PHYS S123: College Physics I
Lab 7: Momentum and Energy
10/21/25 (due 10/28/25)

Name(s):

Topics:

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

In this lab, you will use collisions between carts to explore the concepts of conservation of momentum and conservation of 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. [6 pts]
- Part 3: Plots of total momentum vs. time and total kinetic energy vs. time. [6 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, $\vec{P}$, 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

A perfectly inelastic collision is one in which two or more objects stick together, such as in part 1.6. This type of collision results in a large drop in the total kinetic energy of the system, K_{tot}, which is given by

$$K_{tot} = \sum_{j}^{N} \frac{1}{2} m_j v_j^2$$

where v is the speed of each object. Kinetic energy is energy associated with motion.

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 both carts during an inelastic collision. The motion sensors will point in opposite directions. Since velocity is a vector, you will need to reverse the sign of one of your data sets to ensure that you are consistent with how you define positive velocity. Make sure that your track is as level as possible.

2.1. Submit the following graphs:

- Velocity vs. time: Plot the velocity of both carts on the same graph.
- Momentum vs. time: Plot the momentum of both carts as well as the total momentum on the same graph.
- Kinetic energy vs. time: Plot the kinetic energy of both carts as well as the total moment kinetic energy on the same graph.

Be sure to label the axes and individual lines.

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. 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 carts an initial velocity toward each other (try to push them with roughly the same speed) and again 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 cart 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. As in part 2, you will need to be careful when calculating the momentum since momentum is a vector (i.e., the sign of the velocity matters) and the motion sensors that you are using to observe the carts are pointing in opposite directions.

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