PHY 221 Lab 7

Momentum and Collisions: Conservation of momentum and kinetic energy

Name:

Partner:

Partner:

Goals:

To be able to explore how different collisions between carts can be studied to illustrate concepts of conservation of momentum and conservation of kinetic energy.

To be able to differentiate between elastic collisions and inelastic collisions.

Introduction:

Momentum ($\boldsymbol{p}=m\boldsymbol{v}$ for a single particle of mass m and velocity $\boldsymbol{v}$) is a useful concept in physics. The most important reason that it is useful is that total momentum of any isolated object or system is *conserved* (that is to say, it does not change). The only way to change the value of the momentum is to act on the object or system with an outside force.

(Newton's 2nd Law $\boldsymbol{F}=m\boldsymbol{a}$ can also be written $\boldsymbol{F}=d\boldsymbol{p}/dt$, from $\boldsymbol{F}=0$ it follows $\boldsymbol{p}=const$)

Conserved quantities usually make it easier to solve some classes of physics problems. In this lab, you'll explore collisions, where thinking about momentum and its conservation are the key to understanding what goes on.

In preparation for this lab it is very important you do the Prelab pages 17-18. Please print out these pages and do them to be handed in at the beginning of Lab 7. Print outs of the whole lab will be available in class.

Materials:

Aluminum Track
Two carts with magnets
One cart with spring
Weight set
WEBCam and/or LabQuest and 2 motion detectors

*1. Elastic Collisions (the cars do **NOT** stick together)*

The following section will present you with four different two-cart collision scenarios. They differ only with respect to the initial velocities of the two carts (both speed and direction). Practice the collisions. The carts should not touch during the collision process. For each scenario you are asked to:

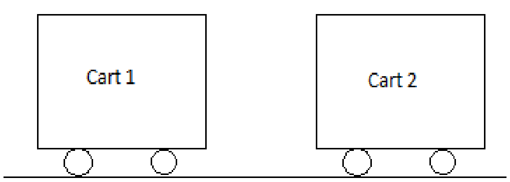
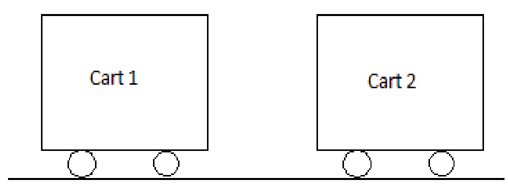
1) Predict the *relative* final velocities of the two carts given their *relative* initial velocities by **drawing velocity vectors** for both the initial and final states (lengths of vectors must be proportional to relative speeds).

2) Conduct an experiment using the WEBCAM to make ***quantitative measurements*** in those cases indicated to investigate your predictions. Make qualitative observations in all other cases. A ***qualitative estimate*** is based on the estimated time to travel a measured distance. You should be able to make a reasonable estimate without using quantitative measurement devices available in the lab, just your estimates of time and distance.

NOTE: To use the WEBCAM please consult the Appendix “Lab 7 Notes”

<u>**Scenario 1**</u>**:** Approximately the same ingoing velocities

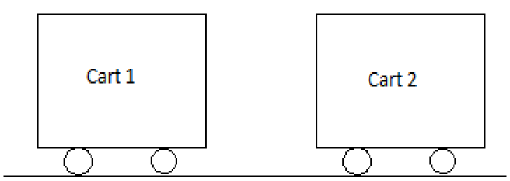
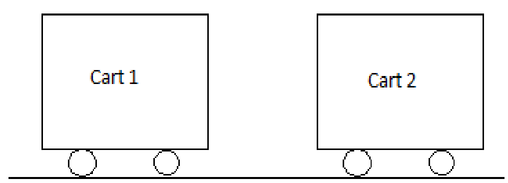
Make *qualitative* estimates of the velocities.

<table>
<tr><th><u>Initial State</u></th><th><u>Final State</u></th></tr>
<tr><td>Draw velocity vectors

</td><td>Draw velocity vectors

</td></tr>
</table>

Experiment	Experiment
$v_{1\,i} =$ $v_{2\,i} =$	$v_{1\,f} =$ $v_{2\,f} =$

Does your experiment confirm your prediction?

