Elastic and Inelastic Collisions

Physics Topics

If necessary, review the following topics and relevant textbook sections from Serway / Jewett "Physics for Scientists and Engineers", 10th Ed.

- Kinetic Energy (Serway 7.5)
- Linear momentum and its conservation (Serway 9.1, 9.2)
- One dimensional collisions (Serway 9.4)

Introduction

You have been hired to investigate a car accident which occurred when the driver of one car was stopped at a stoplight. The driver claims that she was idling at the stoplight and her car was in neutral when she was rear-ended by another car. You have data on the tire skid marks of the two cars, which can help you determine their velocities. You also know the make and model of each car, which helps you determine their masses. To get a handle on the basic physics involved, you want to model the situation with a simple laboratory experiment. Given the masses of the cars, and the initial velocity of one car, can you predict the final velocities of the two cars in an elastic collision and a perfectly inelastic collision?

Pre-Lab Questions

Please complete the following questions prior to coming to lab. They will help you prepare for both the lab and the pre-lab quiz (Found on D2L).

Read through the entire lab manual before beginning

1.) What is the **specific** goal of this lab? Exactly what specific question are you trying to answer? Be as specific as possible. ("To learn about topic X..." is **not** specific!)

2.) What **specific** measurements or observations will you make in order to answer this question?

3.) Perfectly Inelastic Collision

(a) A perfectly inelastic collision is one where the two objects stick together after the collision. Draw two diagrams of the situation, one before the collision and one after the collision. Your diagram should show both cars. Let's call the car which is initially moving "1", while the car initially at rest is "2".

(b) What quantity or quantities are conserved in this problem? Explain how you know.

(c) Using the conservation law(s) you identified in the previous part, write one or more equations relating the masses of the cars m_1 and m_2, the initial velocity of car 1 (v_1) and the final velocity of the two cars v_f.

(d) Solve your equation(s) for v_f. You should now have a prediction for the final velocity of the two cars if you know the initial velocity of car "1" and both masses.

4.) Elastic Collision

(a) In an elastic collision, the cars do not stick together, but bounce off each other. In addition to this fact, what specifically characterizes an *elastic* collision? Make the most precise statement possible. (In other words, what is an elastic collision?)

(b) Prediction: If the car which is initially at rest is twice as massive as the initially moving car, what direction will each car move after the collision? Try to answer this question before completing the derivation below. It is not important that you get this prediction right, it *is* important that you think about it first!

(c) What quantity or quantities are conserved in this problem? Explain how you know.

(d) It may not be so obvious at first sight, but in one dimensional elastic collisions, the following relationship is satisfied:

$$\vec{v}_{1i} + \vec{v}_{1f} = \vec{v}_{2f} + \vec{v}_{2i}. \tag{1}$$

Here $\vec{v}_{1i}$ is the initial velocity of cart 1, and $\vec{v}_{1f}$ is the final velocity of cart 1. The notation is similar for cart 2. Note that in our problem, $\vec{v}_{2i} = 0$

Your goal is to write two equations, one for v_{1f} in terms of m_1, m_2 and v_{1i}, and another one for v_{2f} in terms of m_1, m_2 and v_{1i}. Combine equation (1) with the conservation law(s) you identified in the previous part to acheive this.

Apparatus

- Vernier Computer Interface
- Logger Pro Software
- Vernier Carts (2) with inserted magnets and velcro attachments
- Aluminum Track
- Vernier Motion Sensor (2)
- Additional masses

Procedure

1.) Measure and record the mass of each cart and any weights that will be used as attachments. As always, include an estimate of the uncertainty in these measurements.

2.) Setup

(a) Insert the two motion sensors into CH-1 and CH-2 of the Vernier Computer interface.

(b) Place a sensor at each end of the track. Rotate the pivoting head of the sensor so it is perpendicular to the table. Make sure that the switch on each sensor is set to "cart" mode.

(c) Open Logger Pro. The sensors should be recognized automatically.

(d) In **Experiment** → **Data Collection**, set the sampling rate to 10 samples / second (0.1 seconds per sample). Set the total duration to 5 seconds. Once you have made these changes click Done.

(e) Try taking data by clicking ▶. While the sensors are taking data, move the cart back and forth with your hand. Make sure that the graphs behave as you expect. If you are not seeing the appropriate response, try repositioning the sensor(s) and ask your TA for assistance if necessary.

3.) Perfectly Inelastic collision

(a) Set up the two carts with velcro pads facing each other so that they will stick together upon collision. Do not add any mass to either cart. Practice rolling cart "1" towards cart "2" **slowly** so that the two stick together after the collision. One member of your team should be ready to stop the two carts before hitting the sensor at the end of the track.

(b) When you think you have a reasonable technique, click ▶ (Collect) to start data collection, and then start cart "1" rolling on its collision course with cart "2".

(c) After data collection is finished, you should be able to see from the graph cart "1"'s velocity before and after the collision. If it is not obvious where the collision occurred, try taking data again.

(d) Use the LoggerPro software to measure cart "1"'s velocity before the collision and the final velocity of both carts after the collision. To do this:

i. Click and drag on the position graph to select the range of data you want to fit, then click **Analyze** → **Linear Fit**.

ii. You will be asked which column of data you want to fit. Select **Latest:Position 1** or **Latest:Position 2**, depending on which curve you are using. If the program only gives you the option of fitting **Velocity 1** or **Velocity 2**, click Cancel. Another dialog should then open allowing you to fit the position data.

iii. A best fit equation will be shown on the graph. Note that you can modify the range of data which is being used for the fits by clicking and dragging the black [ ] brackets.

(e) Store the latest data run by selecting **Experiment** → **Store Latest Run**.

