Conservation of Linear Momentum

Fall 2007

Purpose

You will create a collision between two carts on an air track to study both elastic and inelastic collisions and observe the extent to which linear momentum is conserved.

Introduction

If two objects collide with each other, the total momentum of the system (the two objects) is conserved if there are no outside forces – even though there are huge forces between them. We will study the (scalar) x component of the momentum, which can be positive or negative.

There are two types of momentum-conserving collisions: If the two objects stick together after collision, we refer to the collision as *inelastic*; if they move apart after the collision, we call the collision *elastic*.

Equipment Check

0. It is necessary to perform a brief equipment check, so that your results may be interpreted correctly (*actual phenomenon, or equipment problem?*).

   a. **Level track**: With the air supply turned on, place a cart in the middle of the track. It should remain relatively motionless. Place the cart at each end of the track, and again check for motion.
   b. **Timer test**: Set the photogates to the *gate* mode, 0.1 *ms*, and memory "on" (a red light comes on). Push each cart that will be used during the experiment, one at a time, on the track, letting it bounce back and forth. The times on each photogate should be within a few *thousandths* of each other. If there is a significant discrepancy, have the timer replaced. Note any minor inconsistencies you find (e.g. one time consistently reads higher than the other).
   c. **Cart test**: During the timer test, note if any cart slows down significantly. If so, have it replaced.

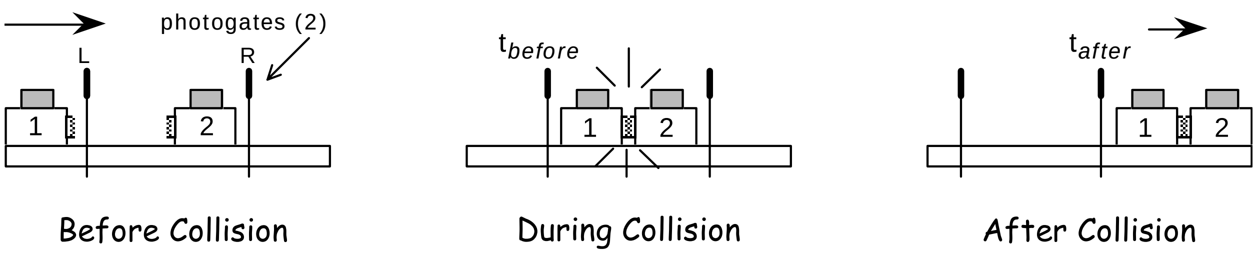
Perfectly Inelastic Collisions

Theory

In the inelastic collision you will perform, the colliding carts stick together and move off as though there were only one cart. The usual bounce, prevented by the Velcro, results in a large loss of kinetic energy, but the momentum should be conserved (*if there are no outside forces*).

Procedure

1. The inelastic collision will look like the sketch below. The arrow represents the direction of the carts motion, and the relative magnitude of the velocity:



2. Begin an initial data table like the one shown below (please include the track number as well). Sketch the *before*, *during* and *after* positions of the carts and timers in your report in order to *define the direction of each velocity* and to know which timer is recording which cart. Leave room for *at least* 10 collisions.

Data Table: Inelastic Collision **Track #_____**

	Left Photogate (L)	Right Photogate (R)
Trial	t_{before} (s)	t_{after} (s)
1	—	—
…	—	—

3. Use the carts *without* bumpers, and place a single 50 *g* mass on each. Put the carts on the track with the Velcro strips facing each other so that the carts will stick together after collision.

   With one cart motionless between the photogates, launch the other cart into it (be sure to perform the collision from *left* to *right*, as shown). The left photogate will measure the time the flag interrupts the beam for the single cart moving in (t_{before}); the right photogate measures the time for the ***pair*** to move out (t_{after}). Perform *ten* inelastic collisions, recording times for each collision in your initial data table. Try collisions at different speeds; later you'll use a spreadsheet to analyze all your data, and it will be interesting to note any dependence upon speed.

4. Measure the mass (cart + flag + extra mass) and flag length of each cart (use a vernier caliper). Enter one trial from your data table into a calculation table (below) and compare the total momentum before and after the collision. Note: you might consider a collision other than the first, since your procedure will improve as the experiment progresses. Make your calculation table large enough to incorporate corrections!

