PHYSICS 121 Experiment 4

The Conservation of Energy

The purpose of this lab is to verify the conservation of mechanical energy experimentally

Equipment

1 air track (with picket fence)
1 glider
1 photo gate (mounted on top of the glider)
1 interface box (photo gate – computer)
1 computer

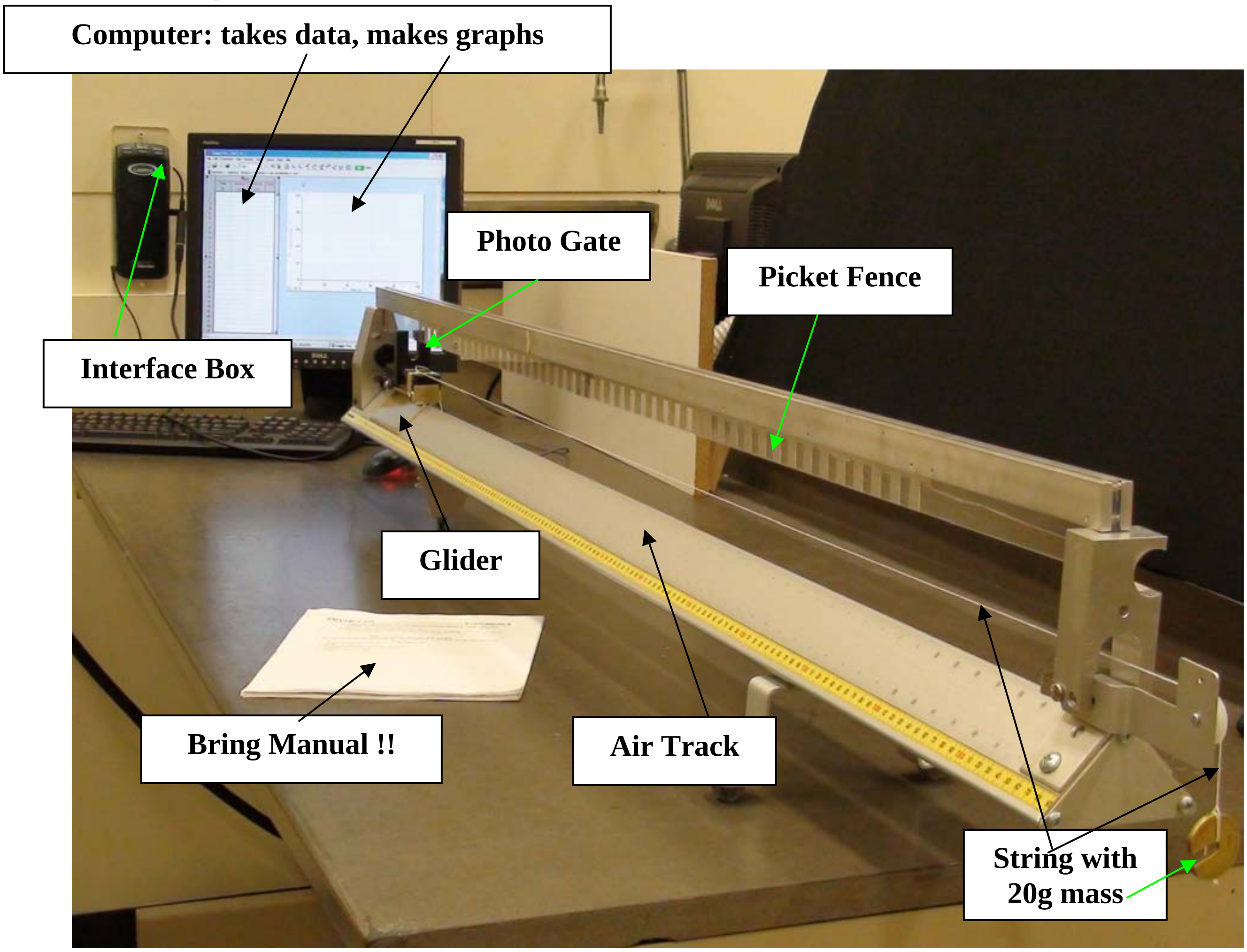

Fig. 1

Introduction

For an isolated system, the total energy must be conserved. In this experiment we will examine the law of the conservation of the total mechanical energy by observing the transfer of gravitational potential energy to kinetic energy, using a glider on an air track that is pulled by a falling mass.

