Course and Section_______ Names ___________________________

Date___________ ___________________________________

LINEAR MOMENTUM EXPERIMENT

Introduction

In this experiment, you will study the relationship between impulse and momentum, as well as conservation of momentum and energy in both elastic and inelastic collisions.

Equipment

Aluminum track, clamp, two carts + magnetic bumpers, 500 g block mass, magnetic stopper.

Preliminary Questions

1. The impulse given to the cart by the bumper is equal to

- a the change in the cart's kinetic energy
- b the change in the cart's momentum
- c the average force exerted on the cart
- d the average acceleration of the cart
- e all the above

2. A cart of mass, *m*, rolls along a track and hits a bumper at speed, *v*. The bumper does not move during the collision. What is the maximum possible impulse for this collision?

PART 1 - Impulse-Momentum

In this part, you will project a cart toward the magnetic stopper mounted at the end of the track, and allow it to rebound.

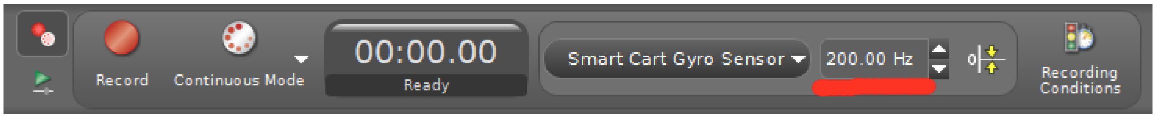
Procedure

Step 1. Open the file: **"v-t_F-t.cap"** contained in the T\:Capstone folder. This file will open Capstone and display a graph of the force vs. time and velocity vs. time of the cart. (Do not open Capstone first and then the file, it might not work property).

Step 2. Pair your cart with Capstone.

Step 3. Tare the force sensor: you want to read a force of value zero if no forces are applied. Go to 'Hardware Setup' on left panel. Click on the circle next to 'Smart Cart Force Sensor'. Then click on 'zero sensor now'. Then click 'ok'.

Step 4. Increase the force sensor sampling rate from 20Hz to 200Hz. On the right side of the timer, select “Smart Cart Force Sensor” and use the upward/downward arrows.



Step 5. Make sure the magnetic bumper at the other end of the track is firmly secured. You also need a second magnetic bumper attached to the cart, it might be already mounted. Orient the cart such that the two magnetic bumpers face each others. Press record and give your cart a push. Start your cart at the 50 cm mark and finish your recording when the cart passes back at the 50 cm mark again.

Step 6. Use Capstone to measure the area under the *F(t)* curve: carefully select the appropriate data points on the graph and click on the icon 

Step 7. Use Capstone to obtain the initial velocity (the velocity right before the collision) and the final velocity (the velocity right after the collision).

Analysis

3. What is the maximum force exerted by the cart on the bumper? (the graph is upside down).

$$F_{max} = \underline{\hspace{3cm}}$$

4. From your graph (area under the *F* vs *t* curve), what is the Impulse?

$$I = \underline{\hspace{3cm}}$$

5. Use the values of the velocities to calculate the change in momentum.

$$\Delta p = \underline{\hspace{3cm}}$$

6. Consider the force exerted by the cart on the bumper *and* the force exerted by the bumper on the cart. How are their magnitudes related during the collision?

7. Compare the value of the impulse *I* and change in momentum *Δp:* find their percentage difference.

$$\%Diff = \left| \frac{I - \Delta p}{(I + \Delta p)/2} \right| \times 100 = \underline{\hspace{2cm}}$$

For a valid measurement you need to obtain a *%Diff* less than 15%. If not check your data and calculations and repeat.

8. Print a copy of the graph you have created in capstone.

PART 2 - Inelastic collision

Procedure

Step 1. Close (don't save) and open again the Capstone software. Click File > New Experiment.

Step 2. Click classic templates and select the option with two images stacked vertically. Click the icon at the center of each open region and select graph.

Step 3. Pair both carts. Click the "select measurement" button in the *y*-axis of each graph. Select velocity so that each graph displays the velocity of one of the two carts.

Step 4. Orient the two carts with the Velcro strips facing each other so that they will stick together when they collide.

Step 5. Choose one cart to be the "incoming" cart m_1 and place the black blocks on top of it. The second cart m_2 is initially at rest in the middle of the track.

Step 6. Press record. Push m_1 towards m_2.