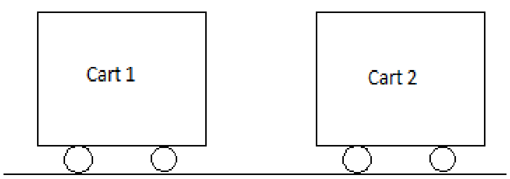
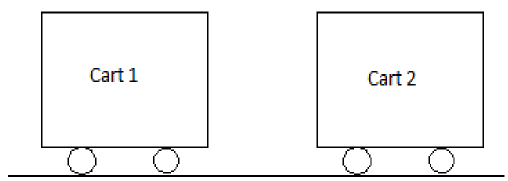
<u>Scenario 2</u>: One cart moving towards a second stationary cart.
Use the WEBCAM to make quantitative measurements of the velocities of each cart before and after the collisions.

<u>Initial State</u>	<u>Final State</u>
Draw velocity vectors  	Draw velocity vectors 
Experiment $v_{1\,i} =$ $v_{2\,i} =$	Experiment $v_{1\,f} =$ $v_{2\,f} =$

Did your experiment confirm your prediction?

Scenario 3: Both carts with ingoing velocities, but with one cart moving twice as fast as the other

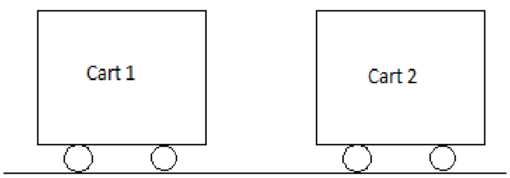
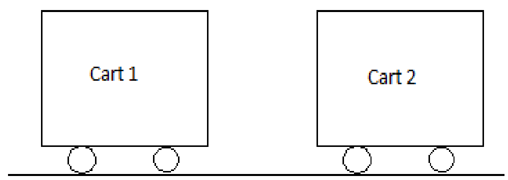
Use the WEBCAM to make quantitative measurements of the velocities of each cart before and after the collisions.

Initial State	Final State
Draw velocity vectors  	Draw velocity vectors 
Experiment $v_{1\,i} =$ $v_{2\,i} =$	Experiment $v_{1\,f} =$ $v_{2\,f} =$

Did your experiment confirm your predictions?

<u>Scenario 4</u>: The faster cart (*2v*) chasing the other cart (*v*), both traveling in the same direction

Make qualitative estimates of the velocities.

<u>Initial State</u>	<u>Final State</u>
Draw velocity vectors  	Draw velocity vectors 
Experiment $v_{1\,i} =$ $v_{2\,i} =$	Experiment $v_{1\,f} =$ $v_{2\,f} =$

Did your experiment confirm your predictions?

2. *Totally Inelastic Collisions.*

When a collision is inelastic, kinetic energy is *not* a conserved quantity. Total momentum of the system is still conserved however. Therefore, we are left with one equation (momentum conservation) and two unknowns (final velocity). In this case we cannot solve this problem for final velocities without additional information about what happened in the interaction.

One example of situation in which additional information is available, are *totally inelastic* collisions. In totally inelastic collisions, both objects *stick* to each other after the collision, therefore there is only one final velocity to find, $v_{1f} = v_{2f} = v_f$.

From conservation of momentum for totally inelastic collisions:

$$m_1 v_{1i} + m_2 v_{2i} = (m_1 + m_2) v_f$$

It can be shown that in totally inelastic collisions, the kinetic energy of the system is reduced by maximal amount possible.

