Incorporating Coding into High School Physics and Astronomy

AAPT Winter Meeting 2022

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Why teach coding in physics?

Physics and physics-related fields like astronomy and engineering have become significantly dependent on coding and students need more experience using code to be successful on their physics paths.

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How did this current effort begin?

Interview with Adam LaMee, lead of the Fermilab Quarknet Coding Fellows Group

Clip answering question: How does a coding-focused group fit in with other physics topics from Fermilab?

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Who is coding for?

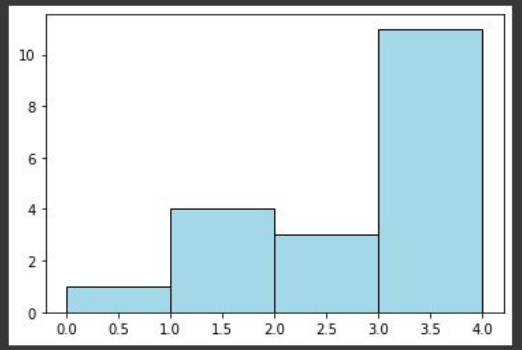
Current Lesson

Demographics:

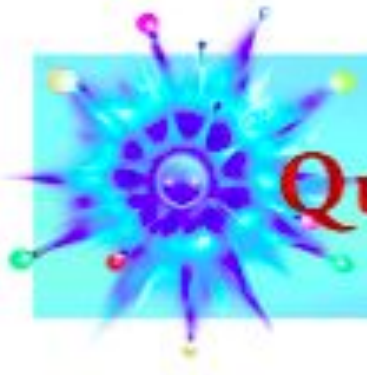
- 9th Grade Physics
- 10th -12th Grade Astronomy
- 11th - 12th Grade Physics
- AP Physics B Parts 1 and 2
- AP Physics C

```
[ ] # Does this model random coin flips? What could you do to improve the model?
    flips = np.random.randint(low=0, high=6, size=25)
    flips

[ ] # create a histogram
    plt.hist(flips, bins = [0,1,2,3,4], color='lightblue', edgecolor = 'black' );
```




```
[ ] # re-center the histogram bins
    bin_list = [0,1,2,3,4,5,6,7,8,9]
    plt.hist(flips, bins = np.subtract(bin_list,0.5), color='lightblue', edgecolor = 'black' );
```



Access to Coding

Google Colab

- Easiest launch point if you currently use Google
- Currently access issues being worked out, you can try these activities using a non-school linked account

Other Options

- Kaggle - best if you don't need to save, students can take screenshots
- Anaconda - needs to be downloaded, free, good for more advanced students

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Introduction to Python

Brief Introduction for All

- **Intro Notebook:** Gives students an explanation of how Jupyter notebooks function. Great for any age group.

Join us! Open up the link and follow along as we go through the intro notebook.

Ask any questions as we go along, we will be monitoring the chat as we walk through each step

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Kinematics

Coding in Physics

- **P vs. T and V vs. T:** Uses modules learned in Intro notebook, extending lesson using more complex mathematical programs.

```
#resets the values to create the next graph listed
xi = 10
vi = 35
a = -9.8
# makes an empty position/time data set
time_list = []
position_list = []
t = 0               # sets a starting value for time

while (t < 11):                  # runs the 4 lines below until time is not < 11
    time_list.append(t)          # saves the time value
    xf = xi + vi*t + .5*a*t**2   # calculates xf
    position_list.append(xf)     # saves xf as the position value
    t = t + 1

#   this creates a scatterplot: plt.scatter(x-variable, y-variable)
plt.scatter(time_list, position_list)
plt.title("Position vs time, projectile")
plt.xlabel("time (s)")
plt.ylabel("position (m)");
```

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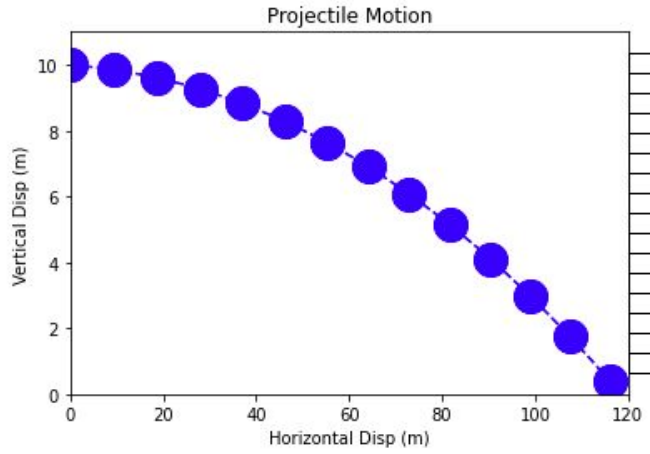
Projectile Motion

