Department of Physics

One- and Two-Dimensional Motion

Lab Objectives

- Data collection
- Video analysis
- Linear and nonlinear fitting
- Two-dimensional motion separation

Lab Equipment

- Vernier Motion Detector
- Tall ring stand with horizontal pole
- Racketball

Overview

This lab has two experiments, the first section is about 1D motion and the second about 2D motion. Please excuse the high number of bullet points in this document!

1D Motion

For this experiment, we will use the Vernier Sonar Ranger to record the motion of a tennis ball bouncing on the table and analyze the motion.

Procedure

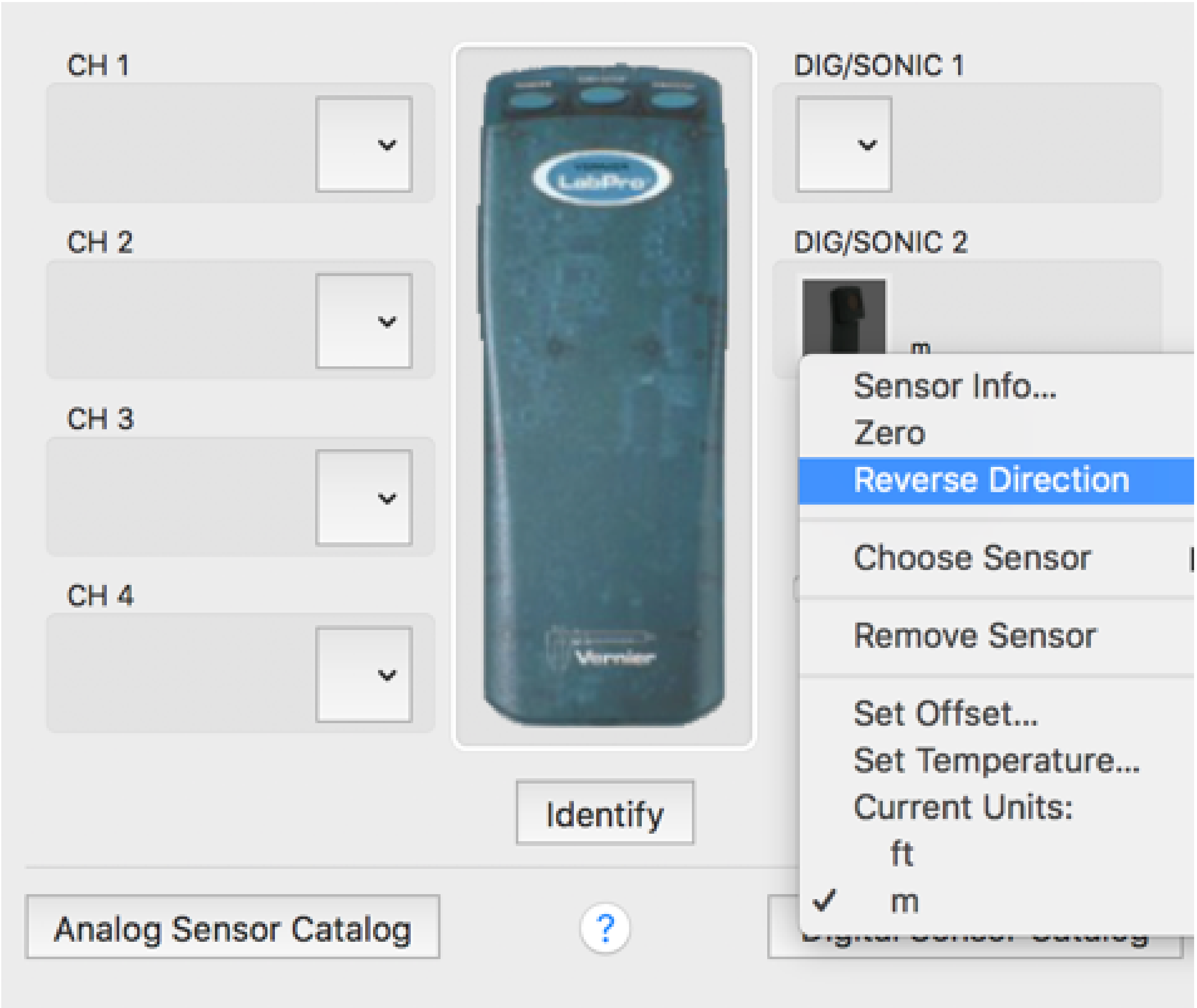


Figure 1: How to reverse the direction of the motion sensor axis.

1. Adjust the motion sensor so that the transducer is pointed down and parallel to the bench top, or towards the floor. You can check that it is by making sure a test data collection smoothly shows the distance to the table top.

2. Reverse the direction of the axis for the motion sensor by going to the menu item `Experiment > Set up Sensors > Show all Interfaces` as shown in Figure 1. You should see a new window with the LabPro in the center and your sonar ranger on one side. Select the `Reverse Direction` option to change the direction of the axis.

Question 1 *What happens if you do not do this step (step 2)? Try it out both ways if you are not sure. (1 - 2 sentences)*

3. Zero the sensor so that the table top will show a distance of zero on the graph. Go to the menu item `Experiment > Zero...`

4. Set the data collection rate to 31 samples per second as shown in Figure 2.

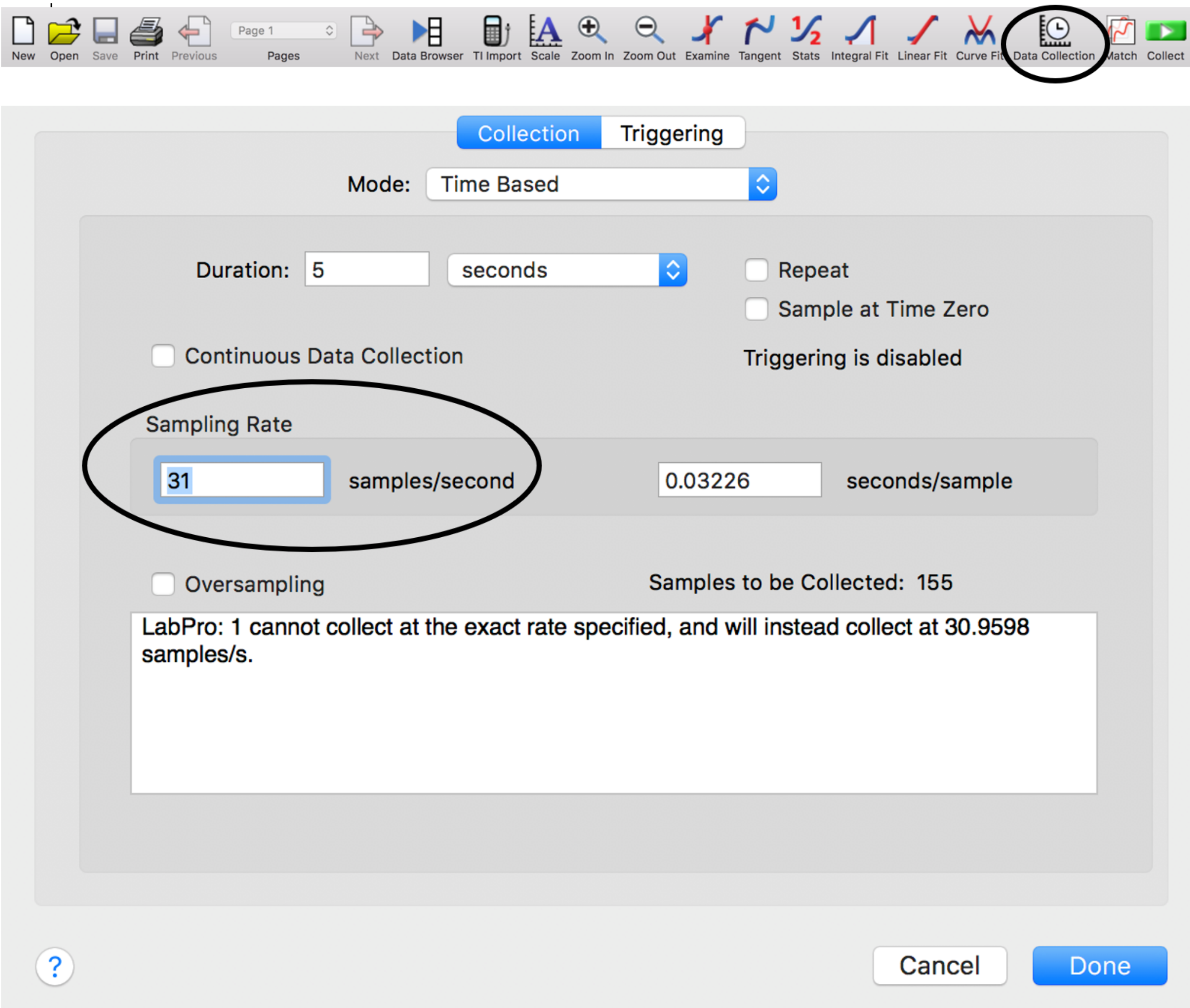


Figure 2: How to set the data collection rate to 31 samples per second.

5. Drop the ball from 15cm below the sensor onto the table and make sure your data has at least one good and complete bounce. This may take a few tries; you can change the position of the switch on the sonar ranger if you are having trouble getting good data.

Question 2 *Why do we need to start the drop 15cm away from the sensor? (1-2 sentences)*

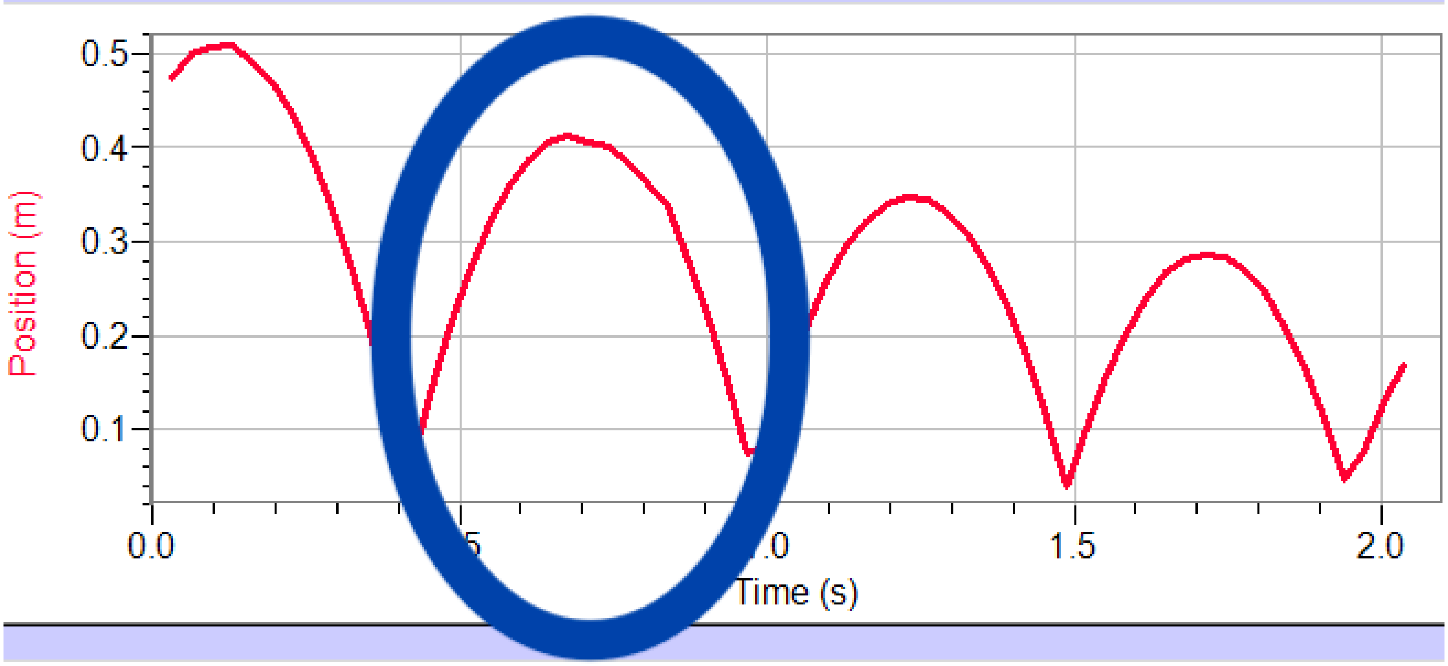


Figure 3: Example of one complete trip from the table surface and back again is circled in blue.

