Elastic Collisions

Apparatus: Air track gliders (2 per track), air tracks, air supplies, air supply hoses & power cords, air track accessories kit, photogate stands, photogate heads, photogate interface cables, PASCO Science Workshop 750 Interface & Power Supplies.

Theory: Elastic collisions on an air track will be studied in today's experiment. According to theory

$$\vec{p_i} = \vec{p_f}$$

where $\vec{p_i}$and $\vec{p_f}$ are respectively the combined initial and final momenta of all objects involved in the collision.

For an elastic collision the objects will bounce off each other and each travel with a different final velocity. For elastic collisions the following equations hold true:

$$m_1\vec{v}_{1i} + m_2\vec{v}_{2i} = m_1\vec{v}_{1f} + m_2\vec{v}_{2f}$$

$$m_1v_{1i}^2 + m_2v_{2i}^2 = m_1v_{1f}^2 + m_2v_{2f}^2 .$$

Don't forget that velocities can be positive or negative (they are vectors).

For a 1D problem, the vector sign can be dropped (assuming one uses +#'s for forward momentum and -#'s for backward momentum). The percent change in momentum can then be calculated using the following formula:

$$\%\Delta p = \frac{(p_f - p_i)}{p_i} \times 100\%$$

Similarly the percent change in kinetic energy can be written as

$$\%\Delta K = \frac{(K_f - K_i)}{K_i} \times 100\%$$

where $K_i = \frac{1}{2}m_1v_{1i}^2 + \frac{1}{2}m_2v_{2i}^2$ and (for the elastic case) $K_f = \frac{1}{2}m_1v_{1f}^2 + \frac{1}{2}m_2v_{2f}^2$.

If a physical quantity is conserved, what should be the percent change in that physical quantity? The answer to that question is the hypothesis of today's lab.

Set-up for elastic collisions:

- Set up the glider with bumpers on each end.
- Put flags on each glider.
- Attach bumpers to either side of one of the gliders.
- Attach the small metal fins to each end of the other glider.
- Be sure that both ends of the air track have a stopper on them.
- The glider that has bumpers on both sides of it will bounce off the stoppers. On the end of the air track that stands to be impacted by the other glider (the one with two metal fins), you will need to place the last bumper.
- Set up photogates to act as timers for each glider. Use the appendix on Data Studio to set up the photogates properly.
- Turn on the air supply and verify it is level. The gliders should stay relatively motionless.

Perform the following elastic collision experiments:

- 1D elastic collision with two objects of equal mass, one initially at rest. **Be sure to mass the gliders with all the attachments on them or you will get inaccurate results!**
- 1D elastic collision with two objects of unequal mass, one initially at rest. First try a heavy glider hitting a stationary light glider. **Be sure to symmetrically weight the glider.**
- 1D elastic collision with two objects of unequal mass, one initially at rest. Now try a light glider hitting a stationary heavy glider. **Be sure to symmetrically weight the glider.**

For each experiment record the mass of each glider and the velocity for each glider (before AND after the collision). **Be sure to record the masses of the gliders with all the attachments on it (or your data could be off significantly).**

Conclusion:

1. The air tracks are not completely frictionless. Obviously both measurements are lowered by friction. Since we don't really care about what initial speed is used, it really only impacts the second measurement in our system. Will friction make $\%\Delta p_{exp}$ more positive or more negative? Will it make $\%\Delta K_{exp}$ more positive or more negative?
2. During the collision of a heavy mass with a stationary light mass state which object:
   - has the greater force acting on it
   - has the longer collision time
   - has the largest acceleration
   - has the largest change in momentum
3. How do your answers to the above question change if it is a stationary heavy mass that is hit by a moving light mass?
4. According to theory what should be the $\%\Delta p$ for an elastic collision? Assuming 5% precision, did each experiment match theory?
5. According to theory what should be the $\%\Delta K$ for each elastic collision? Assuming 5% precision, did each experiment match theory?
6. Suppose your collision was not elastic but actually perfectly inelastic. Derive a result showing that

$$\% \quad \Delta K = \frac{-m_2}{m_1 + m_2} \times 100\%$$

The second page of the Inelastic Collision experiment gives some hints on how to do this derivation.

Energy is conserved in the universe. Our experiments in the lab always show a slight loss of energy. Where does the "lost energy" go in these problems?