PHYS S212: General Physics I
Lab 7: Momentum and Energy
10/25/22 (due 11/1/22)

Name(s):

Topics:

1. Qualitative analysis of collisions
2. Inelastic collisions
3. Elastic collisions

In this lab, you will use carts to explore the concepts of conservation of momentum and energy in collisions and the generation of thermal energy.

What you should turn in:
An informal report in a single document. You may submit a group report.

- Part 1: Responses to qualitative questions. [4 pts]
- Part 2: Derivations, calculations, and responses to questions. [6 pts]
- Part 2: Plots of velocity vs. time, momentum vs. time, and kinetic energy vs. time. [4 pts]
- Part 3: Plots of total momentum vs. time and total kinetic energy vs. time. [4 pts]
- Part 3: Discussion of changes in momentum and energy during the collisions. [2 pts]

Equipment

- Carts and tracks
- LabQuest interfaces
- Motion sensors

PART 1: QUALITATIVE ANALYSIS OF COLLISIONS

You will qualitatively observe different types of collisions between two carts to see how their resultant motion is affected by conservation of momentum. The total momentum of a system, P, is given by

$$\vec{P} = \sum_{j}^{N} m_j \vec{v}_j,$$

where N is the number of objects in the system and m and $\vec{v}$ are the mass and velocity of each of the objects. Conservation of momentum indicates that the total momentum of the system does not change with time if the next external force on the system is 0. In other words,

$$\vec{P}_i = \vec{P}_f,$$

where $\vec{P}_i$ is the initial total momentum and $\vec{P}_f$ is the total momentum at some later time (e.g., after a collision). All *conservation laws* work this way: the total amount of some quantity (in this case momentum) remains the same.

1.1. Elastic collision with equal masses

Orient the carts so that their magnets repel each other. Roll one cart toward the other. The target cart is initially at rest. The mass of each cart should be approximately equal. Just from visually observing the collision, what seems to have happened? (Was momentum conserved, and how do you know?)

1.2. Mirror symmetry

Now repeat the collision from 1.1, but do everything as a mirror image. The roles of the target cart and incoming cart are reversed, and the direction of motion is also reversed. What did you observe during the collision?

1.3. An explosion

Now start with the carts held close together, with their magnets repelling. Make sure to leave a little gap between the carts so that the velcro doesn't stick. As soon as you release them, they'll fly apart due to the repulsion of the magnets. What do you observe during the "collision"? Was momentum conserved?

1.4. Head-on elastic collision

Now try a collision in which the two carts head towards each other at equal speeds (meaning that one cart's initial velocity is positive, while the other's is negative). Have the magnets point toward each other, so that the carts don't quite collide with each other. What do you observe during the collision?

1.5. Unequal masses

Now put a mass on one of the carts and leave the other cart with no additional mass. Make the heavier cart hit the initially stationary cart without additional weight. Does it appear that momentum is conserved? What if the lighter cart hits the heavier cart? Describe what you observe.

1.6. Sticking (perfectly inelastic collisions)

Arrange a collision in which the carts will stick together rather than rebounding. You can do this by letting the velcro ends of the carts hit each other instead of the magnet ends. Make a collision in which the target is initially stationary. What do you observe during the collision?

PART 2: PERFECTLY INELASTIC COLLISIONS

You will now repeat part 1.6 by making quantitative measurements with the LoggerPro software and motion sensor. Using the motion sensor, collect the initial velocity and final velocity of the carts during an inelastic collision. Make sure that your track is as level as possible.

2.1. For this part of the lab you should submit plots of velocity vs. time, momentum vs. time, and kinetic energy vs. time. To do this you will need to export the data to MATLAB, determine the point in time at which the collsion occurred, and calculate the momentum and energy before and after the collision.

2.2. In this experiment, the initial velocity of the target cart is $\vec{v}_2 = 0$. After the collision, the carts move at the same velocity, so that $\vec{v}_{1,f} = \vec{v}_{2,f}$. Use conservation of momentum to derive an equation relating $\vec{v}_{1,f}$ to $\vec{v}_{1,i}$. Is this consistent with your observations?

2.3. In class we'll see that the total energy of a system is constant ($\Delta E = 0$) if there are no external forces acting on the system. There are several different types of energy. Energy associated with motion is referred to as kinetic energy and is given by $K = \frac{1}{2}mv^2$, where v is the speed of the object. The total kinetic energy of the system is the sum of the kinetic energy of all of the objects within the system. Did the kinetic energy of the system change during this collision (i.e., was it converted to thermal energy)? If so, what percent of the kinetic energy was "lost"?

2.4. After the collision you should see that the speed of the (combined) carts decreases due to friction. During this deceleration, what is the average rate at which kinetic energy is converted to thermal energy? (HINT: Look at how the kinetic energy is changing with time.)

PART 3: ELASTIC VS INELASTIC COLLISIONS
You will now compute the change in total kinetic energy during a collision for two different collisions. The set-up is similar to part 2. For both collisions, you will give the parts an initial velocity toward each other (try to push them with roughly the same speed) and you will need to use two motion sensors to record the motion of both carts.

In the first collision, make sure that one of the carts is a dynamic that has a spring (but don't load the spring). The spring should get compressed during the collision. This type of collision is a (general) inelastic collision.

In the second collision, orient the carts' magnets so that the carts don't actually make contact with each other during the collision. This type of collision is referred to as an elastic collision.

3.1. For both collisions you should produce plots of the total kinetic energy vs. time and the total momentum vs. time.

3.2. Describe the changes in kinetic energy and momentum during the collisions. What is a defining characteristic of elastic collisions?