Name: ________________________

Partner(s): ________________________

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Date: ________________________

Collisions

1. Purpose:

The purpose of this lab is to verify the conservation of momentum during a collision of two carts on an airtrack, as well as to explore different kinds of collisions, including (nearly) elastic collisions and perfectly inelastic collisions.

2. Background:

The *momentum* of an object of mass m moving with velocity $\vec{v}$ is defined as

$$\vec{p} = m\vec{v} \tag{1}$$

The usefulness of momentum is that it is *conserved*: the total momentum which exists before any event must equal the total momentum after the event. This is particularly useful when we analyze collisions between objects, since it allows us to solve for the final velocities of the colliding objects without needing to calculate the forces they have on each other during the collision.

The *kinetic energy* of an object of mass m moving with speed v is:

$$KE = \frac{1}{2}mv^2 \tag{2}$$

Although the *total* energy is a conserved quantity, this does not mean that the *kinetic* energy is conserved during a collision, because one kind of energy can turn into another kind. In the case of collisions, it is very common for the kinetic energy to change into sound wave or heat energy. Thus, kinetic energy will generally be lost during a collision. Collisions can therefore be broken down into the following continuum, depending on how much kinetic energy is turned into other kinds of energy:

- *Elastic collisions* are collisions where, ideally, no kinetic energy is lost. At the microscopic level, it is possible for an ideal elastic collision to occur where absolutely zero kinetic energy is lost. For macroscopic objects (as in this lab), there will always be at least some kinetic energy lost and turned into other kinds of energy. Nonetheless, as long as the amount of kinetic energy which is lost is very small, we still generally call it an elastic collision.
- *Inelastic collisions* are collisions where a substantial amount of kinetic energy has been turned into other kinds of energy.
- *Perfectly inelastic collisions* are those where the maximum amount of kinetic energy has been converted into other kinds of energy. It can be shown that perfectly inelastic collisions occur when the objects involved in the collision "stick together," essentially becoming just a single object moving at a single speed.

- What are your expectations for how the momentum and kinetic energy will change during an elastic collision? Include in your answer below not only your expectations according to the theoretical ideal conditions, but also include what you expect other, non-ideal effects (like friction) will have on these quantities.

- What are your expectations for how the momentum and kinetic energy will change during a perfectly inelastic collision, including non-ideal effects?

3. Procedure:

Set up your lab equipment as follows:

- Level the airtrack by adjusting the height of one or the other end as needed.
- If necessary, attach a flag to the top of both carts. It will make your life easier when setting up DataStudio (below) if the flags have *identical* lengths.
- Set up two photogates, one about a third the length of the track from one end and the other a third the length of the track from the other end.
- Set up DataStudio to collect velocity data from the two photogates. Display the velocity in each gate as a data table in DataStudio.
- Measure the length of the flags for your two carts. Put these flag lengths into DataStudio for *each* of the two photogates.
- Record the mass of each of your carts in the data table below. *Be sure to remember which cart has which mass!* If you have a cardboard flag, you can write a '1' or '2' on it.

4. Data:

Mass of carts:

m_1= ________________ m_2=_________________

Elastic collisions:

Do the following:

- Place the two carts at the ends of the track such that one or both carts have a *metal bumper facing the other cart*, such when they collide they will bounce off each other.
- Have each lab partner push a cart (rather gently; don't get crazy with the speed of the carts!) towards the center at the same time such that they collide between the two photogates.
- Allow the carts to pass back through the photogates after the collision.
- If you have set up DataStudio correctly, you should now have two speeds for each cart; its initial speed before the collision and final speed after the collision. Record this data in the data table below. *Since velocity is a vector, be sure to use + and – signs as needed! Also, be sure you know which cart mass and flag length matches up with which photogate!*
- Repeat this procedure 5 more times.

Trial	Initial v_1	Final v_1	Initial v_2	Final v_2
1				
2				
3				
4				
5				
6				

Perfectly inelastic collisions:

Do the following:

- Place cart 1 on one end of the track and cart 2 in the center between the photogates. Arrange things as needed so that the carts will stick together when they collide.
- Push cart 1 (gently!) towards cart 2.
- Allow the two carts (now stuck together) to pass back through the photogate after the collision.
- If you have set up DataStudio correctly, you should now have the speed of cart 1 before the collision and the speed of both carts together after the collision. Record this data in the data table below.

When the two carts stick together, there will also be two flags, so you will have two velocity measurements when these two flags move through the second photogate. If the two velocity measurements disagree, which of the two should be more accurate, *and why?*

- Repeat this procedure 5 more times.

Trial	Initial v_1	Final v_1	Initial v_2	Final v_2
1				
2				
3				
4				
5				
6				

5. Analysis:

Elastic collisions:

Calculate the quantities in the table below using your data for elastic collisions. For the % change columns, be sure to include the sign; positive if the quantity increased, and negative if it decreased.

Trial	Total Momentum			Total Kinetic Energy		
	Initial	Final	% change	Initial	Final	% change
1						
2						
3						
4						
5						
6						

- Does your data match the expectations you had in Part 2 (Background)? Explain.

Perfectly inelastic collisions:

Now fill out the table below using your data for perfectly inelastic collisions.

Trial	Total Momentum			Total Kinetic Energy		
	Initial	Final	% change	Initial	Final	% change
1						
2						
3						
4						
5						
6						

- Does your data match the expectations you had in Part 2 (Background)? Explain.

6. Questions:

1. Suppose that an object with velocity $\vec{v}$ collides elastically with a *much* heavier object (essentially infinitely heavier) sitting at rest. What will the final speed be of the light object be? Give arguments to justify your answer, and give a real-world example of such a collision.

2. What is the maximum possible amount of kinetic energy which can ever be lost in a collision, as a percentage of the total amount of kinetic energy? Is it possible to lose 100% of the energy? Under what circumstances can you lose the maximum amount of kinetic energy? Justify your answer below, and keep in mind that momentum must always be conserved even when kinetic energy is lost.

7. Initiative:

Possible ideas:

- Develop *and carry out* an experiment to determine how much kinetic energy the metal bumper on the cart loses during a collision. You can do this with just one cart and one photogate. For a few different speeds of the cart, find the percentage of kinetic energy which is lost.
- Develop *and carry out* an experiment where you do an elastic collision where one of the carts is initially at rest. Do a few trial runs and test for momentum and kinetic energy conservation.
- Develop *and carry out* an experiment where you do a perfectly inelastic collision where both of the carts are initially moving. Do a few trial runs and test for momentum conservation while determining how much kinetic energy is lost.

8. Conclusions: