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Project 1
ES2

Formula for period of a pendulum:

$T = 2 \cdot \Pi \cdot (L/g)^{0.5}$
Length in meters
g=9.81m/s

Step 1 Length increments:

Setup #	Pendulum length (cm)
1	46
2	41.8
3	35
4	29.5
5	22.8

Part 6: Report
Theoretical period calculations from step 2
We calculated these periods using the formula: **$T = 2 \cdot \Pi \cdot (L/g)^{0.5}$**
Using these values appended into an array we used the matplotlib library to plot the theoretical relationship between pendulum length and time (see below).

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[34, 43, 53, 62, 72]
[11.7  13.15 14.6  15.8  17.02]
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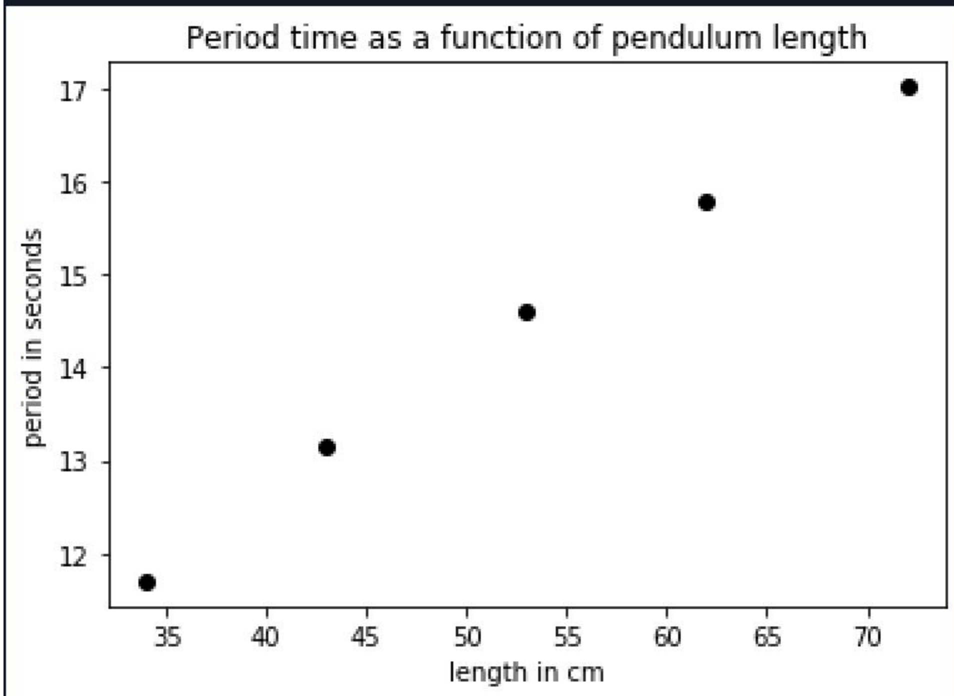
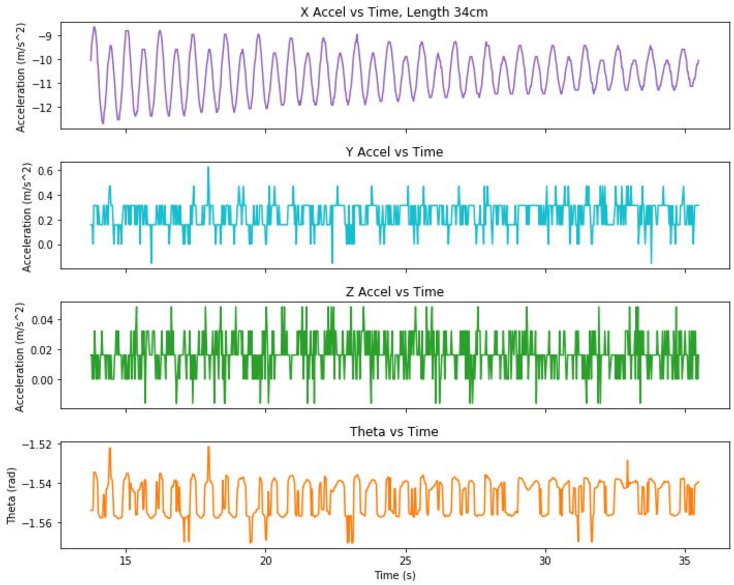


