Department of Physics

Conservation

Figure 1: Overview of the setup for the Conservation Lab, after you mass your carts, make sure you keep track of which one is which.

Lab Objectives

- Data collection
- Data Analysis
- Propagation of Error
- Conclusions

Lab Equipment

- 2 Vernier Motion Detector

- 2 Vernier Dynamics Cart
- Flat Cart Track
- Mass Balance

Overview

Today we will look at the energy and momentum in two different collisions. The main goal will be to calculate if Kinetic Energy (K) and Momentum ($\vec{P}$) are conserved during the collisions. If momentum is conserved, that will mean that the total momentum of the system before the collision ($\vec{P}_1$) will be equal to the total momentum if the system after the collision ($\vec{P}_2$), within your uncertainties. Where $\vec{p}_a$ is the momentum for cart a and $\vec{p}_b$ is the momentum for cart b or

$$\vec{P}_1 = \vec{p}_{a_1} + \vec{p}_{b_1} = m_{a_1}\vec{v}_{a_1} + m_{b_1}\vec{v}_{b_1} \tag{1}$$

and

$$\vec{P}_2 = \vec{p}_{a_2} + \vec{p}_{b_2} = m_{a_2}\vec{v}_{a_2} + m_{b_2}\vec{v}_{b_2} \tag{2}$$

We can use a similar format for Kinetic Energy (K),

$$K_1 = k_{a_1} + k_{b_1} = \frac{1}{2}m_{a_1}v_{a_1}^2 + \frac{1}{2}m_{b_1}v_{b_1}^2 \tag{3}$$

and

$$K_1 = k_{a_2} + k_{b_2} = \frac{1}{2}m_{a_2}v_{a_2}^2 + \frac{1}{2}m_{b_2}v_{b_2}^2 \tag{4}$$

Procedure

Data Collection

You will be collecting data from two different collisions with the carts. One collision will have the plunger on the cart extended so that the carts collide and they bounce away from each other. The other collision will have the velcro facing each other so that when the carts collide, the carts will stay together. It is recommended that one cart starts stationary and the other collides with it, however, the experiment can be done with both carts initially in motion.

- Adjust the motion sensors so that they pick 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

Velocity

Use the statistics function to find the velocity of each cart 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 the uncertainties for your momentums and energies, you should have uncertainties for your velocities and masses. There is a quick review of the propagation of uncertainty equations at the bottom of this lab.

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 paragraph form, 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 if there are any special settings that you used.

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: mass for each cart, velocities before and after collision, momentum before and after, kinetic energy before and after. Don't forget to include units, significant figures and uncertainties.
- Compare the initial and final KE (kinetic Energy) and momentum (p) for both collisions, including your propagated error in the comparison.

Conclusion

- What conclusions are you able to make based on the data you collected for this lab? Back up your conclusions with evidence, use equations, measurements, references to figures, etc when appropriate. If you are not sure where to start, you will want to use the words inelastic and/or elastic and conserved and/or not conserved in your conclusion.

Graph and Data Checklist You should have 2 graphs and a table with complete captions, answered all of the questions highlighted by the gray boxes and written an experimental methods, results, and conclusions section.

1. Velocity vs Time of collision with plunger extended.
2. Velocity vs Time of collision with velcro facing each other.

Table should include (from Results) the following columns: mass for each cart, velocities before and after collision, momentum before and after, kinetic energy before and after. Don't forget to include units, significant figures and uncertainties.

Table Example

Punger Experiment		
	Cart 1	Cart 2
Data to collect in lab		
Mass		
Uncertainty of Mass		
Initial Velocity		
Uncertainty of Initial Velocity		
Final Velocity		
Uncertainty of Final Velocity		
Data to Calculate		
Initial Momentum		
Uncertainty of Initial Momentum		
Final Momentum		
Uncertainty of Final Momentum		
Kinetic Energy Before Collision		
Uncertainty of Kinetic Energy Before Collision		
Kinetic Energy After Collision		
Uncertainty of Kinetic Energy After Collision		

Velcro Experiment		
	Cart 1	Cart 2
Data to collect in lab		
Mass		
Uncertainty of Mass		
Initial Velocity		
Uncertainty of Initial Velocity		
Final Velocity		
Uncertainty of Final Velocity		
Data to Calculate		
Initial Momentum		
Uncertainty of Initial Momentum		
Final Momentum		
Uncertainty of Final Momentum		
Kinetic Energy Before Collision		
Uncertainty of Kinetic Energy Before Collision		
Kinetic Energy After Collision		
Uncertainty of Kinetic Energy After Collision		

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.

.1. Error

Humans can often be a source of error, but describing one’s total error as ’human error’ does little to illuminate the subject. Humans can contribute error to a system, but it is not their mere presence, often, that causes that error. That error is contributed by a specific action, or lack of action of the operator and you should always be specific. If we ask for why there might be error in a system, and someone responses with just human error without explaining what, specifically, that answer will not receive credit.

