PHYS 103 LAB 7: COLLISIONS

INTRODUCTION

In this laboratory you will study the *conservation of linear momentum and kinetic energy* in collisions between carts moving along a track. You will use two **Motion Sensors** (each one tracking the motion of one of the carts) and **Data Studio** to record the *position* and *velocity* of these carts. You will tabulate your results using an **Excel** spreadsheet and verify whether the *momentum* and *kinetic energy* are conserved during these collisions.

THEORY

The *momentum*, $\boldsymbol{p}$, of an object is defined as the product of its *mass*, m, and its *velocity*, $\boldsymbol{v}$, i.e.

$$\boldsymbol{p} = m\boldsymbol{v} \; . \tag{1}$$

Like *velocity*, *momentum* is a vector and has the same direction as the *velocity* vector.

In this lab you will investigate if the momentum of a system consisting of two carts is conserved during various types of collisions. The *principle of momentum conservation* tells us that if the net external *force* acting on a system of objects is zero, then the total *momentum* of this system is conserved i.e. stays constant.

Let subscript ”1” refer to the first cart in our system and subscript ”2” refer to second cart in our system. Then for our system of two carts we have::

initial *momentum*: $\boldsymbol{p}_i = m_1\boldsymbol{v}_{i1} + m_2\boldsymbol{v}_{i2},$ before the collision (2)

(here subscript “i” indicates initial values) and

final *momentum*: $\boldsymbol{p}_f = m_1\boldsymbol{v}_{f1} + m_2\boldsymbol{v}_{f2.}$ after the collision (3)

(here subscript “f” indicates final values).

If *momentum* is conserved then:

$$\boldsymbol{p}_i = \boldsymbol{p}_f \tag{4}$$

We will test this relation in a number of collisions involving carts with different masses, carts with magnets which will bounce away from each other, carts with Velcro bumpers which will remain attached after collision, and carts initially attached which then recoil

In addition you’ll investigate if these collisions *conserve kinetic energy*.

$$KE_i = KE_f \tag{5}$$

where

$$KE_{\text{i}} = \frac{m_1 v_{1\text{i}}^2}{2} + \frac{m_2 v_{2\text{i}}^2}{2} \qquad (6)$$

$$KE_{\text{f}} = \frac{m_1 v_{1\text{f}}^2}{2} + \frac{m_2 v_{2\text{f}}^2}{2} \qquad (7)$$

If the *kinetic energy* is *conserved* during the collision we call it a *perfectly elastic collision*. If the *kinetic energy* is *not conserved* during the collision we call it an *inelastic collision*. An extreme case is that of a *perfectly inelastic collision* where the two objects stick together after colliding. In an *inelastic collision* some energy is dissipated during collision so

$$KE_{\text{f}} < KE_{\text{i}} \qquad (8)$$

In addition, in this experiment you'll also study the *recoil* of two carts by means of the *force* exerted by a compressed plunger. Because the initial *momenta* of each of the carts are zero, so is the initial *momentum* of the whole system. Thus the final *momenta* of the two carts must also add up to zero:

$$p_{\text{f}} = m_1 v_{\text{f}1} - m_2 v_{\text{f}2} = 0 \qquad (9)$$

where the minus sign indicates that the carts are moving in opposite directions after recoil. Thus

$$m_1 v_{\text{f}1} = m_2 v_{\text{f}2} \qquad (10)$$

and so the ratio of the carts' *masses* is equal to the inverse ratio of the carts' *velocities*.

$$\frac{m_1}{m_2} = \frac{v_{\text{f}2}}{v_{\text{f}1}}. \qquad (11)$$

PROCEDURE

PART 1 MAGNETIC CARTS

1. In Excel generate a table similar to table 1 on page3. Include all needed equations: use equation (2) for initial momentum, use equation (3) for final momentum, use equation (6) for initial kinetic energy, and equation (7) for final kinetic energy,

2. Make sure that the switch on each of the **Motion Sensors** is set to the long range designation (large beam).

3. Check that the stereo phone plugs of the **Motion Sensors** are connected to Digital Channel 1 - 4 on the **Interface Box**.

Table 1.

