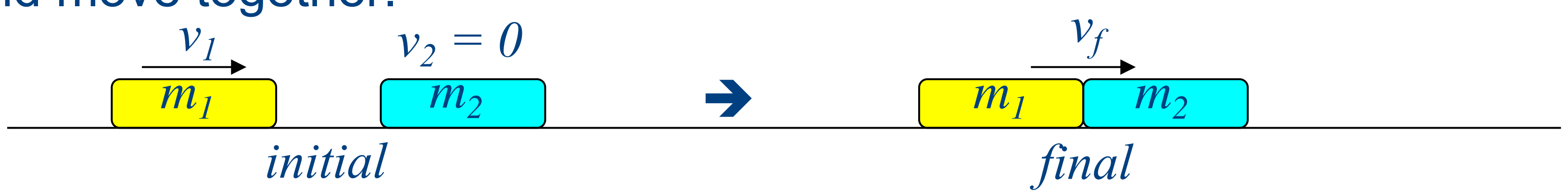
Physics 1050
Experiment 5

# Momentum and Impulse

# Prelab Questions

These questions need to be completed before entering the lab.
Please show all workings.

One cart is pushed towards another stationary cart. They collide, stick, and move together.




**Prelab 1:**
Write the equation for the total momentum before the collision. Write the equation for the total momentum after the collision.

**Prelab 2:**
If $m_1 = 0.500 \pm 0.005 kg$, $m_2 = 1.000 \pm 0.005 kg$, $v_1 = 0.25 \pm 0.01 m/s$, and $v_f = 0.07 \pm 0.01 m/s$, calculate the initial and final momentum and the impulse. Include uncertainty with each calculation.

**Prelab 3:** Write, in a sentence or two, the objective of the experiment.

# Introduction

**Momentum** is a vector defined as the product of an object's mass $m$ and velocity $\vec{v}$

$$\vec{p} = m\vec{v}\,.$$

Momentum is a vector and has the same direction as the velocity vector. It has units of $kg{\cdot}m/s$. If a system has more than one object, the total momentum is the sum of the momentum of each object.

If there is no net external force applied to the system, momentum is conserved and the total momentum of the system *before* a collision equals the total momentum *after* a collision: $\vec{p}_i = \vec{p}_f$ .

If there *is* an external force applied to the system, momentum is not conserved and the total momentum of the system *before* a collision does not equal the total momentum *after* a collision: $\vec{p}_i \neq \vec{p}_f$.

# Introduction

When a force is applied to an object over a time interval, the force will accelerate the object thus changing the object's velocity, and therefore the object's momentum.

We define the **impulse** $\vec{I}$ to be the change in momentum of the object.

$$\begin{aligned}\vec{I} &= m\vec{v}_f - m\vec{v}_i \\ &= \vec{p}_f - \vec{p}_i\,.\end{aligned}$$

Impulse is also given as the product of force with time duration the force is applied

$$\vec{I} = \vec{F}\Delta t\,.$$

# Introduction

You will also study the relationship between **external force** and **momentum** by examining the change in momentum of a system of carts.

Impulse $\vec{I}$ is defined as the change in momentum of an object. Impulse is a vector quantity, given by

$$\vec{I} = \Delta\vec{p} = \vec{p}_f - \vec{p}_i \,.$$

Impulse is also given as the product of force and time, namely

$$\vec{I} = \vec{F}\Delta t \,.$$

If the external force $\vec{F}_{net}$ is zero, then initial and final momentum will be equal:

$$\vec{p}_f = \vec{p}_i \,.$$

# Apparatus

For this experiment, you have been provided with:

- Track
- Dynamics cart (w/plunger)
- Collision cart
- Reflector card
- 3 black masses
- Motion detector (w/cord)


Pick up:

- Piece of masking tape

# Experimental Set-up

Your masses and carts are labeled.

Cart 1 will have **1** black block.

Cart 2 (with the plunger) will have **2** black blocks.