Other examples in physics

- **Projectile Motion:**
  Modeling projectile motion in P vs. t and V vs. t graphs. Great for higher level high school physics courses.

```
plt.plot(data['x'],data['y'],linestyle='--', marker='o', color='b', markersize=20)
plt.table(cellText=data.values.round(3), colLabels=data.columns, loc='right')
plt.xlabel('Horizontal Disp (m)')
plt.ylabel('Vertical Disp (m)')
plt.title('Projectile Motion')
plt.grid(False)
plt.axis([0, 120, 0, 11])
plt.show()
```



t	x	y
0.0	0.0	10.0
0.1	9.412	9.853
0.2	18.737	9.608
0.3	27.978	9.265
0.4	37.135	8.824
0.5	46.21	8.284
0.6	55.205	7.647
0.7	64.121	6.911
0.8	72.959	6.076
0.9	81.72	5.143
1.0	90.407	4.111
1.1	99.02	2.98
1.2	107.56	1.749
1.3	116.029	0.42
1.4	124.428	-1.01

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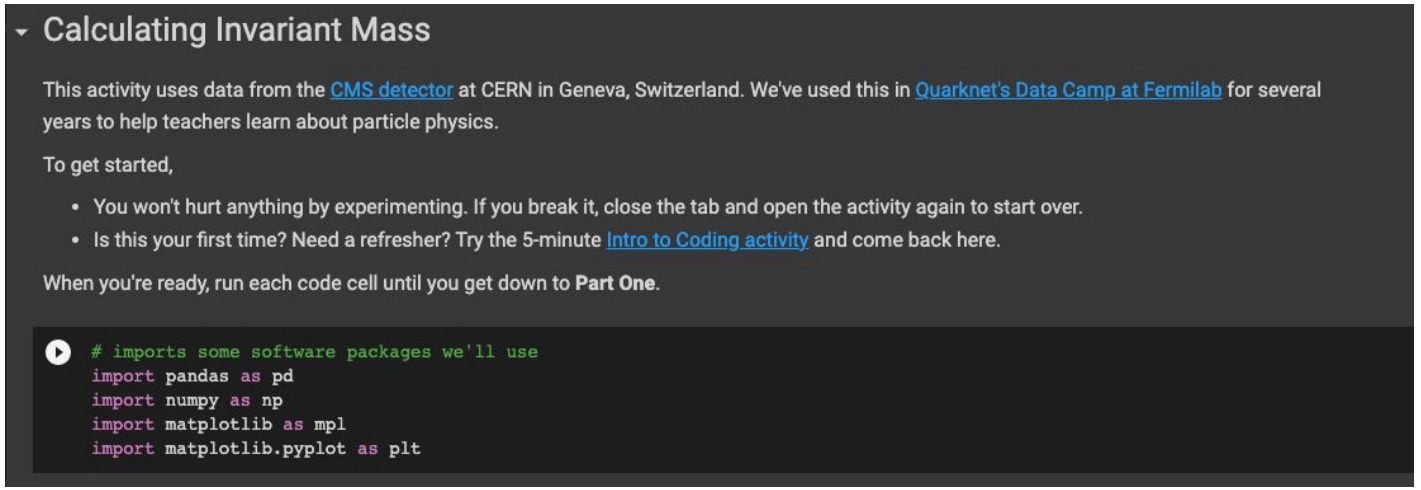
Advanced Topics

Particle Physics

- **Muon Mass Notebook:** Utilising previous and new modules to analyze a large data set from the CMS detector. Great for particle physics integration into high school physics courses.



Calculating Invariant Mass

This activity uses data from the CMS detector at CERN in Geneva, Switzerland. We've used this in Quarknet's Data Camp at Fermilab for several years to help teachers learn about particle physics.

