Name: ______________________________
Partners: ______________________________
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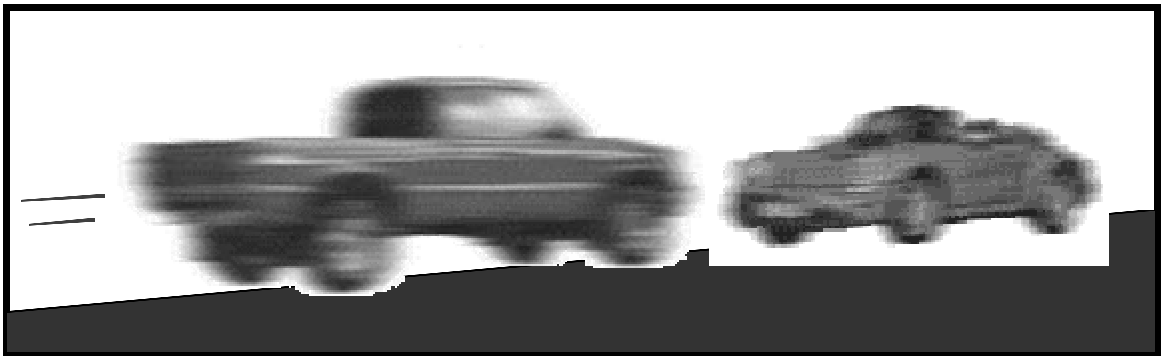
PHYSICS 220 LAB #5: COLLISIONS



A large pickup truck and a small car, both moving at the same speed, are about to collide head on. If they get stuck together, which way will the wreckage move? Newton's Third Law states that interaction forces are equal in magnitude and opposite in direction, but there is usually no way of knowing how large those forces are. However, the motion of the two vehicles can be described without actually knowing the forces between the objects if you use the concept of momentum.

(equipment: 2 carts; 1 track; computer, LabPro, and 2 motion detectors)

OBJECTIVES

1. To understand the definition of momentum, especially that it is a vector.
2. To experimentally verify the Law of Conservation of Momentum for one-dimensional collisions.
3. To get practice determining whether or not collisions are elastic.

PRE-LAB (to be completed before coming to lab)

Prior to coming to lab, read through this write-up and perform all the exercises labeled "**Pre-Lab**". You will also want to copy this work onto the back pages of the lab, which I will collect during the first 5 minutes of lab.

OVERVIEW

The momentum of an object is defined as its mass times its velocity, so it is a vector.

$$\vec{p} = m\vec{v}$$

Each of the collisions in this lab will involve two objects, so the total momentum will be the sum of the momenta of the two objects:

$$\vec{P}_{\text{tot}} = \vec{p}_1 + \vec{p}_2$$

If there is no net external force on a system, its total momentum is conserved during a collision:

$$\text{if } \sum \vec{F}_{\text{ext}} = 0, \text{then } \vec{P}_{\text{tot,i}} = \vec{P}_{\text{tot,f}}$$

Since the total momentum is a vector, this means that the momentum must be conserved in each component (here the capital "P" indicates total):

$$P_{\text{x,i}} = P_{\text{x,f}}$$

$$P_{\text{y,i}} = P_{\text{y,f}}$$

A collision is elastic if the total kinetic energy is the same before and after the collision. Recall that the kinetic energy for a single object is $KE = \frac{1}{2}mv^2$, where v is the speed.

The center of mass for a system can be thought of as the average location of mass in the system. The total momentum of a system is also the velocity of the center of mass times the total mass of the system:

$$\vec{P}_{\text{tot}} = M_{\text{tot}}\vec{V}_{\text{c.m.}} = m_1\vec{v}_1 + m_2\vec{v}_2 + \ldots$$

If the total momentum is conserved, the velocity of the center of mass is constant.

PART ONE: One-Dimensional Collisions

1. You will perform two different one-dimensional collisions between carts. In one collision the carts should stick together and be of different masses, and in the other they should bounce off of each other and be of like masses (this makes the mathematical prediction much easier). You will note that one end of each cart contains magnets. With the magnetic ends of two carts facing each other, the carts will bounce. If the carts do not actually collide, you will get less energy dissipation to sound and heat.
2. Plug two motion detectors into Lab Pro (one in DIG / SONIC 1 and the other in DIG / SONIC 2). Open **Collisions** (in Physics Experiments/ 220 – 221 / Collisions). You will have one motion detector at each end of the track, if aimed properly (and set to their narrow range) each detector should only track the cart nearest to it.
3. Play around a little with your set-up to make sure you've got the motion detectors properly aimed to only sense one car each.
4. Note: Friction will drain momentum from the carts. To minimize friction's effect on your data, use velocity measurements from *immediately* before and after the collisions.

