Version 2

LAKE FOREST COLLEGE

Department of Physics

Physics 114 Experiment 10: Collisions v2 Fall 2024

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Preliminary Instructions

Create a folder for you and your lab partner. Save a copy of these instructions for each student to that folder. Include your name in the filename. Save one copy of the Excel template with both your and your partner's name included in the filename.

Experimental purpose of today's experiment

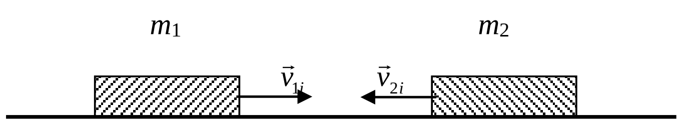
Determine if the momentum and/or kinetic energy is conserved in different types of collisions.

Pedagogical purpose of today's experiment

Study perfectly inelastic and nearly elastic collisions in one-dimension. Practice calculating total momentum and total kinetic energy.

Background

The translational kinetic energy of an object is a scalar quantity, defined as $K = \frac{1}{2}mv^2$. The momentum of an object is a vector quantity, $\vec{p} = m\vec{v}$. This experiment employs an air track, which yields one-dimensional motion: The direction of momentum is given by the sign of the component p_x. For collisions in which there is zero net external force, the *x*-component of the total momentum of a system remains constant. The total momentum of the system is the algebraic sum of the momenta of each of the objects; the signs matter! For *elastic* collisions, the total momentum remains constant and the total kinetic energy before the collision is equal to the total kinetic energy after the collision.



x component of total momentum before the collision $P_{ix} = m_1 v_{1ix} + m_2 v_{2ix}$

x component of total momentum after the collision $P_{fx} = m_1 v_{1fx} + m_2 v_{2fx}$

Total kinetic energy before the collision $K_i = \frac{1}{2}m_1\left(v_{1ix}\right)^2 + \frac{1}{2}m_2\left(v_{2ix}\right)^2$

Total kinetic energy after the collision $K_f = \frac{1}{2}m_1\left(v_{1fx}\right)^2 + \frac{1}{2}m_2\left(v_{2fx}\right)^2$

Two types of collisions will be studied. The goal is to see if $P_{ix} = P_{fx}$ and $K_i = K_f$ for each type.

Procedure

Part I. Setup

1. Preparation
    a. Carefully level the air track with an empty car (without any attachments on either side). This is particularly important in this experiment.
    b. Let Car 1 be the car that is closest to the Motion Detector connected to the DIG/SONIC 1 port of the LabPro interface. This car is closest to the air supply hose and the wall of the laboratory. This gives the red-colored curve on the velocity graph.
    c. Let Car 2 be the car that is closest to the Motion Detector connected to the DIG/SONIC 2 port of the LabPro interface. This gives the blue-colored curve on the velocity graph. "Blue is Two."
    d. The positive direction is away from the wall.
    e. Add a launcher attachment with a small flag to each car.
    f. Place the needle attachment in the *bottom hole* of Car 1 and the clay receptacle in the *bottom hole* of Car 2, so that the cars stick together after the collision. Later, the needle and the receptacle will be replaced by stretchable-band bumpers.
    g. Add one set of cylindrical chrome masses to Car 1 only.
    h. Adjust the rubber band at the launcher at Car 1 to give a greater speed than that of Car 2. See step 7 below.
    i. Check the leveling of the track with each of these cars separately. You may need to add clay to one end of the car to balance it. For each car, check that when they are released from rest, they remain at rest.

2. Download the "Exp 11 Collisions" Logger Pro file from Teams onto the computer desktop and then open the file.

3. Check the alignment of the motion sensors, by slowly launching the cars by hand while Logger Pro collects data. The velocity versus time curves should be smooth and with zero slope (except when the cars collide or a car gets very close to the sensor).

4. Turn on the power supply to the launchers (10 V). Close the switch and position the cars against the launchers. Open the switch and assure that the cars are launched smoothly. You may need to adjust the tension in the stretchable bands. *Turn the magnets off when not launching*.

5. **Paste a picture of the setup here. Label the important pieces**.

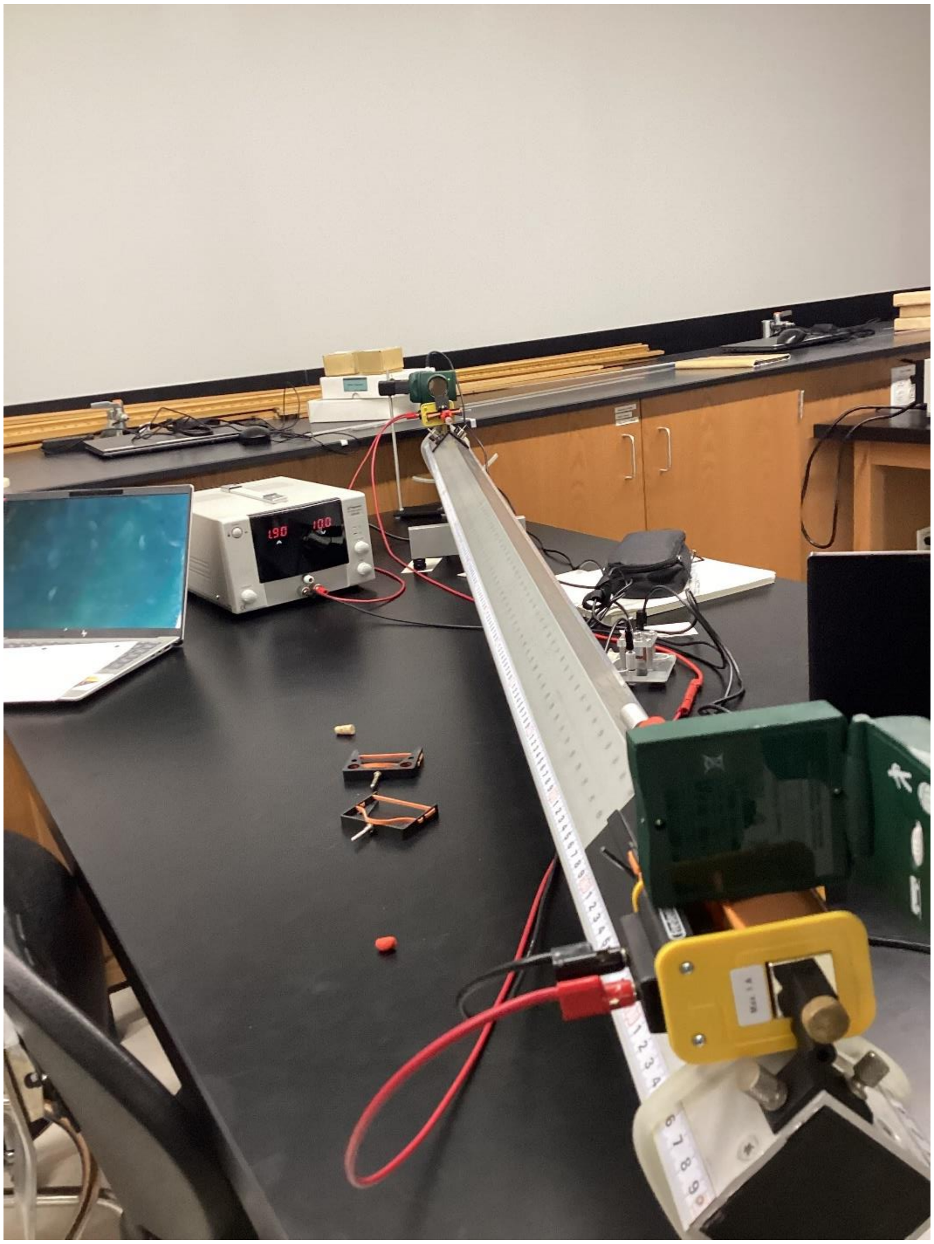


Figure 1. Collision Apparatus. One each end of the Pasco Scientific air track, there is a Vernier Motion Detector 2 and a Pasco Scientific electric launcher. Both electric launchers are connected to the same switch and powered by a Topward DC power supply. The apparatus is set up for inelastic collision. Cart 1, with added weights, is on the far side of the track with the needle attachment and cart 2 is on the near side of the track with the needle holder attachment. The attachments for elastic collision can be seen sitting on the lab bench. The colored sticky tack on the carts acts as a counterbalance.

