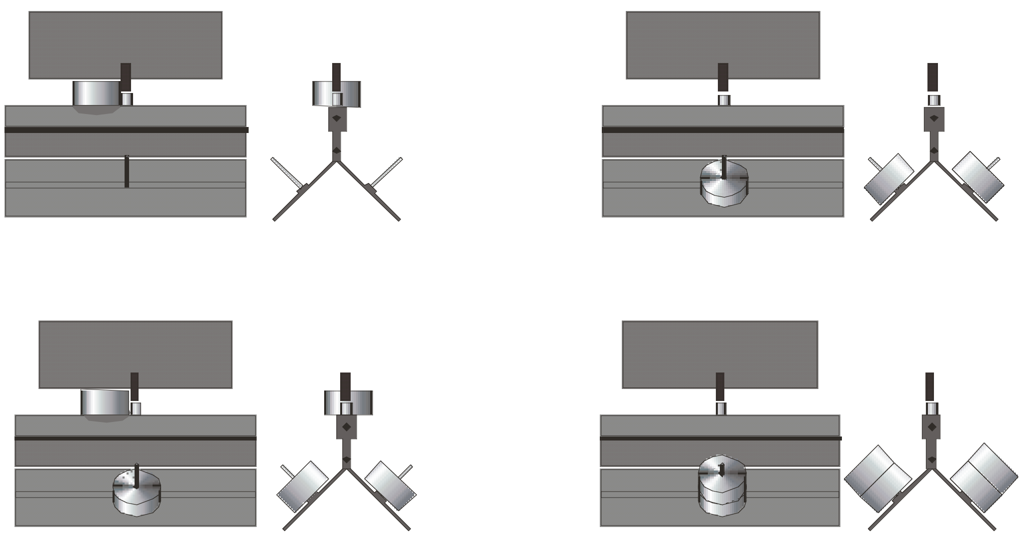
Determine the acceleration of a **varying mass glider** under the influence of a **constant external force**.

Procedure:

Place mass **C** on the mass hanger. Now the tension in the string will have the value for T_{H+C} you recorded in part I. Transfer this value to the data table for part II as the external force acting on the glider.

Turn the air blower on. Remove both of the masses from the pegs on the glider and place the glider at the "start" position from part I. Reset the photogate display to 0.000. Make sure the glider and hanging mass are motionless then release the glider. Again, do not let the glider bounce back through the gate. Record the time in your data table, then repeat with a second run.

Replace the glider at the 'start' position and place just one of the 50g masses on the glider. You must place the mass on the top of the glider as near to the middle of the glider because the glider must always remain balanced. You will have to lift the "flag" slightly to do this and may have to reposition the photogate head a bit higher. See the diagram below for glider mass placement.



For each of the four mass configurations displayed, take two data runs and record the times in the data table for part II. When you have finished collecting data, turn off the blower and photogate. Clean up the area and return the hanging masses to the accessory kit.

Data: Part II:

Constant external force acting on the glider: $F_{EXT}=T_{H+C}$ = ________________ N

Glider mass description:	Glider mass (kg):	t_1(s):	t_2(s):	$t_{average}$(s):	v_o	$v_f = \frac{L}{t_{ave}}$	$a = \frac{v_f^2 - v_o^2}{2\Delta x}$
Empty glider					0		
Glider + 50g					0		
Glider + 100g					0		
Glider + 150g					0		
Glider + 200g					0		

Show a sample calculation (with units) for average time, final velocity and average acceleration values in the space below:

Calculate the reciprocal of the glider mass (1/M) for each case:

$1/M_{Glider}$ = ________________ kg^{-1}

$1/M_{Glider+50}$ = ________________ kg^{-1}

$1/ M_{Glider+100}$ = ________________ kg^{-1}

$1/ M_{Glider+150}$ = ________________ kg^{-1}

$1/ M_{Glider+200}$ = ________________ kg^{-1}

Analysis: Part I:

Construct a graph of the acceleration of the glider as a function of the net force applied to it. Use regular Cartesian coordinates, and clearly label each axis with units. Follow all the instructions in the course download 'How to draw a graph' when making it. You must graph by hand.

Determine the slope of your graph and write the equation of the line suggested by your graph, ignoring any intercept. Make sure to include units in your calculations.

Re-write Newton's Second Law in the form suggested by your graph.

If Newton is correct then the proportionality constant (the slope) relating the variables of the first graph should be physically interpreted as …(write it out in sentence form).

Determine the inertial mass of the glider system from the slope of your graph.

Compare the **inertial** mass of the glider, flag and masses with the **gravitational** mass as measured on the electronic balance. By what percentage do the two values differ? Show your work, with units.

$$\% \, Difference = \frac{2 \times \left| m_{grav} - m_{inertial} \right|}{m_{grav} + m_{inertial}} * 100 \, \%$$

% Difference:_____________

To what do you attribute this difference? Explain your answer.

Analysis: Part II:

Construct a graph of the acceleration of the glider as a function of the reciprocal mass of the glider. Use regular Cartesian coordinates, and clearly label each axis with units. Follow all the instructions in the course download 'How to draw a graph' when making it. You must graph by hand.

Determine the slope of your graph and write the equation of the line suggested by your graph, ignoring any intercept. Make sure to include units in your calculations.

Re-write Newton's Second Law in the form suggested by your graph.

If Newton is correct then the proportionality constant (the slope) relating the variables of the first graph should be physically interpreted as …(write it out in sentence form).

Determine the constant external force acting on the glider from the slope of your graph.

Compare the external force from your graph to the tension produced by the hanging mass (T_{H+C}). By what percentage do the two values differ? Show your work, with units.

$$\%\,Difference = \frac{2 \times \left| F_{graph} - F_{calculated} \right|}{F_{graph} + F_{calculated}} * 100\%$$

% Difference:____________

To what do you attribute this difference? Explain your answer.

Conclusion and Summary of Results:

Write a conclusion, including a brief discussion of the physics involved in this experiment, including possible sources of error and their affect on your results, and indicate whether your results give support or validate the purpose of the lab exercise.