6. Identify a region on the graph that show the motion of the tennis ball during one complete trip from the table surface and back again. For an example of that please see Figure 3. Strike through all other data points by selecting the portion of the graph that we do not want to analyze and use the menu item `Edit > Strikethrough Data Cells`.

   Check with your lab instructor to make sure your data is acceptable before you continue.

7. On each graph, right click and select graph options, select the graph options tab, and deselect the `Connect Points` box and select the `Point Symbols` box.

The Figures and Captions (Review)

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.

Analysis of 1D Bouncy Ball Motion

Velocity Versus Time

1. Perform a linear fit on the velocity graph.
2. Right-click on the box showing the fit information and select `Linear Fit Options` and check the box marked `Show Uncertainty`.

> **Question 3 Velocity versus time questions**
>
> *(a) What is the slope with uncertainty for this fit?*
>
> *(b) What should the slope represent?*
>
> *(c) Does the result match the known value, within the uncertainty of your measurement? (include your numbers)*
>
> *(1-2 sentences per question)*

Position Versus Time

> **Question 4 Position versus time questions**
> *Based on your knowledge from lecture, what form of equation most closely describes the shape of the position graph?*

3. Perform a curve fit on the position graph using your predicted equation. The dialog box is shown in Figure 4, once you chose the appropriate equation form, use the `Try Fit` button to see test the fit on your data. Once you are satisfied that you have the correct equation, you can click `Ok` to return to your graph with the new fit overlaid.

