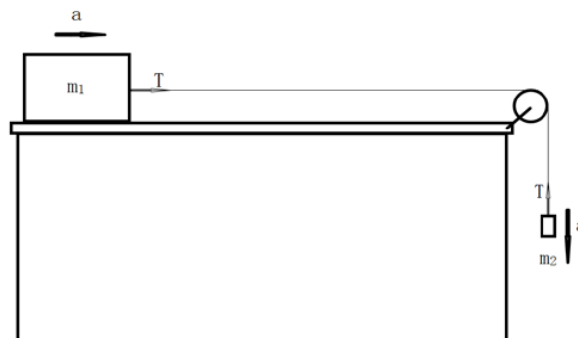


ACCELERATION ON AN AIR TRACK

Theory: If a mass sliding on a frictionless surface is connected to a hanging mass by a string passing over a pulley, the motion of the two masses is described by the following two equations:

$$T = m_1 a \quad \text{and} \quad m_2 g - T = m_2 a$$

Where m_1 is the sliding mass and m_2 is the hanging mass.



From these equations, you can determine the acceleration of the masses and the tension in the string. The results are:

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

$$T = \frac{m_1 m_2 g}{m_1 + m_2}$$

since $T = m_1 a$

Purpose: To observe the variations of position and velocity as a function of time for motion with constant acceleration and by experimentally changing different set of masses to fully understand Newton's laws of motion.

Apparatus:



Procedure: In this experiment, the sliding mass will be a “glider” which moves with very little friction on an air cushion provided by blowing air through holes in an air track. You will connect it to a small hanging mass by a thread which will pass over a small, light, plastic pulley mounted at the end of the air track. Almost all of the friction will be in this small pulley. Check to make sure that no obstruction is making the pulley’s friction unnecessarily large. When released, the glider will move with an acceleration which you are to determine and compare with theory. This will be done for two hanging masses.

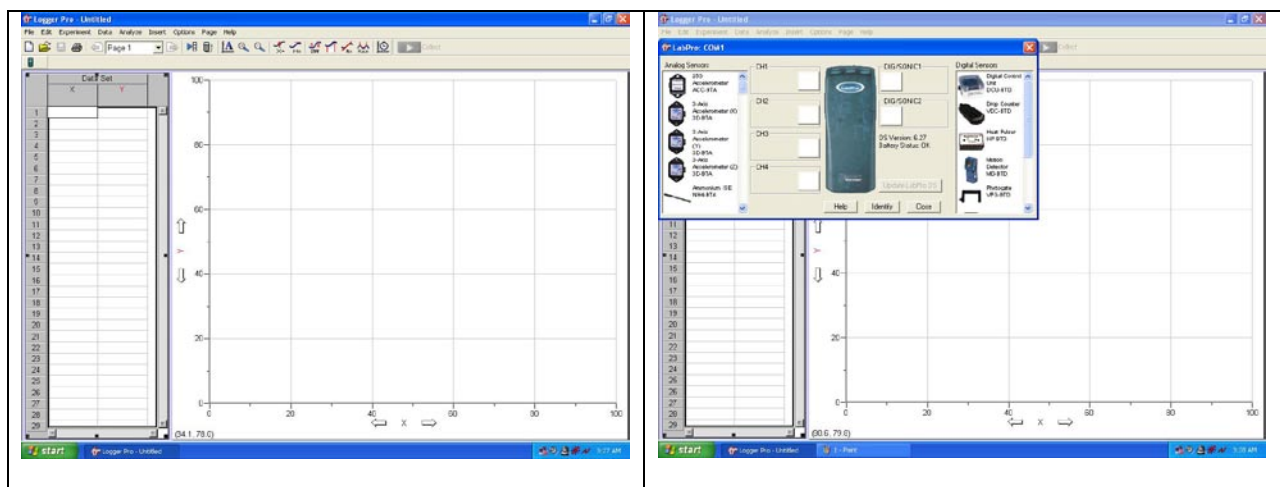
The ultrasonic motion detector emits ultrasonic (higher-than-audible-frequency sound wave) pulses and measures the time until reflected pulses return. Based on the known speed of sound, the computer converts this time to a distance. Once you start the measurement, the motion detector makes the distance measurement 30 times every second, and thus a set of distance-versus-time data is