Click **here** to open a file containing the masses of the rectangular black masses. (Units are grams and uncertainty is 0.1 g)

LW Find your values and record them in **Tables 1** and **2**.

Click **here** to open a file containing the masses of the carts.

LW Find for your values and record them in **Tables 1** and **2**.

! Keep the carts **UPSIDE DOWN** when not in use.

LW Find the total mass for each cart and record in **Tables 1** and **2.**

# Part II: Conservation of Momentum

Before collecting your data and calculating your results, consider your hypothesis of this experiment:

Q

**QUESTION 1:** Draw free body diagrams for each cart just before and after the collision. Do not include the force used to push cart 1, only the forces acting on the carts moments before and after collision.

Q

**QUESTION 2:** Based on your free body diagrams, is there a net external force acting on the carts just before the collision? Considering this, do you expect the total momentum after the collision to be greater than, less than, or equal to the momentum before the collision?

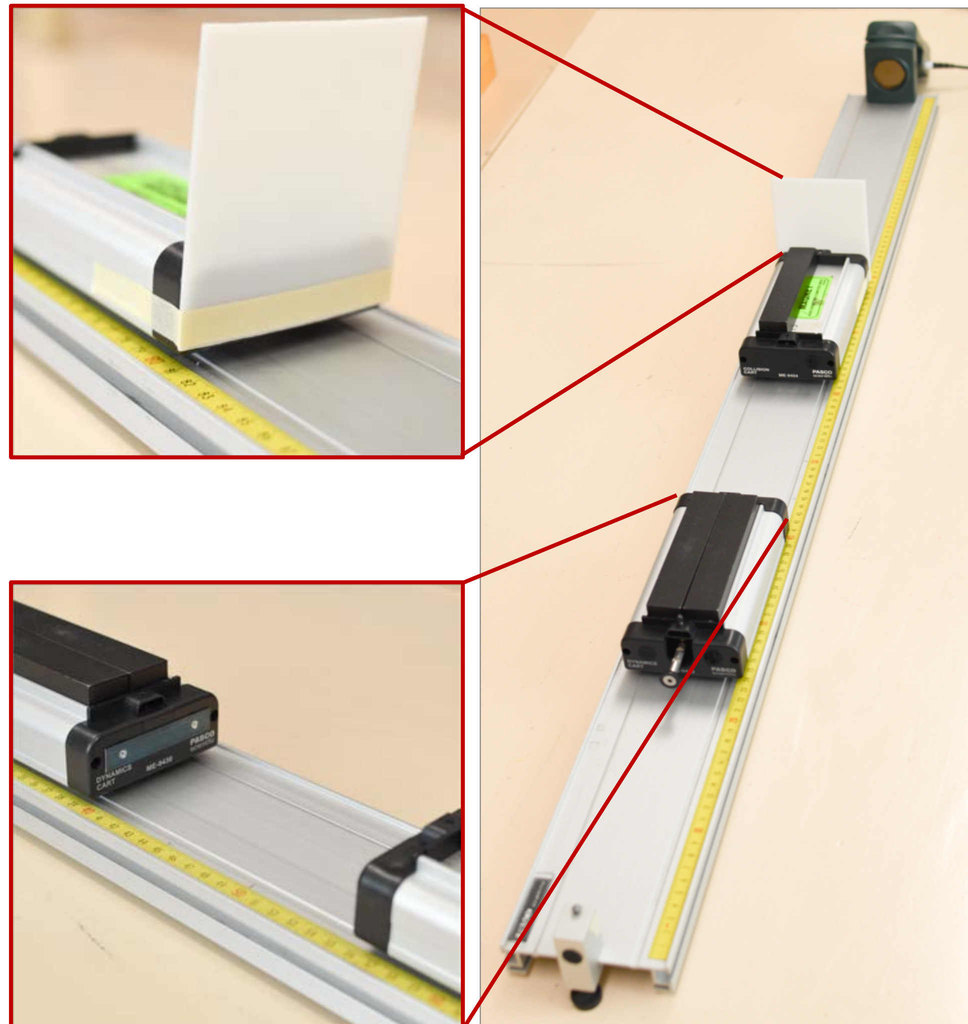
# Experimental Set-up

Make sure your track is level.

