PHYSICS 121 Experiment 5

The Conservation of Momentum

The purpose of this lab is to demonstrate the Conservation of Momentum in collisions of objects.

Equipment

1 air track
1 computer
1 small glider
1 big glider
1 interface box
2 photo gates

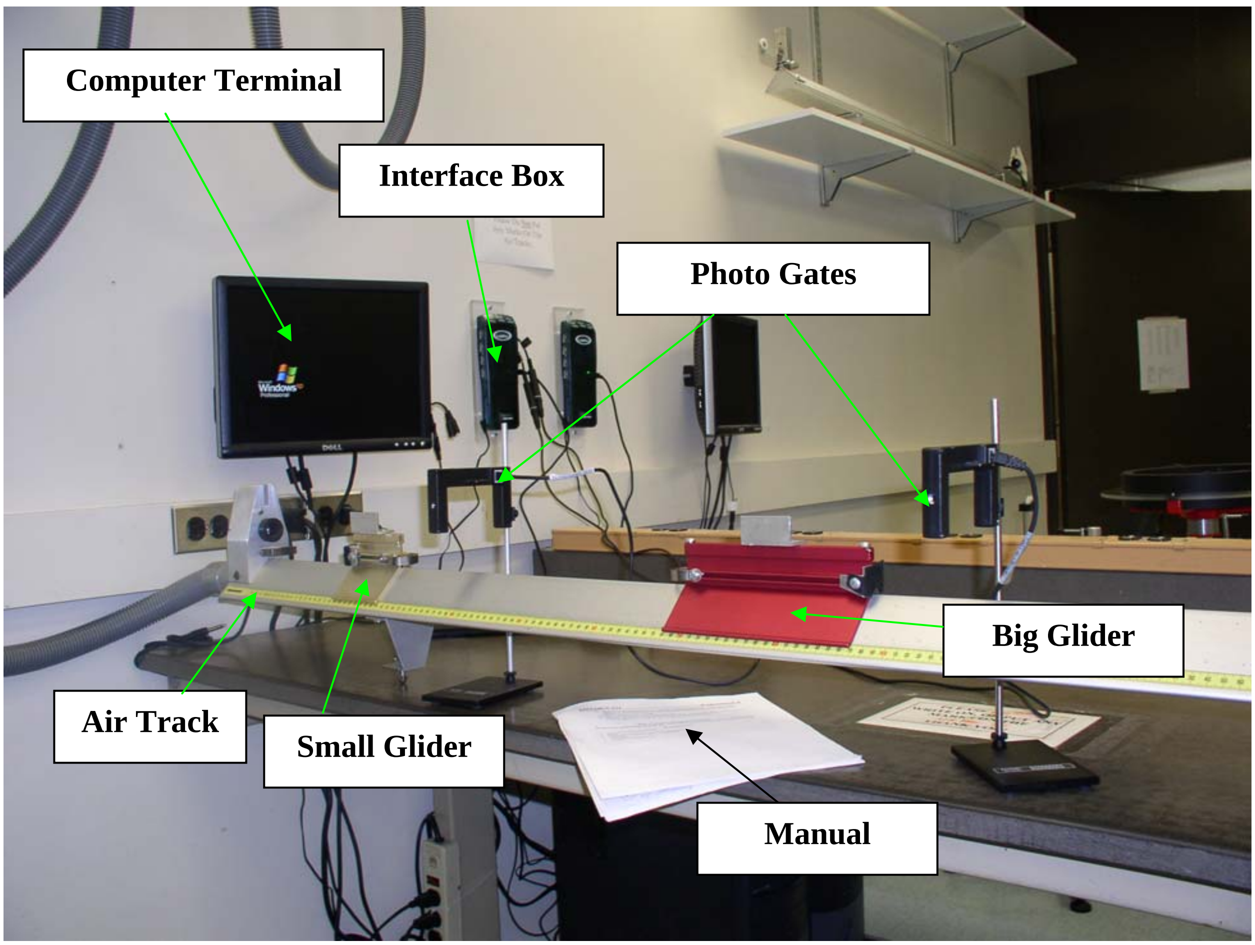

Fig. 1

Introduction

Conservation laws are very powerful tools in understanding physical phenomena. What takes place in collisions of objects is governed by momentum conservation. The experiment will use air track to study collisions in one dimension and demonstrate that momentum is really conserved in these relatively simple processes. (They are simple because no external forces act in the horizontal direction since there is no appreciable friction.)

You will measure the velocity of each glider, before and after the collision, by measuring the amount of time that a metal tab on top of the glider blocks a photogate.

Measure the width, w_s, the width of the metal piece on the small glider and obtain the mass, m_s, of the small glider with the scale at the front of the room. Record your values in the **REPORT SHEET** in SI units. Repeat the two measurements for the big glider. Its mass exceeds the 200g capacity of the scale, so you have to put a 200g mass on the opposite pan – be sure to add 200g to the reading for the big glider. Assume that each width has an absolute error of 2 mm and each mass has an absolute error of 1 g.

Part I Elastic Collision-sliding small glider into big glider:

In this part of the lab, there will be an elastic collision between a moving small glider and a stationary big glider.

