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

computer	Radiation Monitor
Vernier computer interface	Cobalt-60 1 μC source
Logger *Pro*	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 inside the monitor 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.

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 2*r*. *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/SONIC 1 of the computer interface.

2. 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. Prepare the computer for data collection by opening the file "02a Distance" from the *Nuclear Radiation w Computers* folder. One graph is displayed: counts *vs.* time. The vertical axis is scaled from 0 to 15 counts/interval. The horizontal axis is distance scaled from 0 to 300 seconds. Logger *Pro* will count for ten 30 second intervals. Move all sources at least 2 meters from the radiation monitor, and click ▶ Collect. Wait five minutes for data collection to complete.

3. After Logger *Pro* has finished data collection, click once on the graph to make it active. Notice that the number of counts in each interval varies. This is to be expected since radioactivity is a random process. Click the statistics button on the toolbar to determine the average number of counts in an interval. Record the mean value in the data table.

4. Prepare the computer for data collection by opening the file "02b Distance" from the *Nuclear Radiation w Vernier* folder of Logger *Pro*. One graph is displayed: Corrected Radiation (counts/int) *vs.* Distance (m). The vertical axis is scaled from 0 to 300 counts/interval. The horizontal axis is distance scaled from 0 to 0.50 m.

5. Enter your correction for the count rate by modifying a column in the Logger *Pro* data table. To do this, choose Column Options ▶ Corrected Radiation from the Data menu. The Equation field will read "Radiation" –0. Change the zero to your average background count rate. For example, if your average rate was 7.3, your equation should read "Radiation" –7.3. Click Done to complete the modification.

6. If you are using the Digital Radiation Monitor (black plastic case with digital meter) or the Radiation Monitor (brown plastic case with meter) measure all distances from the center of the metal screen, perpendicular to the screen. If you are using the Student Radiation Monitor (black plastic case, no meter), stand the case on edge, with the 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.

7. Click ▶ Collect to begin collecting data. Logger *Pro* will begin counting the number of gamma photons that strike the detector during each 30 second count interval.

8. After at least 30 seconds have elapsed, click the ⊕ Keep button. 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 clicking OK . Data collection will now pause for you to adjust the apparatus.

9. Move the source 0.02 m farther from the source. Click Continue to collect more data, and wait 30 seconds.

10. Click ⊕ Keep , and enter the new distance of **0.08** meters.

11. In the same way as before, move the source away an additional 0.02 m, click Continue , wait thirty seconds, and click ⊕ Keep . Enter the distance in meters. Repeat this process until the distance is at least 0.24 m or the counts in one 30 second interval drops below ten.

12. Click Stop Collection instead of Continue to end data collection.

DATA TABLE

Model expression	
Average background counts	

ANALYSIS

1. Inspect your graph. Does the count rate appear to follow your model?

2. Fit an appropriate function to your data. To do this, click once on your graph to select it, then click the Curve Fit button 📉. Select an equation that has the same mathematical form as your model from the equation list, and then click Try Fit . A best-fit curve will be displayed on the graph. If your data follow the model, the curve should closely match the data. If the curve does not match well, try a different fit and click Try Fit again. When you are satisfied with the fit, click 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 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?