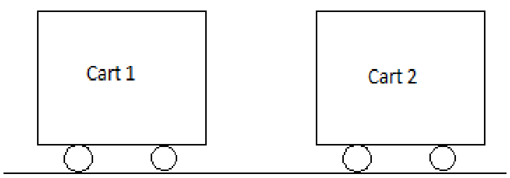
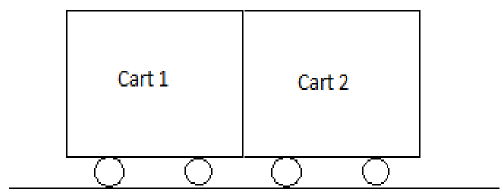
Let us consider carts of the same mass (do not use any weights on top of the carts). Write the above formula for this case:

To realize totally inelastic collisions we will use carts equipped with Velcro fasteners.

Please follow the same procedures as before for the following three scenarios:

Scenario 1: Equal and opposite ingoing velocities

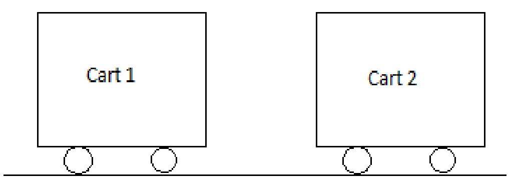
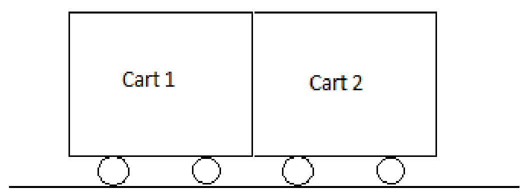
Make qualitative estimates of the velocities.

Initial State	Final State
Draw velocity vectors  	Draw velocity vectors 
Experiment $v_{1\,i} =$ $v_{2\,i} =$	Experiment $v_f =$

Did your experiment confirm your predictions?

<u>Scenario 2</u>: One cart moving towards stationary second cart

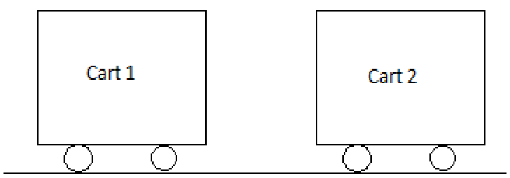
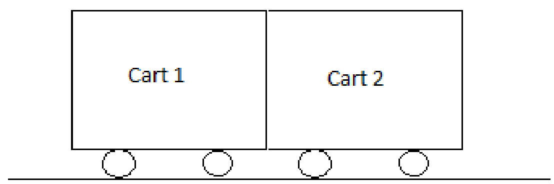
Make qualitative estimates of the velocities.

<u>Initial State</u>	<u>Final State</u>
Draw velocity vectors  	Draw velocity vectors 
Experiment $v_{1\,i} =$ $v_{2\,i} =$	Experiment $v_f =$

Did your experiment confirm your predictions?

<u>Scenario 3</u>: Faster cart (2v) chasing second cart (v), both moving in the same direction

Use the WEBCAM to make quantitative measurements of the velocities of each cart before and after the collisions.

<u>Initial State</u>	<u>Final State</u>
Draw velocity vectors  	Draw velocity vectors 
Experiment $v_{1\,i} =$ $v_{2\,i} =$	Experiment $v_f =$

Did your experiment confirm your predictions?

