Phys 231 AE Group 3
Nelson, Crystal; Parsons, Ben; Sanchez, Alexander; Sorby, Olin

Introduction

BACKGROUND

One of the major phenomena in physics and materials science is the rate at which different materials block radiation and how different factors, such as the type and thickness of the material, affect this. For our experiment, we explored the specific phenomenon of the relationship between the thickness of aluminum and its ability to block gamma and beta radiation from getting through. We decided to vary only the thickness while keeping material constant to only study the effect of thickness and not also the effect of density. Aluminum had the largest number of sheets in the kit, meaning that we could have more points to plot in our final graph, so we chose to use it over plastic or lead.

QUESTION

What is the relationship between the thickness of the aluminum and the amount of radiation that gets through?

HYPOTHESIS

Thicker material will make it more likely for a gamma and beta particles to impact or scatter off of an atom. Thus, we hypothesize that as the thickness of a material increases, assuming density stays constant, the rate of particles passing through the material should decrease.

PREDICTION

Following the logic of our hypothesis, for our specific experiment, we predict that when we insert thicker pieces of aluminum into the geiger counter, we will see less particles detected by the Geiger counter.

VARIABLES

1. Independent (vary): To test this, we isolated our independent variable: the amount of material in the way of the gamma radiation sent through the slides of aluminum.
2. Dependent (measure): For each thickness, the computer ran through 20 trials recording our dependent variable result (the charged particle count in the Geiger counter).
3. Control: For our controlled variables, we kept the voltage (1200 V), element of material used (aluminum), type of radiation (gamma), mass/volume density of the aluminum, distance between the radiation and the detector (1 slot for the radiation source, 0 for barrier - see diagram), and the amount of time the trials ran for (5 seconds). The voltage and timing were measured and controlled by the software we used to reduce any potential for human precision or reaction time affecting the results.

ASSUMPTIONS

One assumption we made in this experiment was that there were no other sources of radiation that greatly varied during the course of data collection. We made this assumption because if there were any sources of background radiation that varied greatly during data collection, they would throw off our measurement of how many counts the Gieger counter detected. To mitigate any effect external radiation might have, we ran blank trials with no added radiation a few times to view the background noise and very little was picked up. Another assumption we made was that the aluminum thicknesses on the box were still accurate and no other substances had collected on the aluminum and that each of the sheets had the same density. Our measuring devices for thickness were not precise enough to check this well, so we used the measurements listed in the package. We made this assumption because if the given thicknesses were not as listed, we would not be able to establish a relationship between thickness and counts, since we wouldn't be able to say that we know the thickness with certainty. Another assumption was that the Gieger counter and computer were both communicating accurate data. We assumed this based on the initial trials' consistency and the very low radiation count recorded when we gave no added radiation. We made this assumption because if the Gieger counter and the computer were not communicating accurately, we wouldn't be able to establish a relationship between thickness and counts, since we wouldn't be able to say we know the counts with certainty.

UNCERTAINTY

Random Error:

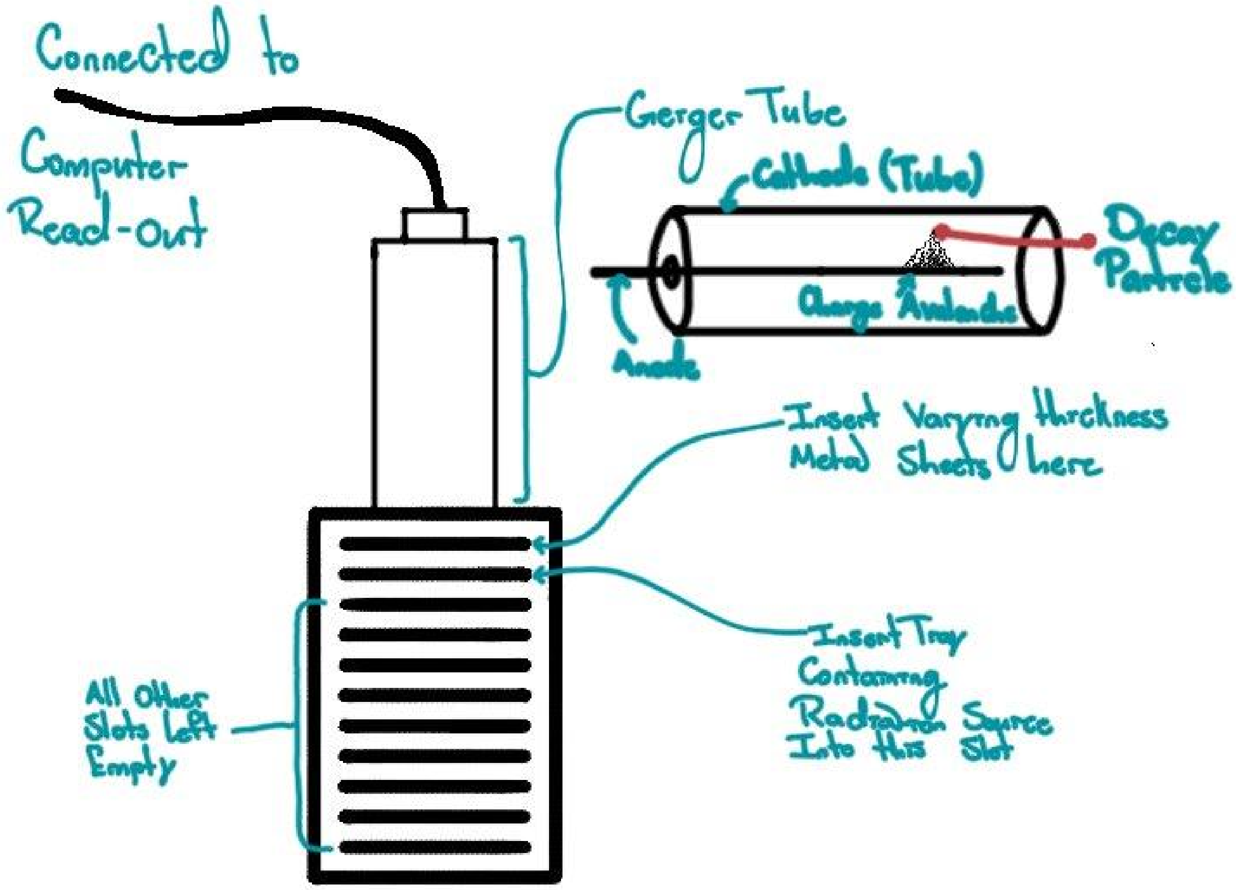
Because we ran the Gieger counter at a voltage of 1200 V, we think a significant source of uncertainty is the background radiation. Due to the nature of our setup, there is no inherent way to mitigate the cosmic radiation and its fluctuations that we receive. However, it is fairly low in magnitude and consistently experienced. There will also be random uncertainty present inherent in our method of detection through the geiger counter, which is not guaranteed to detect every event. This uncertainty is very visible in our large values of Y error, and random error is by far the largest source of uncertainty in this experiment.

Systematic error:

A source of systematic error that we have Identified is the different potential to punch through the aluminum that the gamma and beta particles present. We have no built in way through our geiger counter to differentiate between the two, which might have a constant effect on our data.

Procedure

DIAGRAM



STEPS

1. Set up the geiger counter, connect it to the ST360 software.
2. Turn voltage to 1200V for maximum sensitivity - using the first two slots as shown in diagram
3. Run 20 trials of 5 seconds each with no obstructions and no radioactive material to get an average value for cosmic and ambient radiation (this is the background).
4. Run 20 trials using aluminum with a thickness of 0.02 centimeters.
5. Repeat for using provided thicknesses, ascending to 0.125 centimeters.