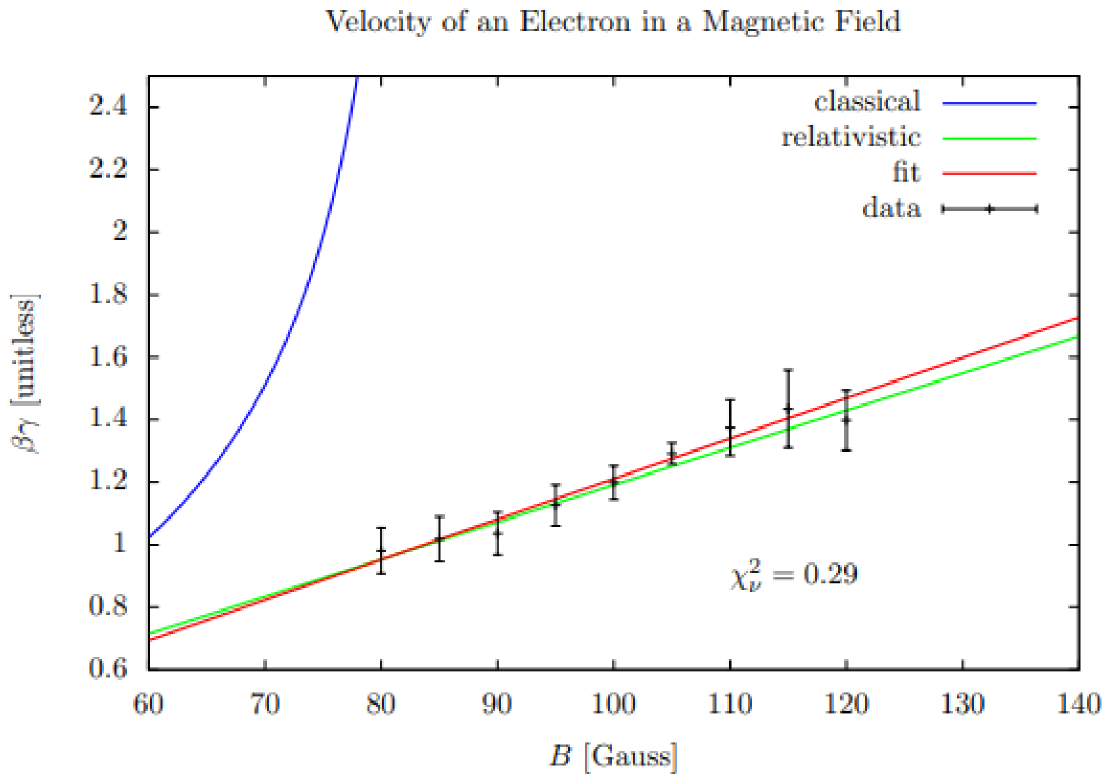

Figure 2: Example of a good figure with excellent error bars and a label. Figure from Philip Ilten of University College Dublin [1].

.2. Python

According to IEEE Spectrum, Python is the most popular programming languages. Python is a free, general purpose, cross discipline programming language that has moved to the forefront of many disciplines.

If you decide to use Python your TA's will help you troubleshoot your code. While they might be able to help you troubleshoot when you use a different program or code, be aware of the fact that they are not familiar with all programming codes. There are many languages (R, Matlab, Opal, Julia, etc.) out there that are just as useful as Python, but we have chosen to use Python here. You may use any programming language you wish, but not Excel or Google Sheets.

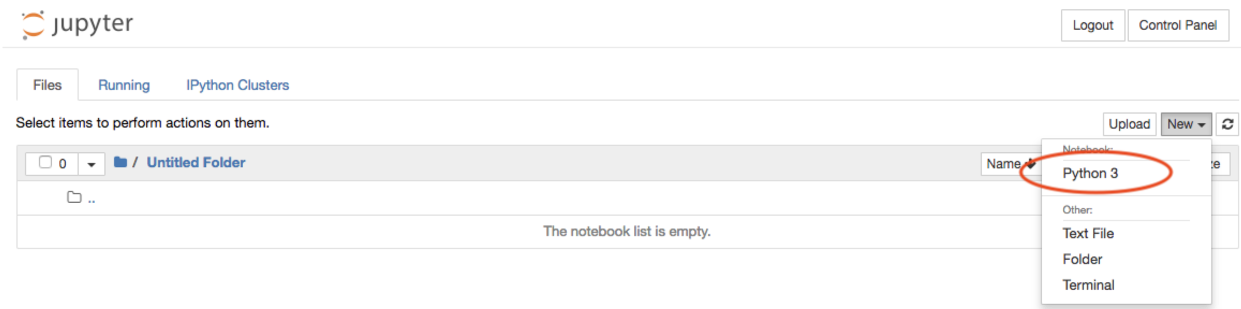

Figure 3: Navigate to `jupyterhub.wpi.edu/hub/login` and sign in with your WPI email address and password, choose an instance to spawn (either is fine) and create a new Python 3 file as shown here

We have set up a Jupyter notebook you may use. The website is https://jupyterhub.wpi.edu/hub/login.[1] There are many ways to learn Python, including reading a book, asking a friend, working through examples, or googling furiously when problems arise. We encourage you to discover which approach works best for you. Going forward this class will provide basic Python examples, but feel free to iterate upon the template we provide. What we provide is a stripped down version, and elaboration is encouraged. See this Github repository for our examples. We hope at the end of this term you will be able to add to your resume "Proficient in Python".

