BNL Labs

ASP High School Event 2024

BNL Labs for ASP HS Event 2024

- BNL will create four (4) hands-on lab activities in support of the ASP HS Event 2024:
  1) **Geiger Counter** – To correlate decay events (from over-the-counter thoriated lantern mantles and TIG welding rods) as a function of distance from an inexpensive detector
  2) **Spectrophotometry** – To catalog substances by their reflectance spectra and to use this database to identify unlabeled materials
  3) **Ohm's Law** – Empirically determine the relationship between resistance, current, and voltage and to predict the resistance of an unlabeled resistor
  4) **Center of Mass** – Mathematically determine the balancing point of 14 and 15-block Jenga cantilevers and physically build those piles

BNL Labs for ASP HS Event 2024

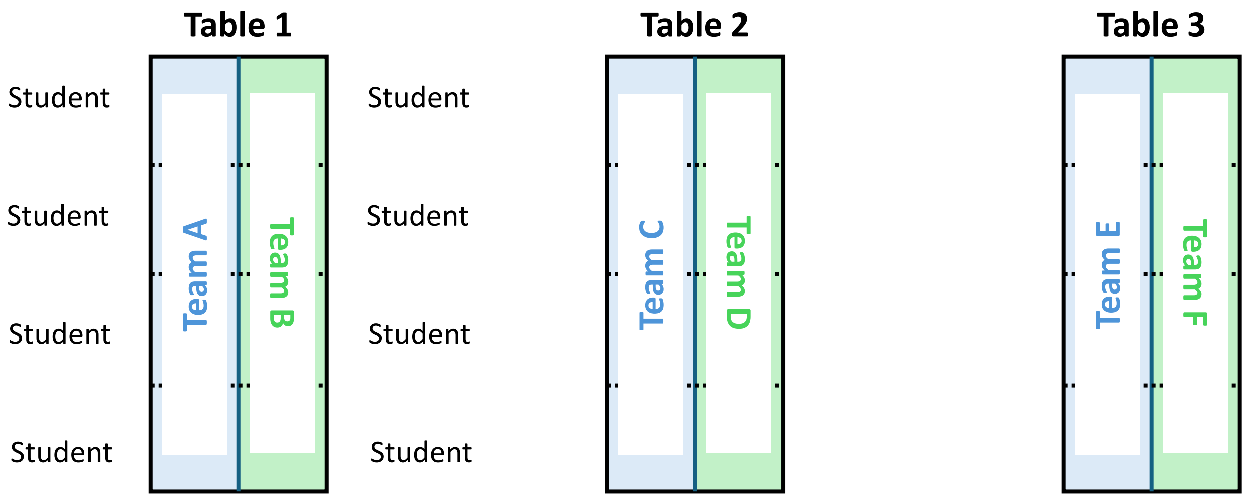
- Each lab has these learning objectives/flow:
  1) A brief introductory lecture about the **theoretical** physical <u>principles</u> driving the output the students will measure
  2) Students will use a **data capture device** to measure signals as they vary experimental conditions
  3) Students will **plot** the resulting observations to gain insight into the underlying physical law (**mathematical correlation**) connecting those data points
  4) Students will use **interpolation/extrapolation** to form a hypothesis about an unknown sample and to <u>verify</u> their intuition by measuring/identifying the unlabeled sample
  5) Gain an appreciation for how **low-cost microcontrollers combined with modern sensors** can greatly enhance traditional high school benchtop science experiments

BNL Labs for ASP HS Event 2024

- 48 students will sit at six (6) tables of eight (8) students per table, with each table split into two (2) four-person teams for a total of (12) teams
- BNL will provide twelve (12) battery-powered microcontroller data capture devices (one per team, two per table) to conduct the labs
- BNL will provide the printed slides, worksheets, graph paper, and calculators for each team to record and analyze the data from each lab

Session 1

Instructor 1

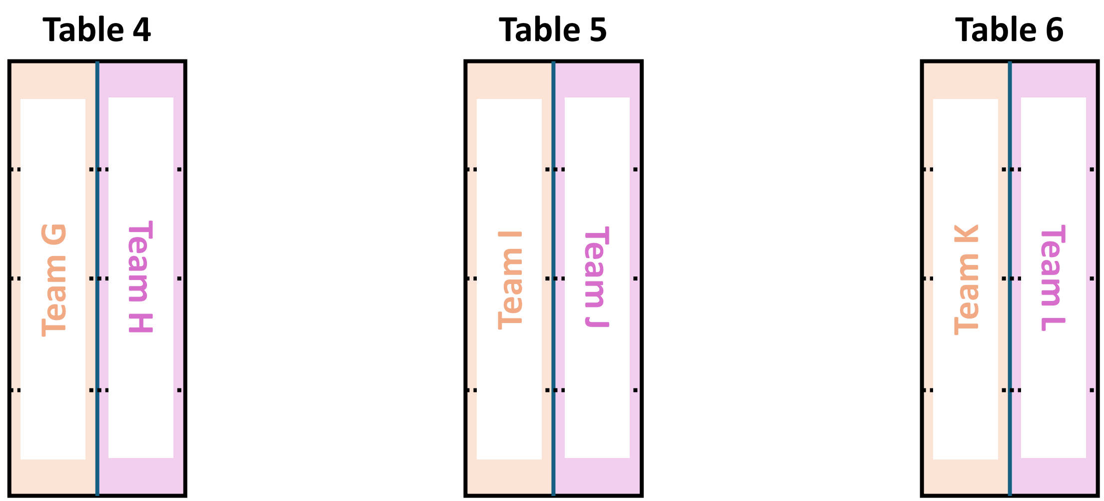


Lab:

Geiger Counter
(50 mins)

Spectrophotometry
(50 Mins)

Instructor 2



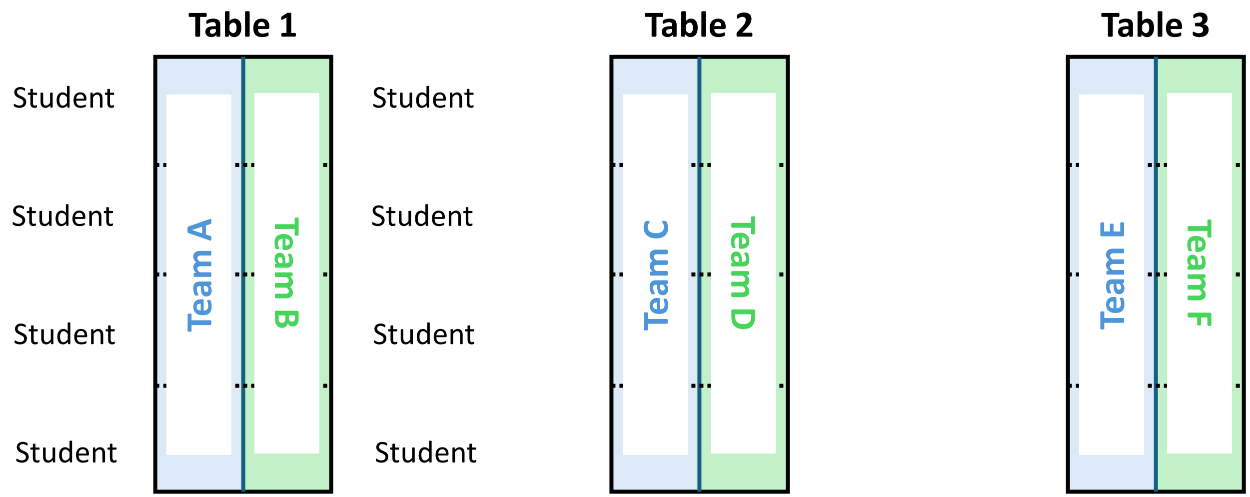
Lab:

Ohm's Law
(50 mins)

Center of Mass
(50 Mins)

Session 2

Instructor 1

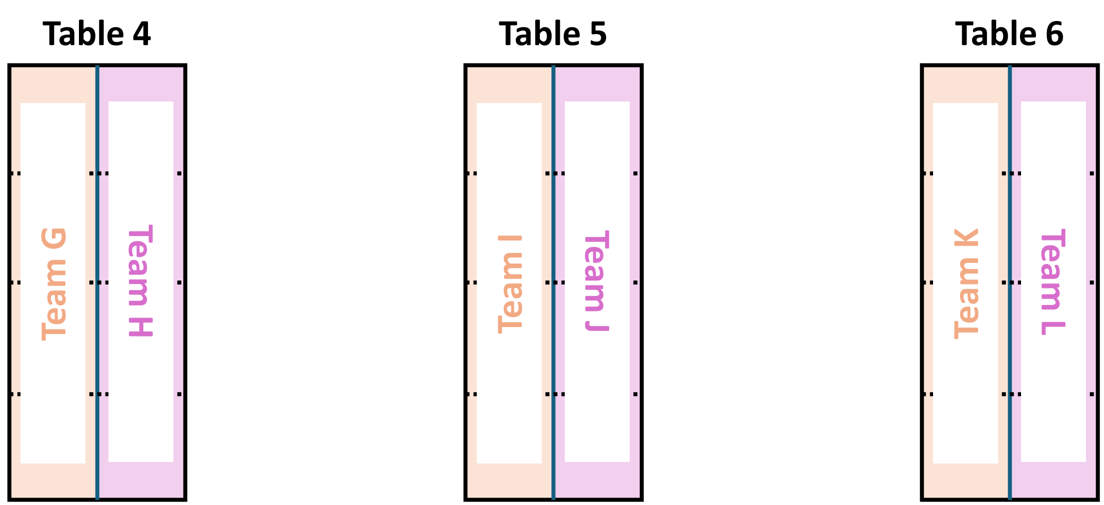


Lab:

Geiger Counter
(50 mins)

Spectrophotometry
(50 Mins)

Instructor 2



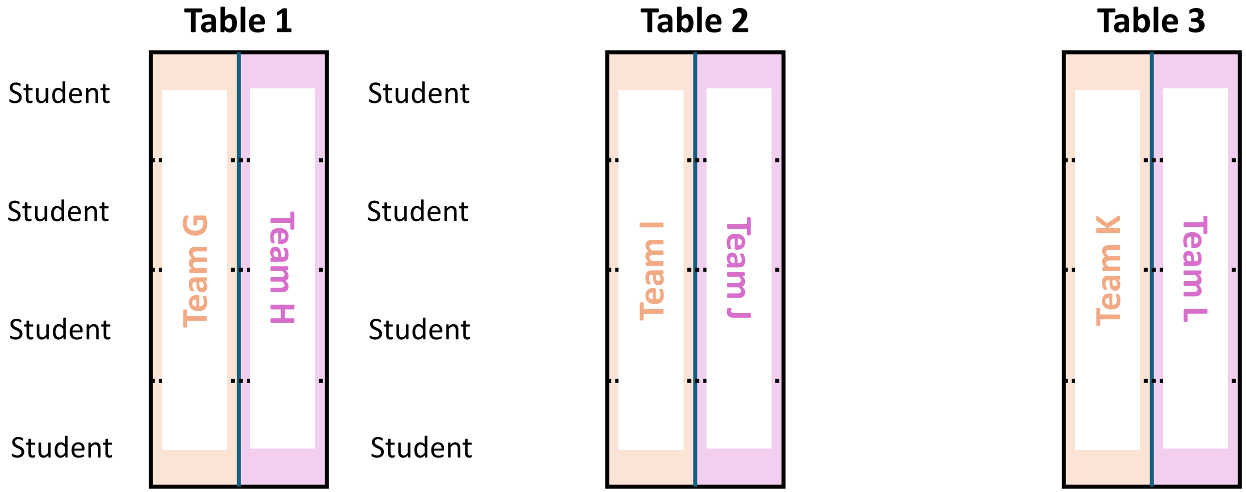
Lab:

Ohm's Law
(50 mins)

Center of Mass
(50 Mins)

Session 3

Instructor 1

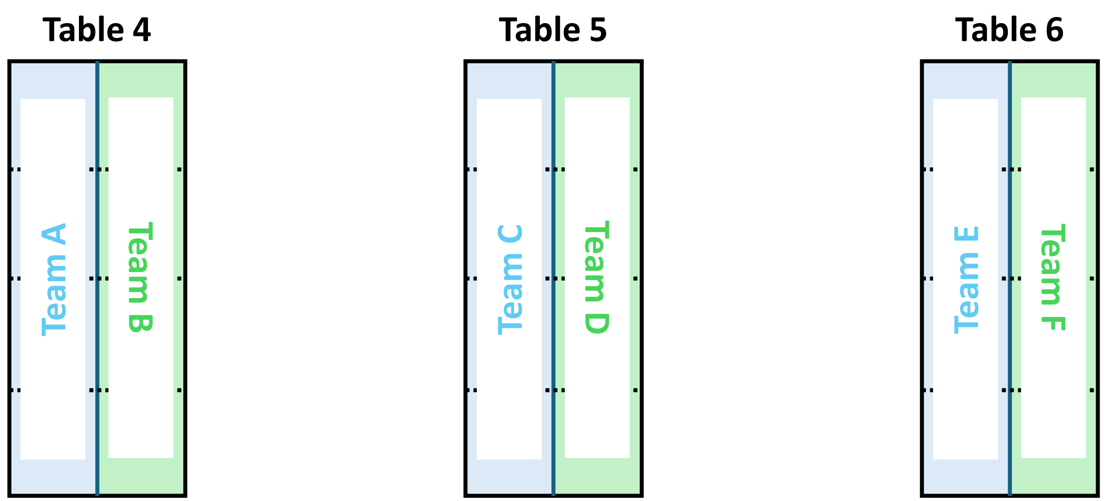


Lab:

Geiger Counter
(50 mins)

Spectrophotometry
(50 Mins)

Instructor 2



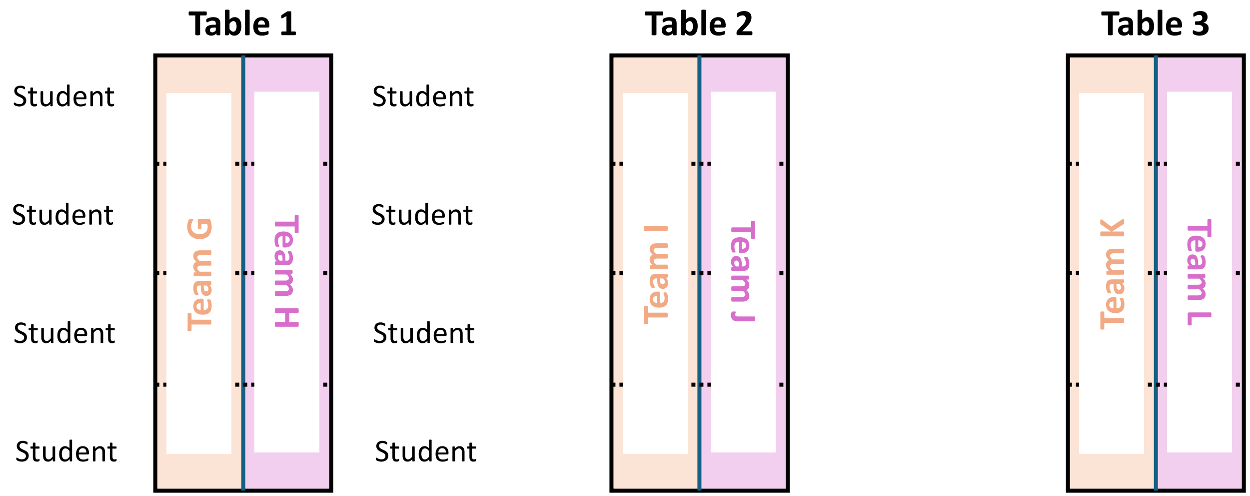
Lab:

Ohm’s Law
(50 mins)

Center of Mass
(50 Mins)

Session 4

Instructor 1

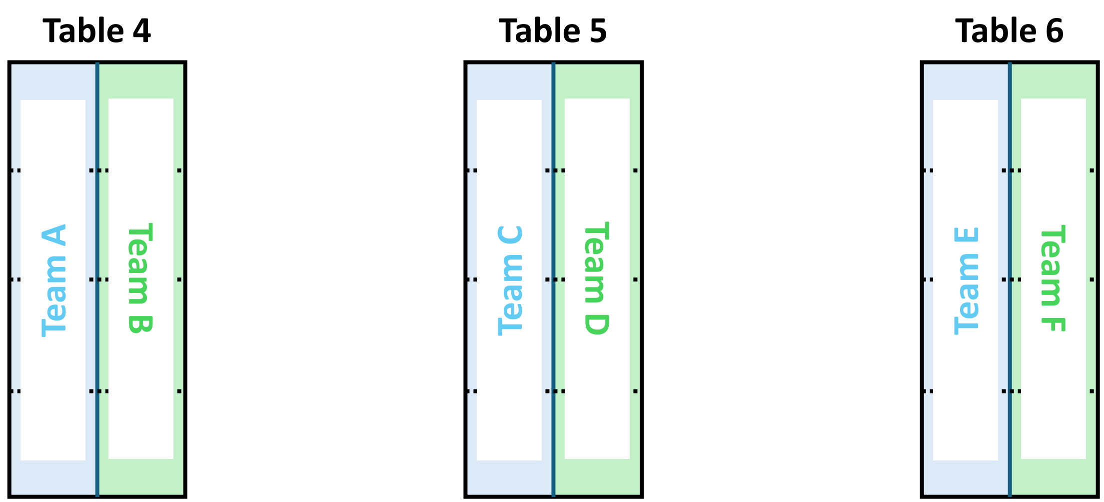


Lab:

Geiger Counter
(50 mins)

Spectrophotometry
(50 Mins)

Instructor 2



Lab:

Ohm's Law
(50 mins)

Center of Mass
(50 Mins)

BNL Labs for ASP HS Event 2024

- Students will not need a computer at their tables, and all lab electronics are powered by rechargeable batteries
- There will be four (4) sessions, with each lab taking 50 minutes to complete, with students working in four-person teams
- Teams will complete Session 1 and Session 2 labs, then move as a team to another table to finish Session 3 and Session 4 labs
- All students will complete all four labs within the allotted 240 minutes

BNL Labs for ASP HS Event 2024

- ASP will need to provide the **two** instructors who must be trained by BNL before the event
  - Instructor #1 will demonstrate & monitor the **Geiger Counter** and **Spectrophotometer** labs
  - Instructor #2 will demonstrate & monitor the **Ohm's Law** and **Center of Mass** labs
- BNL will provide an instructor's guide for each lab that enumerates the learning objectives, step-by-step instructions, and the approved solutions (expected results) to provide students with feedback

BNL Labs for ASP HS Event 2024 - Bill of Materials **US Dollars**

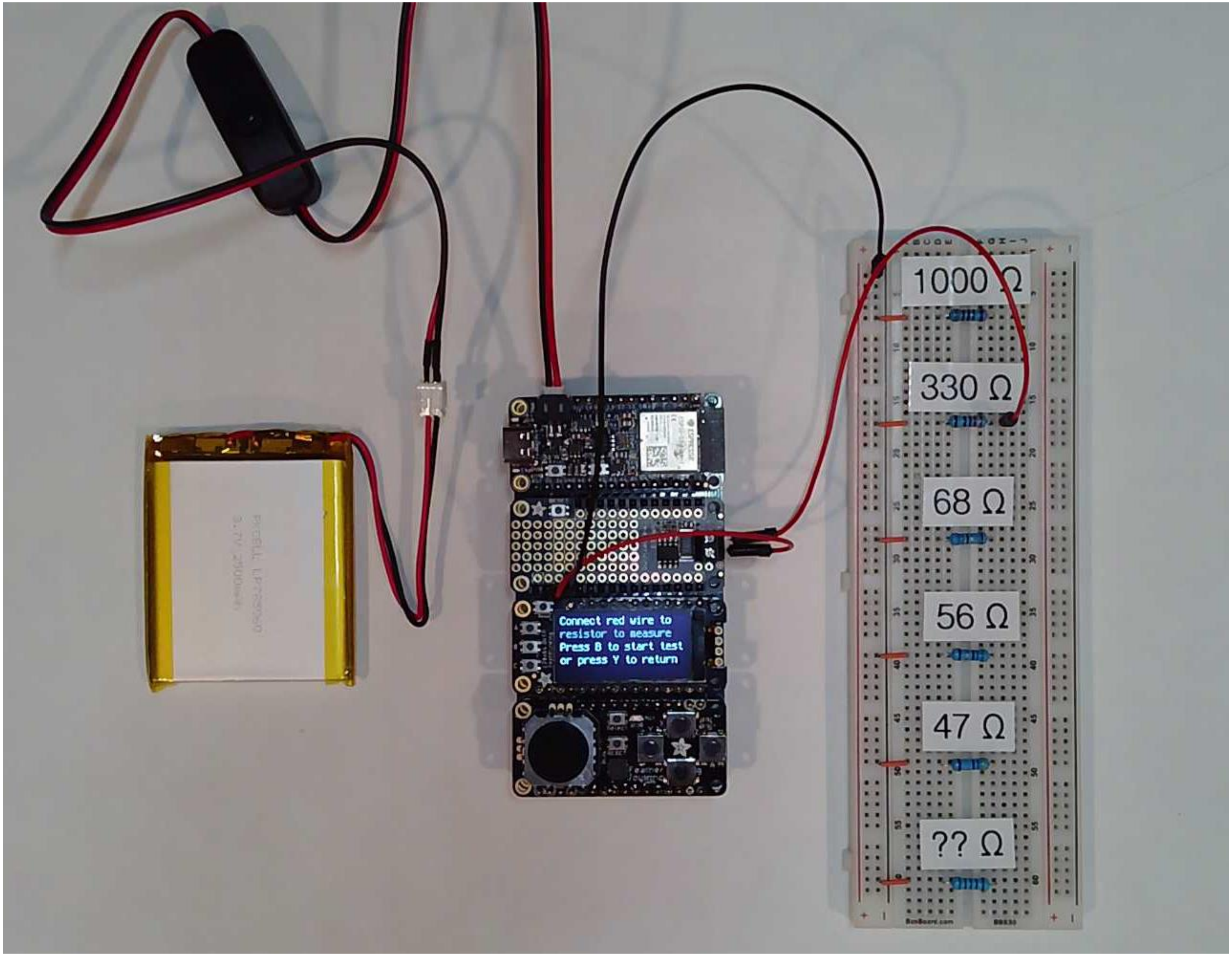
Description	Unit Cost	Qty	Total Cost
Adafruit ESP32-S3 Feather with 4MB Flash 2MB PSRAM, Stemma QT	$ 17.50	12	$ 210.00
Adafruit Joy FeatherWing for all Feathers	$ 9.95	12	$ 119.40
Adafruit FeatherWing OLED - 128x64 OLED Add-on For Feather	$ 14.95	12	$ 179.40
Adafruit INA219 FeatherWing (Current Sensor)	$ 7.95	12	$ 95.40
Adafruit Quad Side-By-Side FeatherWing Kit with Headers	$ 9.95	12	$ 119.40
Premium Silicone Covered Male-Male Jumper Wires - 200mm x 40	$ 9.95	6	$ 59.70
Wall Power Supply with USB C - 5V 3A Output and Switch	$ 5.95	3	$ 17.85
Lithium Ion Polymer Battery - 3.7v 2500mAh	$ 14.95	12	$ 179.40
BusBoard BB830 Solderless Plug-In BreadBoard	$ 8.75	6	$ 52.50
EDGELEC Resistors (1K, 330, 100, 68, 56, 47 Ohm)	$ 5.95	5	$ 29.75
SparkFun Triad Spectroscopy Sensor - AS7265x	$ 69.95	6	$ 419.70
SparkFun Serial Basic Breakout - CH340C and USB-C	$ 9.95	6	$ 59.70
SparkFun LiPo Charger Plus	$ 11.50	3	$ 34.50
Casio FX 260 Solar II Scientific Calculator	$ 9.49	6	$ 56.94
Hasbro Gaming Jenga Classic Game with Genuine Hardwood Blocks	$ 15.95	16	$ 255.20
3.3V Portable Geiger Counter for Arduino	$ 58.99	6	$ 353.94
Ten Specimen Density Set Cube for Periodic Table Collection	$ 51.99	6	$ 311.94
WeldingCity 10-pk Premium TIG Welding Tungsten Electrode Rod	$ 37.99	3	$ 113.97
		Before Tax:	**$ 2,668.69**