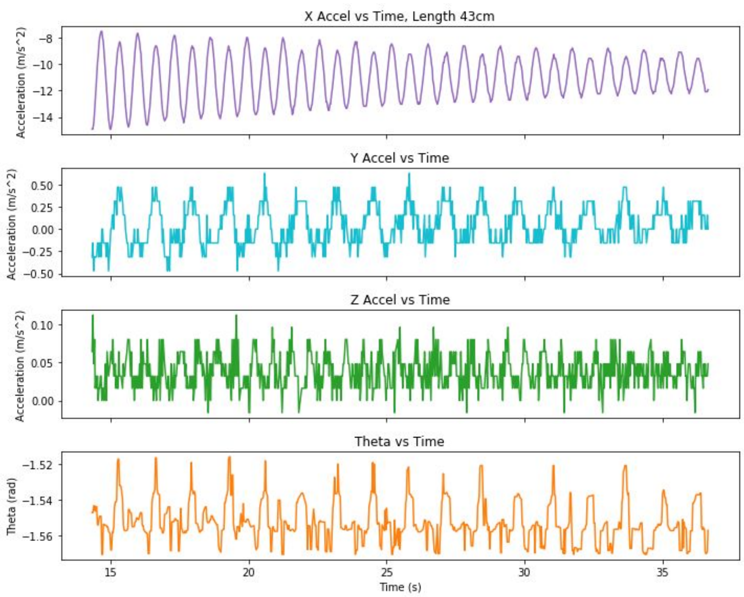
Step 4 Data:

We used the backup data and code provided by Jenn.

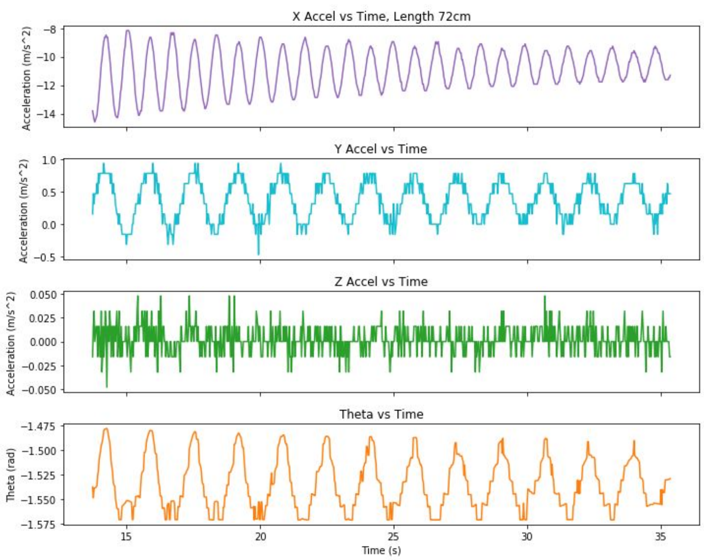
*Graphs on the following page



X Accel vs Time, Length 34cm
Acceleration (m/s^2)
Y Accel vs Time
Acceleration (m/s^2)
Z Accel vs Time
Acceleration (m/s^2)
Theta vs Time
Theta (rad)
Time (s)



X Accel vs Time, Length 43cm
Acceleration (m/s^2)
Y Accel vs Time
Acceleration (m/s^2)
Z Accel vs Time
Acceleration (m/s^2)
Theta vs Time
Theta (rad)
Time (s)



Calculating the period from real world data:

average period for 34cm:

5.85375s

average period for 43cm:

6.58625s

average period for 53cm:

7.17499s

average period for 62cm:

7.68666s

average period for 72cm:

8.29666s

Methodology:
To calculate the period, we used the values in the provided date for the x-acceleration and the corresponding times at those x-values. Using the scipy.signal library, we found the peaks of the x-value data and collected the time stamp at the peaks in a truncated dataset. We subtracted each subsequent time from the previous one corresponding to peaks. We then took the average of each of these periods and converted it to seconds.