Part II: Perfectly Inelastic Collisions

6. **Measure the mass of each car. Record these values in Part II of the spreadsheet (the perfectly inelastic collision worksheet).**

7. Arrange a collision between the two cars. You will tend to get better results if the initial speeds are not very large (v_{1ix} □ 0.4 to 0.5 m/s and v_{2ix} □ -0.4 to -0.3 m/s) and the speed of the cars after the collision is not too small (>0.05 m/s). Start the Logger Pro data collection and launch the cars towards each other.

8. Identify the location of the collision in these plots. Ensure that the data shown in each plot form nearly horizontal lines before and after the collision. Highlight the appropriate regions and use the “statistics” button to determine *x*-component of the average velocity of each car before the collision and after the collision. Record these values in the trial 1 row of your Excel spreadsheet. Note that when the cars stick together, they should have the same final velocity $v_{1fx} = v_{2fx}$.

9. Save the LoggerPro file to your folder. **Paste your graph here. Label or highlight the important parts of the graph** as mentioned in step 8.

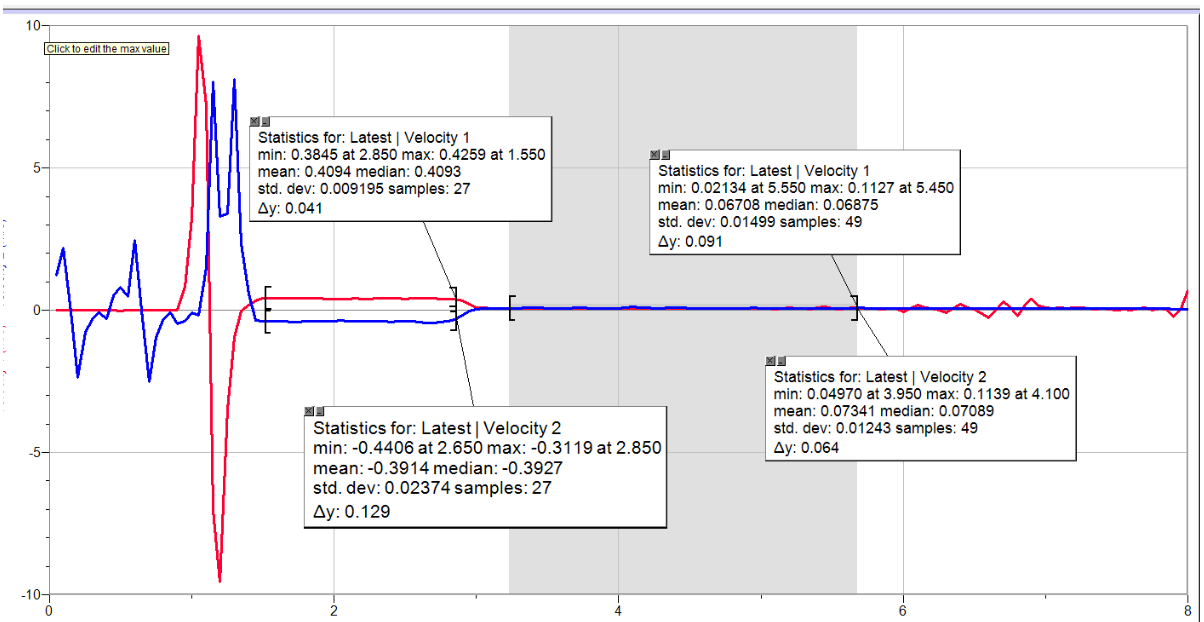


Figure 2. Inelastic Motion LoggerPro Graph Trial 1. The red line comes from the velocity of cart 1 over time. The blue line comes from the velocity of cart 2 over time. The carts start with independent initial velocity in opposite directions. The value of the initial velocities is represented by the first means. After the collision, the carts move together in the same direction

with almost the same velocity. The value of the final velocities is represented by the second means.

