

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

LabQuest
Radiation Monitor

Cobalt-60 1 μC source
meter stick

PRELIMINARY QUESTIONS

1. Place your cobalt-60 source on a table. Turn on the radiation monitor to the audio mode, so that it beeps when radiation is detected. By holding the monitor near the source, determine the most sensitive place on the detector. That is, roughly where in the monitor's case is the radiation being detected?
2. Starting about a meter from your source, slowly move the monitor closer to the source until they nearly touch. How does the beep rate vary with distance from the source? Would you say that the beep rate is proportional to distance from the source? Or is it an inverse relationship?
3. Sketch a qualitative graph of the beep rate vs. distance from the source.

LabQuest 2

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 question 3 above?

PROCEDURE

1. Connect the Radiation Monitor to DIG 1 of LabQuest. Choose New from the File menu. If you have an older sensor that does not auto-ID, manually set it up:
 - a. Choose Sensor Setup from the Sensors menu.
 - b. Select Radiation Monitor from the DIG 1 sensor list.
 - c. Select OK.
2. Set up the data-collection mode.
 - a. On the Meter screen, tap Mode. Change the data-collection mode to Events with Entry.
 - b. Change the Count Interval to 300 seconds.
 - c. Select OK.
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. Determine the background count rate.
 - a. Move all sources away from the monitor.
 - b. Start data collection to prepare the system for data collection.
 - c. Tap Keep. Counts are taken for 300 seconds.
 - d. Enter 0 to indicate that this is the value for the background count. Select OK.
 - e. Stop data collection.
 - f. Record the average background counts per minute in your data table.

4. Set up the data-collection mode.
 - a. Tap the Meter tab.
 - b. On the Meter screen, tap Mode.
 - c. Change the Count Interval to 60 seconds.
 - d. Enter the Name (Distance) and the Units (m).
 - e. Select OK.
5. If you are using the Digital Radiation Monitor or the Radiation Monitor measure all distances from the center of the metal screen, perpendicular to the screen. If you are using the Student Radiation Monitor stand the case on edge, with the plastic Geiger Tube window near the table. Measure distances from the middle of this window, perpendicular to the window. Place the center of the source 6 cm from the monitor.
6. Start data collection. Tap Keep. The number of gamma photons that strike the detector will be counted during the 60-second data collection period.
7. After 60 seconds have elapsed, enter **0.06**, the distance in meters from the detector to the center of the source. Save this data pair by selecting OK.
8. Move the source 0.02 m farther from the source. Tap Keep to count for the new distance. When the data collection period is complete, enter the new distance of **0.08** meters and select OK.
9. In the same way as before, move the source an additional 0.02 m out, tap Keep, 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 ten counts per minute.
10. Stop data collection.
11. Correct the data for background radiation.
 - a. Tap the Table tab.
 - b. Choose New Calculated Column from the Table menu.
 - c. Enter **Corrected count** as the Name and **cpm** as the Units.
 - d. Select X-A as the Equation.
 - e. Enter the average background radiation count from Step 3 as the value for A.
 - f. Select OK to view a graph of corrected counts vs. distance.

DATA TABLE

Model expression	
Average background counts/min	
Fit parameters and equation	

ANALYSIS

1. Inspect your graph of corrected counts *vs.* distance. Does the count rate appear to follow your model?
2. Fit an appropriate function to your data.
 - a. On the Graph screen, choose Curve Fit from the Analyze menu.
 - b. Choose the equation that matches the mathematical form of your model as the Fit Equation.
 - c. Record the fit equation and parameters in your data table.
 - d. Select OK.
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 (120 to 300 s, depending on how patient you are!). 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, choose Model from the Analyze menu 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?