Step 7. Using Capstone, determine the initial and final velocity of each cart by selecting the appropriate data and using the Σ to calculate the mean.

Analysis

8. Record here the velocities.

Initial velocities	Final velocities
$v_1^i =$	$v_1^f =$
$v_2^i = 0$	$v_2^f =$

9. Compute the <u>total</u> momentum and <u>total</u> kinetic energy before and after the collision. For the calculation of the total momentum pay attention to the sign of the velocities: the carts are oriented in opposite directions and so they read opposite signs when moving in the same direction. Instead take all their velocities to be positive.

$p_i =$ $p_f =$

$K_i =$ $K_f =$

10. Conservation of momentum means $p_i = p_f$. Do your results show that momentum is conserved? Calculate the *%Diff* of the two momenta.

$$\%Diff = \left| \frac{p_i - p_f}{(p_i + p_f)/2} \right| \times 100 = \_\_\_\_\_\_\_$$

For a valid measurement you need to obtain a *%Diff* less than 15%. If not check your data and calculations and repeat.

11. Calculate the ratio of the kinetic energies

$$\frac{K_f}{K_i} = \_\_\_\_\_\_\_\_\_\_$$ (measured)

12. In a perfectly inelastic collision, it can be shown that the ration of kinetic energies is

$$\frac{m_1}{m_1+m_2} = \_\_\_\_\_\_\_\_\_\_$$ (exact value)

13. Calculate the percentage error of the ratio of the kinetic energies.

% error = (|measured - exact | /exact) x 100 = ___________

For a valid measurement you need to obtain a % error less than 15%. If not check your data and calculations and repeat.

14. Consider the force exerted during the collision by the incoming cart on the target cart *and* the force exerted by the target cart on the incoming cart. How are their magnitudes related?

PART 3 - Elastic collisions and $m_1 \neq m_2$

Procedure

Step 1. Delete the previous data run.

Step 2. Orient the two carts with the magnetic bumpers facing each other so that they will bounce off each other when they collide.

Step 3. Choose one cart to be the "incoming" cart m_1 and place the black blocks on top of it. The second cart m_2 is initially at rest in the middle of the track.

Step 4. Press record. Push m_1 towards m_2.

Step 5. Using Capstone, determine the initial and final velocity of each cart.

Analysis

15. Record here the velocities.

Initial velocities	Final velocities
v_1^i =	v_1^f =
v_2^i = 0	v_2^f =

16. Compute the total momentum and total kinetic energy before and after the collision. Again, check the comment of question 9

$p_i =$ $p_f =$

$K_i =$ $K_f =$

17. Conservation of momentum means $p_i = p_f$. Do your results show that momentum is conserved? Calculate the *%Diff* of the two momenta.

$$\%Diff = \left|\frac{p_i - p_f}{(p_i + p_f)/2}\right| \times 100 = \_\_\_\_\_\_\_$$

For a valid measurement you need to obtain a *%Diff* less than 15%. If not check your data and calculations and repeat.

18. Conservation of kinetic energy means $K_i = K_f$. Do your results show that the kinetic energy is conserved? Calculate the *%Diff* of the two kinetic energies.

$$\%Diff = \left|\frac{K_i - K_f}{(K_i + K_f)/2}\right| \times 100 = \_\_\_\_\_\_\_$$

For a valid measurement you need to obtain a *%Diff* less than 15%. If not check your data and calculations and repeat.

19. It can be shown that the expected values of the final velocities are given by the two equations below. Use these equations to calculate the expected velocities.

$$v_1^f = \frac{m_1 - m_2}{m_1 + m_2} v_1^i + \frac{2m_2}{m_1 + m_2} v_2^i = \_\_\_\_\_ \qquad v_2^f = \frac{2m_1}{m_1 + m_2} v_1^i + \frac{m_2 - m_1}{m_1 + m_2} v_2^i = \_\_\_\_\_$$

20. Calculate the relative percent differences between the observed $v_1{}^f$ and $v_2{}^f$ and the expected values

$$2\frac{\left|v^f_{1,observed} - v^f_{1,expected}\right|}{\left|v^f_{1,observed} + v^f_{1,expected}\right|} \times 100 = \_\_\_\_\_\_\_ \qquad 2\frac{\left|v^f_{2,observed} - v^f_{2,expected}\right|}{\left|v^f_{2,observed} + v^f_{2,expected}\right|} \times 100 = \_\_\_\_\_\_\_$$

21. Which are the possible sources of error of this experiment?