Place both carts on the track.

Place the motion detector at end of track, $\sim 40cm$ from Cart 1. Attach the white card to Cart 1 so the card faces the motion detector. Cart 2 placed $\sim 40cm$ behind Cart 1.

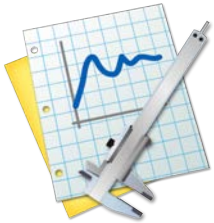
Cart 2 must have magnetic bar facing Cart 1!



# Data Collection

Plug the Motion Detector into **DIG/SONIC 1** on the side of the *LabPro*.

Click the icon to launch Logger Pro.

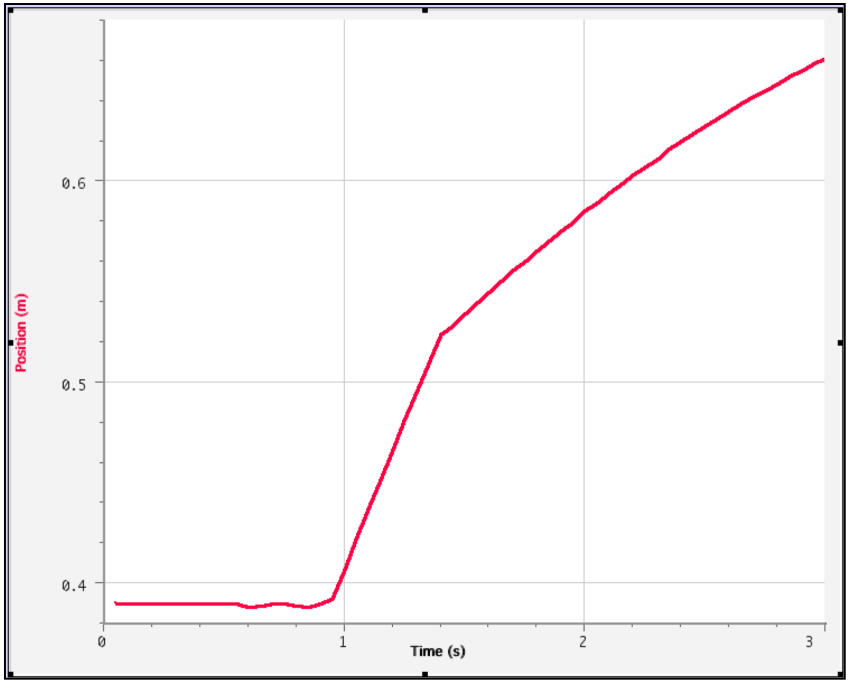


*Logger Pro* should open with a window containing a graph of *Distance* vs. *Time.*

Click collect, wait for the motion detector to make a clicking noise, and apply a gentle push to the <u>cart with the card</u> attached. Push the cart from behind the card so your fingers do not interfere with the motion detectors readings.

It should hit the stationary cart and they should stick together after collision.

# Data Collection




Inspect your graph. It should resemble the graph shown here. If it does not, repeat the experiment. If you are not satisfied with the appearance of your graph after 10 - 15 attempts, consult an instructor.

CP

Have an instructor check your graph and initial your report.

# Data Analysis

Click the examine button in *Logger Pro*.

LW

Move your cursor so it coincides with the collision point. From the pop up box on your graph record the time of the collision in **Table 3**.

To find velocity before the collision: click and drag your mouse to highlight the 10 points before the collision.

Click **Analyze**, then **Linear Fit**. Double click on the pop-up box and check **Show Uncertainty** for slope.

LW

Enter your results in **Table 4**.

