



# WPI

Department of  
Physics

## Impulse Momentum

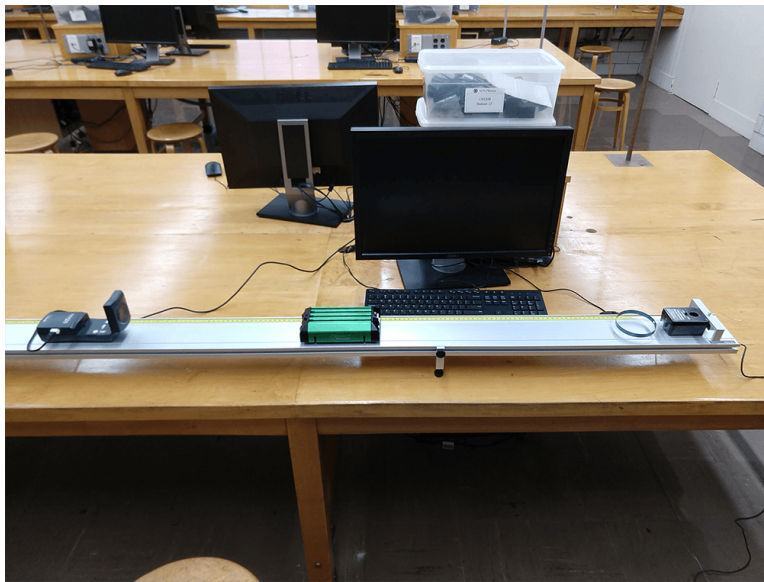


Figure 1: Overview of the setup for the Impulse Momentum Lab, make sure the range switch is in the 10N position and you have zeroed the sensor at rest.

### 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,

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

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

$$\vec{J} = \vec{p}_2 - \vec{p}_1 = \Delta \vec{p} \quad (2)$$

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,

$$\vec{p}_2 - \vec{p}_1 = \int_{t_1}^{t_2} \vec{F}(t) dt \quad (3)$$

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,

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

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: slow, slower and slowest. The hoop bumper should never fully compress, if it does then you will have to take another round of data.

- 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.

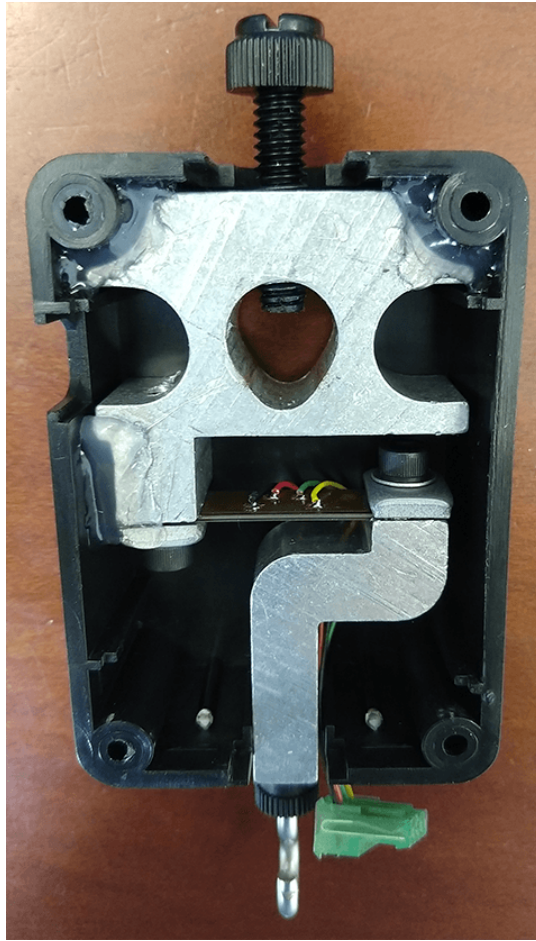


Figure 2: A view inside of the force sensor, the horizontal fiberglass piece is the strain gauge that will change resistance when it is flexed. Be sure to be careful when not to apply too much force on the hook as this could break the fiberglass strain mechanism.

## 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.

## Propagation of Uncertainties

Propagate your uncertainties for the difference in momentums, you should have uncertainties for your velocities and mass. There is a quick review of the propagation of uncertainty equations at the bottom of this lab.

Include your working and commented python code for the propagation of uncertainty. You should copy and paste the code into the answer sheet.

## 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.

## 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.

## Results

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

**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.

**Graph and Data Checklist** You should have six graphs with complete captions and answered all of the questions highlighted by the gray boxes.

## Review

### 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.

## Propagation of Uncertainties

### Addition and Subtraction

In the case of addition and subtraction, the equation for combining uncertainties is

$$\delta x = \delta x_1 + \delta x_2 + \delta x_3 , \quad (5)$$

where  $\delta x$  is the total uncertainty of your calculation and  $\delta x_1$ ,  $\delta x_2$ , and  $\delta x_3$  are the uncertainties of your individual measurements.