METHOD

We decided to use one sheet of aluminum at a time in order to take out any error which could be produced by stacking them. Additionally, we kept voltage constant via computer software control. In order to get precise results, we also decided to take 20 different runs detecting the number of particles for each thickness. 20 runs allows us to have a somewhat high degree of certainty in our values while also fitting into the time constraints of the lab period. The computer setting the voltage, standardizing the time period, and running through the trials all in a row for each thickness improved the accuracy and time efficiency of our experiment.

Data

(Note: We originally had a table for each different thickness. In the interest of organization, we condensed the data into one table by finding measures of central tendency for the particle detected at each length. These are reported in columns 2-4 below.)

Thickness of Aluminum (cm)	Average Number of Particles Detected	Standard Deviation of Particles Detected	Standard Error of Particles Detected	Percent Error
.000	946	34	8	0.85%
.020	87	8	2	2.30%
.025	52	6	1	1.92%
.032	38	6	1	2.63%
.040	37	6	1	2.70%
.050	36	5	1	2.78%
.063	34	6	1	2.94%
.080	34	7	2	5.88%
.090	32	6	1	3.12%
.100	32	7	1	3.12%
.125	31	5	1	3.23%

GRAPHS

Figure 1: Graph of our raw data. Error bars are our standard error in the Y.

