College Physics I
Lab 6: Collisions

Taner Edis and Peter Rolnick

Setup

Hook up *two* motion detectors to the green Vernier box. Make sure they are set to be used with carts. Then double-click on the Logger Pro application on the Desktop. Once it gets going, go the File menu and choose Open. Then go to folder Physics with Vernier. Select Momentum Energy Coll.cmbl.

Now put two magnetic carts on the low-friction track. Orient them so that they bounce off each other due to their magnetic repulsion, without touching one another.

Start with one cart at rest in the middle. Hit Collect and launch the other one toward the the one at rest.

You'll notice that 10 seconds is overly long for taking data. Go into the Experiment menu, choose Data Collection and adjust Length to a value you think is more suitable. You can then also get rid of the position window: expand the velocity graph to fit the whole screen. Then adjust the top and bottom values of the vertical axis to get your velocity graphs to fill the screen as much as possible in a typical run, showing as much detail as you can get.

Play with collisions for a few times, to make sure your display is right and that you understand everything displayed in the velocity graph.

Conservation of momentum

In this lab you will collide two carts on a low friction track. As long as friction is negligible, and as long as the track is perfectly horizontal, then the only forces involved will be those of the carts on each other. Since forces come in action-reaction pairs, whatever the carts do to each other, the net force on the system consisting of the two carts together should be zero. This means the total momentum of the system consisting of the two carts should be the same after the collision as it was before the collision.

The total momentum of the system is the momentum of one cart, $\vec{p}_1 = m_1\vec{v}_1$, plus the momentum of the other cart, $\vec{p}_2 = m_2\vec{v}_2$. Remember that $\vec{p}_1$ and $\vec{p}_2$ are vectors! If they point in the same direction then you add their magnitudes, but if they point in opposite directions you take the difference. In a one-dimensional case like this, dealing with vectors just means you have to be careful about whether your quantities are positive or negative.

To test for conservation of the total momentum

$$\vec{P} = \vec{p}_1 + \vec{p}_2 = m_1\vec{v}_1 + m_2\vec{v}_2$$

all you need to do is measure the mass of each of the carts, and find the velocities of each of the carts before and after the collision.

Conservation of kinetic energy in an elastic collision

In an *elastic collision* the total kinetic energy of the system after the collision is equal to the total kinetic energy of the system before the collision. Since the kinetic energy of an object of mass m and velocity v is $\frac{1}{2}mv^2$, you can calculate the total kinetic energy before and after. You just need to know the mass and velocity of each cart before and after the collision.

$$K = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$$

Part 1: Elastic collision

Since the carts have oppositely oriented magnets facing each other when they collide, hardly any energy is lost in the form of sound or heat. Therefore, to a good approximation, the collision is elastic.

Measure the mass of each cart. Also measure the mass of the metal bar you have: this can be placed on top of one of the carts to vary its mass.

As a first trial, do a collision where the carts have no extra bar on them, and where one cart starts out at rest at the center of the track. Decide (and use the software to read out exact values from the graph) what the values of your initial and final velocities are for each cart, for this collision. Remember that you are looking for the velocities immediately before and after the collision. Print out the graph of your velocities, and indicate your initial and final velocities.

Then perform two additional elastic collisions. Send a cart without a bar on it toward a cart with a bar at rest. Then send a cart with a bar on it toward a cart without a bar at rest.

From these data, find the total momentum and the total kinetic energy before and after the collision.

To hand in for part 1

All your velocity graphs, measurements and all results calculated from those measurements. In particular, clearly present:

- The total momentum before and after each collision, and the percentage of the original total momentum lost or gained during the collision,
- The total kinetic energy before and after each collision, and the percentage of the original total kinetic energy lost or gained.

Perfectly inelastic collisions

In an elastic collision, both total momentum and total kinetic energy is conserved. In an inelastic collision total momentum is conserved, but some of the initial total kinetic energy is lost in the collision to sound, heat, and perhaps work done to bend and break things.

There is, however, an extreme kind of inelastic collision in which you can know something, and that is one in which the maximum amount of kinetic energy allowed is lost. This is called a *perfectly inelastic collision.* In this case, the two carts are attached to each other after the collision; in other words, they move with exactly the same velocity.

Part 2: Perfectly inelastic collision

The simplest way to obtain a perfectly inelastic collision is to make the two carts stick together after the collision, using Velcro. Orient your carts so that they stick together after colliding, rather than magnetically bouncing off one another. Practice doing some perfectly inelastic collisions.

As a first trial, do a collision where the carts have no extra bar on them, and where one cart starts out at rest at the center of the track. Decide (and use the software to read out exact values from the graph) what the values of your initial and final velocities are for each cart, for this collision. Print out the graph of your velocities, and indicate your initial and final velocities.

Then perform two additional perfectly inelastic collisions. Send a cart without a bar on it toward a cart with a bar at rest. Then send a cart with a bar on it toward a cart without a bar at rest.

From these data, find the total momentum and the total kinetic energy before and after the collision. Did either of them change? If so, by what percent of the initial value? Did they increase or decrease?

To hand in for part 2

All your velocity graphs, measurements, and all results calculated from those measurements. In particular, clearly present:

- The total momentum before and after each collision, and the percentage of the original total momentum lost or gained during the collision,
- The total kinetic energy before and after each collision, and the percentage of the original total kinetic energy lost or gained during the collision.

How do these results compare with your results from part 1?