Lab 5 Appendix: Notes on using WEBCAM

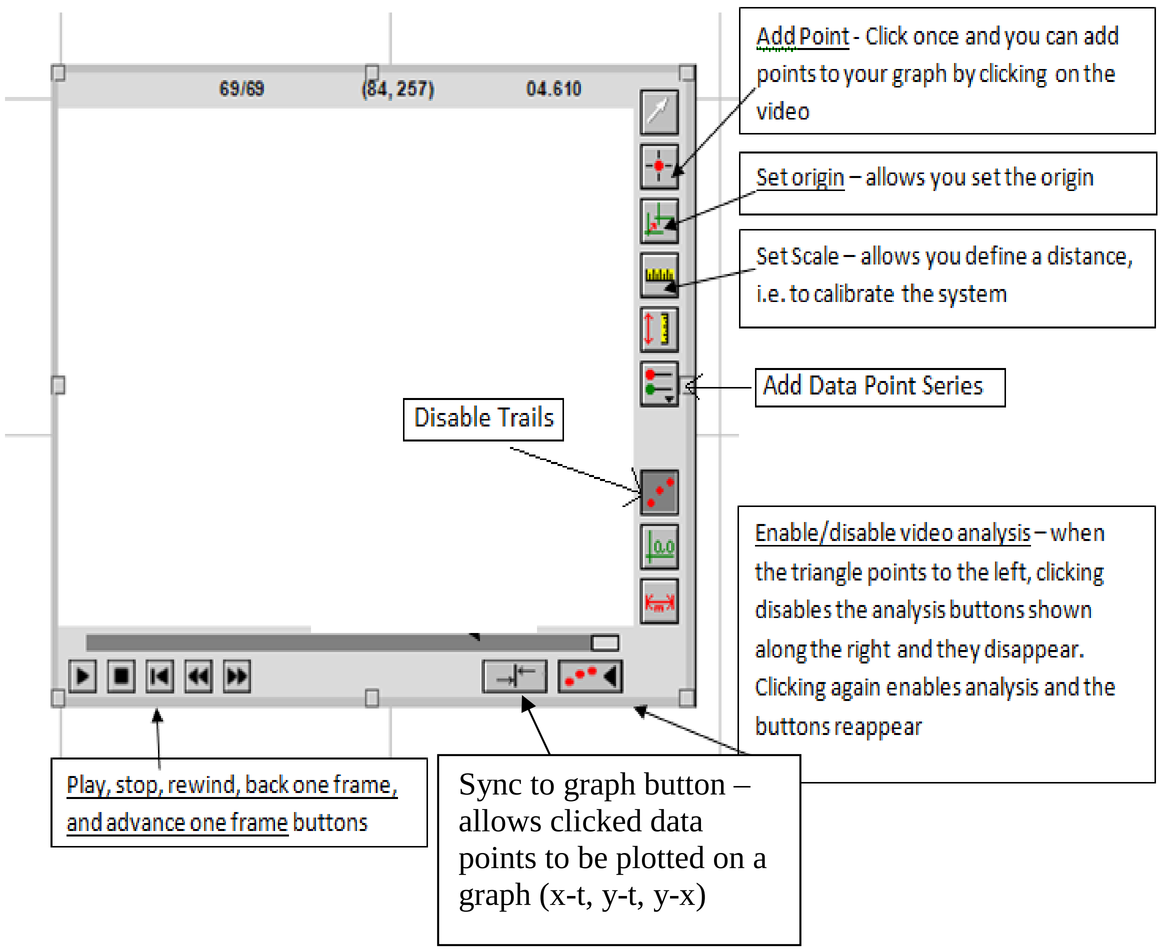
You have already analyzed motion of a *single cart* with the Web Cam and Logger Pro. You will now have to measure the velocities of *two* carts both *before* and *after* they collide. The following will guide you through this process which you will follow for each of the scenarios. This guide is *not* a step-by-step procedure, but rather a suggestion on how to most easily collect the data you require.

The Setup

1) Open Logger Pro 3.8.3 and then click "insert" and "video capture"
2) You'll need to be sure that the camera is facing the track and is as perpendicular to it as can be.
3) Take the video for which ever scenario you are going to analyze and be sure that in it you can <u>see both carts</u> before they collide *and* after they collide.