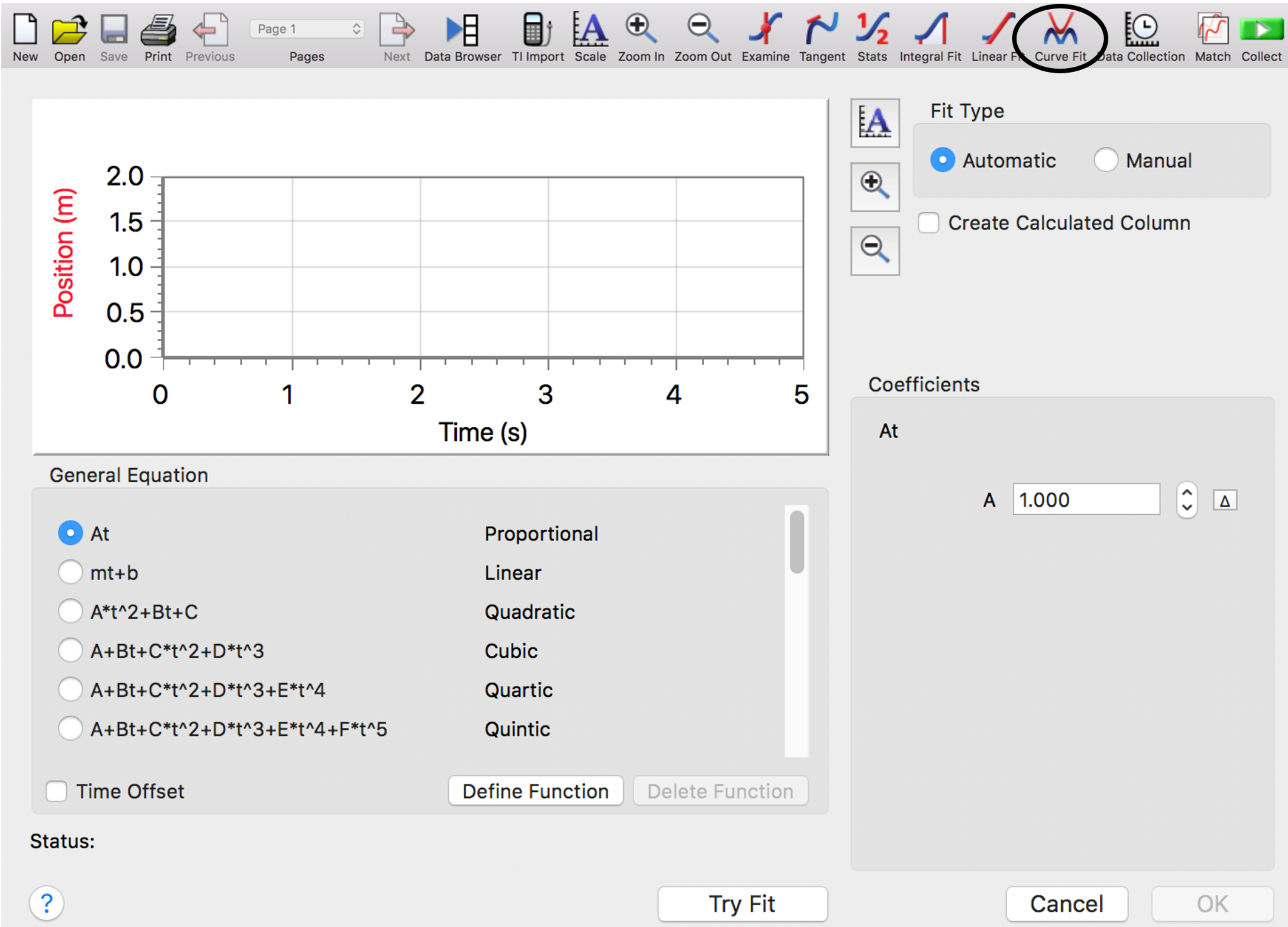


Figure 4: Dialog Box for the Curve Fitting feature.

4. Make sure that the fit boxes are not obstructing the data on the graphs and that they are properly formatted to highlight the important features.

Question 5 *Paste the graphs with the fit parameter boxes here along with captions that include a figure number, explain what the figure is looking at, and qualitatively describe the goodness of the fits.*

Two-Dimensional Motion: Basketball Shot

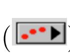
5. Open a new Logger Pro file.

6. Add a blank page by going to the menu item `Page > Add Page`.

7. Insert the movie that is posted on Canvas alongside this worksheet by going to the menu item `Insert > Movie` and select `basketball shot.mp4` (you will have to download this file to your local computer. If you wish to reopen the file in the future, you will need the Logger Pro file as well as the movie file).

8. Resize the movie to fit the screen so you can see the basketball.

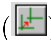
9. Advance the movie until the ball has left the player's hand using the frame advance button in the bottom left corner of the screen ().

10. Open the side bar using the button on the bottom right of the movie screen ().

11. Using the add point button (), mark the center of the ball as carefully as you can. Once you place the point, the movie will automatically advance one frame and you may place another point.

12. Place points until the ball is at the same height it started; this will be around thirty points.

13. Use the scale tool () to set the scale in the movie. There is a two-meter stick on the floor of the gym in the movie; select the full distance by clicking and dragging across the meter stick and mark it as two meters.

14. Using the origin tool (), mark the first data point you took as the origin.

Analysis of 2D Basketball Motion

Logger pro automatically splits the motion into separate x and y graphs for you. If you are not sure of what each graph represents about the motion of the basketball in the movie, please ask your Lab Instructor.

1. Use the curve fit or linear fit to confirm the mathematical shape of each graph.

> **Question 6 2D Basketball Graphs** *Attach the curve fitted graphs along with a caption under each using the same format as presented above.*
> *Please include:*
> *X vs time graph*
> *Y vs time graph*
> *X Velocity vs time graph*
> *Y Velocity vs time graph*

Based on the data that you took today, answer the following questions.