Here are the plotted periods for the real world data. It is clearly much lower than the theoretical periods. This is due partially to the factors outlined below about the inaccuracies in data collection and forces such as friction and mass of the pole in the real-world pendulum.

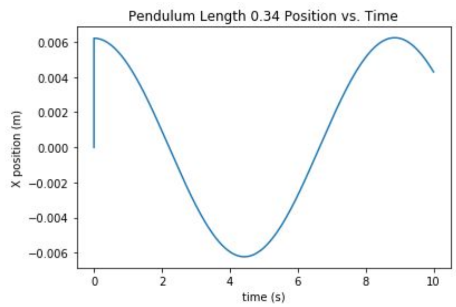
Step 5 Simulation:
Using an inputted theta or starting angle of the pendulum and an array of the 5 different pendulum lengths, we calculated and plotted the theoretical position vs time, velocity vs time, and acceleration vs time graphs for a perfect pendulum.

Using this method of calculations allowed us to account for any error that occurred during the real-world data collections. Some of these errors include: The mass of the pendulum bar, friction in the pendulum, any movement in the z-direction, and accidental discrepancies in the drop angle (theta) of the pendulum swings.

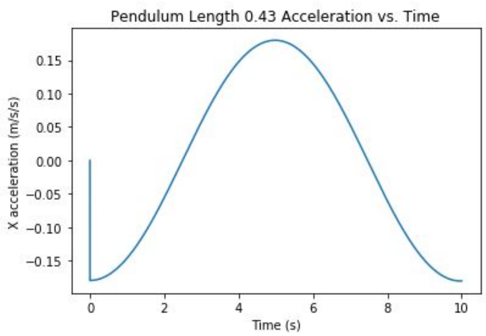
Methodology for part 5 simulation:

When we went to implement our pseudocode we realized we had overcomplicated things quite a bit. We accomplished the simulation by writing three main functions. The initialize function “created” a pendulum at a specified starting length and angle and set initial velocity and acceleration to 0. The update function updated each of these values to the estimated next value in the swing using Euler's Method of calculating position, velocity and acceleration in the curves. The plot function called update in a while loop and appended each updated value into arrays, then plotted these arrays using the matplotlib toolbox. Plot also calculated the period for each length by finding the amount of time in between each time the pendulum position reached zero. Using these three functions we could easily get simulation data for each of the 5 pendulum lengths and see their calculated periods and plots.

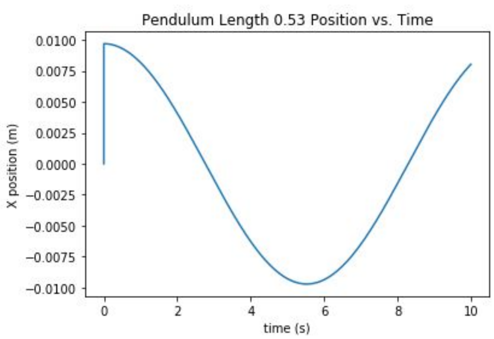
The starting angle is 60 degrees
The period of the pendulum is 6.6417 seconds!

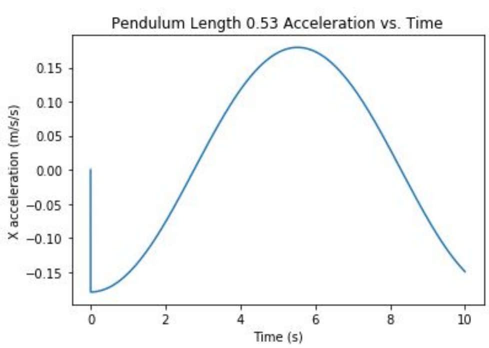


The period of the pendulum is 7.4687 seconds!