10. In Excel, calculate the *x*-component of the *total momentum* of the system before and after the collision and calculate the *total kinetic energy* before and after the collision. *Calculate these quantities and check your results before proceeding*.

11. Repeat this experiment a total of five times. Save each LoggerPro file to your folder, but you do not need to paste all of them into your report.

12. Find the average and standard deviation of the *x*-component of the total momentum before and after the collision and the total kinetic energy before and after the collision. Use the standard deviations of the five measurements as the absolute uncertainties.

13. Calculate the percent difference between the *x*-component of the total initial momentum and the *x*-component of the total final momentum. This tells us how far apart the values are but does not say if they agree with each other.

$$\text{Percent Difference} = \frac{X_f - X_i}{\left(X_f + X_i\right)/2} \quad \text{(Format cell in \%)}$$

    Calculate the ratio test value comparing the *x*-components of the total initial momentum and the total final momentum. This tells us if the difference can be accounted for by the statistical uncertainties.

14. Calculate the percent difference between the total initial kinetic energy and the total final kinetic energy. Calculate the ratio test value comparing the total initial kinetic energy and the total final kinetic energy.

15. **Paste part II of your Excel sheet here. Also paste a picture of the equations that you used in calculating these quantities**.

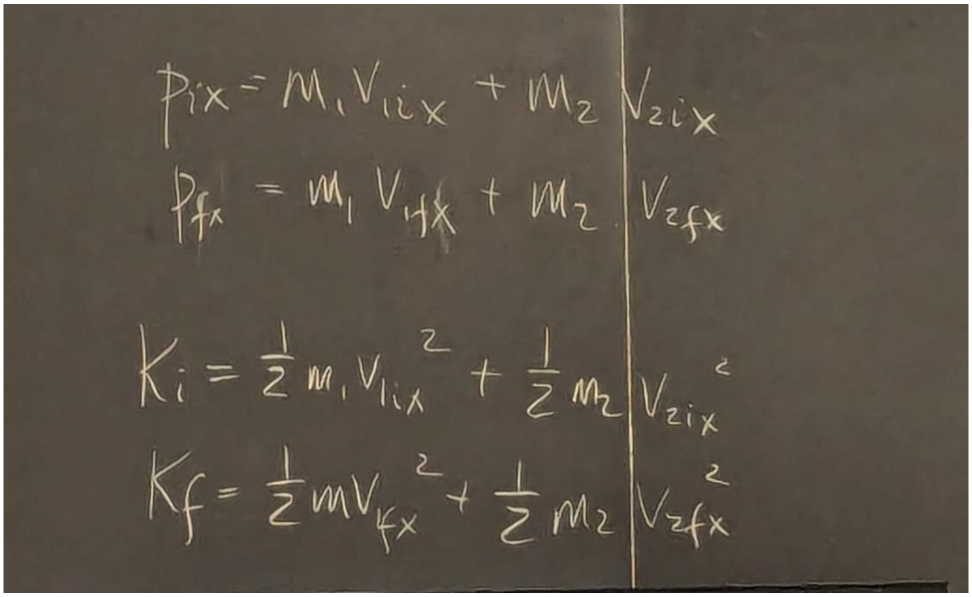


Figure 3. Momentum and Kinetic Energy equations. The subscript i represents initial. The subscript f represents final. The subscript x represents horizontal motion.

m_1 (kg)	m_2 (kg)
0.31049	0.20703

	initial values				final values			
trial	v_{1ix} (m/s)	v_{2ix} (m/s)	$p_{total\ ix}$ (kg m/s)	$K_{total\ i}$ (J)	v_{1fx} (m/s)	v_{2fx} (m/s)	$p_{total\ fx}$ (kg m/s)	$K_{total\ f}$ (J)
1	0.4094	-0.3914	0.04608	0.04188	0.06780	0.07340	0.03625	0.00127133
2	0.4207	-0.3903	0.04982	0.04325	0.07532	0.08061	0.04007	0.001553358
3	0.4040	-0.3822	0.04631	0.04046	0.07183	0.07167	0.03714	0.001332708
4	0.3886	-0.3858	0.04078	0.03885	0.06610	0.07007	0.03503	0.001186536
5	0.4085	-0.3880	0.04651	0.04149	0.06843	0.06738	0.03520	0.001196925
average initial values			0.04590	0.04118			0.03674	0.001308172
std. dev. of initial values			0.003	0.002			0.002	0.0001