The intent is that BNL will temporarily lend this hardware to ASP for the event, and the BNL costs to develop the curriculum will represent an “in-kind” contribution from BNL to ASP – **but this is NOT confirmed yet!**

BNL Labs for ASP HS Event 2024

- Each table has two microcontroller units (MCU), one for each team at that table
- All the lab materials are easily transportable between venues, and the instructors are responsible for ensuring all the materials are returned to BNL shortly after the event

Ohm's Law Lab

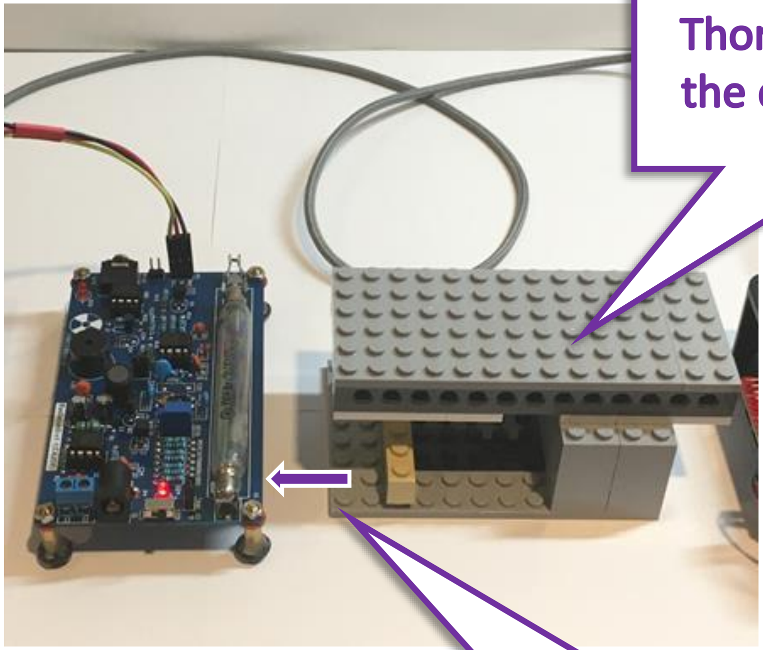

1000 Ω
330 Ω
68 Ω
56 Ω
47 Ω
?? Ω
Connect red wire to
resistor to measure
Press B to start test
or press Y to return

Geiger Counter Lab

The Thorium **Mantles** and Thoriated Welding **Rods** are available for public purchase at any Home Depot. The total radioactivity of these samples is so low that they are not regulated by the U.S. Department of Energy.