The analysis
<u>NOTE</u>: All the buttons described below can be found on the next page of this document.
1) Click the bottom-right button "Enable/disable video analysis" to allow analysis to occur.
2) Recall that you need four velocities: cart 1's initial and final velocities and cart 2's initial and final velocities. The easiest way to do this is to analyze the entire (initial and final) path of *one cart at a time*.
3) You will likely find it useful to click "Disable Trails" which will allow you to make new points without seeing all the points you just created.
4) Go ahead and "add points" from the video for *one cart only*. As you do this a graph will pop up for your viewing. Do *not* click any points when the video shows that the carts are actually colliding! We only care about points before and after the collision!
<u>Scale</u>: Normally for the scaling procedure you would have included a meter-stick in the video so that you could tell the computer the distances its looking at. You may still use this procedure. However, the carts are approximately 0.165m in length, so you may use this instead if you wish.
<u>Origin:</u> You can place the origin anywhere, but you'll likely find it more useful to place the origin at the first data point you created.
5) Now all you have to do is fit a linear function to the resulting graph in the areas that correspond to that cart's initial and final velocities. This is where *your group* must decide what to do. One part of the graph corresponds to the cart before the collision and the other part corresponds to the cart after the collision.
6) <u>Second cart analysis</u>: You'll first need to click "add data point series." Once you click this, any data points that you add will be under the designation "x2, y2" so you'll need to get the appropriate graph up by clicking "insert" and "graph."
7) Repeat the procedures above to find the velocities of the second cart's initial and final velocities.
NOTE: At any time, you may *keep* the current video and *delete* the data points by clicking

"Data" and then "Clear All Data"



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Pre-Lab Questions

Print *Your Name*

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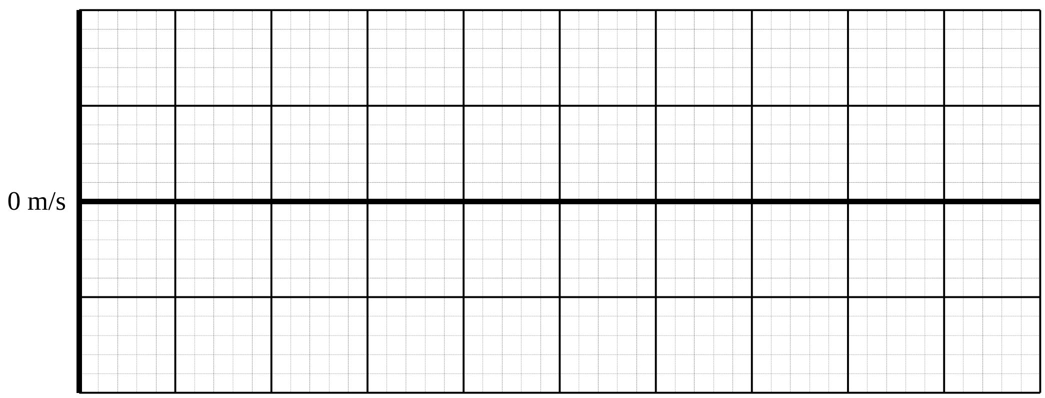
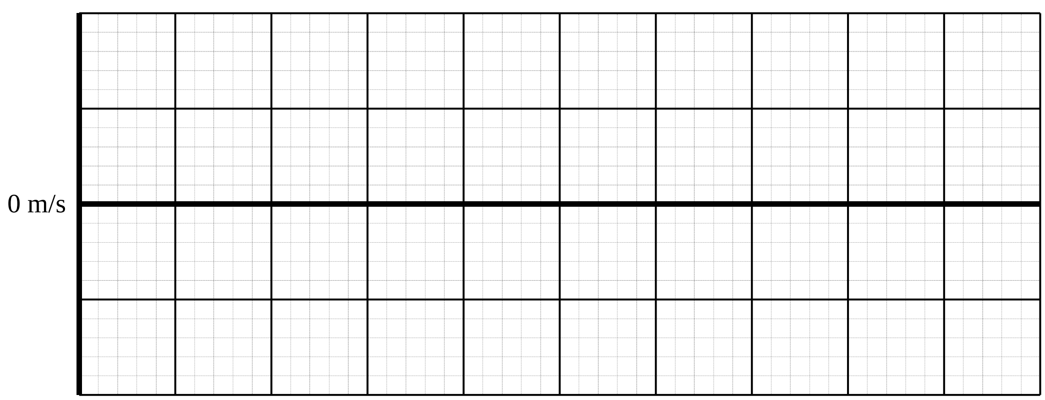
Read the *Introduction* to this handout, and answer the following questions before you come to General Physics Lab. Write your answers directly on this page. When you enter the lab, tear off this page and hand it in.