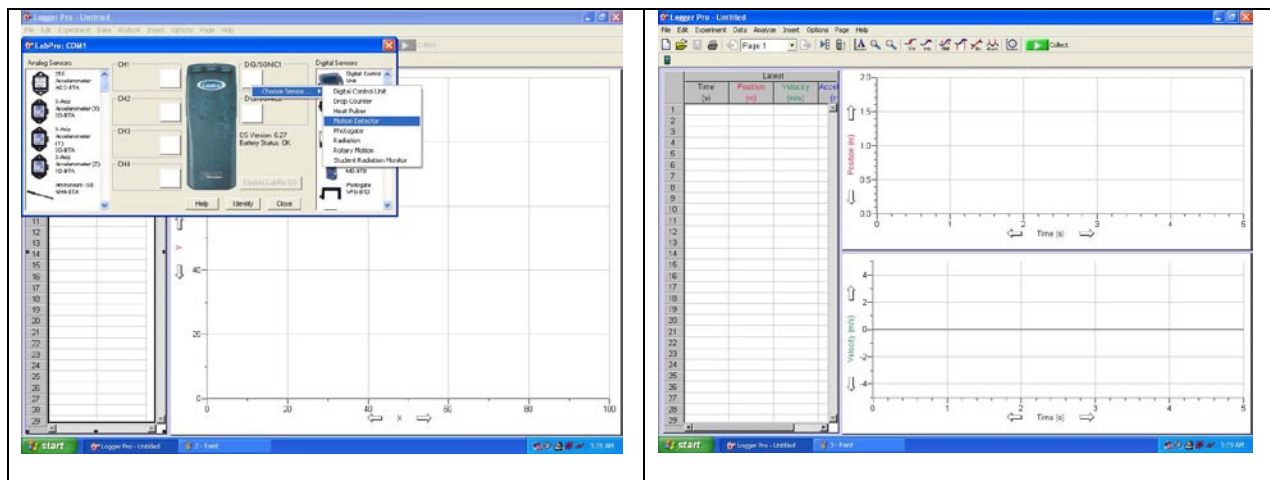
acquired. Based on this data, speed-versus-time is calculated by the computer. You will determine the experimental acceleration from this speed-versus-time function.

From the known values of m_1 (the glider) and m_2 (the hanging mass), the theoretical acceleration may be calculated. In your report, you should compare the experimental and theoretical values of acceleration.

To get started:

1. Use the balance scale to measure the mass of the glider. Also, check the 10-, 20-, and 50-gram masses.
2. Make sure that the track is level. Your instructor will show you how to do this.
3. On the computer screen (see graphs below), double-click on the icon for “**Logger Pro**”. You will see a blank graph and a blank table. Click on the blue icon (top, left), which says “**Set up sensors**”. Check whether you are using **Dig/Sonic 1** or **Dig/Sonic 2** (digital sonic detector – i.e. using sound waves), and click on it. Select Motion Detector. Close the window. Now your screen shows two blank graphs (position vs. time and velocity vs. time), and a blank table (time, position, velocity, acceleration).





4. Turn on the air pump (air supply for the track). Set the glider into motion by giving it a gentle push to the right. It should move back and forth with a (nearly) constant speed.

5. Practice how to use the computer software. Using the left button on the mouse, click on the “Collect” box to start taking data. There is a slight delay (a few seconds) before data collection actually starts; collection will stop automatically after 5 seconds have elapsed. Show them to your instructor before proceeding with the experiment.

