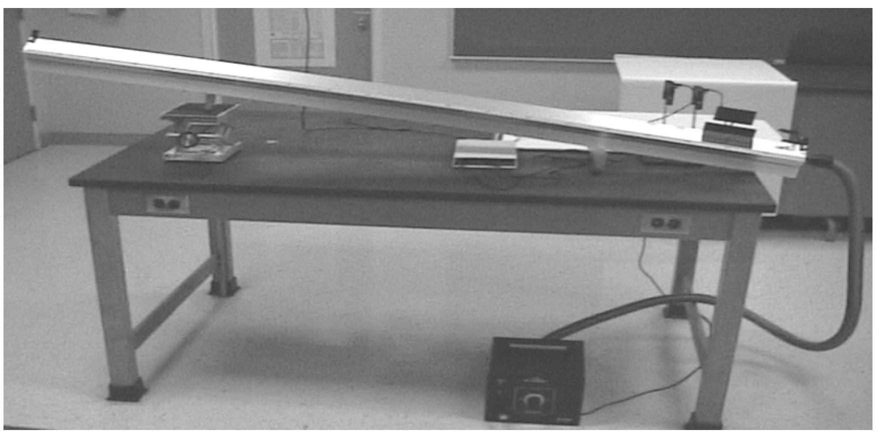
Energy Conservation

Introduction

As an object slides down a frictionless surface its Total Mechanical Energy ($\mathbf{E_T}$) remains constant even though its potential and kinetic energies change. The purpose of this lab is to test the validity of the Conservation of Total Mechanical Energy.

Equipment

Air Track	Computer with Logger Pro	Ring stand, Miniature
Glider	Vernier Photogate	Meter Stick
Air Supply	Vernier Lab Pro	Scale, Digital
Table Jack	Air Track Accessory Kit	



Theory

The Total Mechanical Energy of an object remains constant in the absence of non-conservative forces. This is called the Conservation of Total Mechanical Energy or sometimes, just Energy Conservation for short. This is a fundamental tenet of science and has extremely broad applications in all technical fields. The two types of energy that will be under consideration in this laboratory experiment are the potential energy **PE** and the kinetic energy **KE**. The object in this case will be a glider on an air track system. There are two forces at work in this experiment – gravity and friction. The frictional forces have been minimized by the use of the air track system and will therefore be neglected in our analysis. Gravity exerts a force on the glider and will contribute a gravitational potential energy (**GPE**) to the Total Mechanical Energy (**E_T**). The normal force of the track pushing back on the glider is perpendicular to the direction of the glider motion and so will produce no work and will not affect **E_T**. Therefore, in this experiment the Total Mechanical Energy consists only of the Kinetic Energy (**KE**) and the Gravitational Potential Energy (**GPE**). Since there are no non-conservative forces acting on the glider its Total Mechanical Energy is conserved.

Terminology

Gravitational Potential Energy: **GPE** = mgy

Kinetic Energy: **KE** = ½ mv^2

Total Mechanical Energy: **E_T = KE + GPE** = ½ mv^2 + mgy

General Procedure

As the glider accelerates down the sloped air track you will make measurements of the glider's **GPE** and **KE** for five different locations along the air-track. These five locations should be located at displacements of 0 cm, 30 cm, 60 cm, 90 cm, and 120 cm along the length of the track relative to your launching point.

The glider **GPE** can be calculated if we know its vertical height from the reference level of zero gravitational potential energy. We will choose the zero reference level to be the height of the fifth (bottom) measurement position from the surface of the table. We will first measure the heights of each of the measurement positions relative to the surface of the table and record these in the first column of your Data Table. Then subtract off the height that you measured for the fifth (bottom) position (**y_5**) from all five of the measured height values. Record these results in the second column of your Data Table.

These vertical heights are relative measurements so you can make your measurements from the surface of the table to the bottom of the scale along the side of the air track. The glider will always maintain its constant vertical spatial relationship to this scale throughout all the experimental runs. Hence, you don't need to locate the glider at each measurement position and measure the vertical height to some part of the glider itself.

The velocity needed for calculating the glider KE will be measured at four locations along the air track using the photogate. The velocity of the glider, *v,* at each measurement location will be determined by the photogate which will time the passage of a flag, of known length, mounted in the center of the glider, as it passes through the photogate. Since the glider is at rest at the first location ($\mathbf{y_1}$), the KE at that position is zero.