The apparatus is fairly sophisticated (shown in Fig. 1 above and sketched in Fig. 2 below). Your instructor will tell you how to use it. It is called an air track because an air "cushion" reduces the friction. We consider the system, glider-mass, to be isolated from friction. The position of the glider as a function of time can be accurately recorded by means of a photo gate device.

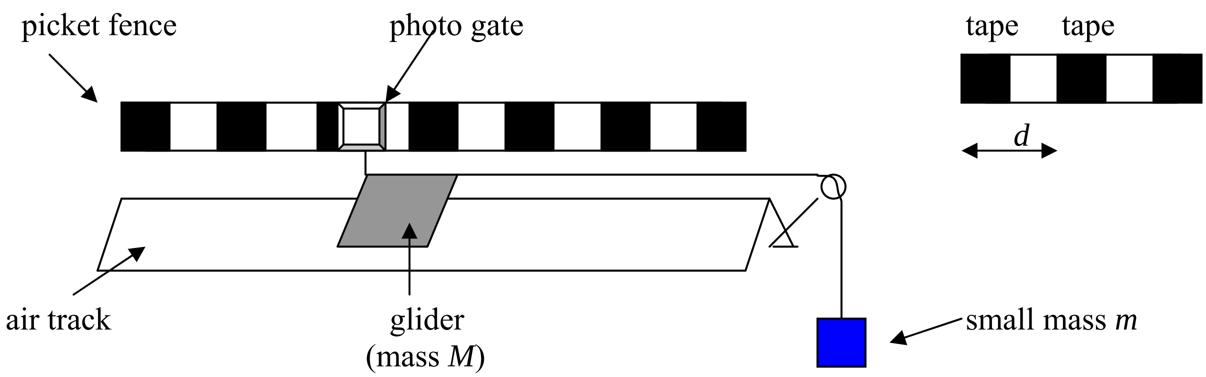

Fig. 2

In this experiment, the glider on the air track obtains kinetic energy due to the loss of potential energy experienced by the small falling mass *m*.

The kinetic energy (*KE*) of the system, glider-small mass, is given in Ch 6, sheet 8. The potential energy of the system is given in Ch 6, sheet 12 where h is the distance the small mass has dropped. Modify the formula for *KE* such that it is valid for the pair of masses *m* and *M*. Copy both formulae into your **REPORT SHEET** and label them as equation (1) and (2) respectively.

Q1: Equation (2) actually describes the **change of the potential energy**. With which sign do you have to apply the potential energy formula, when writing down the change of the potential energy of the small mass *m*, after it has fallen by a certain distance ? Include the sign into your equation (2).

Part I Testing Conservation of Mechanical Energy:

A battery-powered photo gate is mounted on the glider. When activated with the small push button on the side of the glider, the photo gate turns on a bright light emitting diode (LED) whenever the picket fence over the air track blocks the photo gate. A light sensor at the end of the air track receives the LED signals and the timing program in the computer measures and records the times when the light beam of the photo gate is blocked.

A small mass is attached to the glider via a string on a level air track. By dropping the small mass, the change in height of the small mass can be measured, as well as the velocity of the glider-mass system. This will allow the computation of the sum of kinetic and potential energies before and after the change and verify (or dismiss) the law of the conservation of mechanical energy as a useful concept. We define the initial *PE* of the small mass to be zero. (We can do this, since *PE* stands for a **change** of potential energy).

Q2: What is the change in the potential energy of the glider alone?

Procedure

1) Your lab instructor has a list of the masses for all the gliders. Get the number of your glider and obtain its mass, *M*, from your lab instructor. Assume a 1 *gram* error for this mass and record this mass and the error in your **REPORT SHEET**.