For the first collision, you will collide the small glider with the **big glider**, which is **at rest (the target)**. Turn on the air track and make sure that it is level. If you release a glider at rest in the area between the two photo-gates, it should not move. Set the gliders with the **non-velcro ends** of each glider, the **ends with the springs**, **facing each other**. Make sure the spring is rigidly attached to the cart. If it is not, get help from your instructor.

Place the big glider in between the photo gates, not far from the second (downstream) photo gate and **gently** (you want to avoid an up-down wobble of the glider which will cause friction) launch the small glider toward the resting big glider. Observe the directions that the two gliders take after the collision, and enter your observations in the REPORT SHEET.

These questions are to guide your observations in the lab. Make notes for yourself on this sheet, and refer to them as you are completing your analysis and report on MapleTA. But they are not submitted for grading.

Q1. Where do the gliders go after the collision? In the same, or opposite to the initial direction? Ch7 sheet 29, (where velocities are labeled positive in the incident direction) should help you explain your observations (namely, which glider continued or did not continue in the incident direction.

Turn on the computer and double click the icon "**Exp5_t1_t2**". A window with a spreadsheet on the left (having "Time, Status 1, Status 2 columns) comes up. On top is a window "**Sensor Confirmation**", where you may have to click "Connect" twice (two sensors)

You are ready for data taking now.

Position the **small incident glider** upstream of **gate #1** and the **big target glider** close and upstream of **gate #2**. **Make sure your incident glider goes into gate #1** (Time 1 in the table below.) Click the green "Collect" icon and launch the small glider. Make sure that you stop the computer before any of the two gliders hits the end of the track and bounces back. After the collision, you should see something like this table.

Time	State 1	State 2
1.6471	1	
1.7873	0	
2.0445		1
2.2690		0
2.4698	1	
3.3753	0	

This shows that t_I, the time for the incident glider before the collision is 1.7873-1.6471 = 0.1402 *s*, which is the value to be put in Table 1 of your **REPORT SHEET** for t_i for the small glider. Likewise, t_i' for the large glider would be 2.2690-2.0445, and t_i' for the small glider would be 3.3753-2.4698. Of course, you will fill in the data from your own measurement. Note that unprimed variables are before the collision, and primed variables are after.

Calculate the velocity *v* of the gliders before and after the collision by using the formula below and enter them into Table 1:

$$v = w/t \qquad (1)$$

Neglect the error in *t* and assume that the relative error of *w* is equal to the relative error of *v*, calculate the absolute error of *v* according to expression (4) in **"Error and Uncertainty" ("EU")** and enter them into Table 1.

Q2: What do your observations on the direction of the gliders after the collision mean for the sign of the small glider's post-collision momentum, which has to be used in the calculation of the total post-collision momentum?

Calculate the pre-collision and post–collision momentum *p* of the small glider using the following formula and enter them into Table 2:

$$p = m*v \qquad (2)$$

Propagate the error for momentum *p* according to expression (7) in "EU". Show that the error contribution of the mass is negligible relative to the error contribution of the velocity. Repeat the momentum calculations for the big glider and enter it into Table 2.

Analysis:

Q3: Does the big glider have any pre-collision momentum, why or why not?

Calculate the total momentum before the collision and its error ($p \pm \Delta p$) and the total momentum after the collision and its error ($p' \pm \Delta p'$).

Q4: Is momentum conserved, i.e. does the range of ($p \pm \Delta p$) overlap with the range of ($p' \pm \Delta p'$)?

Part II Elastic Collision-sliding big glider into small glider:

This part is exactly the same as the Part I of your lab except that you will slide the big glider into the **small glider that is at rest**.

Procedure

Again, start the data collection and **gently** launch the big glider.
Make sure your incident glider goes into gate #1. Fill your times into Table 3.

Q5: Does the big glider continue in the incident direction after the collision and does your observation agree with the prediction of Ch 7 sheet 25 and 29, where velocities are labeled positive in the incident direction?

Calculate the velocities according to equation (1) and their errors and enter them into Table 3.

Calculate the pre-collision and post-collision momentum p of each glider using equation (2) and enter them into Table 4. Propagate the error for momentum and enter them into Table 4.

Analysis:

Calculate the total momentum before the collision and its error ($p \pm \Delta p$) and the momentum after the collision and its error ($p' \pm \Delta p'$)?

Q6: Is momentum conserved, ie does the range of ($p \pm \Delta p$) overlap with the range of ($p' \pm \Delta p'$)?

<u>Part III   Inelastic Collision-sliding big glider into small glider:</u>

In this part, you will observe a perfectly inelastic collision between a **moving big glider** and a **stationary small glider**. Perfectly inelastic means that the objects stick together after the collision, which is accomplished by a piece of Velcro on each glider

Procedure

For this collision, you collide the big glider into the small glider. Now, make sure that the **velcro ends** of each glider are **facing each other**. Launch the big glider and observe.

Make sure your incident glider goes into gate #1.

For this experiment, you only record two time intervals: the big glider in gate #1 before the collision, and the small glider in gate #2 after the colision.