Logger Pro File – Under the **File** menu select **Open.** The **Experiments** folder will appear, select the **Probes & Sensors** folder, then the **Photogates** folder and finally the **"One Gate Timer"** file.

Flag Length Setting - You will be using one of the cylinders as the flag. The flag should not strike anything as the glider travels down the air track. Measure the diameter of the cylinder with the calipers and record it in your Data Table. This diameter is the Flag Length or Photogate Length Perform the **Flag Length Setting** at this time. NOTE: This adjustment only needs to be performed before the FIRST velocity measurement.

To enter the measured value into the application, double click on the "Photogate Length" display on the screen and a Dialogue box will open. Enter your measured length, in meters, and click the OK button.

After you place the photogate at one of the measurement locations and let the glider accelerate down the air track the photogate will provide the timing information that together with the Flag Length will enable the program to calculate the glider's average velocity at the measurement location.

After each velocity is calculated, record it in your Data Table. Once all the velocity data has been collected, you will calculate the values of the three quantities, **GPE**, **KE**, and $\mathbf{E_T = KE + GPE}$ and record them in your Data Table. Then you will plot (on the same graph) each of these three variables versus Displacement, the position of the glider along the air track. This plot will allow you to test the concept of Energy Conservation as applied to our simple glider and air-track system.

Detailed Procedure

Accuracy - All of your observations should be recorded to **3 significant figures**. You should carry 3 significant figures in all of your calculations as well.

- Measure the mass of your glider using the available scale and record the value in your Data Table.
- Place the jack under the single leg of the air track. The jack should be almost fully compressed. Set up the air-track with an inclination roughly similar to that shown in Figure 1.

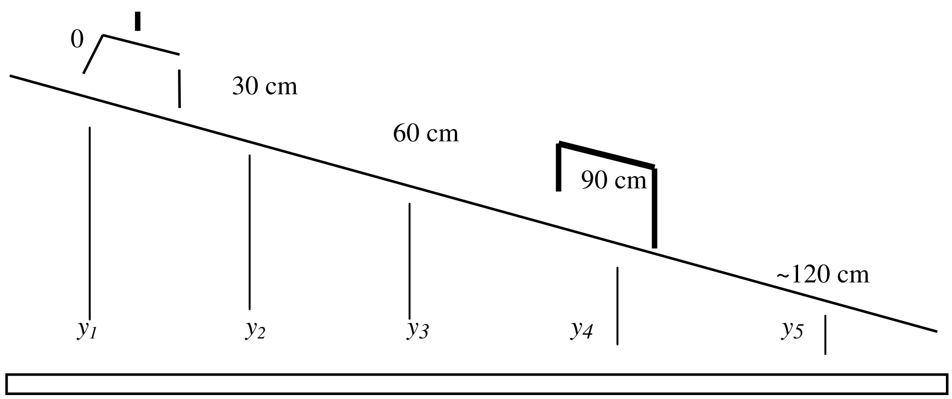


Figure 1. Air-track, glider, and photogate arrangement. Measure the *y*-values from the tabletop surface to the scale along the air track.

- The displacement intervals along the air track are relative and will not agree with the scale values on the track itself. You can't work from the actual end of the track where the "0" is located and the air track legs can get in the way of the ring stand holding the photogate. Therefore, on the side of the track that has the scale oriented with the zero end up, select measurement points 50.0, 80.0, 110.0, 140.0 and 170.0. These will satisfy the 30.0 cm interval requirements and avoid the end of the track and track leg problems. In the end these are simply reference points and their values do not enter into any calculations.
- The vertical height measurements are denoted by the variable $\mathbf{y_i}$. The measurements should be made at positions located at intervals of 0, 30, 60, 90 and 120 cm along the air track from your initial launching location. We will designate the height y_5 as the zero reference level of GPE. The difference in heights relative to this zero level will be designated by the variable **y'** defined as $\mathbf{y'_i = y_i - y_5}$.

- Measure y_1 through y_5, as shown in Figure 1, to three significant figures. Calculate the y'_i values and record them in your Data Table.
- Place the photogate at the 30.0 cm location along the air track. This will allow you to measure the velocity at y_2.