Calculation Table ***Trial #_____***

	m (kg)	ℓ_{flag} (m)	t_{before} (s)	t_{after} (s)	v_{before} (m/s)	v_{after} (m/s)	p_{before} (kg•m/s)	p_{after} (kg•m/s)
Cart 1								
Cart 2								
						Total ⇒		
						%Change⇒		

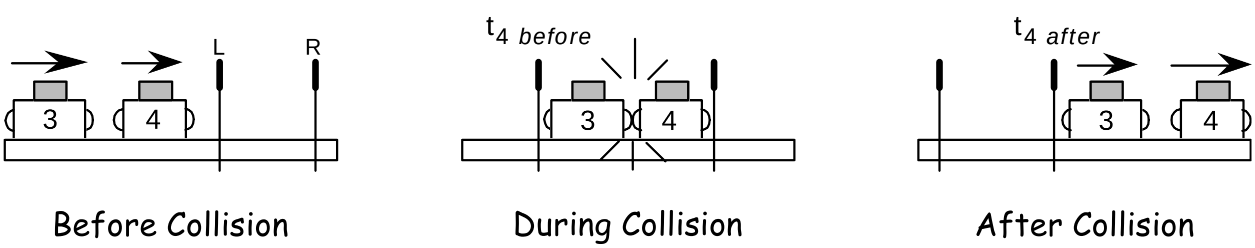
Perfectly Elastic Collisions

Theory

In the elastic collision you will perform, the colliding carts bounce off each other, then continue in the same direction. Both kinetic energy and momentum should be conserved (again, *if there are no outside forces*). *Note that it is **essential** that these collisions occur **between the two photogates** in order to obtain reasonable results!*

Procedure

5. For this collision you will use the carts *with* two attached bumpers. Place a 50 *g* mass on one cart (m_3), but *no additional mass* on the other (m_4), and place them on the track as shown above (in the sketch, $m_3 > m_4$). **Note:** The spreadsheet you will use later to analyze your data assumes that the cart motion moves from *left* to *right*. Be sure to perform your collisions in this manner!



6. During this collision, each photogate will have two carts pass through; therefore, each timer will record two time intervals. After a trial collision, the displayed time on the *left* photogate will be for cart 4 *before* collision ($t_{4\ before}$). Pull the memory switch on the timer to "read" and release to display the *sum* of the times for carts 4 and 3 ($t_{L\ total}$). To get the time before collision for cart 3 ($t_{3\ before}$), subtract the two values. The same reasoning holds for the right photogate, revealing the time for each cart *after* collision. Sketch the cart positions above, and create a data table as shown on the next page to keep track of the times.

Data Table: Elastic Collision

	Left Photogate (L)			Right Photogate (R)		
Trial	$t_{4\,before}$ (s)	$t_{L\,total}$ (s)	$t_{3\,before} = t_{L\,total} - t_{4\,before}$ (s)	$t_{4\,after}$ (s)	$t_{R\,total}$ (s)	$t_{3\,after} = t_{R\,total} - t_{4\,after}$ (s)
1	—	—	—	—	—	—
…	—	—	—	—	—	—

7. Both carts will be traveling in the same direction. Launch cart 4 first, then launch cart 3 so that the collision takes place between the photogates. *Do not allow the carts to pass through the photogates a third time!* Sketch the before and after positions as well as which timer is timing which cart. Perform this collision 10 times, recording your measurements in the data table (again, try collisions at different speeds).
8. Construct *another* calculation table, transfer the four times from one trial, measure the cart masses again and calculate the total momentum before and after collision.

Further Analysis

9. Open the Excel spreadsheet *Conservation of Momentum* (located in T:\Phys151 – click "Enable Macros") and carefully read the instructions on the first page. You will use this spreadsheet to quickly perform momentum calculations for *all* the collisions you performed (go through your data table in the order the collision data was collected, so that trial numbers match up; be sure to double-check the results of your collisions calculated by hand. If there's a discrepancy, you should find the cause!). Be sure to indicate the trial that was used for hand calculations on the printout of your collisions.

   Note: The spreadsheet assumes that the cart motion moves from *left* to *right*. Be sure to perform your collisions in this manner!

10. You'll want to add your names to the results of your calculations before printing; do this as follows:
    a. Click the "View/Print Results" button on the Elastic or Inelastic collisions sheet (note that you'll have to perform these steps for *both* sets of collisions); a preview of the output appears.
    b. Click the **Setup...** button, then the **Header/Footer** tab. Next click the **Custom Header...** button, and replace "[Your names here!]" in the "Center Section" box.
    c. Clicking **OK** twice will return you to the print preview window. Click the **Print** button, and print a copy for each member of the group.

Discussion

- As always, begin by restating your numerical results. In this case, it is not necessary to repeat each momentum value; however, you should state the average loss of momentum percentage (assuming your results were consistent – don't average in results from a bad collision)
- Look at the results for all the collisions you performed. Do you notice any trends in the data (e.g. did slow collisions show a greater loss of momentum?). How consistent were the results with each other?
- Conservation of momentum should not depend on the type of collision but only on whether or not there are outside forces acting on the system. Apply this principle to a discussion of your results for the two types of collisions you studied in this lab. You can be sure that if momentum was not conserved in either collision, there must have been an external force. An interesting point is that since an external friction force is always opposite to the velocity, friction can only *reduce* the magnitude of the momentum.