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NEWTON'S SECOND LAW**LINEAR MOTION****OBJECTIVE**

To investigate the relationship between force and acceleration in linear motion.

INTRODUCTION

According to Newton's second law, the acceleration of a mass is proportional to the net applied force. In this experiment you will apply a force to a glider on a linear air track and measure its acceleration using the Motion Probe.

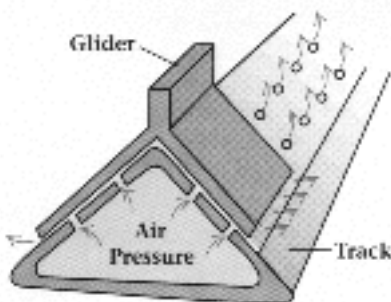


Figure 1. Cutaway view of a glider floating on a linear air track.

We choose the air track because its friction forces are so small that they can be ignored. A typical linear air track is made from a hollow square or triangular rail that has tiny holes drilled into its upper surfaces (Fig. 1). When it is pressurized, a cushion of escaping air supports a carefully fitted glider on the track. The glider floats nearly friction free along a straight line on this cushion of air.

In this experiment you will attach a mass to the glider with a thread that passes over a freely moving pulley. Figure 2 below illustrates the situation.

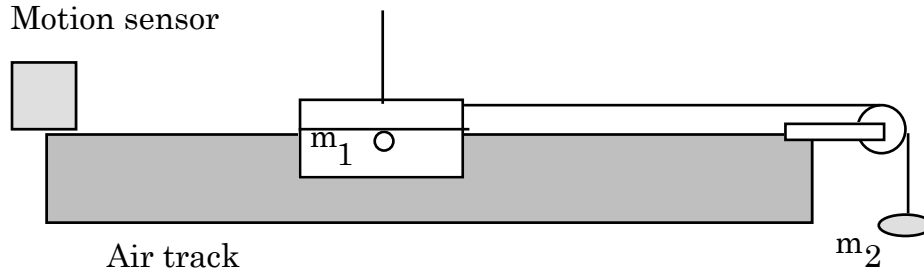


Figure 2. A linear air track showing a glider (with mass m_1) attached by a thread passing over a pulley to a small mass m_2 .

Gravity acts on mass m_2 with a force $F = m_2g$. (See Fig. 2) That force then accelerates both m_2 and m_1 . (The mass of the thread may be neglected here.) Consequently, the acceleration of the glider (and the small mass m_2) is the ratio of the applied force to the total mass:

$$a = \frac{F}{m_1 + m_2}$$

The mass of the thread and the friction in the pulley are small enough that we can safely ignore them also. Thus the gravity force $F = m_2g$ is the net force.

In this experiment you will detect the motion of the glider and determine its acceleration. Then you will graphically compare the acceleration to the applied force F (calculated from m_2g) to see if it behaves as Newton's law predicts. By moving mass from the glider to the end of the thread, the total mass ($m_1 + m_2$) stays constant.

Notice that we can also use these same measurements to determine the value of the gravitational acceleration g . If we substitute m_2 for F in the equation for acceleration and then rearrange the equation, we can find g in terms of the measured quantities of mass and acceleration:

$$g = \frac{(m_1 + m_2)a}{m_2}$$

ACTIVITY 1: PRELIMINARY SET UP

1. Place a glider on the air track. Turn on the blower and observe the glider. Adjust the blower speed so that the glider just floats freely above the track. Do not make it float higher than necessary.

2. If the glider drifts one way or the other, level the track by adjusting the leveling screws underneath the supports. Be sure that the glider is balanced both longitudinally and sideways because uneven air-flow will cause it to move. Then turn off the blower.
3. Connect the motion sensor to your computer. Double-click on the Newton's 2nd Law icon to open the lab in DataStudio™. The usual menus should pop up.
4. Set the Sampling Rate to 20 Hz. Check the Velocity box only.
What are the units?
5. Arrange the track so that the pulley extends over the end of your lab bench. Place the motion sensor on the other end of the track. Aim the sensor so that it is pointing directly down the track towards the pulley.
6. Separately, weigh the cart, the weight hanger, and the individual weights. **Record your measurements.**
7. Place the cart on the track about 20 cm away from the motion sensor. Attach the thread and weight hanger to the cart.

ACTIVITY 2: MAKING MEASUREMENTS

8. Hang one 5-g weight on the weight hanger and place the other weights (25-g total) on your cart (10 g on one side, 15 g on the other). Suspend the weight hanger over the pulley, holding your cart in place on the track.
9. Turn on the air blower. Press the Start button in DataStudio. Wait a few moments, then release your cart so that the suspended masses pull it down the track. Press Stop just before the cart reaches the far end of the track.
10. If the graph does not appear automatically, drag your Run #1 data to the Graph icon. You should have a Velocity graph for this run.

ACTIVITY 3

11. Using your mouse, select the inclined portion of your graph. Be careful not to get the endpoints of the incline in your selection.
12. Do a curve fit and choose Linear. **Record the slope of the curve. Repeat the procedure 4 more times.** You should have 5 slopes for this case. Find the average of these 5 values.

ACTIVITY 4

13. Repeat Activities 2 and 3 (making a new graph) after moving a weight from the cart to the weight hanger. Repeat until all the weights are on the weight hanger. **Record the slopes on your data sheet. Be sure to print one of the graphs to include with your report.**

ACTIVITY 5

14. **Predict what a plot of Acceleration vs. Force should look like and make a sketch of the predicted graph.**
15. **Draw a plot of Acceleration vs. Force for your data. Does it agree with your prediction? Use graph paper.**

ACTIVITY 6

16. Using the known masses and the accelerations determined previously, **calculate the gravitational constant g .** (You should have 6 experimental values for g .)
17. **Compute the average of the experimental values of g obtained in step 16. Compare your average value for g to the standard value $g = 9.807 \text{ m/s}^2$ by computing the percent error.**

Hint: the percent error is given by

$$\% \text{ error} = \left| \frac{\text{measured value} - \text{standard value}}{\text{standard value}} \right| \times 100\%.$$

NEWTON'S SECOND LAW

SLIDING CART: DATA SHEET

ACTIVITY 1: PRELIMINARY SET UP

What are the units for velocity as measured by DataStudio?

Weigh the cart and record your measurement. (Just find its mass in g.)

Mass of the weight hanger and weights. (In g.)

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ACTIVITIES 3 & 4

Record the slope of the curve for each weight arrangement in the following table. Fill in all of the blank cells. Remember that the total mass is the sum of the masses of the glider, the weight hanger, the mass on the hanger, and the mass added to the glider. This total should be kept constant. You will need to use the measured mass values in place of the nominal values of 5, 10, 15, etc.

Mass on hanger (g)	Mass on glider (g)	Total mass (g)	Slope trial 1 (m/s ²)	Slope trial 2 (m/s ²)	Slope trial 3 (m/s ²)	Slope trial 4 (m/s ²)	Slope trial 5 (m/s ²)	Avg. Slope (m/s ²)
5	25							
10								
15								
20								
25								
30								

Be sure to print one of the graphs to include with your report.

ACTIVITY 5

Predict what a plot of Acceleration vs. Force should look like and make a sketch of the predicted graph.

Make a careful plot of Acceleration vs. Force for your data. Does it agree with your prediction? Use the graph paper from your Science Notebook.

ACTIVITY 6

Using the known masses and the accelerations determined previously, calculate the gravitational constant g . (You should have 6 experimental values for g .)

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Compute the average of the experimental values of g obtained above.

Compare your average experimental value for g to the standard value $g = 9.807 \text{ m/s}^2$ by computing the percent error.