  Special Alignment Instructions – Align the pin on the side of the glider with the track scale. For the y_2 location you are 30.0 cm from your launching location and the track scale should read 80.0 cm. With the glider held at this location your lab partner should position the photogate so that the beam path is perpendicular to the path of the glider. The photogate should also be rotated slightly about its mounting axis so that its body is perpendicular to the plane of the air track. The flag should not strike anything as the glider travels down the air track. After taking data at this point this alignment procedure will be repeated at each of the other three positions
- Turn on the air supply to the air track and then turn up the air volume until the glider floats on a cushion of air. Let the glider accelerate from its rest position at Displacement = 0.0. ALL DATA WILL BE TAKEN WITH THE GLIDER RELEASED FROM THIS SAME LOCATION. Record the velocity measured, when the glider passes through the photogate, in the Data Table below. Repeat this velocity measurement two more times for a total of three velocity measurements at this photogate position.
- Repeat these velocity measurements with the photogate positioned at y_3, y_4, and y_5 and record the values in the Data Table below.
- Calculate the average velocity for each measurement location and record the results in the last column of the table below AND in the 5^{th} column of the second Data Table

Data and Analysis

y_i (cm)	s (cm)	v_1 (m/s)	v_2 (m/s)	v_3 (m/s)	v_{avg} (m/s)
y_1	0.0	0.0	0.0	0.0	0.0
y_2	30.0				
y_3	60.0				
y_4	90.0				
y_5	120.0				

Mass of the glider *m* = ___________________ (kg)

Length of flag = _____________(cm) ______________(m)

y (m)	$y' = y - y_5$ (m)	Track Scale Location (cm)	Displace-ment s (cm)	GPE = mgy' (J)	v_{avg} (m/s)	KE = $1/2\ mv_{avg}^2$ (J)	E_T = KE + GPE (J)
y_1=		50.0	0.0		0.0	0.0	
y_2=		80.0	30.0				
y_3=		110.0	60.0				
y_4=		140.0	90.0				
y_5=		170.0	120.0	0.0			

After completely filling in this entire Data Table you are ready to make your graph. The vertical scale will be energy in joules and the horizontal scale will be the Displacement position in centimeters. (it need not be in SI units since it only marks a location).

Draw best-fit lines for _each_ quantity, **GPE**, **KE**, and $\mathbf{E_T}$ for your graph.

You only need to do the line statistics, (ie. LINEST - equation, slope uncertainty and correlation coefficient) for the $\mathbf{E_T}$ best-fit line.

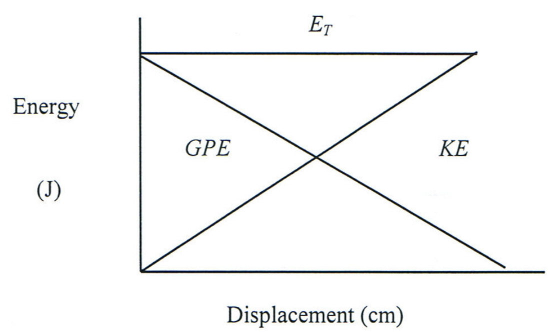


Figure 2. Graph of **GPE**, **KE** and $\mathbf{E_T}$ for the sliding glider.

Questions (Questions should be answered in your Formal Lab Report)

1. The most sensitive measurement in this lab is that of the flag length, what would happen to the values of the velocities if you used a value of the length that was too large? How would this affect the kinetic energy values? What would this do to the value of the Total Mechanical Energy ($\mathbf{E_T}$)?
2. In this lab we neglected friction. If friction was present what would it do to the values of the velocities? How would this affect the kinetic energy values? What would this do to the value of the Total Mechanical Energy ($\mathbf{E_T}$)?
3. Is the best-fit line for the total energy *E* horizontal? In other words, is the slope of your best-fit line to your $\mathbf{E_T}$ data zero within experimental error? Theoretically, should the best-fit line for $\mathbf{E_T}$ be horizontal? Explain why or why not.
4. Within reasonable limits of experimental uncertainty were you able to show conservation of energy for the glider on the air track? In other words, does the interval determined by the value of the slope of your Et line +/- its uncertainty contain the value zero?