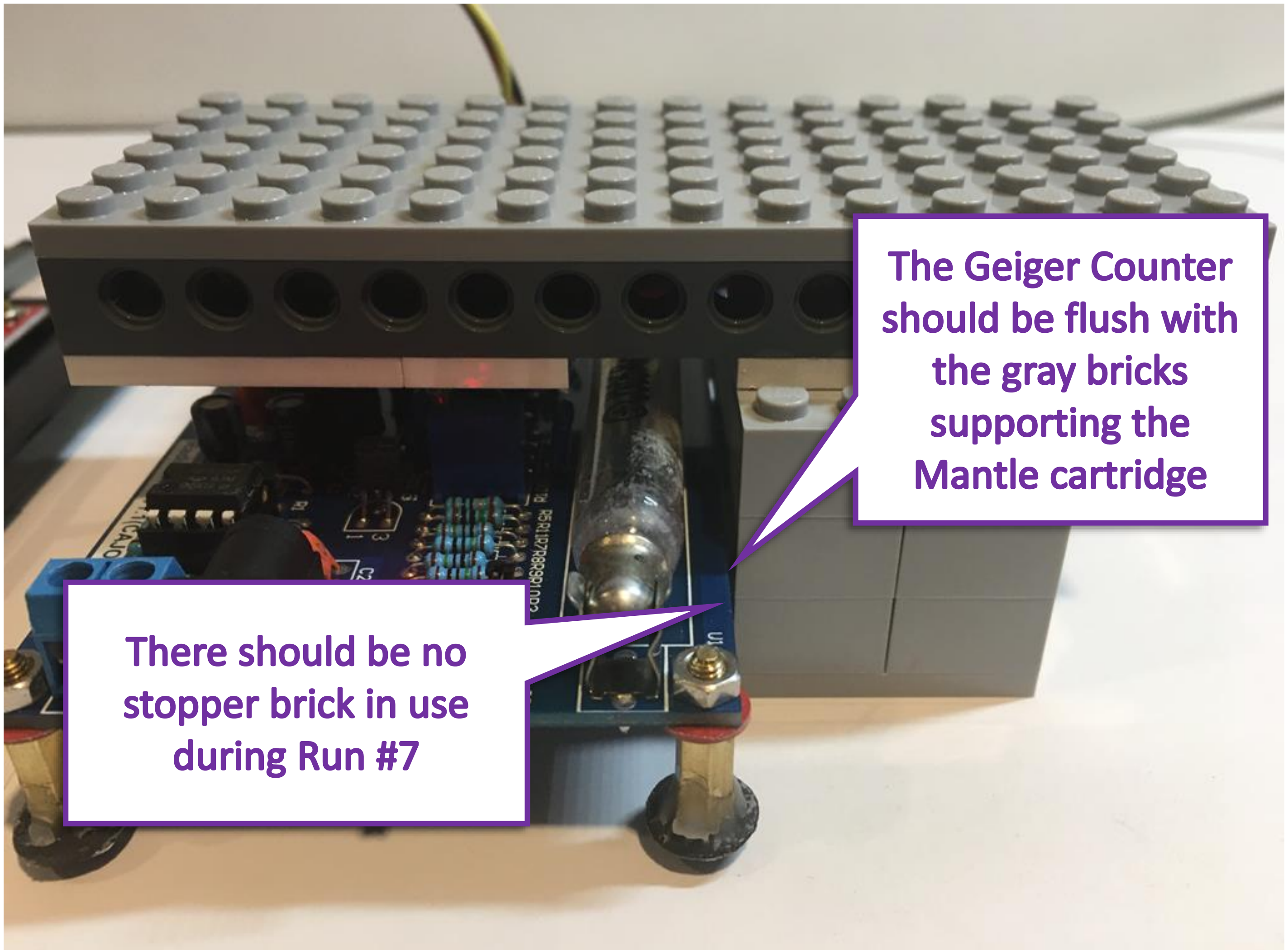
Lab Setup – Thorium Mantle

Do not remove the Thorium Mantle from the carrying cartridge

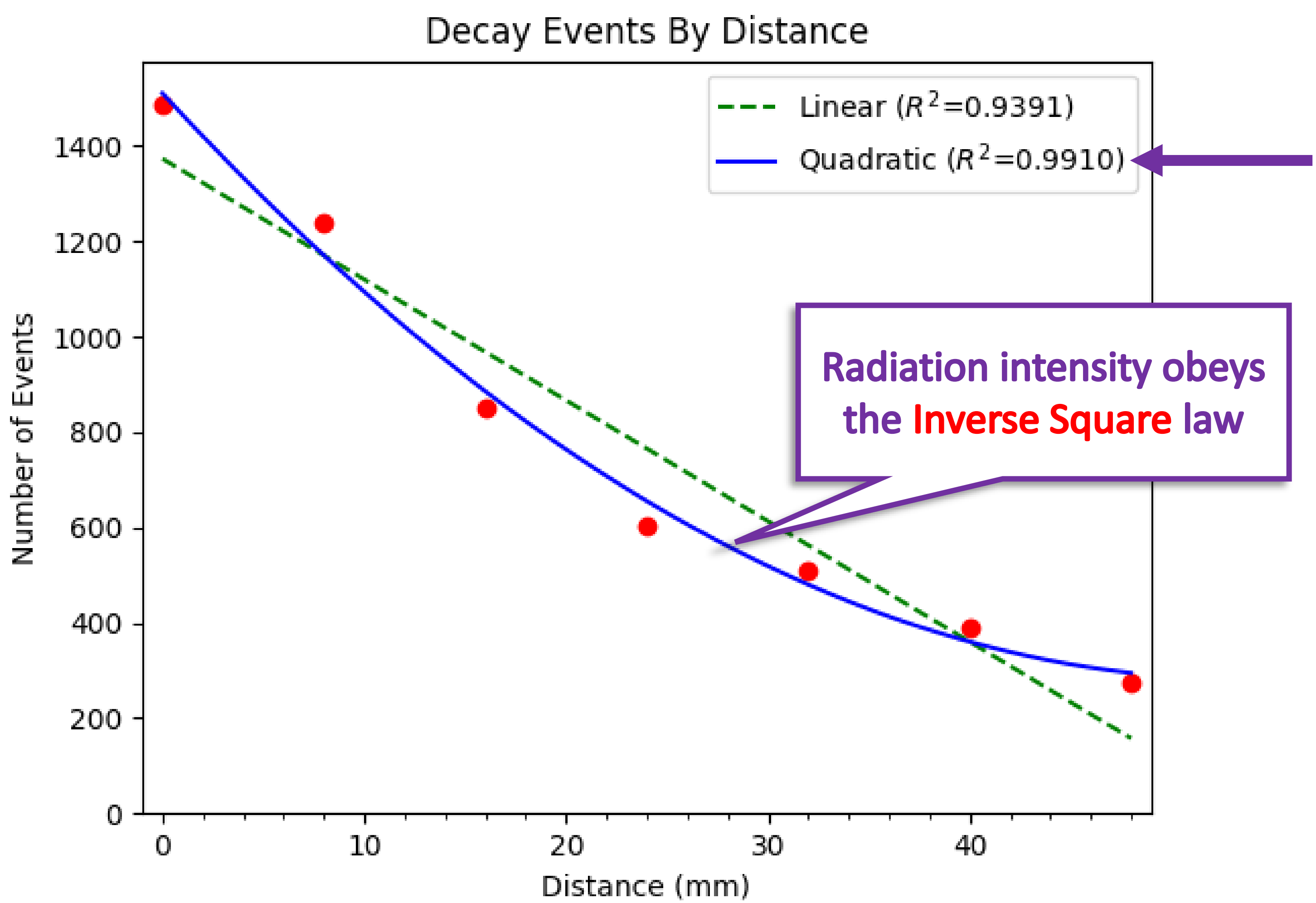


The Mantle Holder slides underneath the Geiger Counter

Lab Setup – Before 7th (Final) Run



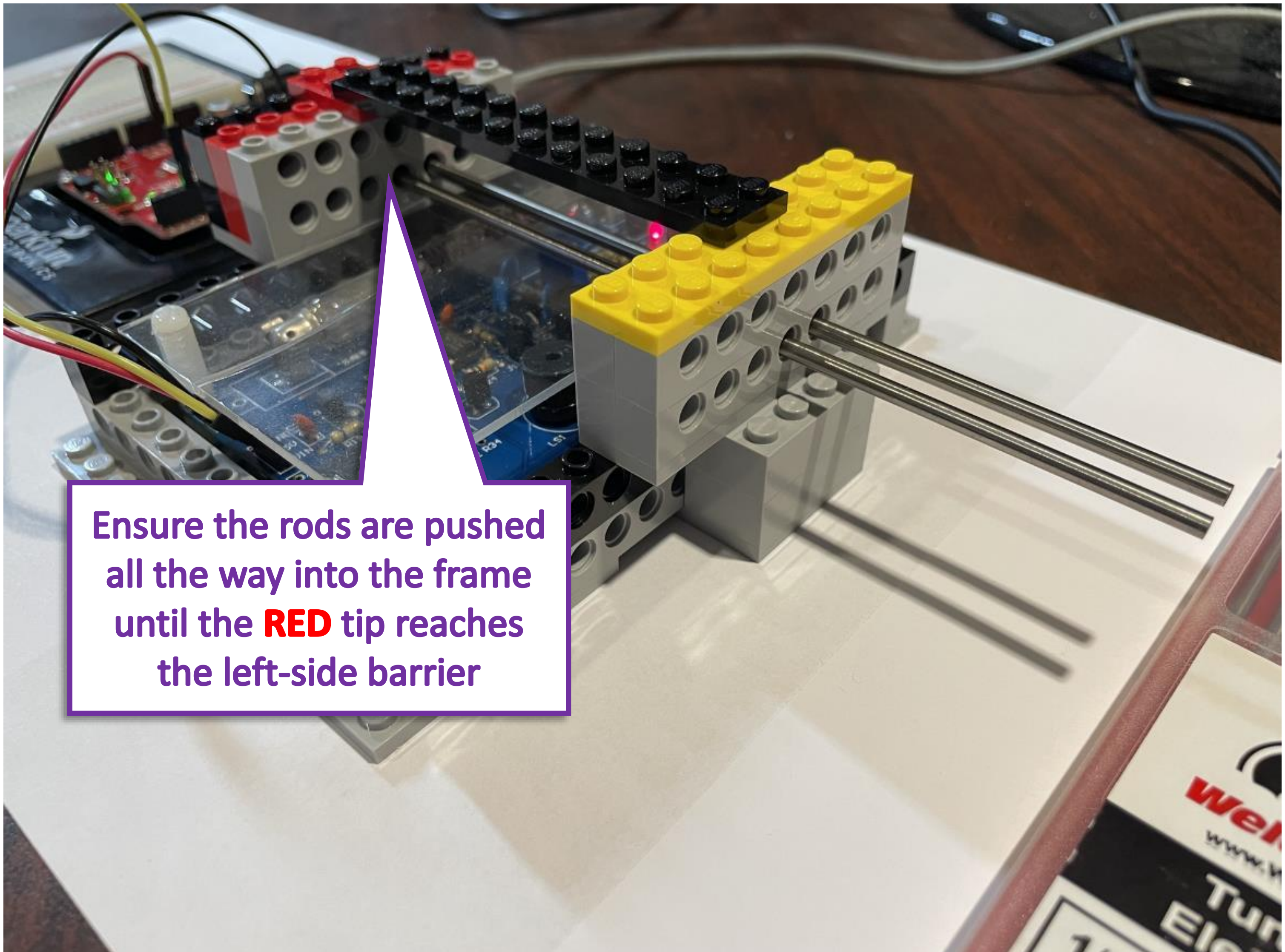
Run plot_distance.py



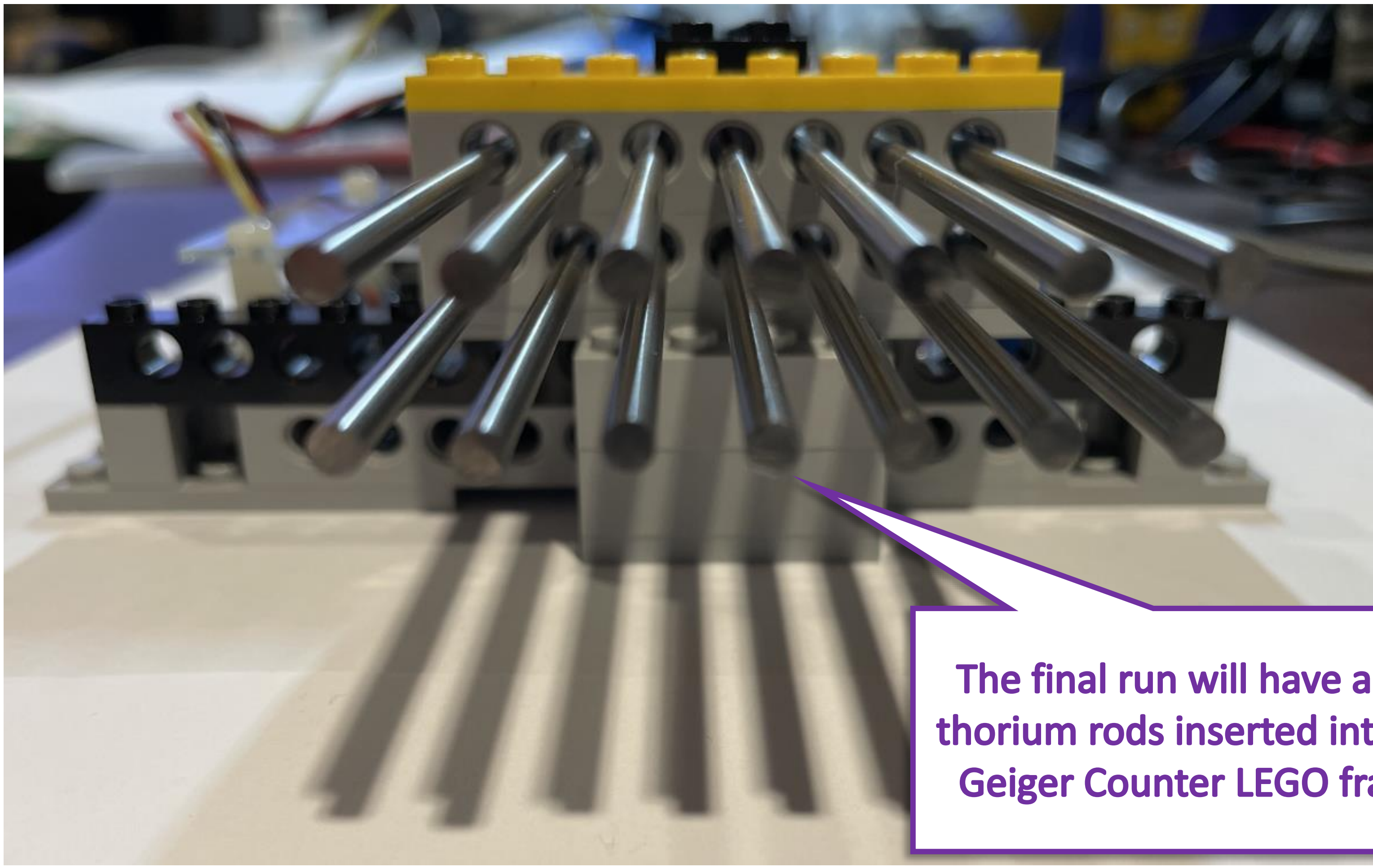
Lab Setup – Thorium Rods

These welding rods have 2% thorium added to the tungsten to improve the heat transfer of the welds

