Counting Statistics

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. This experiment can be done using Logger *Pro* (computers) and DataRad (calculators). LabQuest does not support histograms. 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 lab 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).

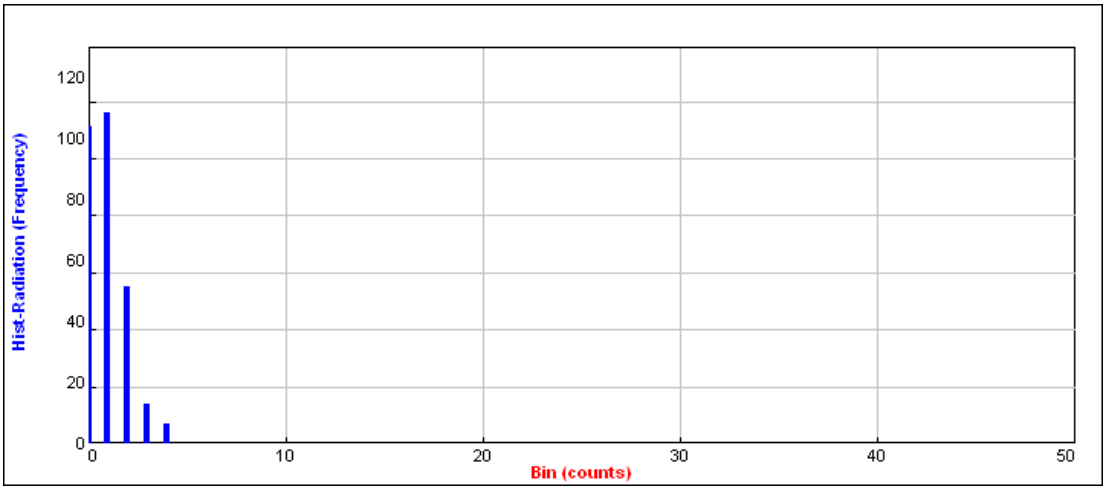
3. The experiment calls for counting times that allow for 200 intervals. This is a minimal collection time. If 400 to 500 intervals are used, the resulting distributions will be cleaner and more "like the textbook." If a fresh 1 μC source is used, the 500-interval count will not take excessively long. Use 500 intervals if time allows. Consider collecting data overnight for even better data.

4. If you are using Logger *Pro*, you may want to have your students collect low-rate and high-rate data several times to compare the histograms. Particularly if only 200 intervals are used, the histograms will vary from run to run. If more intervals are used, the histograms will vary much less from run to run. It is interesting to watch the histogram "grow" during data collection. You'll see the pattern start as a very rough pattern as the first few bars appear, and then as more and more data are collected the pattern will fill in to approximate an ideal distribution. You may want to have your students observe this during data collection.

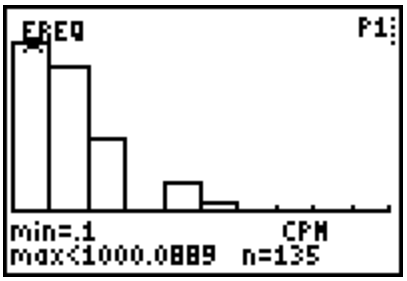
5. If your radiation monitors have an audio mode (e.g., Digital Radiation Monitors), turning on the audio function during the Preliminary Activity will provide an auditory indication of counts in addition to the flash of the LED on the radiation monitor.

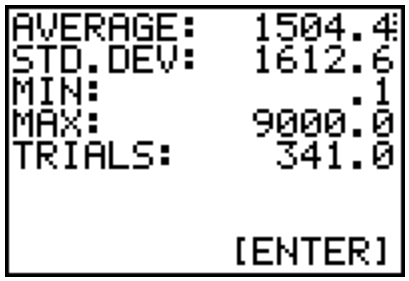
6. Sources are available from these suppliers:
   - Spectrum Techniques: voice: (865) 482-9937, fax: (865) 483-0473, www.spectrumtechniques.com
   - Flinn Scientific: voice: (800) 452-1261, fax: (866) 452-1436, www.flinnsci.com

