WPI | 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 K and 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 with complete captions, answered all of the questions highlighted by the gray boxes and written an experimental methods, results, and conclusions section.

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

$$\delta x = \delta x_1 + \delta x_2 + \delta x_3 \ , \tag{5}$$

where δx is the total uncertainty of your calculation and δx_1, δx_2, and δx_3 are the uncertainties of your individual measurements.

Multiplication and Division

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

$$\frac{\delta A}{|A|} = \frac{\delta x}{|x|} + \frac{\delta y}{|y|} \ , \tag{6}$$

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

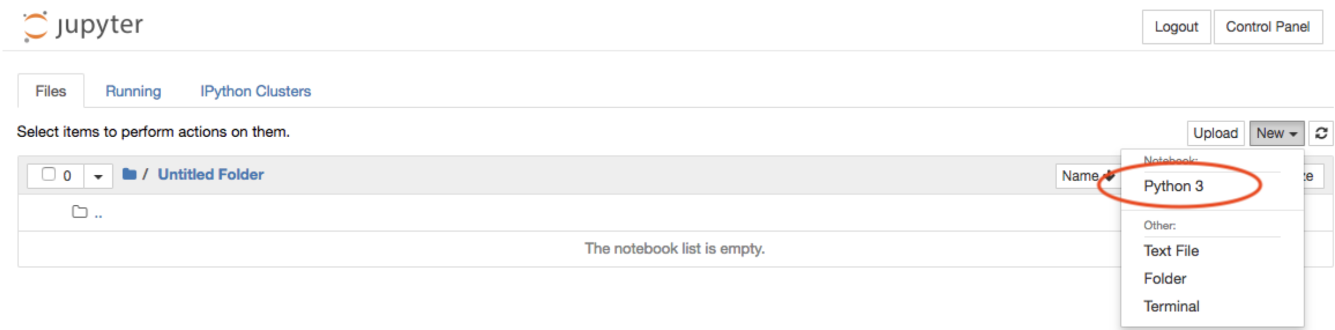
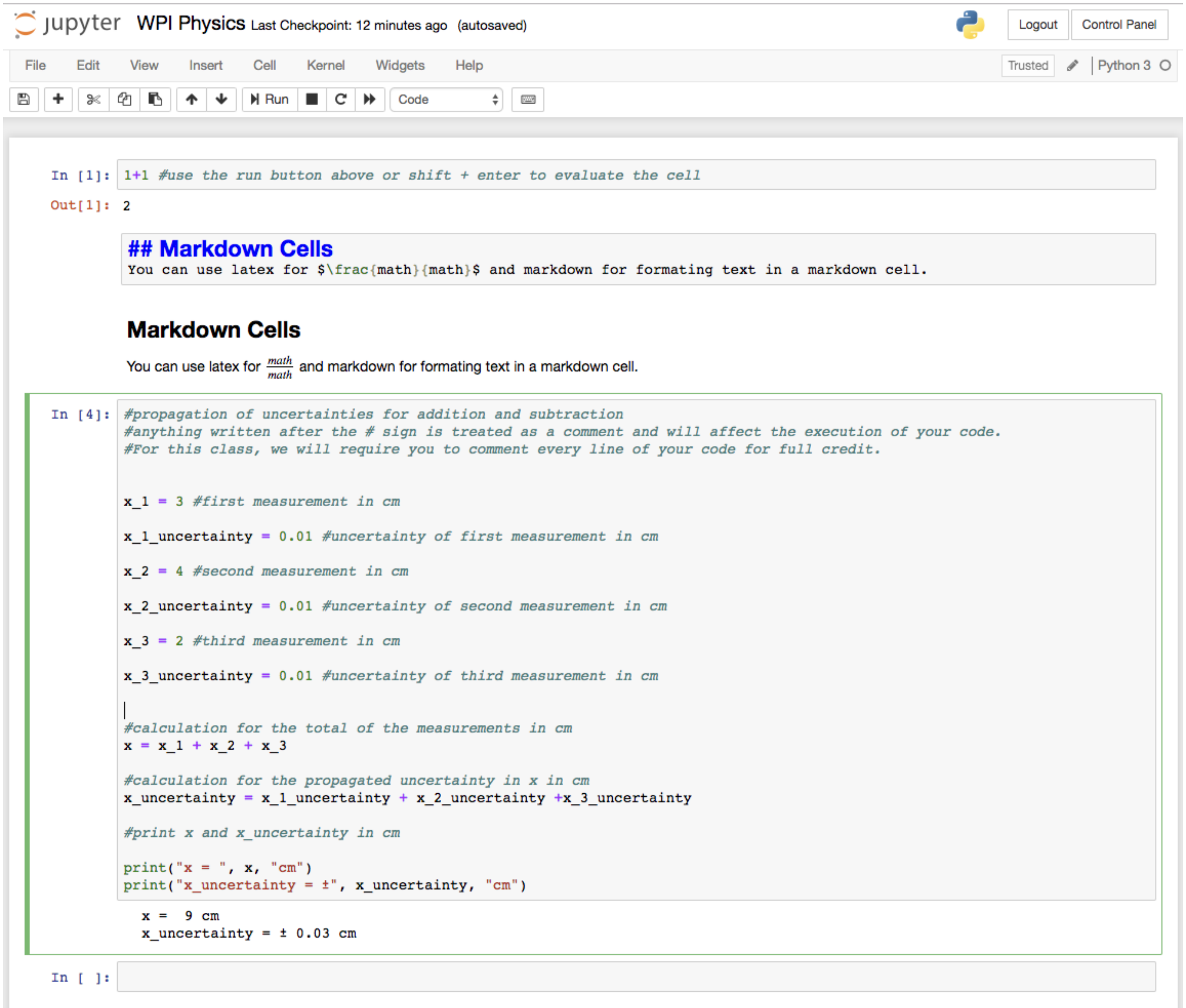


