

Distance and Radiation

Scientists and health care workers using intense radiation sources are often told that the best protection is distance; that is, the best way to minimize exposure to radiation is to stay far away from the radiation source. Why is that?

A physically small source of radiation, emitting equally in all directions, is known as a point source. By considering the way radiation leaves the source, you will develop a model for the intensity of radiation as a function of distance from the source. Your model may help explain why users of radiation sources can use distance to reduce their exposure.

In this experiment you will use a small source of gamma radiation. Gamma rays are high-energy photons. If your source behaves as a point source, and if the air absorbs little or none of the gamma radiation, then the radiation intensity should be described well by your model. *Follow all local procedures for handling radioactive materials.*

OBJECTIVES

- Develop a model for the distance-dependence of gamma radiation emitted from a point source.
- Use a counter to measure radiation emitted by a gamma source as a function of distance.
- Analyze count rate data in several ways to test for consistency with the model.

MATERIALS

TI Graphing Calculator
LabPro or CBL 2
DataRad calculator program
Vernier Radiation Monitor
cobalt-60 $1\mu\text{C}$ gamma source
meter stick

PRELIMINARY QUESTIONS

1. Place your cobalt-60 source on a table. Connect the Radiation Monitor to a DIG port on your interface and start the data-collection software if it doesn't start automatically. The LED on the Radiation Monitor flashes as the monitor detects radiation. The LED will flash more quickly when the monitor detects higher radiation level. Using this information and the cobalt-60 source, determine the most sensitive place on the detector. That is, roughly where inside the monitor case is the radiation being detected?

Experiment 2

2. Starting about a meter from your source, slowly move the monitor closer to the source until they nearly touch. How does the flash rate vary with distance from the source? Would you say that the flash rate is proportional to distance from the source? Or is it an inverse relationship?
3. Sketch a qualitative graph of the flash rate vs. distance from the source.
4. Suppose a small radiation source (a point source) is placed at the center of two spheres. The spheres are transparent to the radiation. One sphere has a radius r , and the other a radius $2r$. N particles leave the source each second and travel outward toward the spheres. How does the number of particles passing through the inner sphere per unit area compare to the number *per unit area* passing through the outer sphere? Solve this problem by considering the following:
 - a. How many total particles pass through the first sphere? How many pass through the second sphere?
 - b. How do the surface areas of the two spheres compare?
5. From your answer to the previous question, write down an expression for the intensity of radiation (number of particles passing through a unit area each second) as a function of distance from a point source. Assume that N particles leave the source each second. This expression is your model for the way radiation intensity varies with distance. Record your model in the data table.
6. Is your model consistent with the qualitative sketch you drew in Preliminary Question 3?

PROCEDURE

1. Connect the radiation monitor to a DIG port of LabPro or CBL 2 if it isn't already connected. Use the black link cable to connect the TI graphing calculator to the interface. Firmly press in the cable ends.
2. Turn on the calculator and start the DataRad program. Press **CLEAR** to reset the program.
3. When your source is far from the Radiation Monitor, the monitor still detects background counts from cosmic rays and other sources. You will need to correct for this background by determining the average count rate with no source near the monitor. Measure the rate of background events.
 - a. Move all sources at least 2 meters from the Radiation Monitor.
 - b. Select SETUP from the main screen.
 - c. Select SET INTERVAL from the SETUP MENU.
 - d. Select SET INTERVAL from the INTERVAL SETTINGS screen.
 - e. Enter **60** as the count time interval in seconds. Complete number entries with **ENTER**.

- f. Select OK from the INTERVAL SETTINGS screen.
 - g. Select BACKGROUND CORRECTION from the SETUP MENU.
 - h. Select PERFORM NOW from the BACKGROUND CORRECTION screen.
 - i. Enter **5** as the number of intervals. The calculator is then ready to count background events for $5 \times 60 = 300$ seconds.
 - j. Press **ENTER** to begin counting background events. The remaining time will count down after each interval on the calculator screen.
 - k. After 300 seconds, the calculator will display the average background count rate. For the following measurements the count rates will be reduced by the indicated value. Press **ENTER** to continue.
4. Now that the calculator will correct for background events, you are ready to study the relationship between distance and count rate. Prepare the calculator for this new mode by selecting EVENTS WITH ENTRY from the SETUP MENU.
 5. Place the center of the source 6 cm from the monitor screen of the Radiation Monitor.
 6. Select START from the main screen. You will see a new screen from which you will control the counting for each distance between the source and the radiation monitor. Press **ENTER**, and the interface will begin counting the number of gamma photons that strike the detector during a 60 second count interval. The screen will display COUNTING...
 7. After 60 seconds have elapsed, you will see a prompt. In the entry field that appears, enter **0.06**, which is the distance in meters from the detector to the center of the source. Complete your entry by pressing **ENTER**.
 8. Move the source 0.02 m farther from the source. Press **ENTER** to count for the new distance. When you see the prompt, enter the new distance of **0.08**.
 9. In the same way as before, move the source an additional 0.02 m out, press **ENTER**, and wait for counting to complete. Enter the new distance in meters. Repeat this process until the distance is at least 0.24 m or the rate drops below 10 counts per minute.
 10. Press **STO>** to end data collection. You will see a graph of count rate vs. distance.

DATA TABLE

Model expression	
Average background counts	
Fit parameters and equation	

ANALYSIS

1. Inspect your graph. Does the count rate appear to follow your model?
2. Fit an appropriate function to your data.
 - a. To do this, press **ENTER** to return to the main screen.
 - b. Select ANALYZE from the main screen.
 - c. Select one of the curve fit relationships from the list on the CURVE FITS screen. Choose the one that matches the mathematical form of your model.
 - d. Record the fit equation and parameters in your data table.
 - e. Press **ENTER** to see your data with the fitted curve.
3. Print or sketch your graph.
4. From the evidence presented in your two graphs, does the gamma radiation emitted by your source follow your model? Does the relationship seem to fail at larger or smaller distances?

EXTENSIONS

1. Replot your data using a suitable transformation of the x-coordinate so that the resulting plot should be linear if the data follow your model. For example, if your model were an inverse-cube function, replot the data using the inverse-cube of the distance values for the horizontal axis. Do your data follow the model well using this test?
2. Why were you instructed to place the source no closer than 0.06 m from the detector? Repeat the experiment, using distances of 0, 0.02, 0.04... out to 0.24 m. **Hint:** Is the detector a spherical surface?
3. Use a longer counting interval so that you collect at least 300 counts at 0.06 m. Is the agreement with the inverse-square relationship any different? Try a much shorter count interval. How is the resulting graph different? Why?
4. Sometimes the table surface can scatter gamma rays, interfering with data collection. Use a ring stand or other support to hold the sample above the monitor, so that there are no surfaces near the source. Repeat data collection. Do your data agree any better with your model?
5. Instead of using one of the built-in curve fits for your data, use the ADD MODEL function on the ANALYZE OPTIONS screen in DataRad to superimpose an equation with exactly the same form as your model on your data. Does this equation fit your data? Is this a better test of your model? Why? To use ADD MODEL you must first enter an equation in the calculator's Y1= field, making use of one or more parameters A, B, C, D or E.