1988

Energy in Perspective Laboratory #11: Radiation

Robert G. Fuller
University of Nebraska-Lincoln, rfuller@neb.rr.com

ADAPT Energy in Perspective
Laboratory #11

Radiation

or: Yet Another Mathematical Relationship to Learn!

Exploration

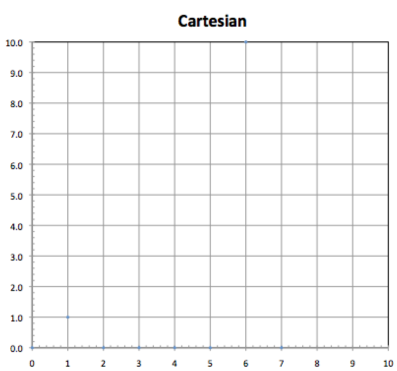
Plot all 3 sets of data on each different kind of graph paper (below). You will end up with 3 plots on each graph.

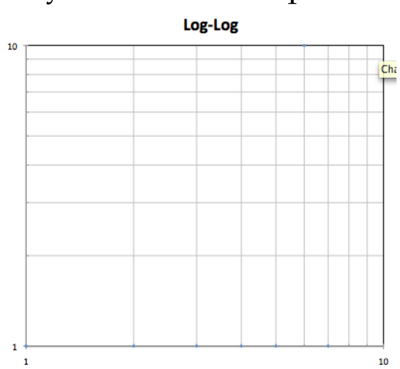
Set 1	
x	**y**
1	1.0
2	2.8
3	4.6
4	6.4
5	8.2
6	10.0
7	?

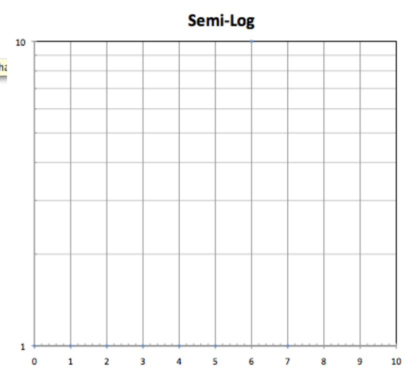
Set 2	
x	**y**
1	1.0
2	2.4
3	4.1
4	5.9
5	7.8
6	10.0
7	?

Set 3	
x	**y**
1	1.0
2	1.6
3	2.5
4	4.0
5	6.3
6	10.0
7	?

Predict an exact value of y to one decimal place for each x=7 value.







Describe your results in words.

What is constant for data set 1?

What is constant for data set 2?

What is constant for data set 3?

Set 4	
x(yr)	**y**
1	1.00
2	1.05
3	1.10
4	1.16
5	1.22
6	1.28
7	?

Set 5	
x(yr)	**y**
1	1.00
2	1.07
3	1.14
4	1.23
5	1.31
6	1.40
7	?

Invention

Exponential change is change by a fixed rate each time period. Examples are given at the bottom of the 1st page as data sets 4 & 5 of an interest rate of 5%/year and 7%/year .

The plot of this on Cartesian graph paper gives a J curve which we know from class to be exponential.

Also we know the doubling time of an exponential rate to be:

$$\mathbf{DT = .693 / (decimal\ growth\ rate)}$$

Check data set 5 to see if the calculated doubling time is true.

For a set of data which shows a fixed doubling time has an exponential relationship (rather than power law relationship) and may be expressed by the mathematical equation:

$$y = A\,2^{x/T}$$

T is the doubling time. A is the value of y when x = 0 (why?)**.** Exponential decrease may expressed mathematically by thinking of the doubling time as negative. That is find the halving time and put a negative sign in front of it. This will give you the time it takes for y to be decreased to half its starting value.

Write the equations for data sets 1 -> 5 in your data sheets and make sure to have them clearly marked!

Review:

What to look for when finding mathematical relationships:

Linear $y = mx + b$

linear on Cartesian graph paper
constant change in y for a given change in x

Power Law $y = Ax^B$

linear on log-log paper
constant 'powered' change in y for a given change in x

Exponential $y = A2^{x/T}$

linear on semi-log paper
constant doubling time (or halving time)
constant percentage change in y for a given change in x

Application

Three variables influence the amount of radiation you receive. They are:

1) Distance away from the source of radiation
2) Thickness and type of shielding between you and the radiation
3) Length of time exposed to the radiation

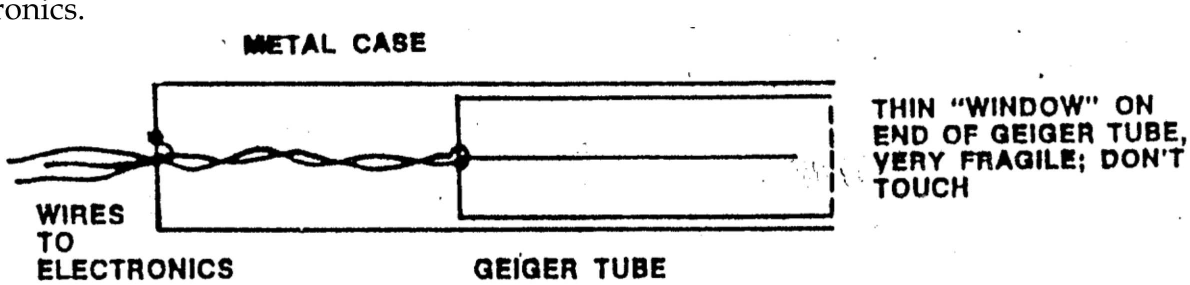
You will use a simple Geiger counter and various sources of radiation to investigate these variables and how they influence the amount of radiation at a given location.