Lab Setup – Before 2nd Run

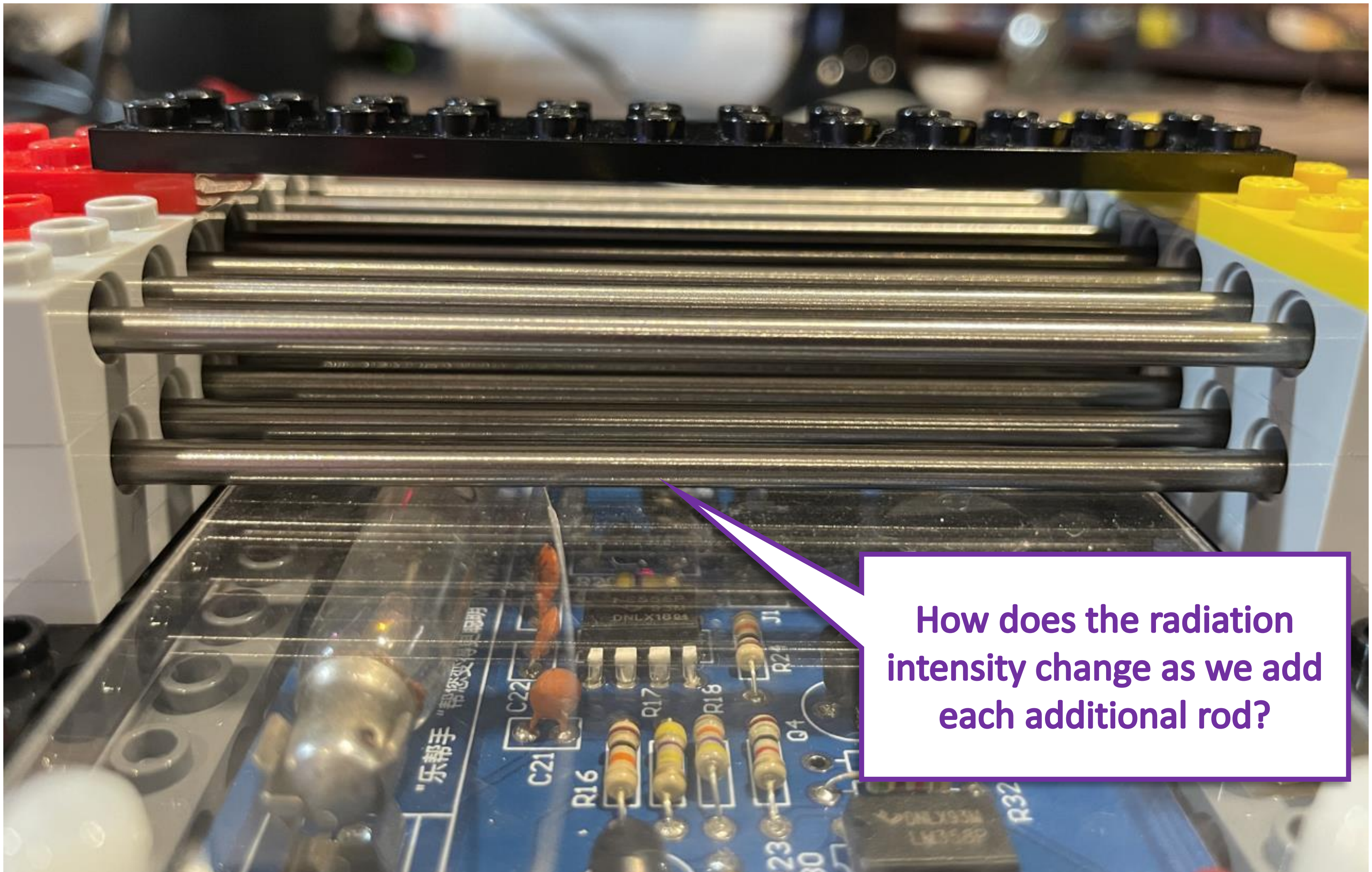


Lab Setup – Before the 14^{th} (Final) Run

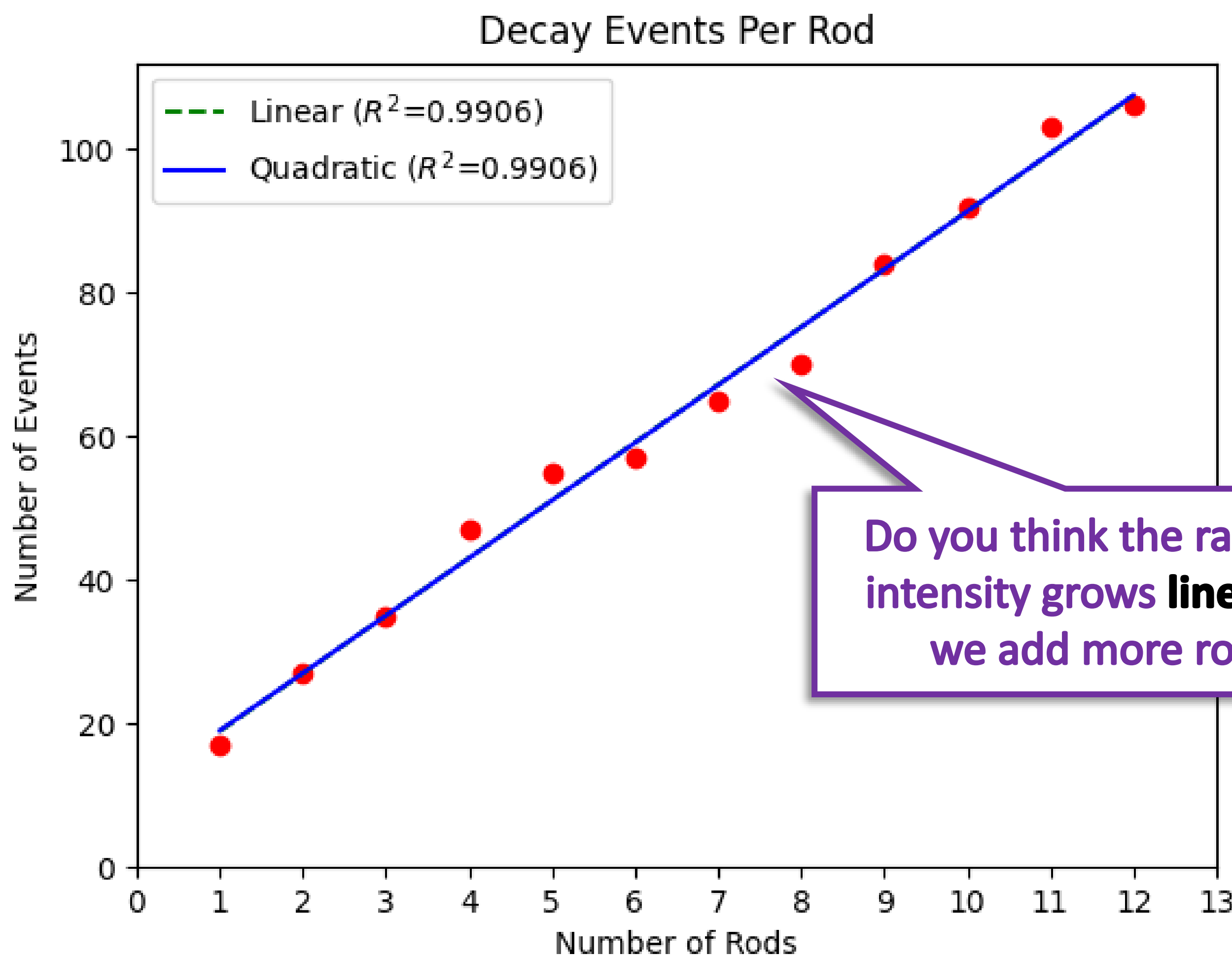


The final run will have all 14 thorium rods inserted into the Geiger Counter LEGO frame

Lab Setup – Thorium Rods

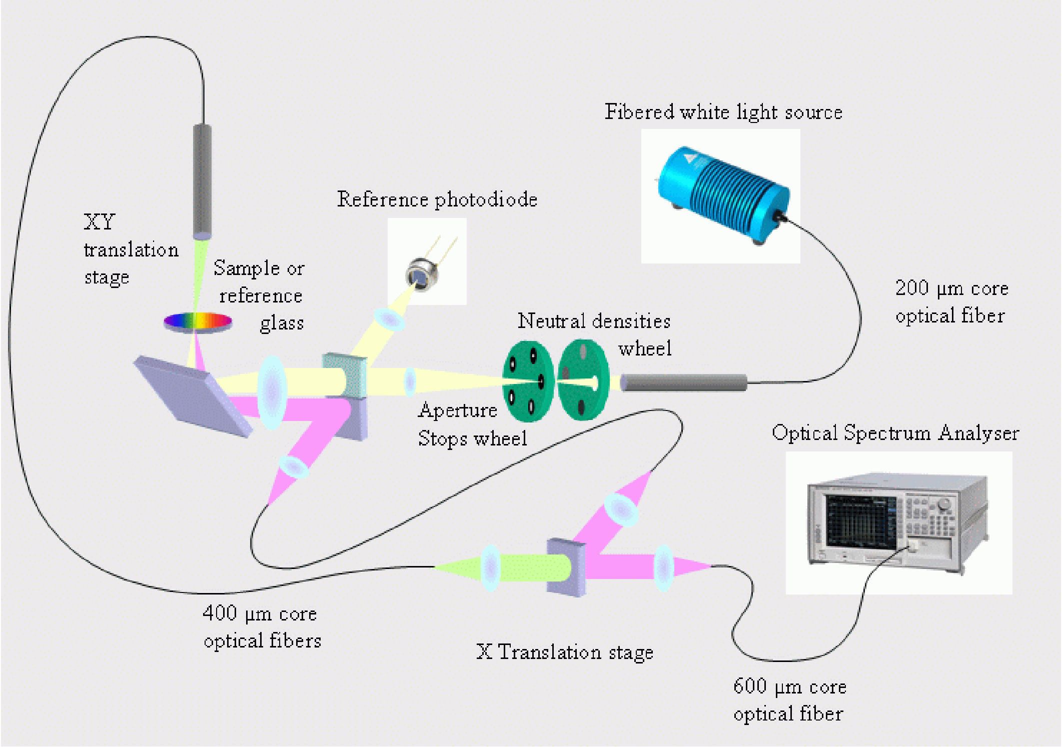


Run plot_rods.py



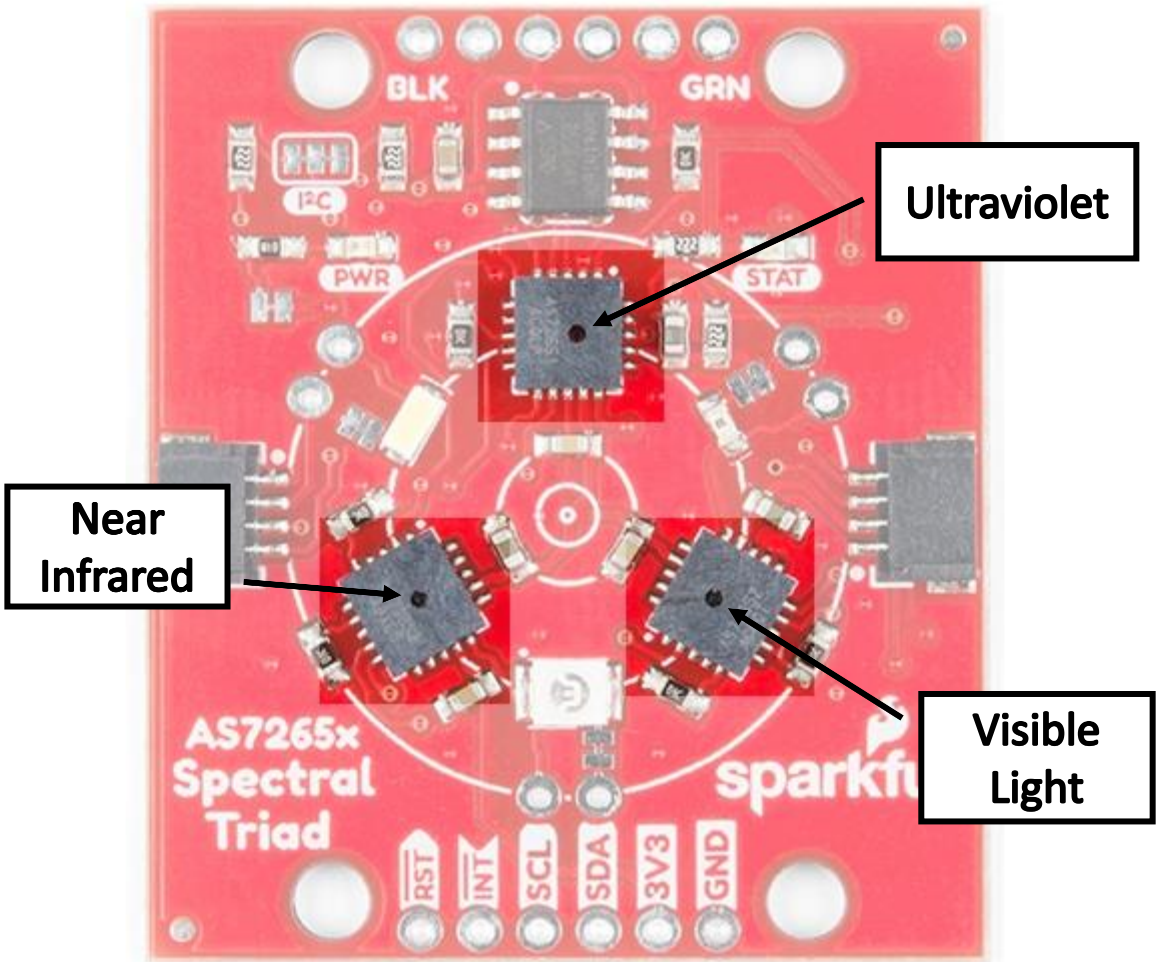
Do you think the radiation intensity grows **linearly** as we add more rods?