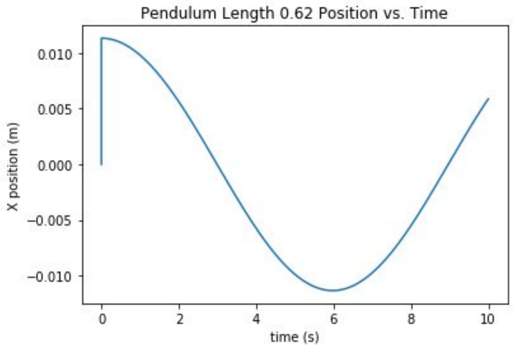


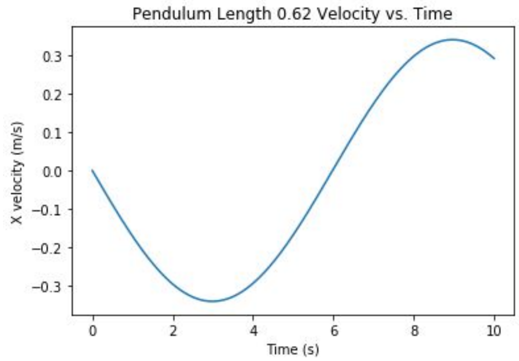
The period of the pendulum is 8.2918 seconds!



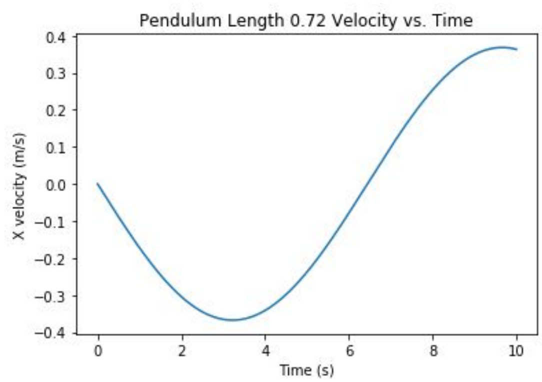


The period of the pendulum is 8.9689 seconds!

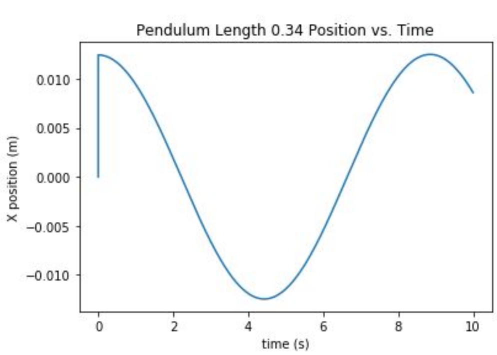


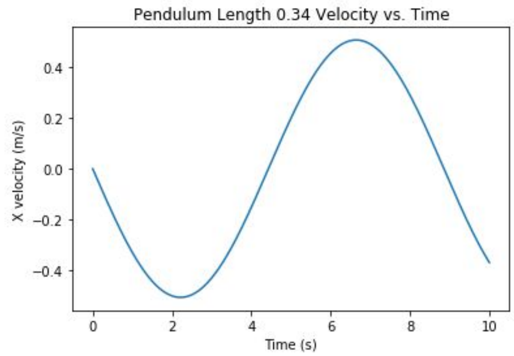


The period of the pendulum is 9.665 seconds!