Q7: In which direction do both gliders move after the collision and do they move together? Do your observations agree with the definition of "perfectly inelastic collision" (see Ch 7,sheet 13) ?

Record the times in Table 5. Calculate the velocities according to equation (1) and their errors and enter them into Table 5.

Calculate the pre-collision and post-collision momentum using equation (2) and enter them into Table 6. Calculate the errors for momenta and enter them into Table 6. Note you will need to propagate the post collision momentum error according to expression (6) and (7) in "EU".

Analysis:

Calculate the total momentum before the collision and its error ($p \pm \Delta p$) and the momentum after the collision and its error ($p' \pm \Delta p'$)?

Q8: Is momentum conserved for inelastic collisions, i.e. does the range of ($p \pm \Delta p$) overlap with the range of ($p' \pm \Delta p'$)?

Part IV   Kinetic Energy of Elastic and Inelastic Collisions:

In this part, you will calculate the kinetic energies in the elastic collision from Part II and the kinetic energies in the inelastic collision from Part III.

Analysis:

There is no need to collect any more data for this part of the lab, you will compute the kinetic energies using data from Part II and Part III.The kinetic energy can be calculated using the following formula (see Ch6 sheet 8) :

$$KE=1/2*m*v^2 \qquad (3)$$

Calculate the error for *KE* according to expression (3), (7), and (8) in "EU". Enter the calculated values of *KE* for the **elastic** collision into Table 7. Enter the *KE* calculations for the **inelastic** collision into Table 8.

Calculate the total KE before the **elastic** collision and its error ($KE_{total} \pm \Delta KE_{total}$) and calculate the total KE after the **elastic** collision and its error ($KE'_{total} \pm \Delta KE'_{total}$). You can **neglect the error** due to the masses here (The error is dominated by the errors of the velocities.)

Q9: Is KE conserved for **elastic** collisions, i.e. does the range of ($KE_{total} \pm \Delta KE_{total}$) overlap with the range of ($KE'_{total} \pm \Delta KE'_{total}$)?

Calculate the total KE before the **inelastic** collision and its error ($KE_{total} \pm \Delta KE_{total}$) and calculate the total KE after the **inelastic** collision and its error ($KE'_{total} \pm \Delta KE'_{total}$).

Q10: Is KE conserved for **inelastic** collision,i.e. does the range of ($KE_{total} \pm \Delta KE_{total}$) overlap with the range of ($KE'_{total} \pm \Delta KE'_{total}$)? You can **neglect the error** due to the masses here (The error is dominated by the errors of the velocities.)

Q11: Is momentum conservation expected to be valid for both elastic and inelastic collisions? What is the expectation for kinetic energy in elastic and inelastic collisions?

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

EXPERIMENT <u>The Conservation of Momentum</u>

Name: ________________________________ Section:____________

SB#: ________________________ Date: ______________________

Lab Instructor:___________________________

$w_s \pm \Delta w_s$: ______________________[ ] $m_s \pm \Delta m_s$: ____________________[ ]

$w_b \pm \Delta w_b$: ______________________[ ] $m_b \pm \Delta m_b$: ____________________[ ]

Part I Elastic Collision-sliding small glider into big glider:

Table 1:

Glider	t_i [ ]	t_i' [ ]	v_i [ ]	$\Delta v_i / v_i$	v_i' [ ]	$\Delta v_i'/v_i'$
small						
big						

Table 2:

Glider	p_i [ ]	Δp_i [ ]	p_i' [ ]	$\Delta p_i'$ [ ]
small				
big				

Part II. Elastic collision sliding big glider into small glider

Table 3:

Glider	t_i [ ]	t_i' [ ]	v_i [ ]	$\Delta v_i /v_i$	v_i' [ ]	$\Delta v_i'/ v_i'$
small						
big						

Table 4:

Glider	p_i [ ]	Δp_i [ ]	p_i' [ ]	Δp_i' [ ]
small				
big				

Part III. Inelastic collision sliding big glider into small glider with velcro

Table 5:

	t_i [ ]	t_i' [ ]	v_i [ ]	$\Delta v_i / v_i$	v_i' [ ]	Δv_i'/ v_i'
Pre-collision						
Post-collision						

Table 6:

	p_i [ ]	Δp_i [ ]	p_i' [ ]	Δp_i' [ ]
Pre				
Post				

Part IV. Kinetic Energy of Elastic and Inelastic Collisions

Table 7 (KE for Elastic Collision):

Glider	v_i^2 [ ]	$\Delta v_i^2 / v_i^2$ [ ]	$v_i'^2$ [ ]	$\Delta v_i'^2 / v_i'^2$ [ ]	KE_i [ ]	ΔKE_i [ ]	KE_i' [ ]	ΔKE_i' [ ]
small								
big								

Table 8 (KE for Inelastic Collision):

Glider	v_i^2 [ ]	$\Delta v_i^2 / v_i^2$ [ ]	$v_i'^2$ [ ]	$\Delta v_i'^2 / v_i'^2$ [ ]	KE_i [ ]	ΔKE_i [ ]	KE_i' [ ]	ΔKE_i' [ ]
big								
both								