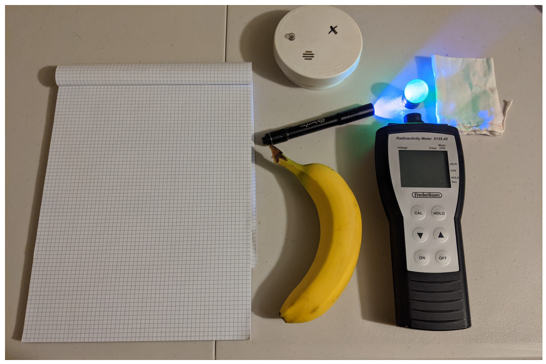
Lab 2

Counting on Uncertainty



Physical Models: Ionizing Radiation, Poisson Distribution, Background Radiation

Analysis Tools: Mean, Standard Deviation, Standard Deviation of the Mean, t-score

Experimental Systems: Background Radiation, Uranium Marble, Smoke Detector, Po-210 Source, Various Household Items, Paper, Lead, Wood, Aluminum Foil

Equipment: Geiger Counter, graph paper, caliper, goniometer, PASCO optics angle display

Safety Concerns: Radioactive materials can be very dangerous, BUT none of the radioactive sources used in this lab are dangerous to humans *unless they are consumed*. So, do not eat the radioactive sources (and we'd appreciate it if you also didn't eat any other equipment).

Introduction

In the Prelab for this week, you were introduced to *ionizing radiation*. A simple model for how this radiation is produced and detected was introduced based on the "Poisson Distribution". Although this has a basis in statistics, it will be part of what we're testing as a physical model in today's lab. In particular, we will test the model by checking if the following relation is true [1] :

$$\mu = \sigma^2 \tag{2.1}$$

where μ is the mean value of counts of detected radiation in a given period of time, and σ^2 is the square of the standard deviation of the same quantity. You were also introduced to the notion of background radiation. In order to determine if a given object is radioactive, we'll need to account for the ambient radiation in the room.

An example of an instrument which can detect radiation is a Geiger Counter. We'll rely on one of these for our work in this lab.

[1] Because in this case the value at issue is just a number (a count of events) the units can match between μ and σ^2

Part 1. Radioactivity of Background and Sources

Your goal in this part of the lab is to investigate the model to see how well it describes background radiation, and to see if you can distinguish any samples from the background.

In this lab, you'll use a Geiger counter with the PASCO Capstone application on the lab desktop computer. To set this up, make sure the PASCO Universal Interface is turned on, and plug in the Geiger counter to Analog Input 1. Now log into the desktop computer with your UT EID. When prompted to connect to the network, press "Connect." You should see the PHY105 folder on the Desktop: open this folder, and drag the file GeigerCounter.cap onto the Desktop. To view your experiment, open PASCO Capstone from the Dock on the bottom of the screen, and open the file Desktop/GeigerCounter.cap by using option Open from the upper ribbon File menu.

Quick Check: Let's first explore a bit. When you press "Record," you the Geiger counter will count how many events it detects over the course of 10 seconds. The result is the displayed in the table.

Point your Geiger Counter at your partner and wait a bit. Do you detect radiation? Likely yes. Does this mean your partner is radioactive???

Most likely not. Try pointing the Geiger Counter at empty space. You likely detect about the same amount per 10 seconds, though it may be hard to discern given the variation. Try waiting out a few 10 second periods so you get a feel for the average behavior.

Now, take a look at the green marble. Shine the UV light on it. It glows! Why? Because the marble is made of Uranium Glass, which includes (surprise) Uranium, giving it the glow you see. Try pointing the Geiger counter at it. Can you (qualitatively) notice any difference?

Many smoke detectors rely on the decay of Americium, which is also radioactive, to ionize air molecules and detect smoke. Take a look at your smoke detector. "X" marks the spot of the Americium. Can you detect anything there?

Now select a 3rd object to investigate. It can be an item you brought yourself, as indicated in the Prelab Activity, or it can be an item from the front of the room. Give it a check with the Geiger Counter.

Designing Your Experiment: Now design an experiment to systematically investigate the model and the radioactivity of the background and each sample. Keep in mind:

- For *the background only* you'll want to compare μ_{10s} with σ^2_{10s} to see if they're the same, as would be true if the model is correct and the radiation is truly random.
- The uncertainty in μ is the standard deviation in the mean. However we've never discussed how to determine the uncertainty $\delta\sigma^2$! We will be compiling the class's data to compute statistics and get you the the uncertainty $\delta\sigma^2$.
- You'll want to compare *each sample* to the background to see if its distinguishable or not. If it isn't, then we wouldn't consider it radioactive.
- You'll need to reduce uncertainty sufficiently in order to get good results. The variation from one 10 second interval to another can be a lot, so this will require a lot of samples!

Refer to the lab rubric for a reminder of what else to consider and what to record.

Conducting Your Experiment: Go ahead and give it a shot. You can change your method around while you're at it; you don't need to treat your previous decisions as a contract. Just make sure to record any changes for sake of your eventual final writeup. Make sure all your data is labeled clearly with units, and that you keep track of uncertainty.

Above all, try to minimize uncertainty as much as you can!

Forming a Conclusion: Does your data support the model that the radiation emission/detection is completely random? Are any of your sources genuinely radioactive? Which/how much?

Check in with Another Group: Check with another group to see if they got similar results. You can also compare if you used different objects.

Post results to the board: On the board post what you found for the background levels (μ_{10s} and σ^2_{10s}).

Part 2. Radioactivity vs. Distance, Angle, and Medium

In this part of the experiment, you'll conduct a new investigation. See below for possibilities.

Deciding on a New Hypothesis :You're welcome to use the traditional flow chart to come up with new possibilities for Part 2, but here are some additional ideas for you to consider:

- Presumably, the ability to detect radiation depends on how close you are to the source. If you are very far away, you may think you can't detect a source, even if it is highly radioactive. Develop a quantitative hypothesis for how the radioactivity of a source depends on distance (i.e. for the Po-210 source) and test this with a systematic experiment.
- It might be the case that radiation is not emitted in the same amount in all directions. Decide on an item (the marble, the smoke detector, etc.) and design an experiment to test whether the radioactivity depends on the direction you aim the Geiger Counter at it. To do this, you might consider drawing a line under your source and measuring radiation at a few different angles from that line. Keep in mind that the shape of your object may play a role here.
- Since (large) amounts of radioactivity can be dangerous, scientists are often interested in shielding it. Since ionizing radiation can be blocked by some materials and not others, its important to identify which. In the front of the room are a number of materials you can use. Design an experiment to test which/if any of these block radiation. OR: use the beakers how/if radiation levels fall off while travelling through various depths of water.

You might consider using a powerful source of radiation for these options, so you can ask your TA for a Po-210 source.

Quick Check: Explore qualitatively, tinker, etc. to decide what you think of your new hypothesis and how best to test it.

Designing Your Experiment: Design an experiment like in Part 1, but this time to investigate your new hypothesis.

Conducting Your Experiment: Conduct the experiment as planned. As always, make sure to minimize uncertainty! And feel free to change your approach around as needed, just be sure to record any changes.

Forming a Conclusion: What did your new experiment reveal?

A Final Question: What would you say about the radioactivity of household items? Is this something to be concerned about?

Writing Up Your Lab Notes for Submission

Write up your notes for Part 1 and Part 2 in an organized way according to the rubric provided.