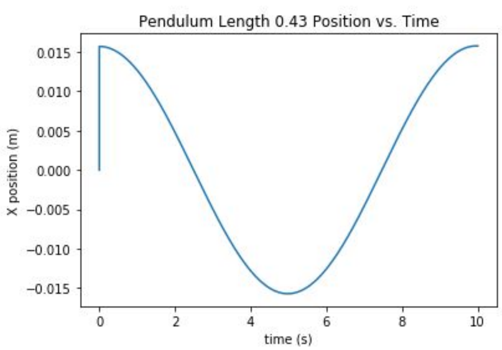


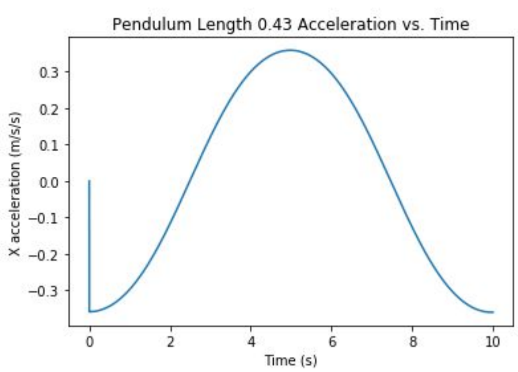
The starting angle is 120 degrees
The period of the pendulum is 6.6417 seconds!



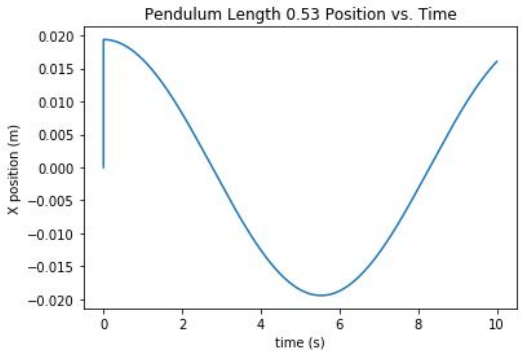


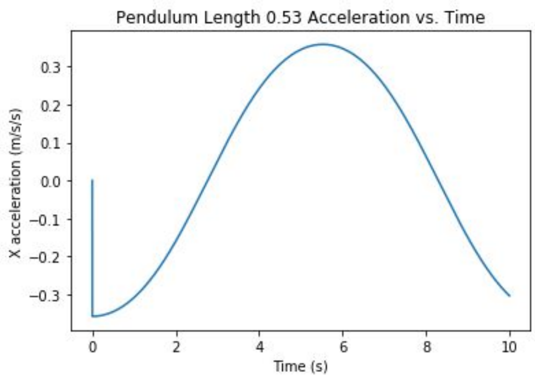
The period of the pendulum is 7.4697 seconds!



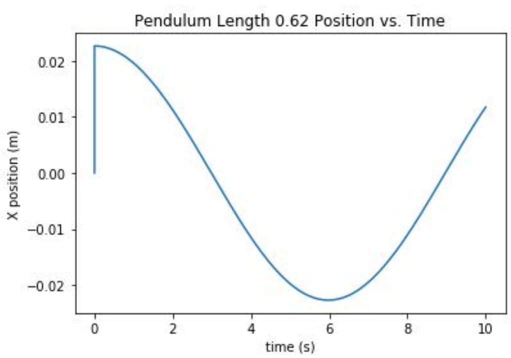


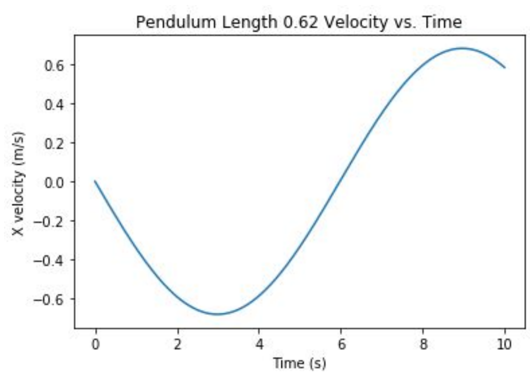
The period of the pendulum is 8.2928 seconds!

