Department of Physics

# Impulse Momentum

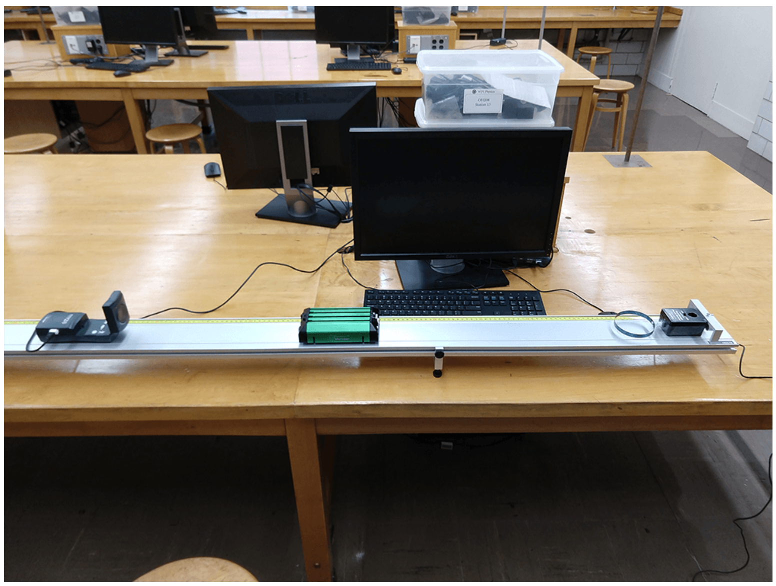

Figure 1: Overview of the setup for the Impulse Momentum Lab, make sure the range switch is in the 10N position and you have zeroed the sensor at rest.

**Lab Objectives**

- Data collection
- Data Analysis
- Integration
- Propagation of Error

**Lab Equipment**

- Vernier Motion Detector
- Vernier Dynamics Cart
- Vernier Dual Range Force Sensor
- Vernier Hoop Bumper
- Flat Cart Track
- Mass Balance

**Overview**

Impulse ($\vec{J}$ ) is a quantity that is closely related to momentum, today we will be looking only in one dimension and so Impulse is defined as the integral of the force applied to an object over time,

$$\vec{J} = \int_{t_1}^{t_2} \vec{F}(t)dt \tag{1}$$

Impulse is related to momentum ($\vec{p}$ ) by,

$$\vec{J} = \vec{p_2} - \vec{p_1} = \triangle\vec{p} \tag{2}$$

In our lab we can collect force data over time with our force sensor, this allows us to plot the function of Force vs time and we can combine these equations into,

$$\vec{p_2} - \vec{p_1} = \int_{t_1}^{t_2} \vec{F}(t)dt \tag{3}$$

We can also measure position over time to calculate velocity with the motion sensors, and we can measure mass using the mass balances. With this in mind, we can rearrange the above equation to,

$$mv_2 - mv_1 = \int_{t_1}^{t_2} \vec{F}(t)dt \tag{4}$$

which we will use to test if the change in momentum is equal to the force applied.

**Procedure**

**Data Collection**

You will be performing three variations of the same experiment and employing the same analysis techniques on all of them. The variations will be in how fast the cart is going when it encounters the hoop bumper on the force sensor.

**The three speeds will be:**

1. **slow**
2. **slower**
3. **slowest.**

The hoop bumper should never fully compress, if it does then you will have to take another round of data. **You should be saving your data after every trial.** Please see Question 5 for more details on what data for each graph you need.

- Make sure that the force sensor is zeroed and that the range selector switch is in the 10N position.
- Adjust the motion sensor so that it picks up the cart motion well for the whole range of motion on the track.
- Take your data. Your data should be of sufficient quality to perform the analysis on in the next section, if it is not, you should repeat that trial.

**Analysis**

**Integral Fit**

Logger Pro offers an integral fit tool 

that will measure the area under a curve numerically. Much like the other fits and statistic functions, you will need to specify the range of the graph that you want the function to operate on.

**Velocity**

Use the statistics function to find the velocity before and after the collision, while the velocity may not be exactly constant, avoid areas of large change. Make sure your group agrees on how to get the uncertainty in the mass of your cart.

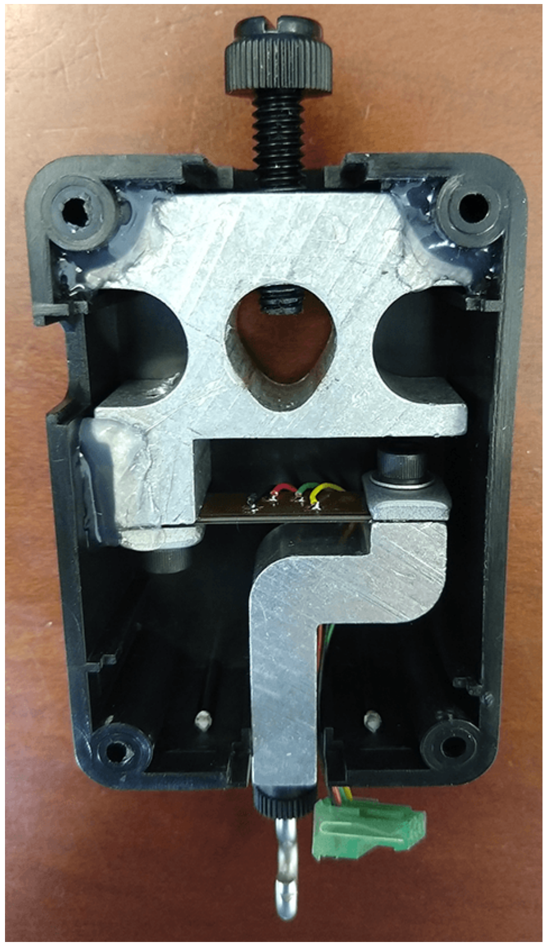

Figure 2: A view inside of the force sensor, the horizontal fiberglass piece is the strain gauge that will change resistance when it is flexed. Be sure to be careful when not to apply too much force on the hook as this could break the fiberglass strain mechanism.

