FORCE AND ACCELERATION ON THE AIR TRACK

Objective: To verify Newton's Second Law by investigation of acceleration as a function of (1) the external force and (2) the total mass of the system.

Apparatus: 1) Air track, 2) Glider, 3) Weight hanger, 4) Two photogates, 5) two 5 gm, four 10 gm, two 20 gm and two 50 gm weights.

Theory: Serway Chapter 4, Section 3.

Timing Sequence:

1. The average velocity of the glider is observed at two positions on the air track. This is achieved by use of the two photogates.

2. The timing sequence is started when the glider blocks photogate #1.

3. $\mathbf{t_1}$ is the time the glider takes to pass through photogate #1.

4. $\mathbf{t_3}$ is the time from photogate #1 unblocked to #2 blocked.

5. $\mathbf{t_2}$ is the time the glider takes to pass through photogate #2.

Experiment:

The experiment is to be carried out in two modes:

1. Constant total mass where weights are transferred from the glider to the weight cradle keeping the total mass of the system constant.

2. Constant accelerating mass where weights are added to the glider and the mass on the weight cradle is kept constant.

The experimental sequence is the same for both modes.

1. Set up the air track as shown in fig. 1. Check that the air track is level. The glider should sit on the air track without accelerating in either direction.

2. Measure the length of the glider and record the value as **L** in the result table. (This length combined with the passage times $\mathbf{t_1}$ and $\mathbf{t_2}$ of the glider through the photogates allows calculation of the average velocities $\mathbf{V_1}$ and $\mathbf{V_2}$.)

3. Photogates 1 and 2 should be positioned at approximately 50 cm apart. The first photogate (photogate #1) should be plugged into channel 1. Photogate two should be plugged into channel 2. Measure and record **D**, the distance the glider moves on the air track from where it triggers the first photogate to where it triggers the second photogate. (Move the glider and

watch the photogates. When the LED on top of the photogate lights the photogate has been blocked.)

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4. Weigh the glider and record your result in kilograms. Add the two 5 gm and four 10 gm weights to the glider and record the sum of the glider mass and these weights as **m** in your table of results. (The glider must be loaded symmetrically, i.e. equal mass on each side.)

5. Attach one end of the thread to the weight hanger and the other end to the hook on top of the glider.

6. The weight hanger has an unloaded mass of .005 kg. This will be your first accelerating mass and should be recorded as $\mathbf{m_a}$ in your table of results.

7. Hold the glider steady at one end of the track and hang the thread over the pulley at the other end of the track. One student should release the glider and allow it to pass through both photogates. The other student should attempt to catch the glider as it exits the second photogate. (Be careful to ensure that it has passed completely through the photogate!) The computer will measure $\mathbf{t_1}$, $\mathbf{t_2}$ and $\mathbf{t_3}$. Repeat this measurement four or five times and check consistency of your results. **BE CAREFUL NOT TO BLOCK PHOTOGATE 1 BETWEEN MEASUREMENTS. BE CAREFUL NOT TO TRIGGER THE PHOTOGATES WITH THE STRING.**
Remove the glider from the air track to reposition it for the next measurement.

8. Vary $\mathbf{m_a}$ by moving weights from the glider to the weight hanger (thus keeping the total mass $\mathbf{m + m_a}$ constant). Record the new values of **m** and $\mathbf{m_a}$ and repeat steps 7-9. (Enter the Main Menu by choosing "X" and press "RETURN".) Try at least four different values for $\mathbf{m_a}$, e.g. 5 gm, 15 gm, 35 gm, and 55 gm.

9. For the second phase of the experiment leave $\mathbf{m_a}$ constant at some previously used value (e.g. 5gm). Vary **m** by adding or removing weights from the glider. Repeat steps 7-9. Record your data for each value of **m**. Try at least four different values for **m**.

Calculations:

1. Use the length of the glider L and your measured times to determine V_1 and V_2, the average glider velocity at each photogate.

2. Use the equation

$$a= (v_2-v_1)/(t_3 + t_1/2+t_2/2)$$

to determine the average acceleration of the glider as it passed between the two photogates

3. Determine F_a, the force applied to the glider by the hanging mass. ($F_a = m_a g$; $g=9.8\ m/s^2$)

4. Graph the acceleration as a function of the accelerating force $F_a = m_a g$. Is the graph linear? Is it linear for constant $m + m_a$?

5. Graph the acceleration a in the constant m_a experiment as a function of total mass $m + m_a$. Is the graph linear? Perhaps the acceleration is inversely proportional to the total mass? Plot a graph to check this hypothesis. From the graphs can you define the relationship between the acceleration a, the force F_a and the total mass of the system $m + m_a$.

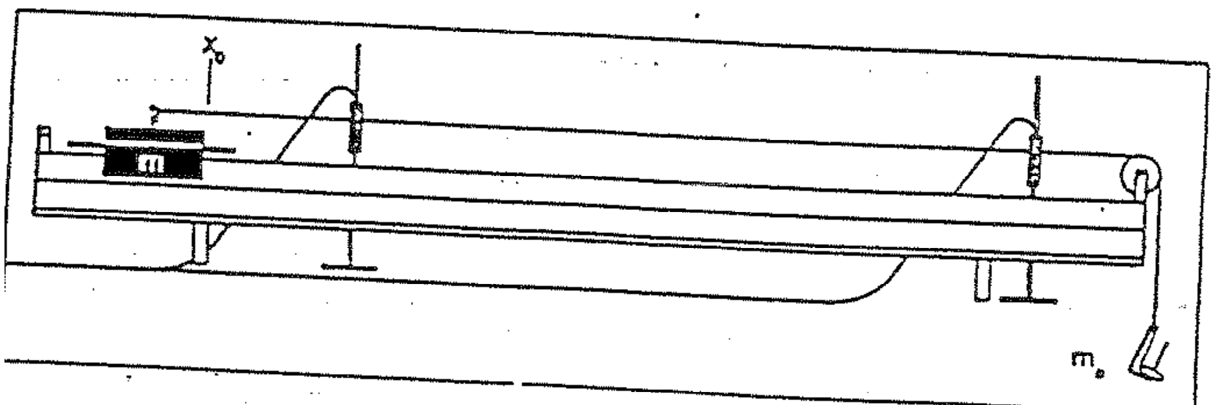

Figure 1 Equipment Setup

Data Table:
Length of the glider: (L) = meters
Distance between photogates: (D) = meters
Mass of unloaded glider: = grams
Mass of the unloaded weight cradle: = 5 grams

Part I: Constant Total Mass

Constant Total Mass

Mass on Glider (gms)	Cradle Mass m_a(gms)	t_1	t_2	t_3	v_1(m/s) L/t_1	v_2 (m/s) L/t_2	a (m/s^2)	F_a (N)
	5							
	15							
	25							
	35							
	45							

Part II: Changing Total mass

Cradle Mass (m_a)= 5 grams
m = mass of unloaded glider + mass on the glider

Changing Total Mass

Mass on Glider (gms)	Total Mass ($m+m_a$) (gms)	t_1	t_2	t_3	v_1 (m/s)	v_2 (m/s)	a (m/s^2)
40							
60							
80							
100							

Use the equation

$$a= (v_2-v_1)/(t_3 + t_1/2+t_2/2)$$

to determine the average acceleration of the glider as it passed between the photogates.