6. Turn off the air supply and attach the string to the glider. Specifically, carefully pull out the sound-reflecting rectangle and slip one looped end of the string around the post of the rectangle. **Do not grab the rectangle itself, but rather the base support, to avoid breaking the reflector. Put the rectangle back in the glider, making sure it is perpendicular to the track!**

Note: To avoid damaging the air track or the glider, please do not drag the glider along the track when the air is turned off. To reposition the glider on the track, either lift it up slightly or turn the air on while moving it, then turn the air off when you have it in the position you want.

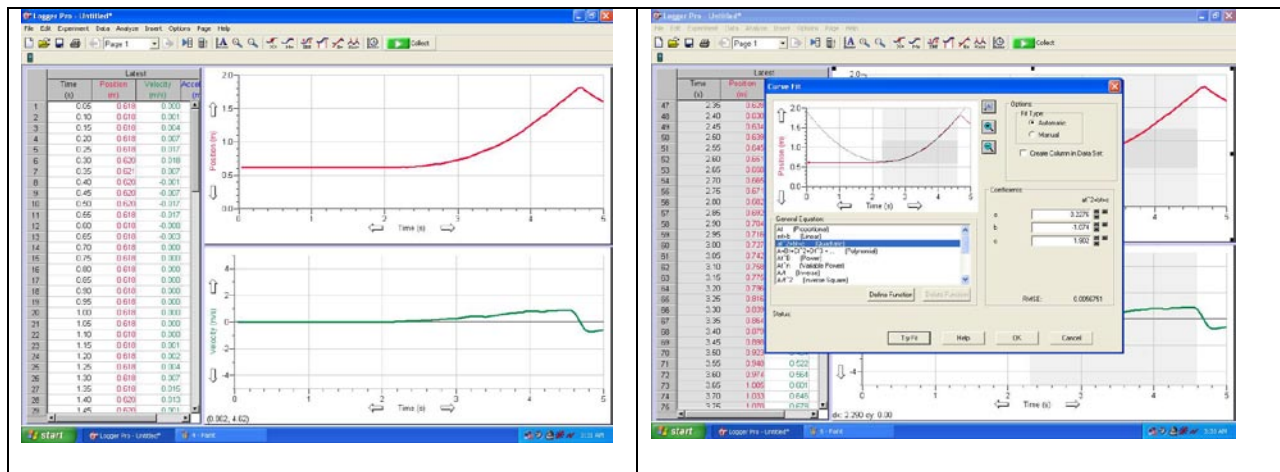
7. Position the glider at the end of the air track opposite the pulley. Run the string over the pulley, and attach the other end of the string to the 10-gram mass.

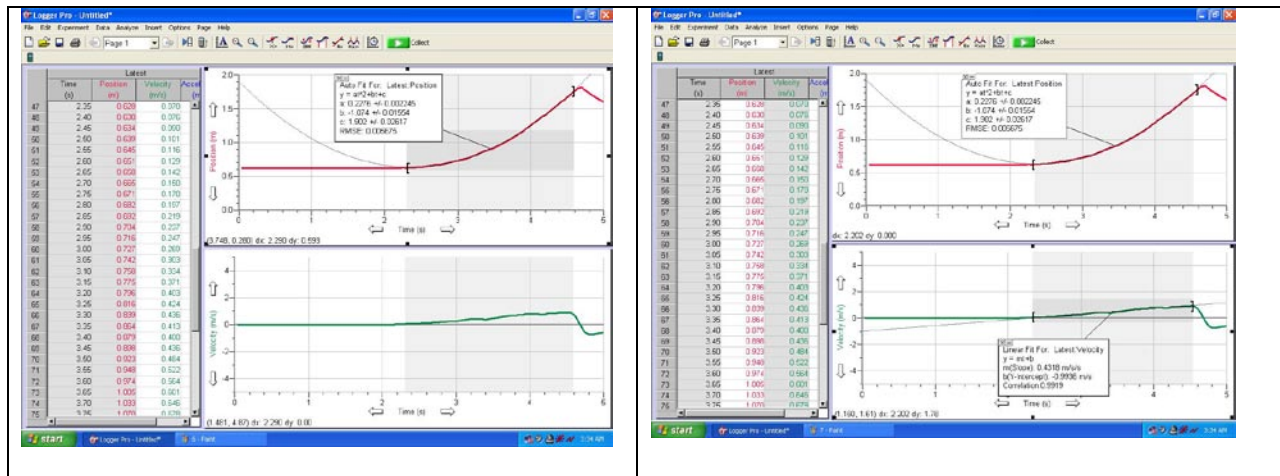
8. Click on the “Collect” box to start taking data. Immediately after clicking, turn on the air blower to set the glider in motion. The glider should accelerate along the air track while the motion detector measures and plots graphs of distance versus time and velocity versus time. If the graphs do not look good (consult with your instructor) then you must repeat the measurement. To collect new