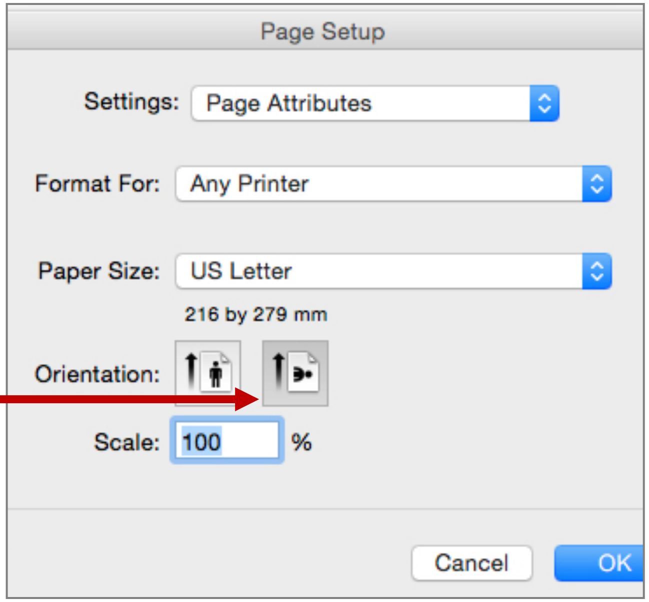
Highlighting 10 points on your graph after the collision, determine the velocity and associated uncertainty after the collision.

LW

Enter your results in **Table 4**.

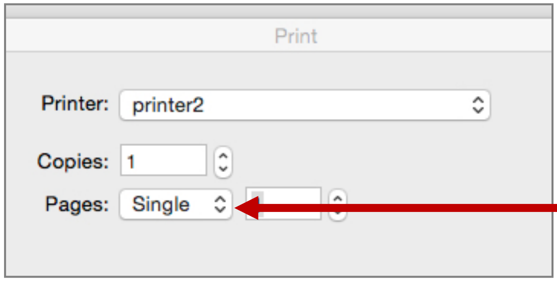
# Printing Your Graph

Click **File** then **Page Setup** and choose the landscape orientation.




Click **File** then **Print**.

To select the only necessary page:
Click Pages and choose Single.




Staple your graph in your workbook.

# Data Analysis

Using the equations from **Prelab 1**, determine the total momentum both before and after the collision.

Include uncertainties.

LW

Record your results in **Table 4**.

LW

Also calculate and record the impulse and its uncertainty in **Table 4**.

Q

**QUESTION 3:** Is the impulse zero or non-zero (within the uncertainty)? Is momentum conserved in this collision? Is there an external force acting on the carts during the collision? If yes, what do you think this force is?

# Analysis

Q **QUESTION 4:** Considering your free body diagrams of the carts. During the collision between the carts, is there a net force on:

a) Cart 1?

b) Cart 2?

Q **QUESTION 5:** Considering Newton’s Third Law, how do you expect the net forces on cart 1 and cart 2 to be related?

Q **QUESTION 6:** Considering your answer to the previous question, how do you expect the impulse on cart 1 and cart 2 to be related? Why?

# Analysis

Use the data recorded in Tables 1 — 5 to determine:

LW

- The initial momentum of cart 1. (Record in **Table 6**)
- The final momentum of cart 1. (Record in **Table 6**)
- The impulse of cart 1. (Record in **Table 6**)

LW

- The initial momentum of cart 2. (Record in **Table 7**)
- The final momentum of cart 2. (Record in **Table 7**)
- The impulse of cart 2. (Record in **Table 7**)

Q

**QUESTION 7:** Write the ranges of the impulse on each cart. Do your answers agree with your expectations from Question 6? Comment.

# Summary

**QUESTION 8:** List at least three sources of the experimental uncertainties. Classify them as random or systematic.

**QUESTION 9:** Write a brief paragraph summarizing the experiment and your findings.

Ensure that you have completed all **Tables** and answered all **Questions** completely.

Attach your **graph** to the appropriate page.

Submit your workbook to the appropriate shelf/box as directed.