1. State the law of conservation of momentum, both in words and as a formula.

2. Billiard ball #1 is rolling directly toward billiard ball #2, which is motionless on the billiard table. Both balls have the same mass, and they hit exactly head on, which causes billiard ball #1 to come to a complete stop while billiard ball #2 is sent rolling forward in the direction that billiard ball #1 had been moving and with the same speed that billiard ball #1 used to have. On the two graphs below, plot velocity versus time for both billiard balls from a little before they collide until a little after they collide.

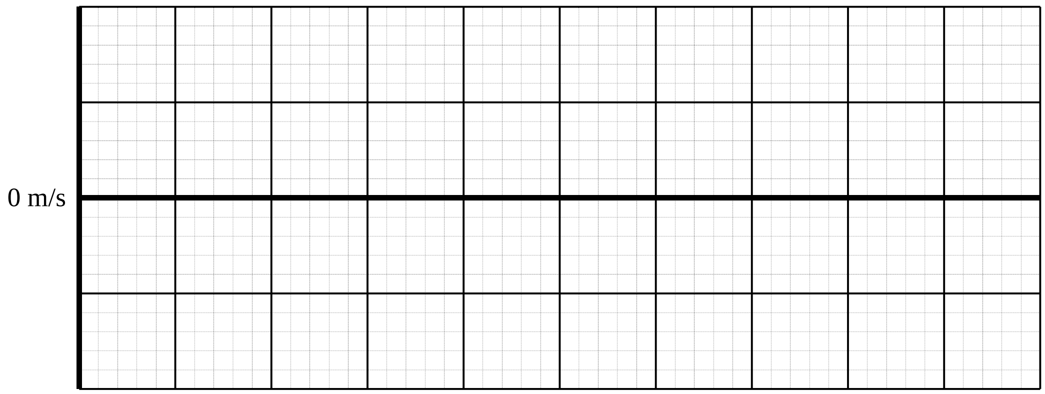


Velocity versus Time for ball #1

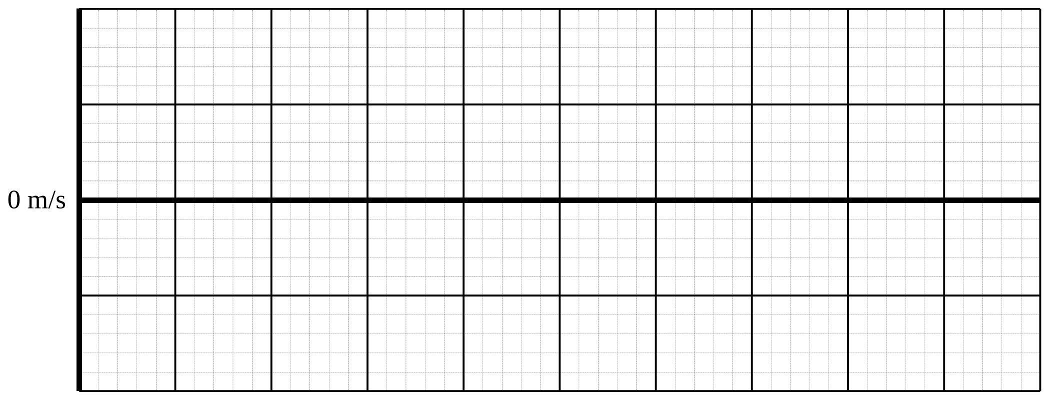


Velocity versus Time for ball #2

3. Now billiard ball #1 and billiard ball #2 are rolling directly toward each other. Both balls have the same mass and the same speed, and they hit exactly head on, which causes both to bounce straight back with the same speed they had when they hit, though in opposite directions. On the two graphs below, plot velocity versus time for both billiard balls from a little before they collide until a little after they collide.



Velocity versus Time for ball #1



Velocity versus Time for ball #2