1) Measure the radiation count for several distances from the source
2) Measure the radiation count rate for 3 kinds of shielding (paper, aluminum, lead)
3) Measure the radiation count as a function of time (see handout)

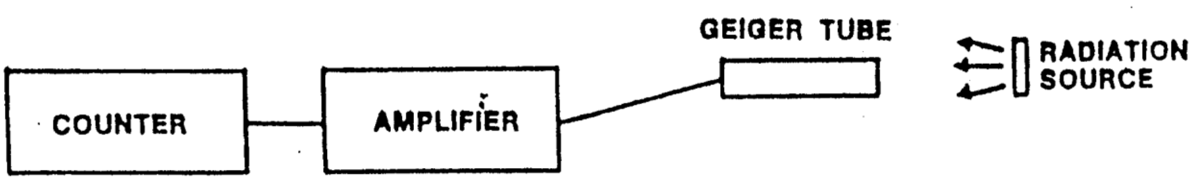
Equipment:

You'll be using γ gamma and β beta sources, a Geiger counter (actually called a Geiger-Mueller tube), an electronic counter, a meter stick, and masking tape.

Figure 1 shows the construction of a G-M tube. Very briefly, it functions as follows: when a β or γ particle enters the inner chamber through the window, it produces ions in the gas molecules within the tube. A potential difference of several hundred volts between the wire (inner electrode) and the cylinder (outer electrode) attracts the ions to the appropriate electrodes. The resulting pulse of current is then detected and counted by the attached electronics.



Set up the apparatus as indicated in Figure 2. Try it out until you're convinced that you know what you are doing and everything is working properly. You may find that switching on the stop clocks causes spurious counts; avoid this by counting without turning them off.



1st Expt. Distance

Record the number of counts/minute, N, versus the distance, d, between the G-M tube and the γ source. Do this from 2 cm -> 26 cm in 2 cm increments. Make sure to use a long enough counting time at each distance to get at least several hundred counts.

Corrections to the data

Background: This refers to the counts made even when your source is far away. Background counts come from natural radioactivity in the atmosphere and ground and from cosmic rays. **The background must be found and subtracted from all your results!**

Finite size of G-M tube: The correct distance between the source and the G-M tube is to some average position in the tube. For your tube this is 1.8 cm inside the window. **You must account for the average position in all your results!**

Next, do the same measurements with a β source.

Compare the difference in the mathematical relationships (corrected N vs corrected d) for β and γ particles.

Why is there a difference?

2nd Expt. Shielding

A) Using a distance that gives around 100 counts/minute without any shielding, measure the absorption of γ particles by: a book, your hand, lead plates, etc. Do the same for β particles and compare your results.

B) Obtain several small pieces of lead, aluminum, and paper.

Measure the thickness or 10 layers of each material and determine an average thickness for each layer.

Measure the count rate for 0 -> 5 layers of shielding while using a β source and then a γ source. (count until you get several hundred counts each time.)

3rd Expt. Lifetimes

Radioactive materials can be characterized by how long it takes for half the original amount to decay. The data sheet given lists corrected counts/sec at specific times. The curves will be exponentially decreasing and the half-life of the data set can be found.

Sample >> Time (sec)	**UX_2** Count Rate (counts/sec)	Sample >> Time (hours)	**Rn** Count Rate (counts/sec)
0	1000	0	1000
4	959	4	977
8	926	8	950
12	896	12	905
16	857	16	874
20	809	20	870
24	791	24	843
28	744	28	809
32	711	32	795
36	684	36	765
40	654	40	733
44	646	44	708
48	625	48	692
52	585	52	674
56	563	56	657
60	554	60	646
64	513	64	624
68	506	68	606
72	488	72	588
76	462	76	557
80	437	80	546
84	429	84	534
88	403	88	512
92	400	92	504
96	378	96	491
100	357	100	468

Laboratory #11

Radiation

Write-up:

Note: When the write up asks for a mathematical relationship, you should include it in the typed part of your write up! Make sure you do so and make a clear reference to where the corresponding plot, calculations, and mathematical relationship are in your data sheets.

I PURPOSE

II EXPERIMENTS

A) 1st Expt. Distance
   1) Plot corrected counts/minute vs corrected distance.
   2) Find the mathematical relationship from the graph.
   3) Does doubling the distance cut the count rate in half?
      Check this mathematically.
   4) Give a *physical* explanation of your results.

B) 2nd Expt. Shielding
   1) Comment on the absorption of the various objects used in part A.
      Include count rates.
   2) Plot corrected counts/minute vs shielding thickness for paper, aluminum, and lead. Make 1 graph with 3 plots.
   3) Find mathematical relationships for each plot and label it clearly.
   4) Which material shields the best? Why do you think it is so?
   5) Which radiation is most penetrating? Why do you think it is so?

C) 3rd Expt. Lifetimes
   1) Determine the radioactive half-life for the data sets given.
      see half-life data page.

III CONCLUSIONS

Summarize, contrast, and compare the 3 influences on the amount of radiation exposure incurred.

IV DATA