> **Question 7 Experimental Method**
> *For just the 1D motion experiment (not the 2D basketball motion experiment), write down with bullet points the five most important steps for your data collection, including why the particular step is important. Use complete sentences (one per bullet point) not just a copy and paste of the instructions above.*
>
> -
> -
> -
> -
> -

> **Question 8 Results**
> *Write a sentence or two for each question asked below.*
>
> 1D experiment
>
> 1. *Using mathematical and physics terms, describe the motion of the tennis ball on the table.*
> 2. *What was the velocity and acceleration of the tennis ball, if either value was changing, what were the limits of the values and what mathematical shape was the graph of those values?*
>
> 2D experiment
>
> 1. *Using mathematical and physics terms, describe the motion of the basketball in the movie.*
> 2. *For the X direction motion, what was the velocity and acceleration, if either value was changing, what were the limits of the values and what mathematical shape was the graph of those values?*
> 3. *For the Y direction motion, what was the velocity and acceleration, if either value was changing, what were the limits of the values and what mathematical shape was the graph of those values?*

> **Question 9 Conclusion** *Based on your results listed above, what similarities of motion are there in the experiments you performed? What are the differences?*

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 have 2 graphs from the 1D motion (bouncy ball)

1. Position vs time with a trend line and a caption.
2. velocity vs time with a linear trend line, with uncertainty shown and a caption.

You should have 4 graphs from the 2D motion (basketball)

3. X position vs time with a curve or linear fit and a caption
4. Y position vs time with a curve or linear fit and a caption
5. X velocity vs time with a curve or linear fit and a caption
6. Y velocity vs time with a curve or linear fit and a caption

Extra Credit Please see the end the Lab Modules for the Worm Extra Credit opportunity. You can use Tracker or the Logger Pro video analysis software, whatever you are most comfortable with.

Meme extra credit

For up to 3 points of extra credit please create and submit a meme about LoggerPro.