Comparisons	
Total momentum percent difference	22.18%
Total kinetic energy percent difference	187.69%

Total momentum ratio test	1.730351839
Total kinetic energy ratio test	22.25240543

Table 1. Inelastic Motion Excel Table. 5 trials were conducted for inelastic motions. The last three trials were conducted twice to improve data, even so the momentum percent difference shows that the data does not match that well.

Part III: Nearly Elastic Collisions

16. Replace the needle and the receptacle with stretchable-band bumpers in the top hole of each car. For each car, check that when they are released from rest, they remain at rest. As in step 1i, you may need to add clay to one end of the car to balance it.

17. Remeasure the mass of each car. Record your data for this part in Part III of the Excel sheet (the nearly elastic collision worksheet).

18. Start the Logger Pro data collection and launch the cars towards each other.

19. Measure the *x*-component of the initial and final velocities on the graph.

20. **Paste a picture of your graph here and label the important features**.

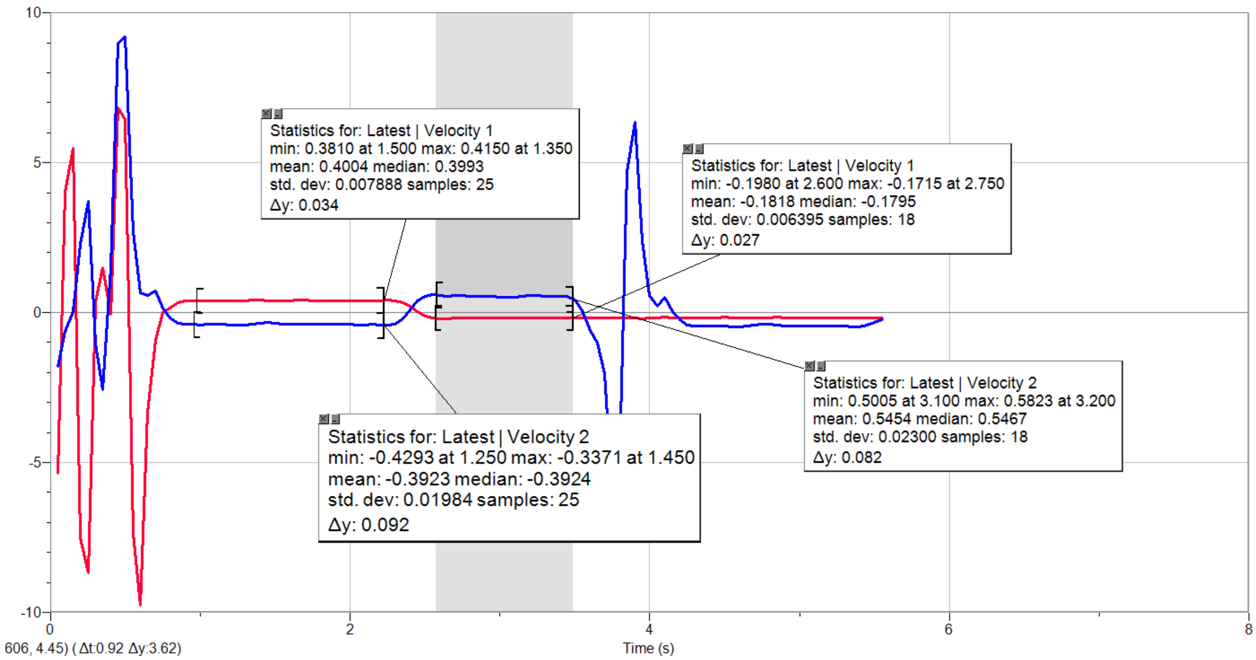


Figure 4. Nearly Elastic Motion LoggerPro Graph Trial 3 The red line comes from the velocity of cart 1 over time. The blue line comes from the velocity of cart 2 over time. The carts start with independent initial velocity in opposite directions. The value of the initial velocities is represented by the first means. After the collision, the carts rebound off each other and reverse direction. The value of the final velocities are represented by the second means. The moment that the carts reverse is the moment when both velocities equal 0.