To get started,

- You won't hurt anything by experimenting. If you break it, close the tab and open the activity again to start over.
- Is this your first time? Need a refresher? Try the 5-minute Intro to Coding activity and come back here.

When you're ready, run each code cell until you get down to **Part One**.

```
# imports some software packages we'll use
import pandas as pd
import numpy as np
import matplotlib as mpl
import matplotlib.pyplot as plt
```

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Astronomy

Other subjects: Astronomy

- **The HR Diagram:** Creating a graph of star brightness vs. heat using online database. Can be used for all high school levels.

```
[5] # We wish to look at the first 5 rows of our data set
    data.head(5)
    # click on the blue icon at the bottom to make an editable table
```

index	proper	ra	dec	dist	mag	absmag
0	Sol	0.0	0.0	0.0	-26.7	4.85
1	Proxima Centauri	14.495985000000001	-62.679485	1.2959	11.01	15.447000000000001
2	Rigil Kentaurus	14.660765	-60.833976	1.3248	-0.01	4.379
3	NaN	14.660345999999999	-60.8383	1.3248	1.35	5.739
4	Barnard's Star	17.963472	4.693388	1.8238	9.54	13.235

Show 25 per page

Like what you see? Visit the data table notebook to learn more about interactive tables.

```
# The .shape command displays the (number of rows , number of column
data.shape
```

```
(119614, 16)
```

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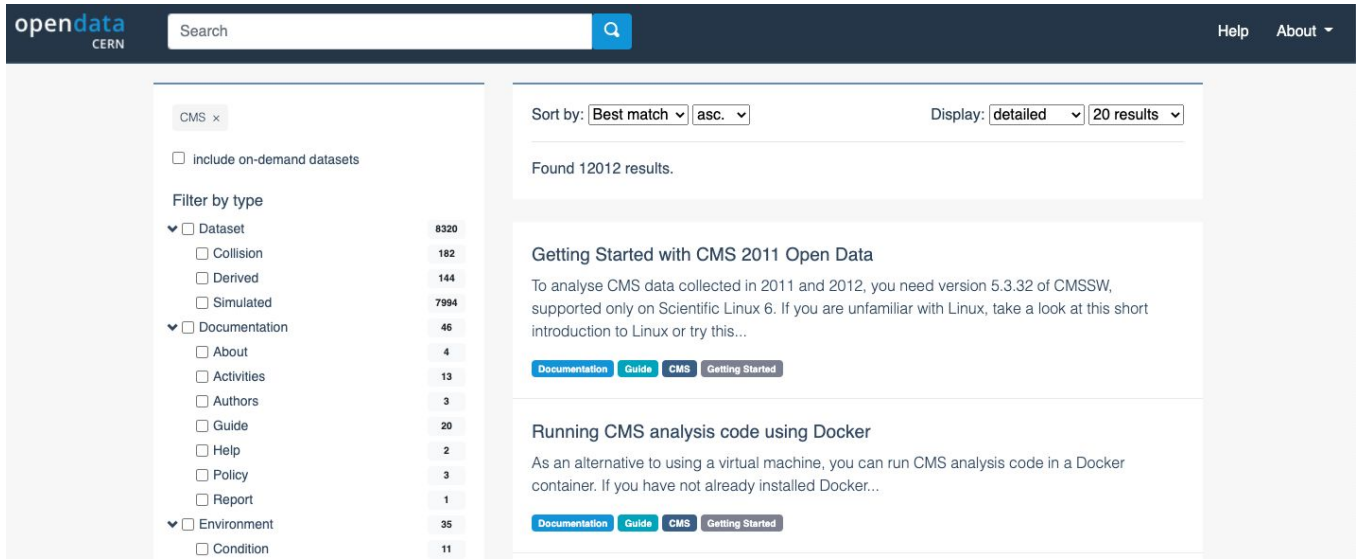
Where is coding useful?

- Analyzing large data sets, student created (any csv file)
- Analyzing large data sets pulled from online sources
- Making graphs
- Streamlining calculations



https://opendata.cern.ch/

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Try it out!

Check out the activity folder, posted here:
https://drive.google.com/drive/folders/1QA3hgEHgOYi6h2IRA3y7XmAj3bj9BhUU?usp=sharing

Make copies of Colab activities in your own Google Drive

Share any great changes or additions you make that go well

Let us know if you find any mistakes

Any questions?