### Propagation of Uncertainties

Propagate your uncertainties for the difference in momentums. You should have uncertainties for your velocities and mass. For the uncertainty on your velocity please use the standard deviation of your linear fit to your velocity. There is a quick review of the propagation of uncertainty equations at the bottom of this lab.

**Question 1** *Include your working and commented python code for the propagation of uncertainty. You should copy and paste the code into the answer sheet. Using the uncertainty on the mass and velocity please find a final uncertainty on the differences in momentum. Consider reviewing the Appendix after attempting this section.*

### Writing

Based on the data that you took today, write and answer the questions in the following sections. Remember that even though you will have the same data as your partner, the writing in these sections should be done individually.

**Question 2 Experimental Method**

- *In complete sentences, communicate the steps that you took when collecting and analyzing your data. Pretend you are writing this so a fellow student that missed this lab could take and analyze the data using only this section. For example, you do not need to tell them to press start in Logger Pro or open the program, but you would want to tell them what sensors you used to collect data and setting to use on the force sensor.*

**Question 3 Results**

- *Report the results of your experiment in complete sentences using your calculated numbers, you should* ***also*** *include you numbers in table. At minimum, your table should have the following columns: Trial Number, Type of motion (Slow, Slower, Slowest), Impulse and Change in momentum. Don't forget to include units and significant figures.*
- *You should place your graphs* ***with captions*** *in this section as well.*

**Question 4 Conclusion** *Write a sentence or two for each question asked below. Back up your conclusions with evidence. For example, use equations, measurements, references to figures, etc when appropriate.*

- *Based on your results listed above, does the change in momentum equal the impulse within your measured and calculated uncertainty (Include your numbers)?*
- *Does your conclusion hold true for the different speed collisions?*
- *If so, what might be an interesting extension to this experiment?*
- *If not, what change to your experiment might help you get better results.*

**Question 5 Graph and Data Checklist** *You should have six graphs with complete captions and answered all of the questions highlighted by the gray boxes. You should also have a table, as indicated under Results. For each trial (slow, slower, slowest) you should have a graph of:*

- *Velocity vs time: use the statistics function to find the velocity before and after the collision.*
- *Force vs time: use the integral function to find the force under the curve for during the collision*

*Please include proper captions.*

**Table Example**

| Item | Slow | Slower | Slowest |
|---|---|---|---|
| Impulse | | | |
| Initial Velocity | | | |
| Initial Velocity Uncertainty | | | |
| Final Velocity | | | |
| Final Velocity Uncertainty | | | |
| Mass of cart | | | |
| Uncertainty on Mass | | | |
| Change in Momentum | | | |
| Final Uncertainty on Change on Momentum | | | |

## I. Appendix

### The Figures and Captions

There are a few very important aspects to creating a proper figure and caption. If you follow these rules, not only will you get points on your physics lab grades, you will impress your instructors and peers in the future.

### The Caption

- The caption should start with a label so you can reference the figure from other places in your paper/report. For this course you should use “Figure 1”, “Figure 2”, etc.
- The caption should allow the figure to be standalone, that is to say, by reading the caption and looking at the figure, it should be clear what the figure is about and why it was included without reading the whole paper.
- The caption should contain complete sentences and be as brief as possible while still conveying your information clearly (this is not always easy).

### The Figure

- Make sure that the resolution is high enough to not be pixelated at its final size.
- Check that any text is readable at the final size (Using a smaller graph in Logger Pro will cause the text to be larger in relation to the graph when inserted into another program).
- For graphs, ensure that the axes are labeled (including units) and that there is a legend if you have multiple data sets on the same graphs.

Please change these values below for your own results from Lab 4: Momentum and Impulse

In [4]:
```
### 1: velocity
v_Ai = 0.1 #initial velocity
dv_Ai = 0.0001 #uncertainty of velocity

v_Af = 0.2  #final velocity
dv_Af = 0.0002 #uncertainty of "

delta_vA = v_Af - v_Ai #change in velocity
dvA = dv_Ai + dv_Af #propogation of uncertainty for velocity



### 2: mass
m = 0.4975 #measured mass of the cart in kg
dm = 0.0001 #uncertainty in "
```

Everything after this line you do not need to edit to find the propogation of uncertainty for Lab 4: Momentum and Impulse Strikes Back

In [6]:
```
### 3: momentum
p_0 = (m * v_Ai) #initial momentum of the system
dp_0 = p_0 * ((dm/m)+((dv_Ai)/abs(v_Ai))) #uncertainty in "
#Some notes on the above equation

#Don't need to do absolute value of m
#because it's already positive
p_f = (m * v_Af) #final momentum of the system

#uncertainty in momentum
dp_f = p_f * ((dm/m)+((dv_Af)/abs(v_Af)))

delta_p = p_f - p_0 #change in momentum
dp = dp_f + dp_0 #uncertainty of "
print("change in momentum:",delta_p,"±",dp," kg * m/s")
#print the change in momentum and its uncertainty
```

```
change in momentum: 0.04975 ± 0.00017925  kg * m/s
```



Figure 3: Example Python code for propagation of uncertainty. Please consider double checking this code before running against doing the math out by hand once.