Reflectance Spectrophotometry

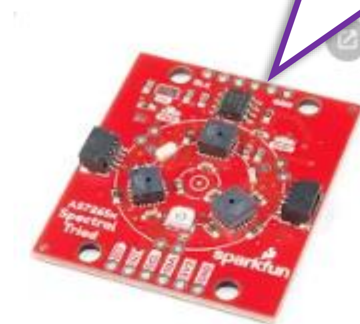


Web Price
$9,439.00 / each

The SparkFun Triad Sensor



The sensor talks to the computer over a serial (UART) port

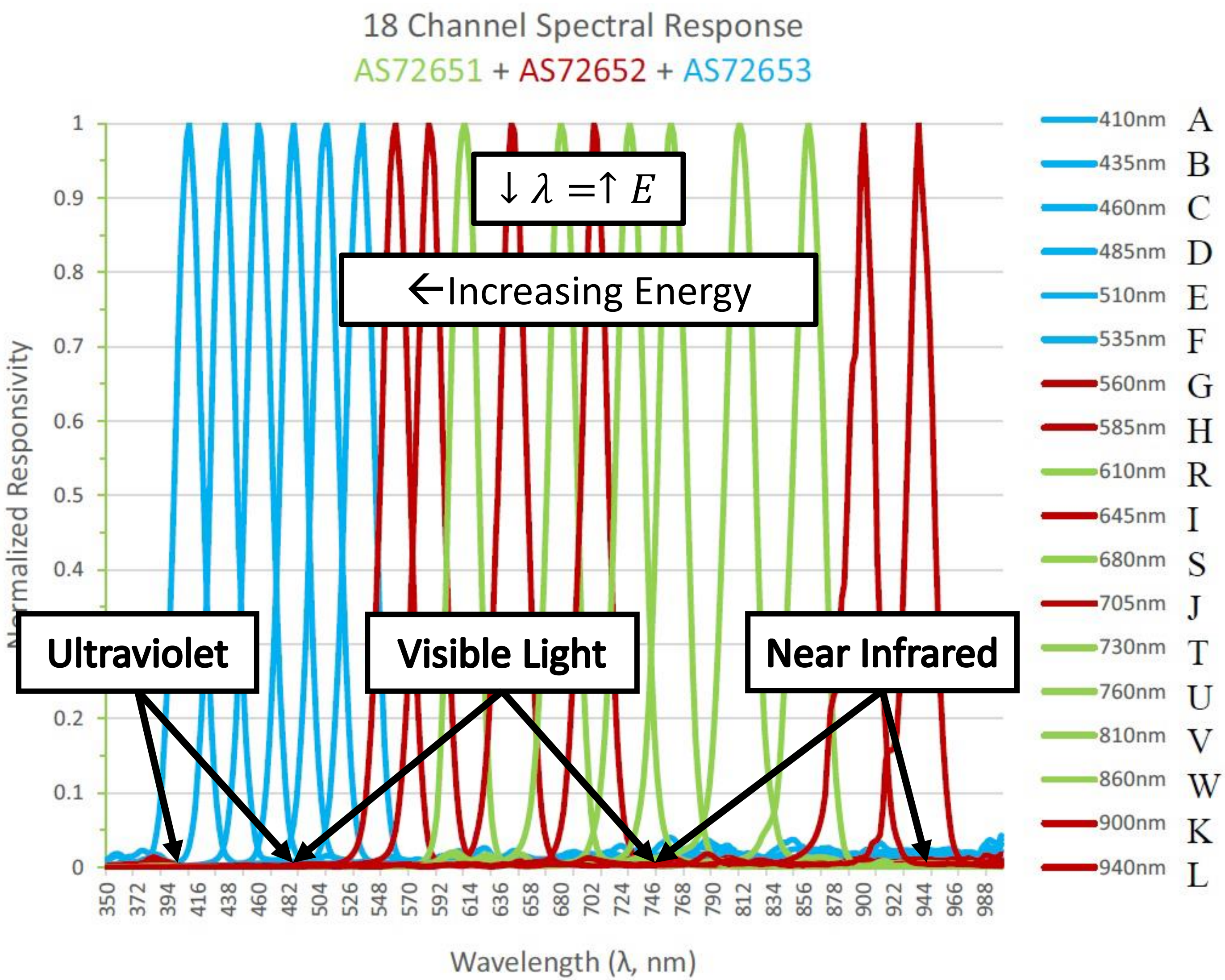


$64.95

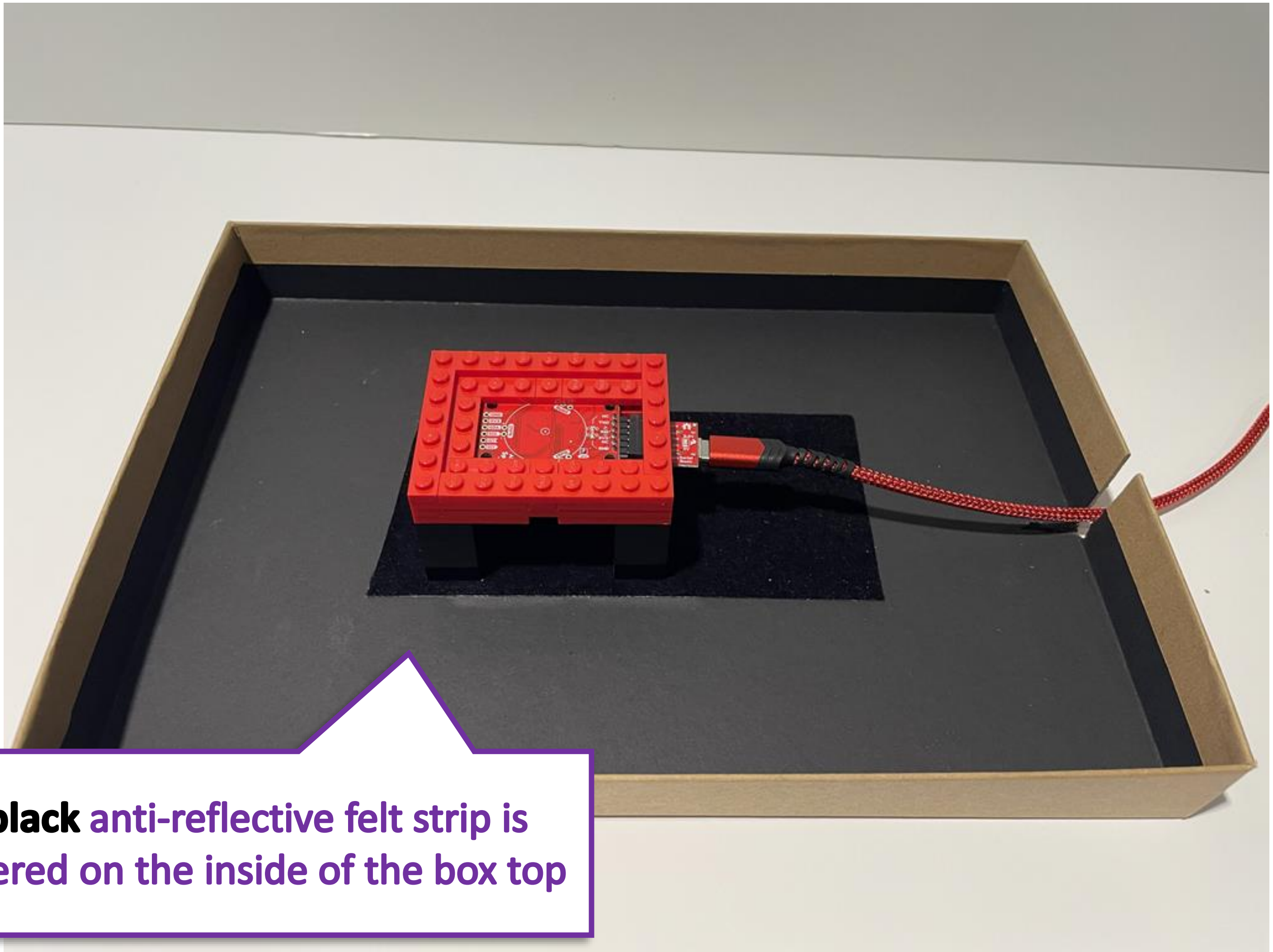
SparkFun Triad Spectroscopy Sensor - AS7265x (Qwiic)