Incident cart	Target cart	Incident cart	Target cart	Incident cart	Target cart	Momentum of the system (eqs. (2) and (3))			Energy of the system (eqs. (6) and (7))		
m_1 (kg)	m_2 (kg)	v_{1i} (m/s)	v_{2i} (m/s)	v_{1f} (m/s)	v_{2f} (m/s)	p_i $(\mathrm{kg}\frac{\mathrm{m}}{\mathrm{s}})$	p_f $(\mathrm{kg}\frac{\mathrm{m}}{\mathrm{s}})$	**Momentum % diff**	KE_i (J)	KE_f (J)	KE % diff
0.5	**0.5**		**0**								
1.0	**0.5**		**0**								
1.5	**0.5**		**0**								

4. Now, open **Data Studio** and install the two **Motion Sensors** by dragging the **'Motion Sensor'** icon from the list of sensors to the picture of the **Interface Box** as shown here. For each **Motion Sensor** double click on the **'Motion Sensor'** icon, select **'Motion Sensor'** and reset the sample rate to 25 Hz.

5. Create one *position* vs. *time* graph for both **Sensors**.

6. Pick a pair of carts and place them on the track with the magnetic ends repelling each other. These magnets are strong and you should keep your watch away from them.

7. Use the electronic scale to measure the *masses* of the dynamics carts. Also measure the *masses* of each of the weights to be placed on the cart. For the purpose of this experiment we'll assume that each of them has a mass of 0.5 kg. You should convince yourself that we won't introduce much error by making this assumption.

8. Level the track. The track is leveled if the stationary cart placed on it remains stationary.

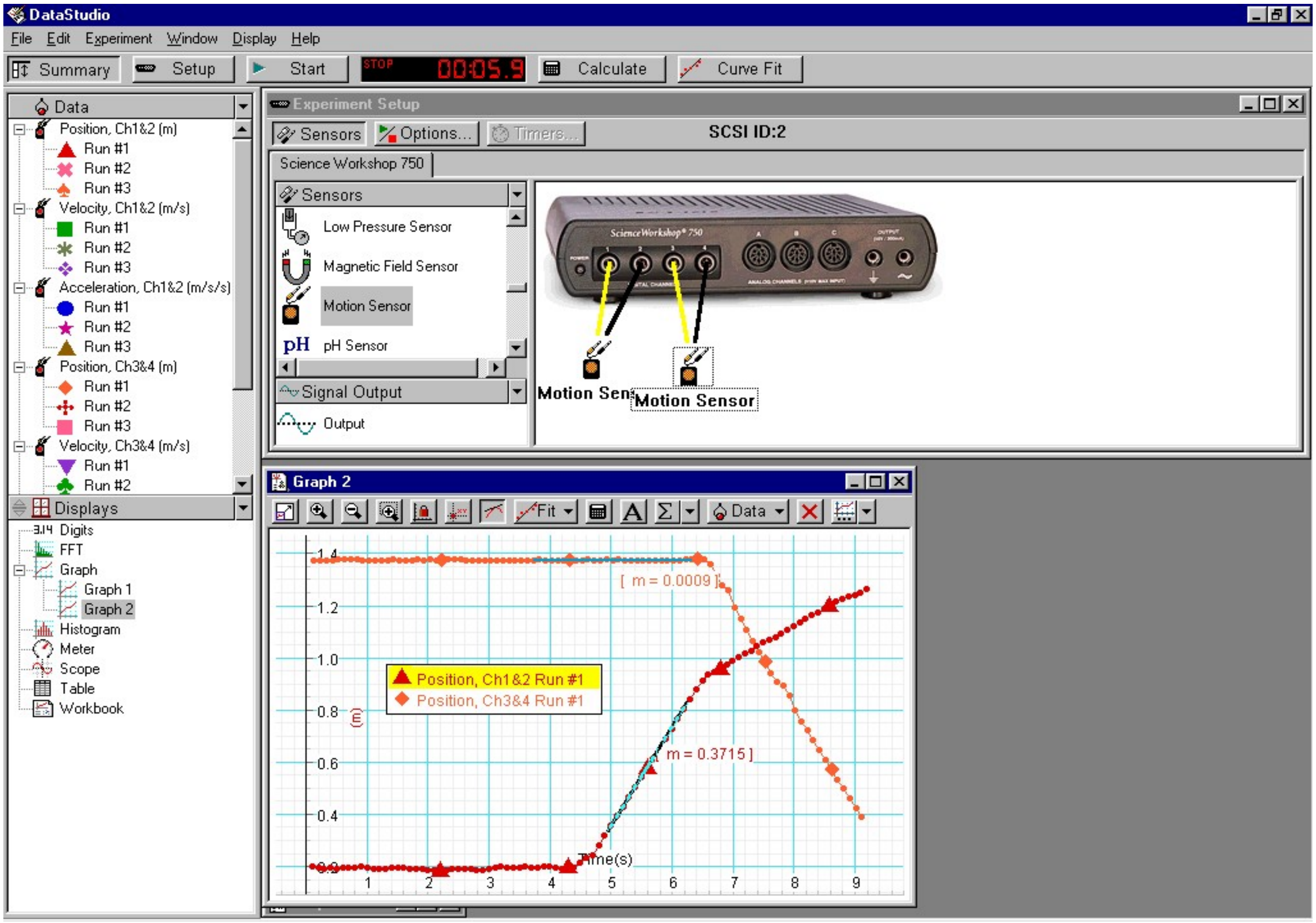
9. Position the carts along the track. The cart you'll launch should be about 15 cm from its sensor, the other cart about 20 cm away from the first cart.

