Distance and Radiation

1. See *Appendix A* for information about the word-processing files of the student experiments, as well as any other electronic resources available for this book.

2. Calculator users: If you are collecting data with TI graphing calculators, an application such as VST Apps or DataRad may need to be installed on the calculators. You can determine which app you need at www.vernier.com/til/2672

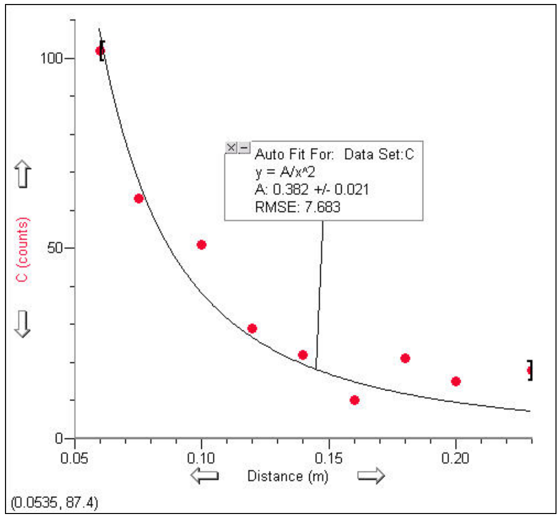
   The calculator instructions for this experiment are not intended for use with TI-Nspire handhelds or computer software. Radiation Monitors cannot be used with color-screen TI-84 Plus calculators (TI-84 Plus C Silver Edition and TI-84 Plus CE).

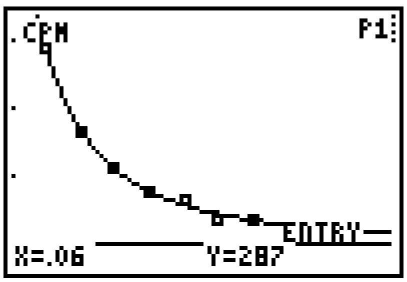
3. Because the radiation monitors detect individual gamma ray arrivals, Poisson statistics apply. The more counts that arrive in a counting interval, the better the precision. The standard error of a count of n is $n^{1/2}$, so do not be surprised to see considerable run-to-run variation in the long distance counts where n is only 10 or 20. To achieve better precision requires larger count numbers, and hence longer count intervals. The student files use a 30-second counting interval as a compromise between good results and a rapid experiment. Better results will require longer counting intervals.

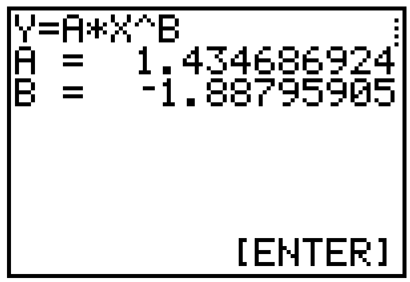
4. If your radiation monitors have an audio mode (e.g., Digital Radiation Monitors), turning on the audio function during the Preliminary Activity will provide an auditory indication of counts in addition to the flash of the LED on the radiation monitor.

5. Sources are available from these suppliers:
   - Spectrum Techniques: voice: (865) 482-9937, fax: (865) 483-0473, www.spectrumtechniques.com
   - Flinn Scientific: voice: (800) 452-1261, fax: (866) 452-1436, www.flinnsci.com

SAMPLE RESULTS







Note: The computer-based sample data were collected using a Radiation Monitor, while the calculator data were collected using a Student Radiation Monitor.

DATA TABLE

Model expression	$I\,(r) = N/(4\pi\, r^2)$
Average background counts	8.45

ANSWERS TO PRELIMINARY QUESTIONS

1. The screen at the end is the most sensitive spot.

2. Since the rate of flashing of the LED increases sharply with decreasing distance, the intensity appears to be an inverse function of distance. It is hard to say from the flashes alone if it is inverse, inverse-square, or otherwise.

3. Sketch should be a decreasing function with distance.

4. The number of particles passing through a unit area decreases as the inverse of the square of the distance from the source. The same number of particles pass through each sphere, but the area of the larger sphere (radius $2r$) is four times the area of the smaller sphere (radius r).

5. $I(r) = N/(4\pi r^2)$, where N is the number of particles leaving the source each second, and $I(r)$ is the number of particles per second per unit area at a distance r from the source. That is, the intensity I is an inverse-square function of distance.

6. Yes, this model is also a decreasing function.

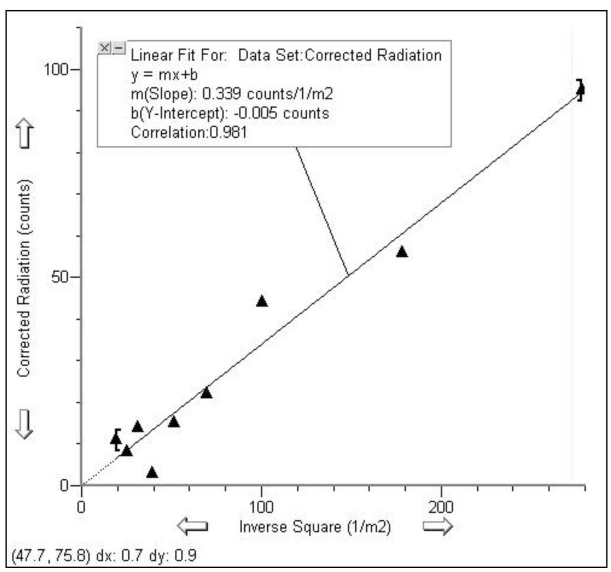
ANSWERS TO ANALYSIS QUESTIONS

1. The count rate falls off rapidly with increasing distance. This is consistent with the inverse-square relationship predicted by the model.

4. The inverse-square function fits the data well, so it appears that the gamma rays do follow the inverse-square law over the range of distances investigated.

ANSWERS TO EXTENSIONS

1. A graph using the inverse-square of the distance from the source for the horizontal axis appears proportional, supporting the inverse-square model.

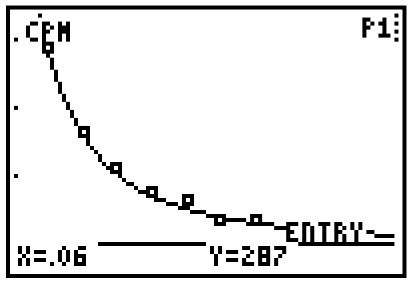


2. At very small distances the entire detector is not a uniform distance from the source, so the effective distance is larger than the source-to-detector center distance. The count rates will then be systematically small. This effect is more significant with the Student Radiation Monitor than with the Radiation Monitor, since the Geiger tube of the former is larger.

3. Longer counting intervals improve the statistics so there is less interval-to-interval variation. As a result the data closely follow an inverse-square function. Shorter count intervals result in more variation, so there is more scatter of points about the inverse-square function.

4. Results will vary. Comparison of different runs is potentially difficult due to counting statistics unless n is very large. See Experiment 4 for more information on statistics.

5. (calculator only) Using an inverse-square function of $y1=A/x^2$ and adjusting A so that the curve passes through the first data point produces this graph:



From the excellent agreement we can conclude that the data support the inverse square model.