Figure 2: Navigate to `jupyterhub.wpi.edu` and sign in with your WPI email address and password, choose an instance to spawn (either is fine) and create a new Python 3 file as shown here

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 2). 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 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.



jupyter WPI Physics Last Checkpoint: 12 minutes ago (autosaved)

Logout Control Panel

File Edit View Insert Cell Kernel Widgets Help

Trusted Python 3

Run Code

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

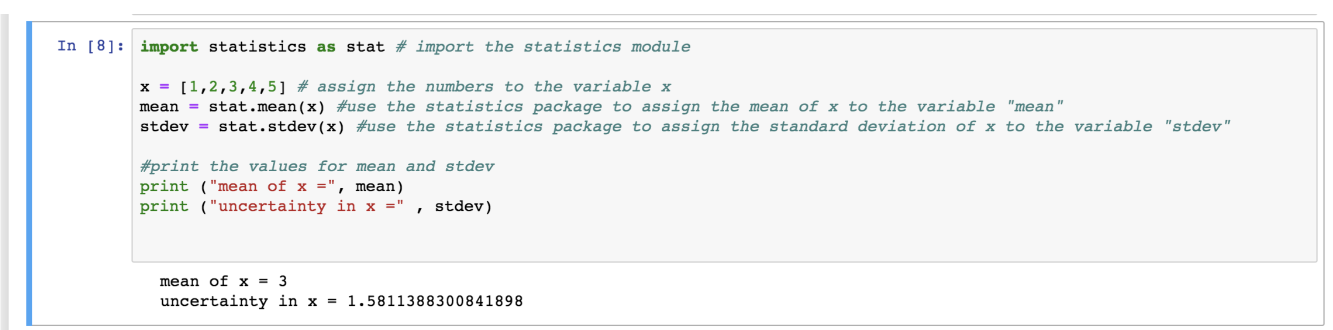
```
## Markdown Cells
You can use latex for $\frac{math}{math}$ and markdown for formating text in a markdown cell.
```

Markdown Cells

You can use latex for $\frac{math}{math}$ and markdown for formating 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 3: Above is the code that you could use 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 4: Above is the code that you could use use to calculate the mean and standard deviation. Always remember to comment every line of your code in this class.