21. In Excel, calculate the *x*-component of the *total momentum* of the system before and after the collision and calculate the *total kinetic energy* before and after the collision. Calculate these quantities and check your results before proceeding.

22. Repeat this experiment a total of five times. Save each of your Logger Pro files, but you do not need to paste them all into this report.

23. Find the average and standard deviation of the total momentum before and after the collision and the total kinetic energy before and after the collision. Use the standard deviations as the absolute uncertainties.

24. Calculate the percent difference and the ratio test value comparing the *x*-components of the total initial momentum and the total final momentum.

25. Calculate the percent difference and the ratio test value comparing the total initial kinetic energy and the total final kinetic energy.

26. **Paste part III of your Excel table here.**

m_1 (kg)	m_2 (kg)
0.33148	0.20819

initial values					final values			
trial	v_{1ix} (m/s)	v_{2ix} (m/s)	$p_{total\ ix}$ (kg m/s)	$K_{total\ i}$ (J)	v_{1fx} (m/s)	v_{2fx} (m/s)	$p_{total\ fx}$ (kg m/s)	$K_{total\ f}$ (J)
1	0.4030	-0.3958	0.0511 8	0.04322	-0.1879	0.5784	0.05813	0.04068
2	0.3973	-0.4006	0.04830	0.04287	-0.1884	0.5501	0.05207	0.03738
3	0.4004	-0.3923	0.05105	0.04259	-0.1818	0.5454	0.05328	0.03644
4	0.3989	-0.4134	0.04616	0.04416	-0.2020	0.5503	0.04761	0.03829
5	0.4034	-0.4005	0.05034	0.04367	-0.1915	0.5516	0.05136	0.03775027
average initial values			0.04941	0.04330			0.05249	0.03811
std. dev. of initial values			0.002	0.0006			0.004	0.002

Comparisons	
Total momentum percent difference	6.05%
Total kinetic energy percent difference	12.76%

Total momentum ratio test	0.518444907
Total kinetic energy ratio test	2.34761352

Table 2. Nearly elastic Excel table. 5 trials were done of elastic collision. None of the trials were redone. The momentum and kinetic energy were calculated with the same equations used for inelastic collision.

27. **Write an analysis here**. For Part II, what external forces are present that may cause systematic errors in our comparison of the initial and final momenta? If the initial and final kinetic energies do not agree with each other, then where did the energy go? For part III, why is the collision called "*nearly* elastic"?

In the inelastic collision the kinetic energy is not conserved as shown by the ratio test and percent difference. The energy of cart 1 is absorbed by cart 2 and the sticky tack in the needle holder. The excess kinetic energy, since cart 1 has a larger mass, reverses the direction of cart 2. The momentum of the inelastic collision should have been more conserved, and the ratio test supports that the value are similar, however the percent difference is relatively high. This may be because of the high standard deviation.

In the elastic collision both momentum and kinetic energy are conserved. The collision was not perfectly elastic so not all of the kinetic energy was conserved, the ratio test shows that the numbers are inconclusive for kinetic energy and the percent difference is relatively high. The momentum was conserved, as shown by the ratio test and the lower percent difference.

28. **Write a brief conclusion here**.

If the carts had the same velocity and the same mass in theory, they would just stop moving in an inelastic collision. In a perfectly elastic condition, they would reverse direction but retain the same velocity.

We has some issues with the motion detectors and we also had slight issues getting the electric launcher to hold cart 1 which may explain some of the issues with the data.

29. Adjust the formatting (pagination, margins, size of figures, etc…) of this report to make it easy to read. Save this report as a PDF document. Upload it to the course Moodle page.

30. Clean up your lab station. Put the equipment back where you found it. Remove any temporary files from the computer desktop. Make sure that you logout of Moodle and your email, then shut down the computers. Ensure that the laptop is plugged in.

31. Check with the lab instructor to make sure that they received your submission before you leave.