Jupyter uses a cell based system and evaluated variables carry over to the next cell. There are a few different types of cells, Figure 4 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.

[1]If you cannot log in please email WPI's IT department, and they will be happy to help polite students. The first thing they will tell you, however, is to check to make sure you don't have to change your password and try a VPN if you are off campus.

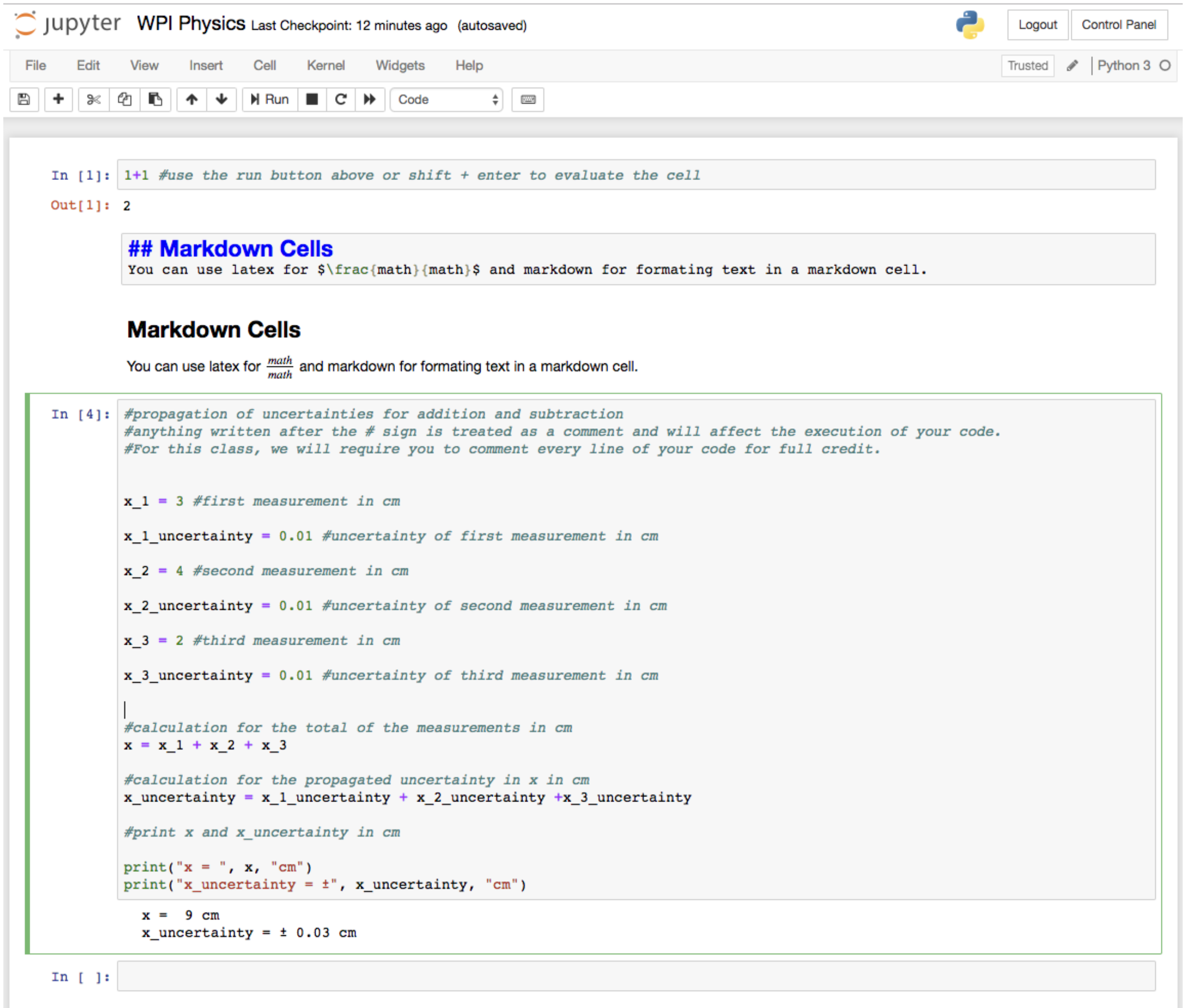

Figure 4: Above is the code that you could use use to propagate uncertainty for values that are added or subtracted. Always remember to comment your code.

If you prefer to work through a book or examples we recommend Mark Newman's book, which is available for free on his website [2]. Chapter Two is a basic introduction to the syntax for Python. Chapter Three covers graphs and visualizations, and we hope you will look into it if you learn best from a book. If you wish to get a head start in this class we recommend reading this book.

If you wish for a more advanced textbook there is a compilation of free online computational physics books here.

References

[1] Philip Ilten. The hitchhiker's guide to first year physics labs at ucd. 2010.

[2] Mark Newman. *Computational Physics with Python*. CreateSpace Independent Publishing Platform, 2012.