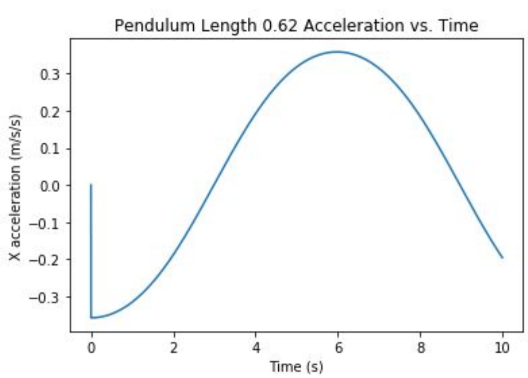




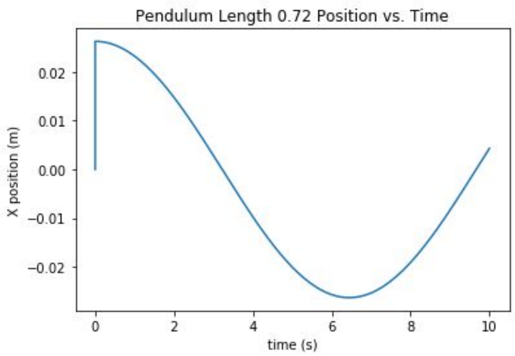
The period of the pendulum is 8.9689 seconds!

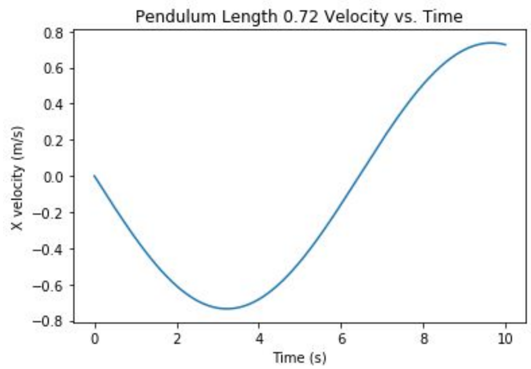


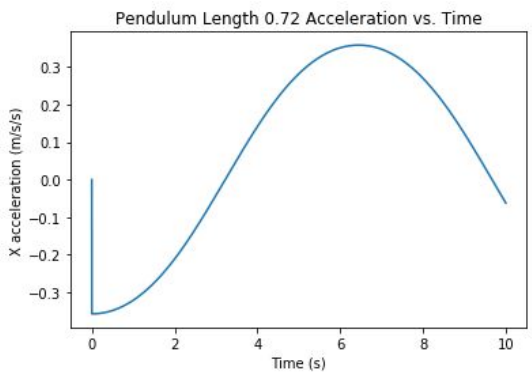




The period of the pendulum is 9.665 seconds!







Comparison of Data:

Analysis of the relationship between pendulum length and period calculated from real world data and simulation data:

Pendulum Length (cm)	Theoretical period (s)	Actual Period (s)	Simulation period (s)
34	11.7	5.85375	6.6417
43	13.5	6.58625	7.4687 seconds
53	14.6	7.17499	8.2918
62	15.8	7.68666	8.9689
72	17.02	8.29666	9.665

There are clearly big variations in the periods obtained from these three separate methods. It makes a lot of sense that the real world periods would be different for a number of reasons:

- There is friction in the pendulum joint which would slow down the pendulum significantly and make the distance it travels less far.
- The pendulum had clear acceleration in the z direction--that is it didn't move perfectly forward and backward. The movement in this direction would take away from the acceleration in the x and y directions so that would affect the arc of the pendulum and make it non-uniform.
- We did not account for the mass of the bar in the pendulum. Since this was made out of plastic, it actually would have a significant effect on the effective length of the pendulum. The length of the pendulum is counted as the distance to the center of mass, so if the bar has mass, the length of the pendulum would be shorter since the center of mass would be moved upward in the system. Therefore the real world period would be shorter than that of a pendulum that has the same length to the micro bit (aka mass at the bottom) but with a massless bar.

Theoretically, neglecting dampening should not be a considerable factor in the period of the pendulum. Within a certain margin, the amplitude of a pendulum should not matter. Much like a grandfather clock or a metronome, the pendulum can keep swinging for a long time, and while the amplitude will get smaller, the period will remain exactly the same. The amplitude will get smaller due to forces like friction, but as we saw in the real world model, this should not matter.