(f) Add mass to cart "1". You should add enough mass so that the total mass of cart "1" increases by at least 50%. Record the new mass of each cart; then go back to step 3b and repeat all steps to measure the initial and final velocities for this set of masses. Note that you can show or hide different data sets on the graph by selecting **Data** → **Show Data Set (or) Hide Data Set**.

(g) Remove the mass from cart "1", and add it to cart "2" so that cart "2" becomes the heavier cart. Record the new mass of each cart; then go back to step 3b and repeat all steps to measure the initial and final velocities for this set of masses.

(h) You should now have 3 data sets for the three different mass carts in a single Logger Pro file. Save your Logger Pro file to the desktop of the computer with a descriptive name like *PCS211_Firstname_LastName_Inelastic.cmbl*. **Then copy the file to a USB key or e-mail it to yourself. All files will be deleted from the computers when you log off!**

4.) Nearly Elastic Collision

(a) Now that you have your "inelastic" data saved in a safe place (or e-mailed to yourself), start a fresh LoggerPro file by selecting **Data** → **Clear All Data**. Once the data is cleared, save the file to the desktop with a new name, for example *PCS211_Firstname_LastName_Elastic.cmbl*.

(b) Setup the two carts so that the magnets on the ends of the carts face each other. Check that when the carts are close, they repel each other. Do not add any mass to either cart. Practice rolling cart "1" towards cart "2" **slowly** so that the two bounce off of each other **without touching**.

(c) When you think you have a reasonable technique, click $\boxed{\blacktriangleright}$ (Collect) to start data collection, and then start cart "1" rolling on its collision course with cart "2".

(d) After data collection is finished, you should be able to see from the graph cart "1"'s velocity before and after the collision, and cart "2"'s velocity after the collision. If it is not obvious where the collision occurred, try taking data again.

(e) Use the LoggerPro software to measure cart "1"'s velocity before the collision and the final velocity of each carts after the collision as you did for the perfectly inelastic collision.

(f) Store the latest data set by selecting **Experiment** → **Store Latest Run**.

5.) Add mass to cart "1". You should add enough mass so that the total mass of cart "1" increases by at least 50%. Record the new mass of each cart; then go back to step 4c and measure the initial and final velocities for this set of masses. Note that you can show or hide different data sets on the graph by selecting **Data** → **Show Data Set (or) Hide Data Set**.

6.) Remove the mass from cart "1", and add it to cart "2" so that cart "2" becomes the heavier cart. Record the new mass of each cart; then go back to step 4c and measure the initial and final velocities for this set of masses.

7.) You should now have three sets of data for the elastic collision in a single Logger Pro file. **Save this file to the desktop, then copy to a USB key or e-mail it to yourself. All data will be deleted from the lab computers after you log off!**

Analysis

1.) Perfectly Inelastic Collision

(a) For the perfectly inelastic collision, calculate the value of v_f for each trial from your prediction equation. Compare with your measurements and calculate a percent error for each one. Watch out for minus signs! Remember that the motion sensors measure an object moving away from it as a positive velocity and an object moving toward it as a negative velocity. These signs may or may not agree with a particular coordinate system you have chosen with deriving your prediction equation.

(b) For each trial, calculate the momentum for the system of two carts before and after the collision. Is the momentum conserved? If not, what percentage of the initial momentum was lost in the collision?

(c) For each trial, calculate the kinetic energy for the system of two carts before and after the collision. Is the kinetic energy conserved? If not, what percentage of the initial kinetic energy remained after the collision?

2.) Nearly Elastic Collision

(a) For the perfectly elastic collision, calculate the value of v_{f1} and v_{f2} for each trial from your prediction equations. Compare with your measurements and calculate a percent error for each one.

(b) Calculate the momentum for the system of two carts before and after the collision. Is the momentum conserved? If not, what percentage of the initial momentum was lost in the collision?

(c) Calculate the kinetic energy for the system of two carts before and after the collision. Is the kinetic energy conserved? If not, what percentage of the initial kinetic energy remained after the collision?

Wrap Up

The following questions are designed to make sure that you understand the physics implications of the experiment and also to extend your knowledge of the concepts covered. Your report should seamlessly answer these questions in their noted sections.

1.) [Theory] For the collisions that did not conserve (kinetic) energy, what happened to that energy? Give a few possibilities.

2.) [Theory] Two particles collide: one of which is initially at rest. Is it possible for *both* of the particles to be at rest after the collision? If so, give the conditions under which this might occur. If not, explain why it is not possible.

3.) [Discussion] For the elastic collision: under what conditions will cart “1” bounce backward after the collision? Explain in words using your experimental data and your predicted equations.

Report

Here is a brief guide for writing the report for the lab. The report should include the following sections:

- **Title Page**
  - Include: Report Title, Your Name, Course, Section Number, Instructor, TA Name, and Date of Submission.
- **Introduction**
  - What is the experiment's objective?
- **Theory**
  - Derivations of the physics being investigated, or reference to a source that provides a description/equation representing the physics being investigated.
  - Providing graphs that illustrate or predict how the system under study is expected to behave.
- **Procedure**
  - Briefly explain the systematic steps taken for the experiment.
- **Results and Calculation**
  - Tabulate the measurements in an organized manner.
  - Based on the procedure, one should have a sense of how the tables will look like prior to taking measurements.
  - Graph the main results.
  - Provide examples of any calculations.
- **Discussion and Conclusion**
  - Discuss the main observations and outcomes of the experiment.
  - Summarize any significant conclusions.
- **References**
  - Very important to include to avoid plagiarism claims.
- **Appendices**
  - If large quantities of data are obtained, or lengthy details are needed, but break the overall flow of the report, they should be referenced and placed in the appendix.