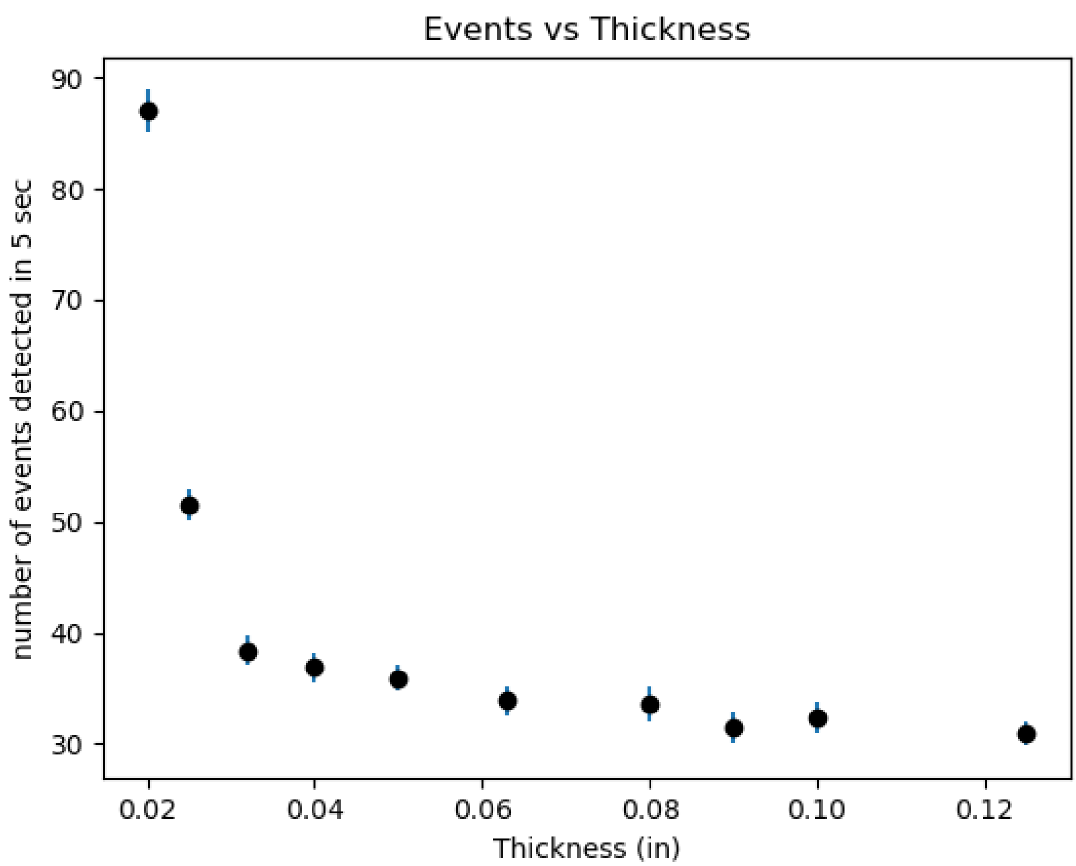
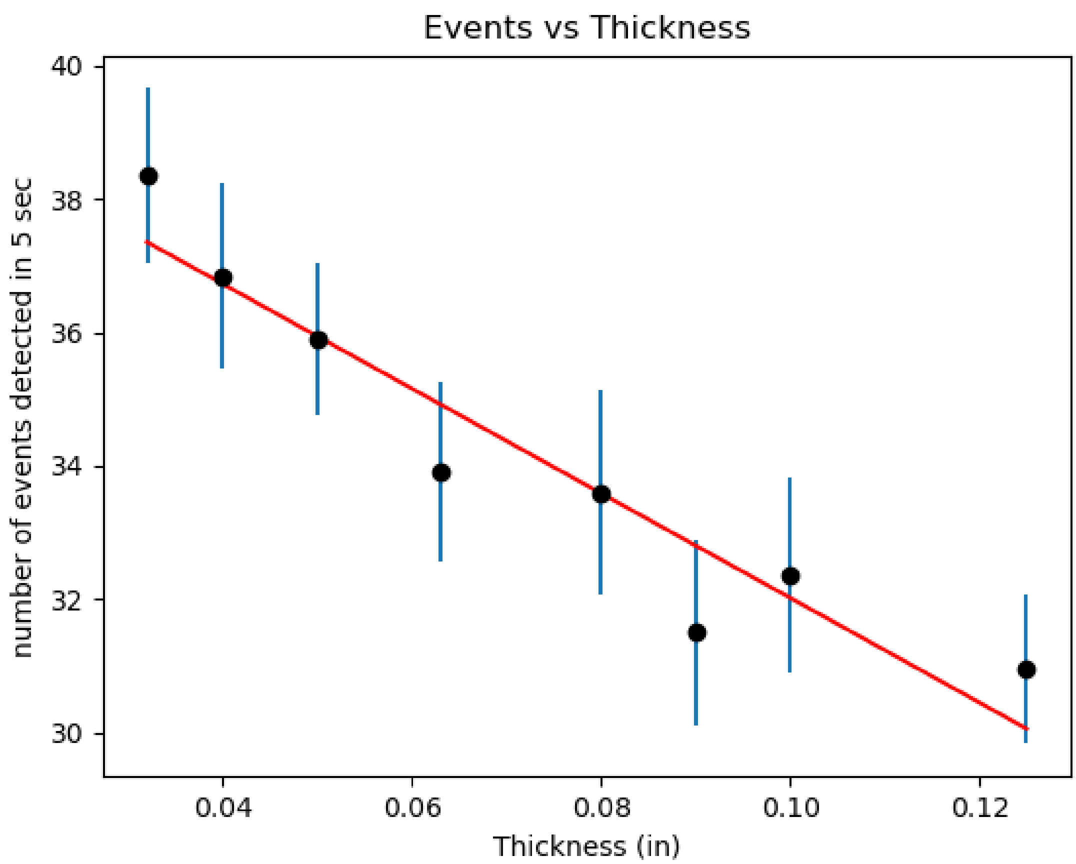


Figure 2: Graph of our data vs inverse thickness both with and without our first three data points. All error bars come from the standard error in the Y of the mean. A line of best fit for this subsection is included, error is included below.