RobotShop.com

The SparkFun Triad Sensor



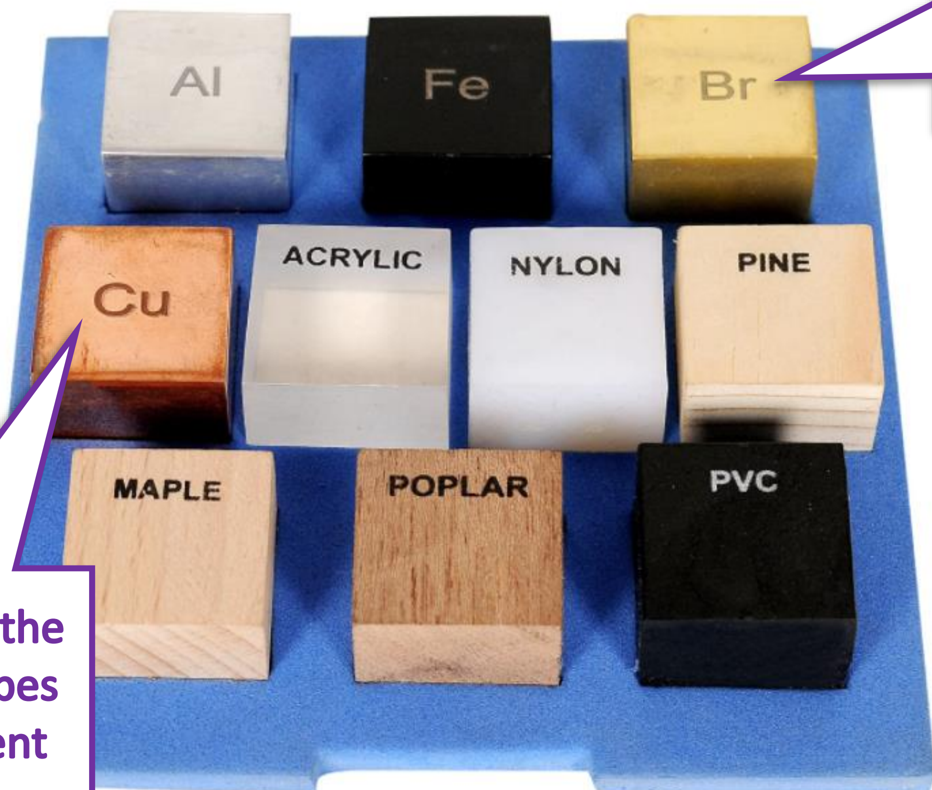
Lab Setup



A **black** anti-reflective felt strip is centered on the inside of the box top

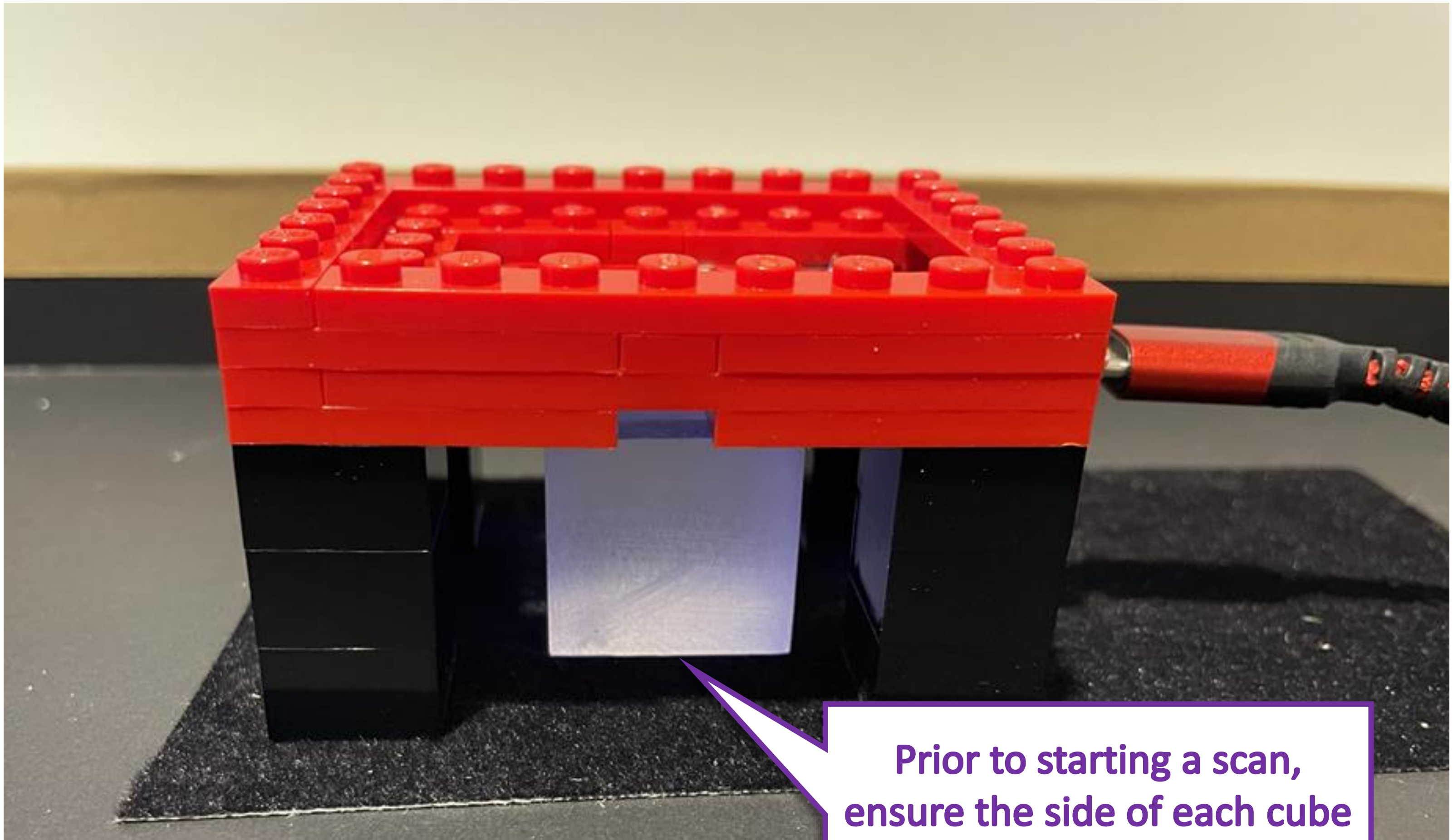
Lab Procedure

Some cubes will contain materials composed from several different types of atoms



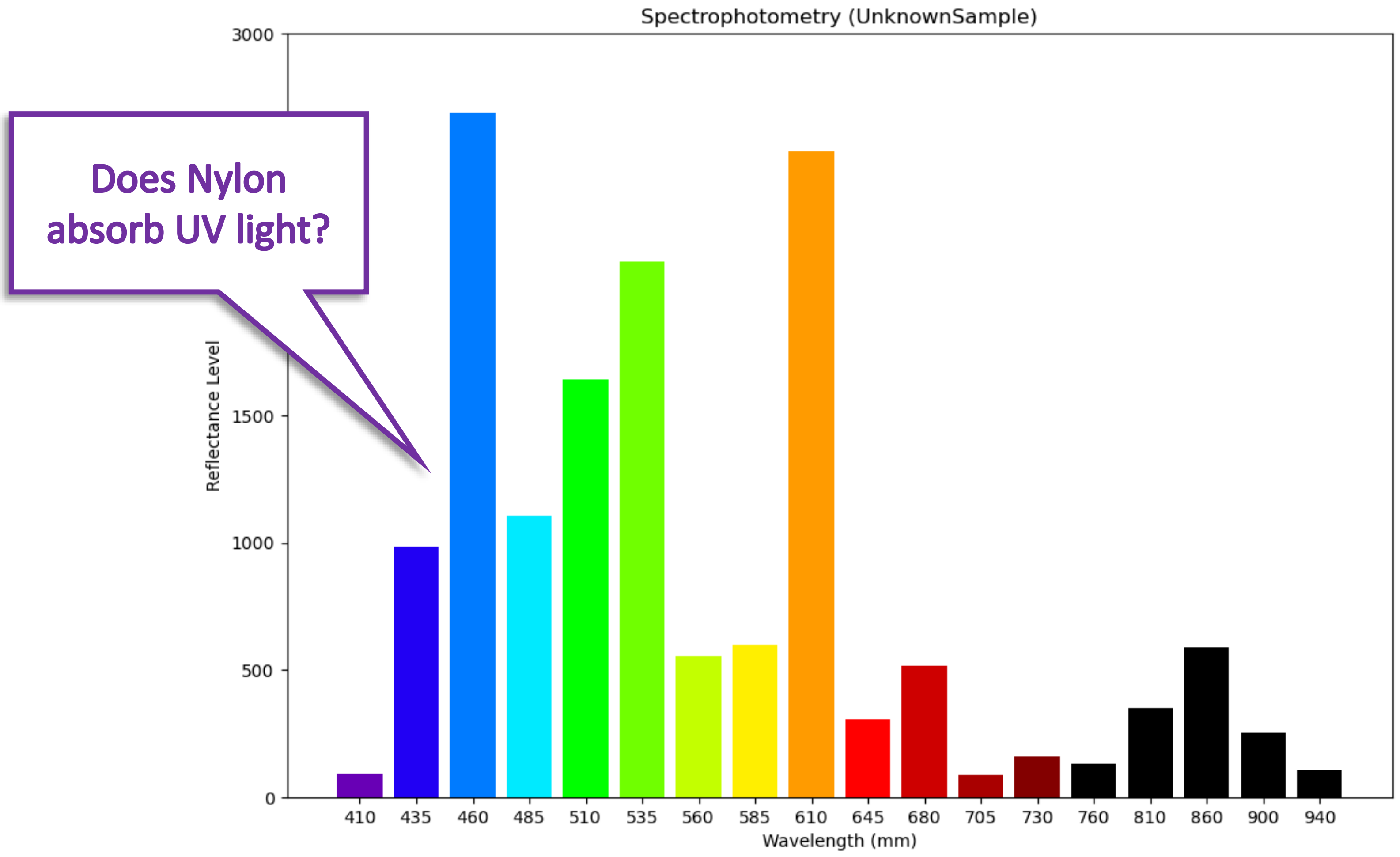
You will measure the reflectance of cubes of a single element

Lab Procedure



Prior to starting a scan, ensure the side of each cube that has writing faces down from the scanner

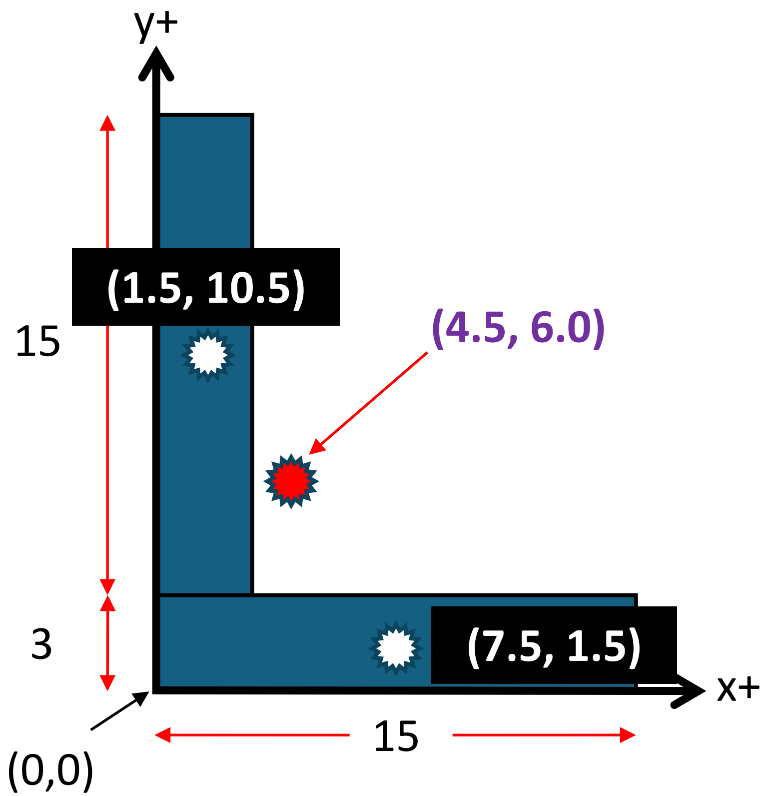
Reflectance Spectra for **Nylon**



Jenga Block Dimensions

Leslie Scott created Jenga in 1983

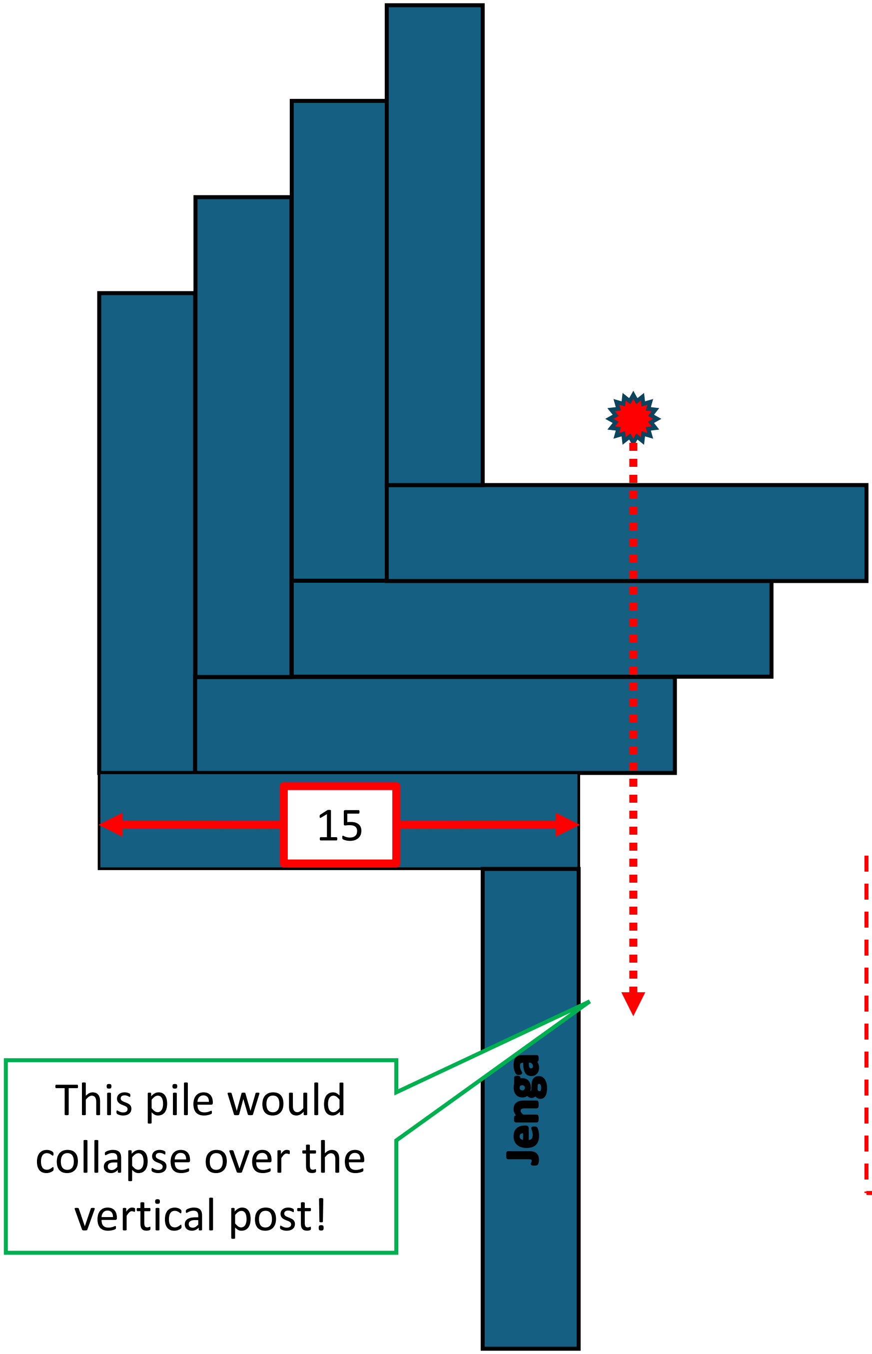
1st **Ensemble** *(first two blocks)*



Center of Mass = Average of the centers of all blocks (in **each** **X** & **Y** dimension)

