Radiation Shielding

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).

3. 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

4. Because the radiation monitors detect individual particle 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 many-layer points where n is only ten or twenty. Longer count intervals are required to achieve better precision.

5. This activity asks students to generalize the transmission through zero, one, two, three… absorbers of f^0, f^1, f^2, f^3, to the transmission through x absorbers: f^x.

6. It is critical that the geometry of the experiment remain constant as the absorbers are added. If either the monitor or the source is moved during data collection, the resulting run will probably be poor.

7. The final analysis question requires manipulating the fitted equation. Students who are weak in mathematics may need assistance with this step.

8. The analysis asks that the student choose an appropriate fit equation based on the mathematical form of the model. The model is an exponential function: $N = f^x N_0$. There are two exponential functions offered in Logger *Pro*. One is a base-10 exponential function of y = A*10^(B*x), or $Y = A10^{Bx}$. Another is a natural exponential function of y = A*exp(–C*x) + B, or $Y = Ae^{-Cx} + B$. The different base of the exponential function does not affect the shape of the function, but the natural exponential has the extra additive term of "+ B." Because the count rate is usually significantly higher than background, the additive term will have little effect on the fit. As a result, either function could be chosen for this experiment. The additive term does affect the fit slightly, however, so the exponential parameter will not be directly comparable in the two fits (aside from the base change). Since

the base 10 exponential more closely matches the form of the model developed by students, it is the more natural choice, but either form can be used. The LabQuest and calculator programs do not offer the base 10 choice.

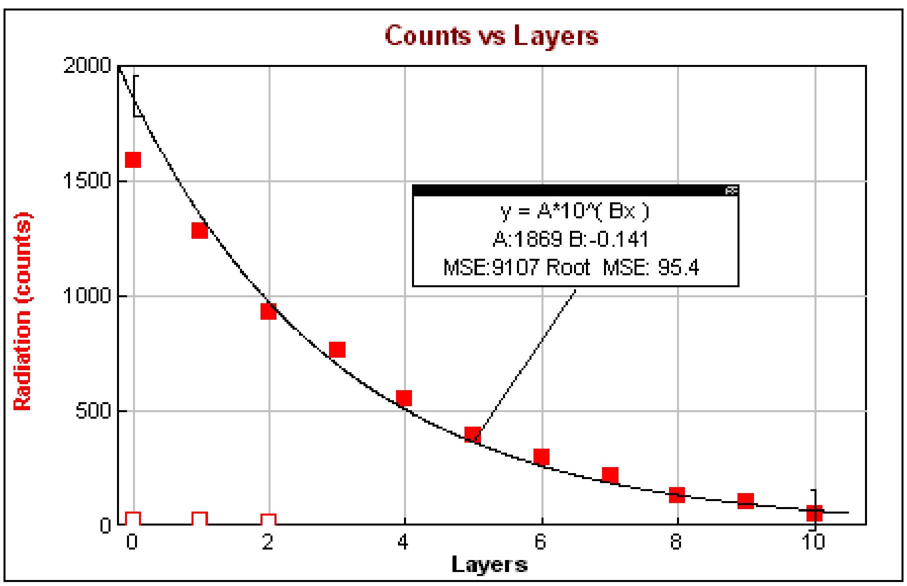
9. The cardboard used for the sample data was cut from a standard cardboard shipping box. The transmittance will vary with type and thickness of cardboard.

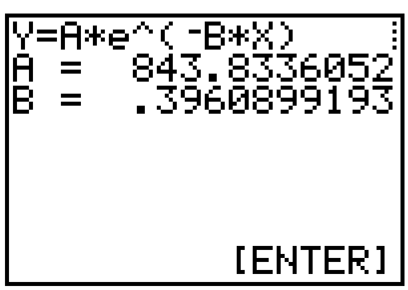
10. The strontium-90 source used in this activity is a pure beta source. No gamma rays are emitted, so there is no confounding effect of differing absorption of gamma and beta radiation by the shielding material.

11. 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.

SAMPLE RESULTS

1. The model fits the experimental data well. The additional three points at lower left are measures of background radiation from cosmic rays; the background count rate was small compared to the count rate using the Sr-90 source.





ANSWERS TO PRELIMINARY QUESTIONS

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

2. Yes, the cardboard appears to shield the radiation monitor from the beta radiation of the Sr-90 source. Adding more layers of cardboard further reduces the count rate.

3. Graph is a decreasing function with additional layers of cardboard.

4. $N = N_0 f^x$, where f is the fraction of beta particles transmitted by one layer, and x is the number of layers.

5. Model function is also a decreasing function with additional layers x, since f is less than one.

DATA TABLE

Model equation	$N = N_0 f^x$
Fitted equation with parameters	$Y = 1870 \times 10^{(-0.141\,x)}$

ANSWERS TO ANALYSIS QUESTIONS

1. The count rate falls off rapidly with added absorbers. This is consistent with the model, which predicts reduced rates with increased numbers of absorbing layers.

4. Yes, the experimental data match the model fairly well, especially for the larger numbers of layers of absorbers. It appears that the simple multiplicative model does predict the transmission of radiation through matter.

5. (computer data) Using the base-10 fit, and noting that 10^{Bx} corresponds to f^x, we have $10^B = f$. So, $10^{-0.141} = 0.72$. One layer of cardboard (of the type used for the sample data) transmits 72% of the beta particles striking it.

   (calculator data) Noting that e^{-Bx} corresponds to f^x, we have $e^{-B} = f$. So, $e^{-0.39} = 0.68$. One layer of cardboard (of the type used for the sample data) transmits 68% of the beta particles striking it.

ANSWERS TO EXTENSIONS

1. For longer collection times, the total number of counts in each interval will be longer. As a result, the precision of each measurement will be greater. We would expect less scatter about the model line. For shorter collection times, the precision will be reduced and we would see more scatter about the model's function.

2. The sample data show three points below the main curve. These are background counts made with no source. The average was approximately 25 counts in each 50-second count interval. To correct for background radiation, subtract 25 from each of the data points collected using the source and the absorbers, and repeat the graphing and fits.

3. One layer of foil absorbs a much smaller fraction of the betas, so larger stacks of absorbers will be required. You may want to use ten layers of foil in place of each single layer of cardboard.