### Multiplication and Division

This method is valid for both multiplication and division of measurements with uncertainties.

$$\frac{\delta A}{|A|} = \frac{\delta x}{|x|} + \frac{\delta y}{|y|} , \quad (6)$$

where  $A$  is the area,  $x$  is the length,  $y$  is the width,  $\delta x$  and  $\delta y$  are the uncertainties associated with these measurements, and  $\delta A$  is the propagated uncertainty of the product or quotient.

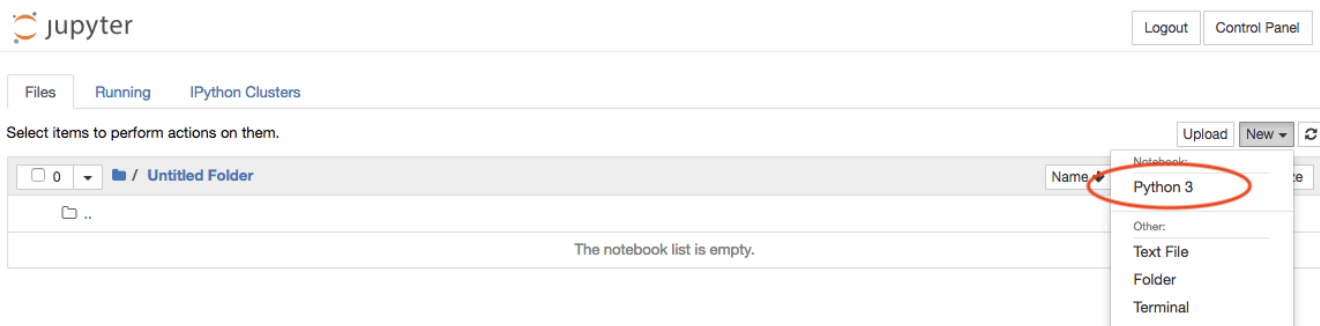


Figure 3: Navigate to `jupyterhub.wpi.edu` and sign in with your WPI email address and password, choose an instance to spawn (either is fine) and create a new Python 3 file as shown here

## Python

Python is a high level programming language that is regularly used by the scientific community for general and research computation. We will be introducing it and using it in a very limited way in this lab course although we encourage you to explore it more on your own. We will primarily make use of the Python to calculate statistical values and propagate uncertainties. We will be using an interface for Python called Jupyter and WPI has set up a JupyterHub server that you can access from any browser (Figure 3). The files you create on the server will stay for at least the term, probably much longer.

Jupyter uses a cell based system and evaluated variables carry over to the next cell. There are a few different types of cells, Figure 5 shows 2 kinds, the code cell, which we will be using most of the time, and the markdown cell, which you can use to add nicely formatted notes to you file.

Jupyter WPI Physics Last Checkpoint: 12 minutes ago (autosaved) Logout Control Panel

File Edit View Insert Cell Kernel Widgets Help Trusted Python 3

```
In [1]: 1+1 #use the run button above or shift + enter to evaluate the cell
Out[1]: 2
```

## ## Markdown Cells

You can use latex for  $\frac{math}{math}$  and markdown for formatting text in a markdown cell.

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You can use latex for  $\frac{math}{math}$  and markdown for formatting text in a markdown cell.

```
In [4]: #propagation of uncertainties for addition and subtraction
#anything written after the # sign is treated as a comment and will affect the execution of your code.
#For this class, we will require you to comment every line of your code for full credit.

x_1 = 3 #first measurement in cm
x_1_uncertainty = 0.01 #uncertainty of first measurement in cm
x_2 = 4 #second measurement in cm
x_2_uncertainty = 0.01 #uncertainty of second measurement in cm
x_3 = 2 #third measurement in cm
x_3_uncertainty = 0.01 #uncertainty of third measurement in cm

|
#calculation for the total of the measurements in cm
x = x_1 + x_2 + x_3

#calculation for the propagated uncertainty in x in cm
x_uncertainty = x_1_uncertainty + x_2_uncertainty + x_3_uncertainty

#print x and x_uncertainty in cm
print("x = ", x, "cm")
print("x_uncertainty = ±", x_uncertainty, "cm")

x = 9 cm
x_uncertainty = ± 0.03 cm
```

In [ ]:

Figure 4: Above is the code that you could use to propagate uncertainty for values that are added or subtracted. Always remember to comment every line of your code in this class.

```
In [8]: import statistics as stat # import the statistics module

x = [1,2,3,4,5] # assign the numbers to the variable x
mean = stat.mean(x) #use the statistics package to assign the mean of x to the variable "mean"
stdev = stat.stdev(x) #use the statistics package to assign the standard deviation of x to the variable "stdev"

#print the values for mean and stdev
print ("mean of x =", mean)
print ("uncertainty in x =" , stdev)

mean of x = 3
uncertainty in x = 1.5811388300841898
```

Figure 5: Above is the code that you could use to calculate the mean and standard deviation. Always remember to comment every line of your code in this class.