data, simply click on collect and the program will write over and erase the previous data. When you have good data, **save it in a file** with a name of your choosing.

Note: Make sure that no one is standing in front of the motion detector. If the sound waves are reflected from objects other than the glider then you will get wrong data.

9. When you have graphs that look as good as possible, ask your instructor to confirm that you are now ready to print out your data. Analysis is more or less the same as in the Air Table experiment (see graphs below). Click on the graph you wish to analyze. Drag the cursor from some position on the left of the graph to the right, to select the portion of the graph you want. There may be spurious motions at the beginning or end that you can eliminate. Go to the menu **Analyze** at the top of the screen. You can select **Linear Fit**, which gives you the best straight line fit to the data. This will appear as a line on the graph, and as slope (m) and y-intercept (b), in $y = mx + b$. [Remember, “x” in the Analyze program means the horizontal axis in your graph, which is “time” in your experiment, and “y” means the vertical axis, which may be x or v.] You can also select other fits to the data, such as a polynomial fit of power 2. In this case the polynomial will be written: ax^2+bx+c . The quantities a, b, c are the coefficients of $(\text{time})^2$, $(\text{time})^1$, and the constant. You can **Print** a copy of the graphs or the table, one for each member of the lab group.





10. Repeat steps 7 through 9 using the 20-gram hanging mass.

11. Load the glider with the two 50-gram masses, one on each side, and repeat steps 7 through 10 above, i.e. measure the acceleration of the loaded glider using both the 10- and 20- gram hanging masses.

12. When you are finished, you will have 4 sets of measurements.

Computations:

First, let's check the speed-versus-time graph calculated by the program. At a certain time, the instantaneous speed can be calculated from the raw data (the graph of distance-versus-time). Draw a line tangent to the graph of distance-versus-time at a particular time of interest. Then determine the slope of this tangent line. This slope represents the instantaneous speed. For two well-separated times in the 10-gram-mass measurement, make estimates of the instantaneous speed based on the distance-versus-time graph. Compare these to the speeds calculated by the program for these times.

Determine the acceleration of the glider for both the 10-gram and 20-gram masses by using the graph of speed-versus-time. Specifically, draw the best straight line through your data points, and determine the slope of this line.

Arrange your results in a tabulated format:

m_1 (kg)	m_2 (kg)	a (m/s^2)		%error	T (N)
		Experiment	Theory		
	0.01				
	0.02				
	0.01				
	0.02				

Questions to be answered in the report:

1. The speed of sound is about 340 m/s. Assume that when the motion detector emits an ultrasonic pulse, it must detect the reflected pulse before it can emit its next pulse. Assuming that the length of the air track is about 2 meters, what is the maximum number of pulses per second that the motion detector can emit for measuring distance?

2. The mass of the thread was neglected in the experiment. If this mass were 0.2 gram, estimate the largest error in the acceleration that it might have caused. Could this account for your observed errors?

3. Were the accelerations measured by experiments are consistently larger than the theoretical values, consistently smaller, or neither? What is the most likely cause for this?