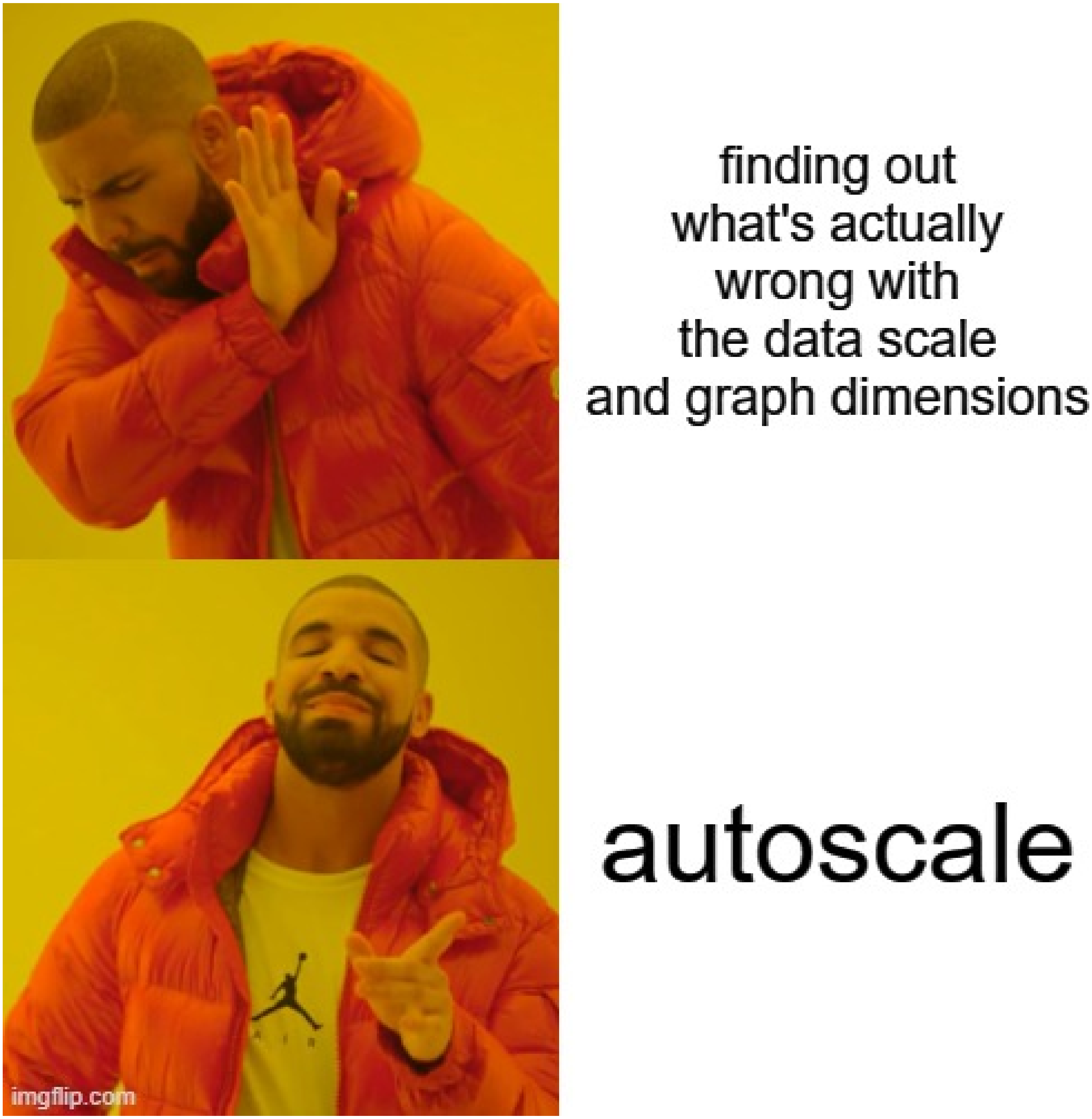


Figure 5: Example of a LoggerPro meme made by lab instructor Neil Kale and Camille McDonnell.

Figure 6: Example of a LoggerPro meme made by lab instructor Neil Kale and Camille McDonnell. Extra credit in lab only applies to lab. So if lab counts for 20% of your grade in this class, you can get a total of 20 points factored into your final grade. You cannot get over a 100% lab grade. Extra credit in lab is meant to be a challenging, interesting way to gain some points you may have lost for small errors. The extra credit assignments are often things we would love to include in the main experiment, but we just are not sure if there would be time in the two hours assigned to lab.

I Appendix

The Figures and Caption Rules

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- The caption should contain complete sentences and be as brief as possible while still conveying your information clearly (this is not always easy).
- Please add captions to your tables as well, otherwise we will not know what we are looking at.

The Figure

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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.

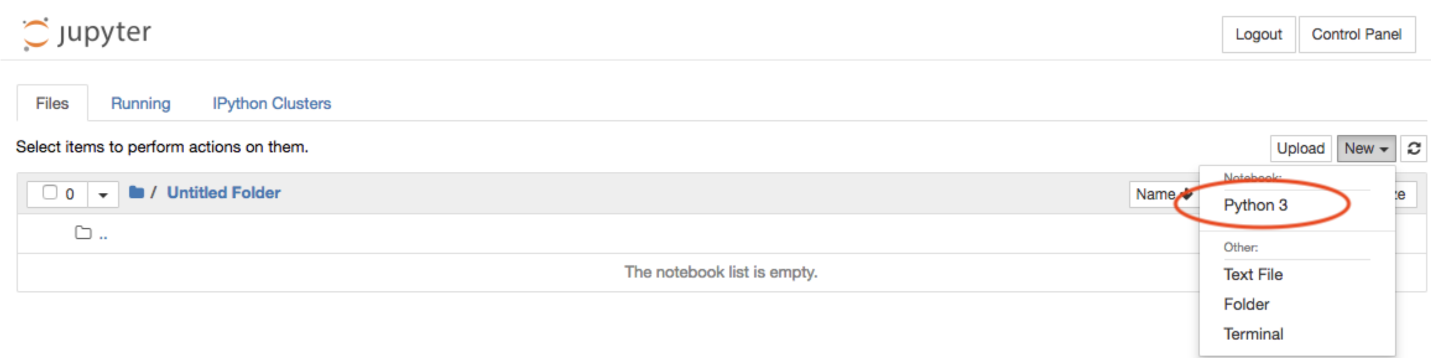

Figure 7: Navigate to `jupyterhub.wpi.edu/hub/login` and sign in with your WPI email address and password, choose an instance to spawn (either is fine) and create a new Python 3 file as shown here

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

[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.

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 8 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.