Using the least squares method, the line of best fit above (without our first three data points) is y= .317x + 28.9. With our worst fit error, the best fit line not including our first three data points is (.317 +/- 0.3)x + 28.9 +/- 2. We did not have error values for the aluminum thickness, as these errors were not reported on the box, and we did not have sufficiently accurate tools to take our own measurements. Thus, the independent variable is reported as exact.

Analysis

Our prediction that an increase in aluminum thickness produces a decrease in the amount of gamma and/or beta radiation which passes through to the Geiger counter matches our data (shown plotted in Figure 1). Thus, our data is also in support of the hypothesis that there is a negative correlation between material thickness and radiation detected (due to blockage by the material).

Upon inspection of the data, it looks like there might be some sort of inverse relationship between the thickness of the material and the rate of pass through. This is because both of these put more material between the radiation source and the detector the probability of a gamma ray not colliding with the material should go down. The results, ignoring the first two data points, seem to suggest this relationship between thickness and pass through, but since we kept the density constant we cannot say anything on the relationship between density and pass through. Our percentage error was very low in this experiment as well, meaning that there is a very low chance that this result is by random chance.

We tried a number of different linearizations for our data, none of which seemed to describe the data accurately enough to draw conclusions from. The best fit that we had tried was a 1/x^2 form of linearization, but including all of the data we collected presented a gigantic error in the slope with almost 100% uncertainty on the slope. Using a 1/x model was only therefore slightly worse, and all other models that we tried were significantly worse. In many of these models, there appears to be a negative linear relationship between counts and thickness, which is also apparent in the raw data. This is plotted in figure two, but as you can see, the relatively tiny difference in counts between these specific data points causes the random error to keep us from saying anything definitive about this relationship. In the discussion portion below, we speculate on a possible cause of this. We can therefore conclude that the counts were decreasing, but little about a mathematical model that describes this.

Our biggest source of error was random uncertainty, as far as we could determine (since we did not have error values for the independent variable). We determined this because the instrumental uncertainty was much smaller than the variation we got in the event values. The percent uncertainty generally increased as the thickness did in our experiment, with the first value having an error of less than 1% and the last several having errors exceeding 3%. This relatively small error allows us to conclude that the decrease in counts is definitive.

We can determine that we have a negative relationship where the thicker the aluminum is, the less radiation gets through. However, because the percentage uncertainty we got was so high, there was a decent but not ideal fit of the data to nearly all linearized models we attempted. In other words, we could not conclude anything further about the relationship with certainty.

Discussion

If we were to do this experiment again we would like to expand the range of thicknesses to further explore the region between 0.02 and 0.125 as well as larger thicknesses to insure that as the thickness increases the rate of penetration continues to decrease inversely proportional to the thickness. It would also be interesting to explore the relationship between density and the pass through rate, and see if it follows a similar relationship to thickness.

Our suspicion is that because we were measuring both beta and gamma radiation simultaneously, these forms of radiation may have different curves which contribute to the distribution we found. Further investigation may reveal whether, as we suspect, the beta radiation is getting blocked much faster than the gamma radiation. This would produce the distribution of points that we have, where the counts fall rapidly for the first few thicknesses and then drop off at a much slower rate after the first few points. To test this one could find a source of pure gamma radiation, and a source of pure beta radiation and measure the thickness vs counts for each source of radiation individually.

Conclusion

With the percentage errors we have above, it is clear that the count is decreasing with thickness, and that it is dropping off at a lesser rate as we increase the thickness. However, with the large random error with respect to the difference in counts in the last seven data points, we cannot conclude that there is a linear relationship in those counts and we cannot conclude on a specific mathematical relationship in this experiment. In this manner our hypothesis was in agreement with this experiment, but further exploration is needed to reveal the most proper mathematization for this experiment.

More accurate equipment which picks up beta and gamma radiation equally well, larger data sets, and especially more data points nearer to length zero may help to create a clearer picture. Our assumption about the thickness for the aluminum being reported accurately may also need to be reexamined in future experiments to take out the maximum possible sources of error, so accurate length measurements are key.