Conservation Of Linear Momentum

Fall 2007

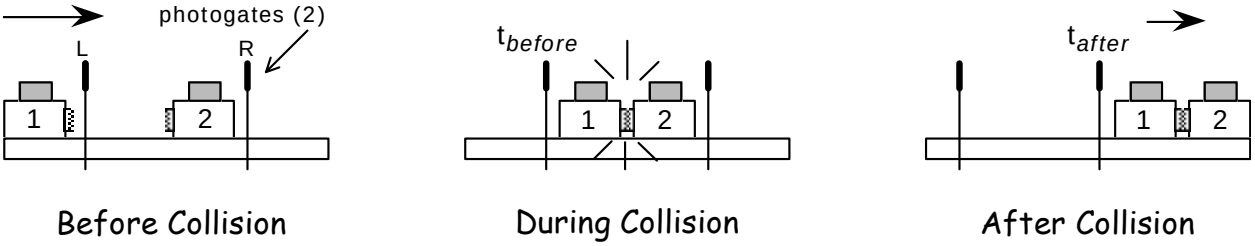
Introduction

The purpose of this lab is to measure the momentum before and after a collision to see the extent to which momentum is conserved. Both *elastic* and *inelastic* collisions will be studied. If there are *no external forces* during the collision of two or more masses, the total momentum before and after collision is always the same number. This result is found for both types of collisions. However, kinetic energy is conserved *only* during an elastic collision.

Equipment Check

1. It is necessary to first 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 both 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: *The carts stick after collision.*



2. Begin an initial data table (as shown below) in your report beneath a sketch of the *before*, *during* and *after* positions of the carts and timers; this will *define the direction of each velocity* and indicate which timer is recording which cart. Leave room to record data 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.

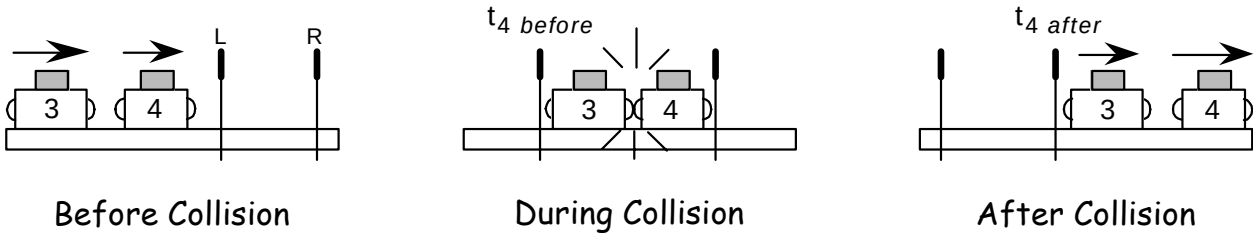
   With one cart motionless between the photogates, launch the other cart into it (be sure to perform the collision from *left* to *right*, as shown). The left photogate will measure the time the flag interrupts the beam for the single cart moving in (t_{before}); the right photogate measures the time for 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). Record these measurements in the calculation sheet (use *kilograms* and *meters* for the units).

5. Enter one trial from the initial data table above into the calculation sheet (each member of the group should check a different trial, in case you pick a 'bad' run). Calculate the velocity, momentum, and kinetic energy of the carts before and after the collision (*show sample calculations in your report, not the calculation sheet*). Be sure to indicate which trial was used on the calculation sheet. Note that momentum does not have a special 'named' unit assigned to it; simply use $kg \cdot {}^{m}\!/_{s}$.

6. Complete the summary table on the calculation sheet for the *total* momentum and kinetic energy before and after the collision.

Perfectly Elastic Collisions: *The carts rebound after collision.*



7. 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!

   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. Create a data table as shown below 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	—	—	—	—	—	—
…	—	—	—	—	—	—

8. 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).
9. Again transfer the times from one trial to the calculation sheet, and calculate velocity, momentum and kinetic energy.
10. Fill out the summary table for elastic collisions.

Further Analysis

11. Open the Excel spreadsheet *Conservation of Momentum* (located in T:\Phys103 – 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!

Discussion

- For both types of collisions, the total momentum after collision should equal the total momentum before collision (i.e. a low percent difference). Was this the case for the collisions you performed? If not, speculate on the cause. (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.)
- For an elastic collision the kinetic energy is also conserved. Compare the kinetic energy loss between both types of collisions (what was the average loss percentage for each type?).
- Look at the results for all the collisions you performed. Discuss the consistency of your results, and any trends in the data that may have appeared (e.g. did slow collisions show a greater loss of momentum?).