10. Now you are ready to start taking data. Press the **Data Studio 'START'** button and launch the cart so that it collides with the stationary one. After the collision, catch the carts before they hit the **Motion Sensor**. Press the **'STOP'** button.

11. Identify the range of data for each of the carts on your *position* vs. *time* plot corresponding to the *time* interval **right before and right after the collision**. Use this data to estimate the carts' initial and final *velocities* right before and right after collision. (Fit them with a linear function to obtain the slopes (*velocities*))

12. Tabulate your data in **Excel**. If you are satisfied with the outcome move to the next step, otherwise try to refine your measurements.

13. Repeat the procedure from step 9 on, but vary the *mass* of the incident cart by placing additional weights on it as indicated in the table 1. In the table m_1 denotes the *mass* of the incident cart, and m_2 denotes the *mass* of the stationary one.



14. Look at your table and discuss your results:

a) Is *linear momentum* conserved during collisions? Should it be? Why or why not? Justify your answer.

b) Is *kinetic energy* conserved during collisions? Justify your answer.

c) Were the collisions perfectly *elastic*? Justify your answer.

PART 2 VELCRO CARTS

Repeat the procedure from Part 1 but now use the carts without magnets (at least one) and have the carts oriented in such way that their velcro ends are towards each other so the carts will stick together after collision. Tabulate your results in table 2 similar to table 1 above. You can copy the entire table and just clear content from columns 3, 5 and 6 (except for the headers).

Look at your table and discuss your results:

a) Is *linear momentum* conserved during collisions? Should it be? Why or why not? Justify your answer. Justify your answer.

b) Is *kinetic energy* conserved during collisions? Justify your answer.

c) Were the collisions *perfectly inelastic*? Justify your answer.

PART 3 RECOIL

1. In **Excel** prepare a table similar to table 3 below.

Table 3.

Cart 1	Cart 2	Cart 1	Cart 2	Mass ratio	Velocity ratio	% diff (between ratios)
m_1 (kg)	m_2 (kg)	v_{1f} (m/s)	v_{2f} (m/s)	$m_1/\ m_2$	$v_{2f}\ /v_{1f}$	
0.5	0.5					
1.0	0.5					
1.5	0.5					

2. Place two carts, one with a plunger, in the middle of the track against each other with the plunger completely depressed, facing the other cart.

3. Press the **'START'** button and tap the plunger release button with a ruler so that the plunger will push the carts apart. Make sure to catch the carts before they hit the **Motion Sensors**

4. Press **'STOP'** button. Find the final *velocity* of each one of the carts and record them in **Excel.**

5. Look at your table and discuss your results:

   a) Is *linear momentum* conserved during recoil? Justify your answer.

   b) Is *kinetic energy* conserved during recoil? Justify your answer.

   c) Did you verify relation (11)? Discuss your results.

6. Print your Excel tables.

Print all your data, graphs, and tables, and attach them to your report.
Delete your files from the computer.
Disconnect all equipment, close all applications, and log off your PC.

LAB 7 REPORT

Group name:..

Partners' names:..

....

....

INTRODUCTION:

DATA PRESENTATION:

PART 1 MAGNETIC CARTS

14. a)

b)

c)

PART 2 VELCRO CARTS

a)

b)

c)

PART 3 RECOIL

a)

b)

c)

REMINDERS: Include units.
Make sure to attach all your data and graphs. No data = No credit
Please do not hand in the manual, just the report.

<u>CONCLUSION:</u>