2) We need to determine the distance *d* from one "picket" to the next and enter it into the computer later on. (see Figure 2 ; note that *d* is the same quantity as in Experiment 2 - Acceleration). Measure 10*d* and estimate the absolute error for it. From this measurement determine the distance *d* and its error according to expression (1) in **"Error and Uncertainty" ("EU")**. Record all values in your **REPORT SHEET**.

Level the air track by carefully adjusting the single leveling screw at one end of the track. When the track is level, the glider should remain nearly stationary at any point on the track. Be sure to tighten the wing nut on the leveling screw when the track is level.

3) **Attach a 20 *gram* mass (NOT more than 20 g !!)**, *m*, to the glider with a piece of string and rest the string on the pulley at the end of the air track so that the mass hangs over the edge of the table and can fall freely. Record the value of this mass and an assumed error of 0.2 *grams* in your **REPORT SHEET**. Make sure the string with the weight attached is long enough so you can reach the far end from the pulley and can start the motion with the photo gate in front of the first "picket". The string should not be too long. The weight should not hit the ground before the glider is ~ 10 pickets from the end on the pulley side.

4) Get the computer ready for data taking:
Double click the icon "**Exp4_xv_t**". A window with a spreadsheet on the left (having "Time, Distance, Velocity" columns) and an empty graph on the right with velocity and time axes comes up. On top is a window "**Sensor Confirmation**".
Click "Connect", again "Connect".

5) Enter your value for the distance *d* in Fig. 2 above from step 2) into the program:
Click Data->User Parameters: the window "**User Parameters**" comes up and should show:

Name:	**Value:**	**Units:**	**Places:**	**Increment:**	**Editable:**
PhotogateDistance1			4	1.0000	✓

enter your value of *d* in meters here
Click OK.

You are ready to take data now.

6) Click Experiment->Start Collection.
Hold the glider on the air track at the far end from the pulley with the photo gate ~ 3 *cm* in front of the first picket. Mouse-click the green button to start taking data, then release the glider. Hit the **space bar** (stops data taking) when the glider is ~ 10 pickets from the end at the pulley side. (You may want to practice this a few times.)
After a good run you should have ~10 **velocity-time** pairs in the spreadsheet and a **straight line** velocity vs time graph. If you do not get a linear graph, repeat the measurement (step 6). If your

final graph still has a kink at the begin **use** only **data after the kink**. Copy the **first 8** data points (rows which **contain a velocity !!)** from your spreadsheet into Table 1 in your **REPORT SHEET**. The first point you enter is your data point "1" in the analysis below.

The height *h* in your equation (2) is the distance traveled by the weight from the data point 1 to 2, 1 to 3, 1 to 4,… etc. Thus for data point 2, *h* =(2-1) *d*, for data point 3, *h* =(3-1) *d*, etc. This *h* has to be used to calculate the change of the potential energy given by your equation (2). Calculate all values of *h* and enter them into Table 1 in your **REPORT SHEET**. NOTE! AS a check the values of your heights *h* have to be equal to the recorded values $(x_n - x_1)$.

Analysis:

Below **watch absolute** and **relative** errors! You will have to change absolute errors into relative errors and the other way around, using expression (4) in "Error and Uncertainty".

Q3: Calculate the error of *h* from the error in *d,* using expression (1) in "Error and Uncertainty", and enter the values of *h* with their errors into Table 1. On your report sheet, show the steps of your computation for the fifth point ($n = 5$).

Q4: In the present circumstance, the error of *t* is regarded as negligible. Show that this implies that $\Delta v/v = \Delta d/d$. Calculate the errors of *v* and enter them into Table 1.

Q5: Calculate all potential energy changes and their errors from the errors in *m* and *h* using expression (7) and (3) in "EU", and enter them into Table 2.

Q6: Calculate the kinetic energies for all data points using equation (1) from this lab and enter them into Table 2 in your **REPORT SHEET**. Next take the differences of the kinetic energies, δKE, of point 2 minus point 1, point 3 minus point 1, etc. and enter them into Table 2. (Note that δKE=0 for the $n = 1$ row!)

Q7: Calculate the relative error of the factor ½(m+M) from the errors of *m* and *M*, using expression (6), (1) and (2) in "EU".