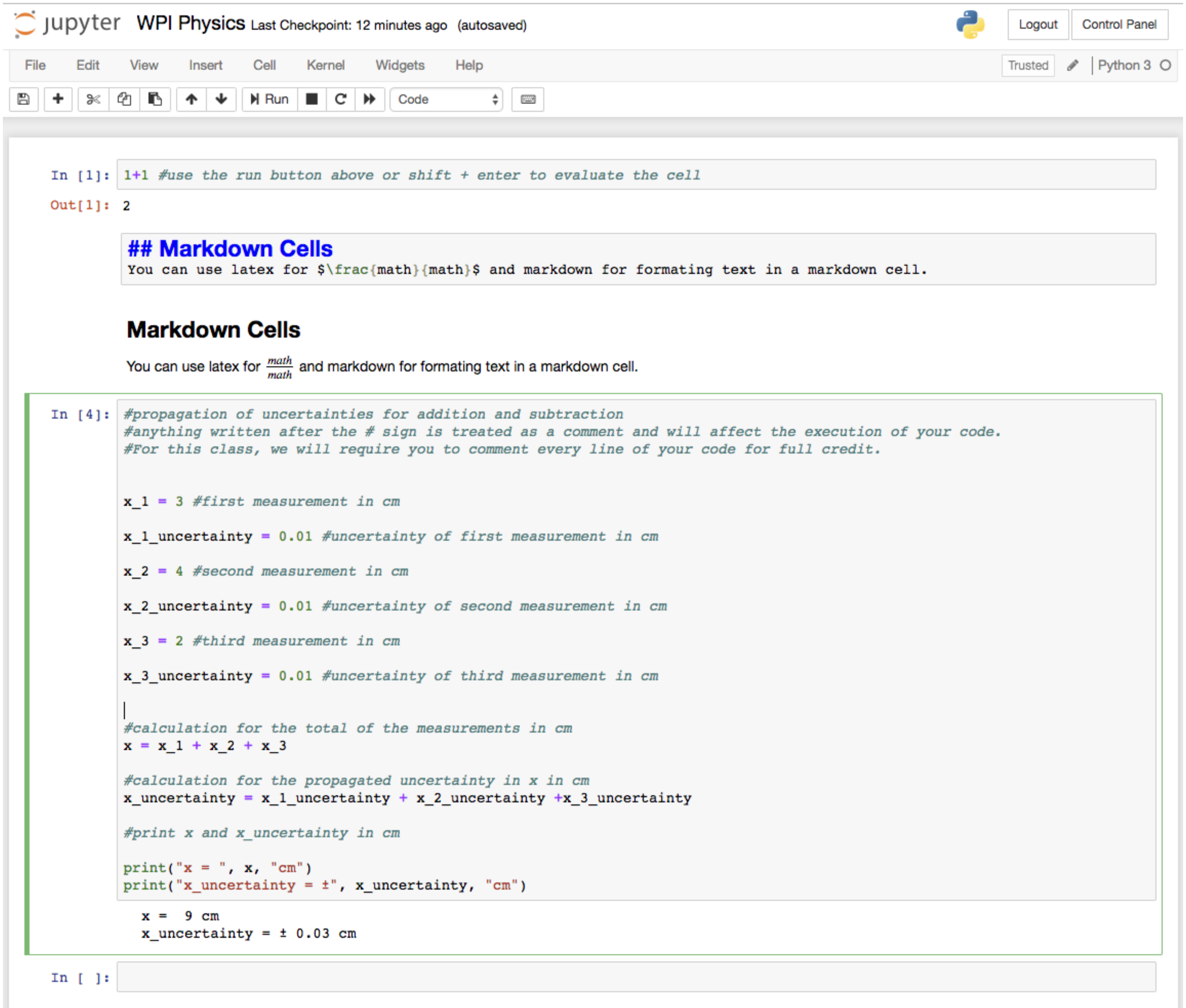

Figure 8: Above is the code that you could use use to propagate uncertainty for values that are added or subtracted. Always remember to comment your code.

If you prefer to work through a book or examples we recommend Mark Newman's book, which is available for free on his website [?]. 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.