Collision #1 (stick together, different masses)

(a) You'll start with the lighter cart (1) sitting stationary and the heavier one (2) rolling toward it.

(b) **Pre-Lab**: Sketch the initial and final situations. Be sure to label the carts and indicate the directions of their velocities.

(c) **Pre-Lab:** Develop an equation for the final speed of the carts, (v_f) depending only on m_1, m_2, and v_{2i}.

v_f = ____

(d) Record the masses of the carts.

$m_1 =$ ______________ $m_2 =$ ______________

(e) Record the initial and final velocities of the carts <u>including the signs</u> (on the Analyze menu, select Examine).

$v_{1i} =$ ____0____ $v_{2i} =$ ______________

$v_{1f} = v_{2f} =$ ________________

Question: Plug the measured masses and initial velocities into the equation you developed. How does the predicted velocity compare with that measured? (Calculate the percentage difference.)

$$\frac{v_{f-calc} - v_{f-measured}}{v_{f-measured}} \times 100\%$$

Before Proceeding: *Check with the instructor that you have an acceptable value (<10%).*

Question: How does the initial total kinetic energy compare with the final total kinetic energy? (Calculate the percentage change.)

$$\frac{K.E._{f-measured} - K.E._{i-measured}}{K.E._{i-measured}} \times 100\%$$

Question: How does the initial total momentum compare with the final total momentum? (Calculate the percentage change.)

$$\frac{\vec{p}_{f-measured} - \vec{p}_{i-measured}}{\vec{p}_{i-measured}} \times 100\%$$

Questions: Was momentum conserved in the collision ($\Delta\vec{p} = 0$)? Was the collision elastic ($\Delta K.E. = 0$)? Note: We're interested *during the instant* of the collision, but we can measure a little while before and a little while after – thus we're seeing both the effect of the collision and a small (on order of 5%) effect of friction. So if either change is on order of only 5%, *during the collision itself* that quantity was probably conserved.

Before Proceeding: *Check with the instructor.*

Collision #2 (carts bounce apart, same mass)

You will again start with one cart (1) stationary.

(a) **Pre-Lab**: Sketch the initial and final situations. Be sure to label the carts and indicate the directions of their velocities.

(f) **Pre-Lab:** Assuming a completely elastic collision ($\Delta K.E. = 0$), and conservation of momentum ($\Delta p = 0$), develop an equation for the final speed of cart 1, the initially stationary one, (v_{1f}) depending only on v_{2i} (not on v_{2f}.) *note: it would depend on the masses, but they'll cancel out if they're equal to each other.*

v_{1f} = ____

(b) Record the masses of the carts.

m_1 = _______________ m_2 = _______________

(c) Record the initial and final velocities of the carts <u>including the signs</u>. Note: don't let the carts actually hit, their magnetic repulsion will suffice to cause the bounce.

v_{1i} = _______0_______ v_{2i} = _______________

v_{1f} = _______________ v_{2f} = _______________

Question: How does the initial total momentum compare with the final total momentum? (Calculate the percentage change.)

Question: How does the initial total kinetic energy compare with the final total kinetic energy? (Calculate the percentage change.)

Questions: Was momentum conserved in the collision? Was the collision elastic?

Before Turning In: *Check with the instructor.*

Pre-Lab #5 **Name: _______________**

Collision #1 (stick together, different masses)

Pre-Lab: Sketch the initial and final situations. Be sure to label the carts and indicate the directions of their velocities. The lighter, initially stationary cart is #1 and the heavier, moving cart is #2.

Pre-Lab: Develop an equation for the final speed of the carts, (v_f) depending only on m_1, m_2, and v_{2i}.

v_f = ____

Collision #2 (carts bounce apart, same mass)

(d) **Pre-Lab**: Sketch the initial and final situations. Be sure to label the carts and indicate the directions of their velocities. The initially stationary cart is #1.

(g) **Pre-Lab:** Assuming a completely elastic collision ($\Delta K.E. = 0$), develop an equation for the final speed of cart 1 (the one initially stationary), (v_{1f}) depending only on v_{2i} (not on v_{2f}.)

v_{1f} = ____