Q8: You have put the differences of kinetic energies in Table 2, and now we have to consider the errors of those values. Since δKE_n = ½$(m+M)[v_n^2 - v_1^2]$, we will assume that the error of $[v_n^2 - v_1^2]$ is dominated by the error of v_n^2 and simply **neglect the error contributions of v_1^2, *m*, and *M***. Use your result from **Q4** to calculate $\Delta v_n / v_n$, calculate the relative error $\Delta(v_n^2)/v_n^2$ applying expression (8) in "EU", use your result from **Q7** to calculate the errors for the δKE values by applying expression (7) of "EU", and complete Table 2.

Plot your values of *PE* (including its sign!), the change in potential energy, vs. δKE, the change in kinetic energy, together with their error bars in the grid provided in your **REPORT SHEET**.

Q9: What is the expected slope of this graph if mechanical energy is exactly conserved? Measure your slope and its error according expression (10) and (11) in “EU”. Compare your slope to the expected slope. If your measured slope of the PE vs δKE plot is less than the expected one (include the correct sign!), would non-negligible friction explain your result ?

Part II Newton’s Second Law:

In this part, you will use your collected data and verify that the experiment can also be viewed as a test of Newton’s second law. In Ch 4 sheet 20, you get a sketch of your experiment by simply setting the angle θ equal to zero. On sheet 23, point 2, the derivation of your acceleration, a, for the combined object ($m + M$) is given. Repeat it and label the final equation as equation (3) in your **REPORT SHEET**.

Using your data from Table 1, plot the velocity (vertical axis) *vs.* time (horizontal axis) on the second grid provided in your report sheet, including the error bars for the velocity. Determine your experimental value a_{exp} from the slope. Get the slope and its error according to expression (10) and (11) in “EU”.

Calculate the “theoretical” value of a, the acceleration of your weight-glider system (mass = m + M) using your mass values and equation (3) from this lab. This is your “theoretical” value of a. Neglect its error from the masses m and M.

Q10: Compare the “theoretical” value of a to your a_{exp} and its error. If your measured slope of the v vs t plot is less than the expected one, would non-negligible friction explain your result?

PHY 121 **REPORT SHEET (to be signed by instructor)**

EXPERIMENT 4 <u>The Conservation of Energy</u>

Name: ________________________________ Section:____________

SB#: _________________________ Date: _______________________

Lab Instructor:____________________________

Equation (1): ____

Equation (2): ____

Q1: ____

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<u>Part I Testing Conservation of Mechanical Energy:</u>

Q2: ____

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Glider mass $M \pm \Delta M$: ____[ ]

Small mass $m \pm \Delta m$: ____[ ]

10d: ______________________________[ ] $\Delta(10d)$: ________________________[ ]

d: _______________________________[ ] Δd:___________________________[ ]

____

Table 1:

n	t [ ]	x_n [ ]	h [m]	v_n [ ]	Δv_n [m/s]
1					
2					
3					
4					
5					
6					
7					
8					

Q3: Show your calculations explicitly for n = 5____

Q4: Show your proof and your calculations explicitly for n = 5______________________________

Q5: Show your calculations explicitly for n = 5____

Table 2:

	PE[J]	Δ PE[J]	v_n^2 [$(m/s)^2$]	KE [J]	δKE [J]	$\Delta(\delta KE)$ [J]
1					0	
2						
3						
4						
5						
6						
7						
8						

Q6: Show your calculations explicitly for n = 5 ____

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Q7: Show your calculations explicitly ____

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Q8: Show your calculations explicitly for n = 5____

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PE (including its sign) vs. δ*KE*, label all axes, include error bars, units and mark the ranges used for calculation of slope:

Show explicitly the calculation of slope and its error and units______________________________

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____[ ]

Q9: ____

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Part II   Newton's Second Law:

Equation (3) and its derivation:

Show explicitly the calculation of the "theoretical" *a*:

[ ]

Velocity vs. Time, label all axes, units and mark the ranges used for calculation of slope:

Show explicitly the calculation of slope and its error and units____________________

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____________________________________[ ]

Q10:

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