$$C_x = \frac{1.5 + 7.5}{2} = 4.5$$

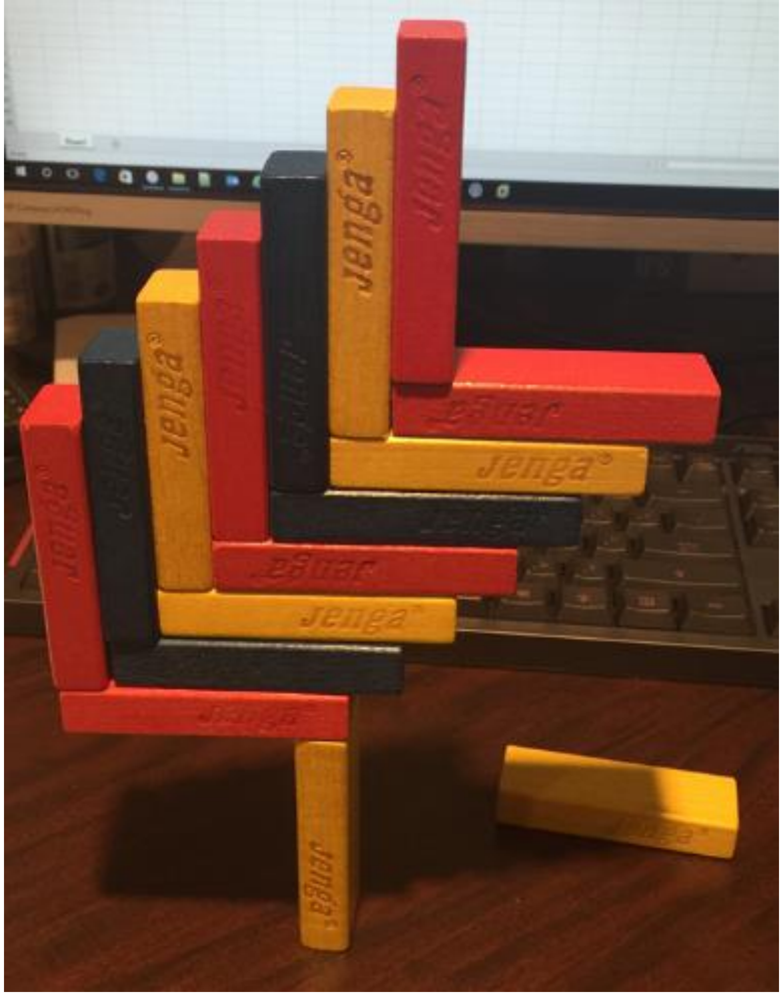
$$C_y = \frac{10.5 + 1.5}{2} = 6.0$$



How many **2-block** ensembles can be balanced on a single vertical post?

The center of mass (of the entire pile) in the **x-dimension** must remain **< 15.0** or else the bottom *horizontal* block **cannot** be supported by a vertical post!

My successful **14-block** (7 ensemble) Jenga pile



Can we ***simulate*** the construction of a **15-block** Jenga cantilever?

Functional Equation

$$Pile\ Center\ of\ Mass_X = \frac{\sum_{n=1}^{blocks} Center\ Coordinate_x\ of\ Block_n}{Number\ of\ Blocks}$$

$$C_x = \frac{1}{4}(B_{1x} + B_{2x} + B_{3x} + B_{4x})$$

Assume we have **4** blocks in the pile

$$= \frac{1}{4}\big((B_{1x} + \Delta x) + (B_{2x} + \Delta x) + (B_{3x} + \Delta x) + (B_{4x} + \Delta x)\big)$$

Moving all blocks by Δx just moves C_x by Δx

$$= \frac{1}{4}\big(4\Delta x + (B_{1x} + B_{2x} + B_{3x} + B_{4x})\big)$$

$$C'_x = \Delta x + \frac{1}{4}(B_{1x} + B_{2x} + B_{3x} + B_{4x})$$

Functional Equation – 14 Block Cantilever

$$\sum X_{centers} \text{ (of a 2 block ensemble)} = 7.5 + 1.5 = \mathbf{9}$$

$$\sum \Delta X_{centers} \text{ (after moving 2 block ensemble)} = 3 + 3 = \mathbf{6}$$

2 Blocks	9
4 Blocks	$(9 + 6) + 9$
6 Blocks	$(9 + 6 + 6) + (9 + 6) + 9$
8 Blocks	$(9 + 6 + 6 + 6) + (9 + 6 + 6) + (9 + 6) + 9$
10 Blocks	$(9 + 6 + 6 + 6 + 6) + (9 + 6 + 6 + 6) + (9 + 6 + 6) + (9 + 6) + 9$

Functional Equation – 14 Block Cantilever

# of 9's	# of 6's	$\sum Center_x \, of$ **Ensembles**
1	0	9
2	1	$(9 + 6) + 9$
3	3	$(9 + 6 + 6) + (9 + 6) + 9$
4	6	$(9 + 6 + 6 + 6) + (9 + 6 + 6) + (9 + 6) + 9$
5	10	$(9 + 6 + 6 + 6 + 6) + (9 + 6 + 6 + 6) + (9 + 6 + 6) + (9 + 6) + 9$

Functional Equation – 14 Block Cantilever

# of 9's	# of 6's	n
1	0	1st Ensemble
2	1	2nd Ensemble
3	3	3rd Ensemble
4	6	4th Ensemble
5	10	5th Ensemble

$$9n + 6\left(\frac{n^2 - n}{2}\right)$$

$$9n + 3(n^2 - n)$$

$$3(3n + n^2 - n) = 3n(n + 2)$$

$$Center\ of\ Mass_x = \frac{3n(n+2)}{2n}$$

There are two blocks per ensemble

Functional Equations

Jenga 14 Block Cantilever

$$Center\ of\ Mass_X = \frac{3n(n+2)}{2n}$$

$$n \equiv Number\ of\ Ensembles$$

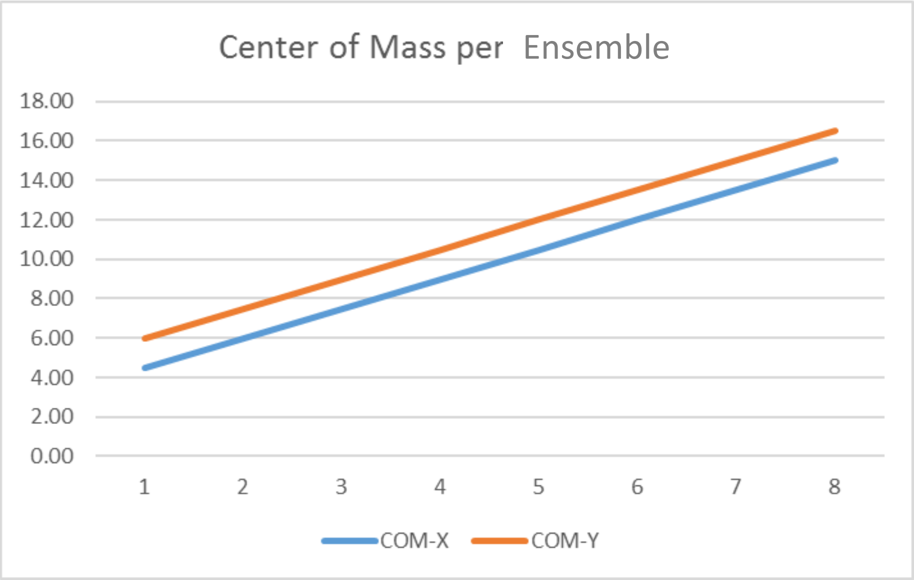
Jenga 15 Block Cantilever

$$Center\ of\ Mass_X = \frac{19.5 + 3(n-1)(n+4)}{2n+1}$$

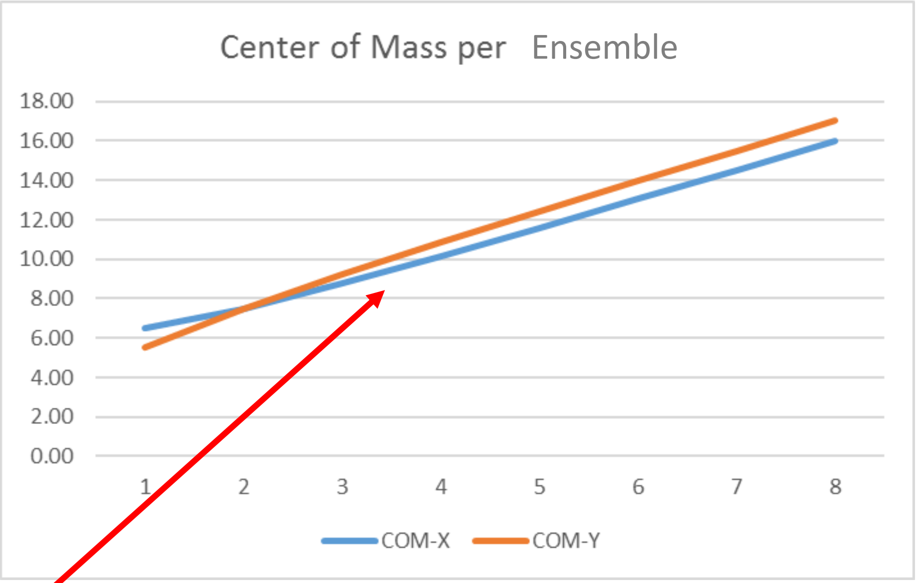
$$n \equiv Number\ of\ Ensembles$$

Functional Equations

Jenga 14 Block Cantilever



Jenga 15 Block Cantilever



The center-of-mass in the X & Y dimensions are closer in a 15 block cantilever so it can rotate (tip over) more easily than a 14 block cantilever

14 Block Jenga Cantilever