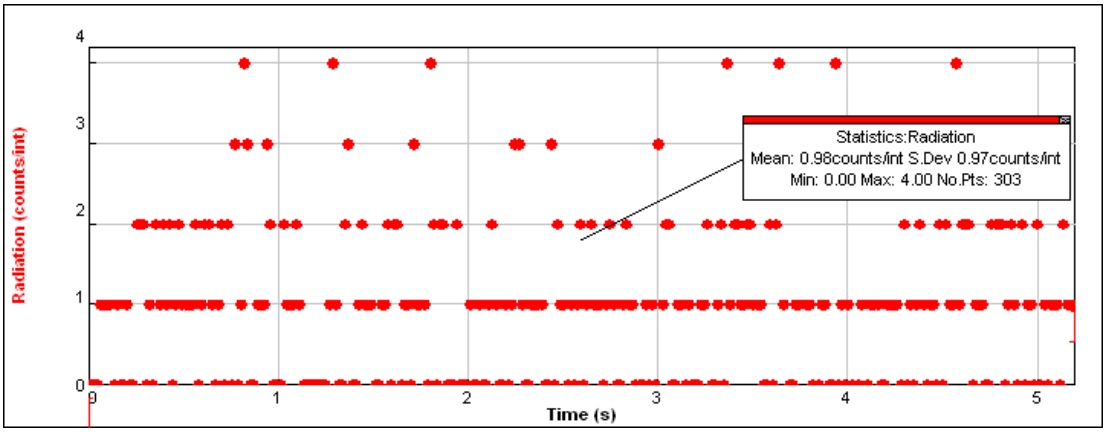
SAMPLE RESULTS



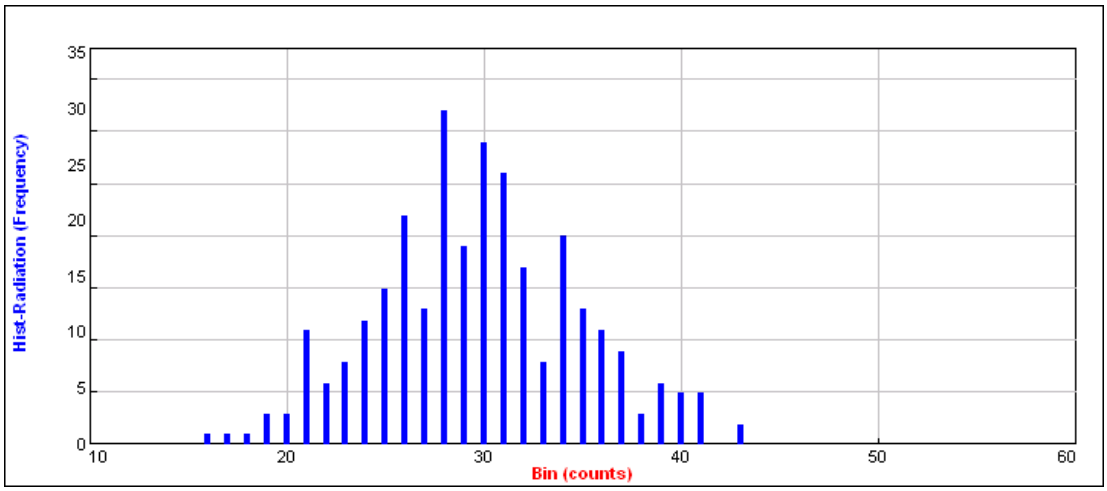
Low count rate results with asymmetric histogram:

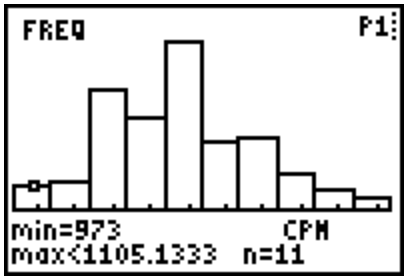


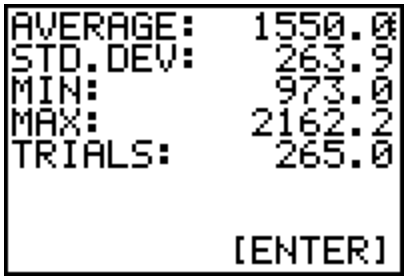


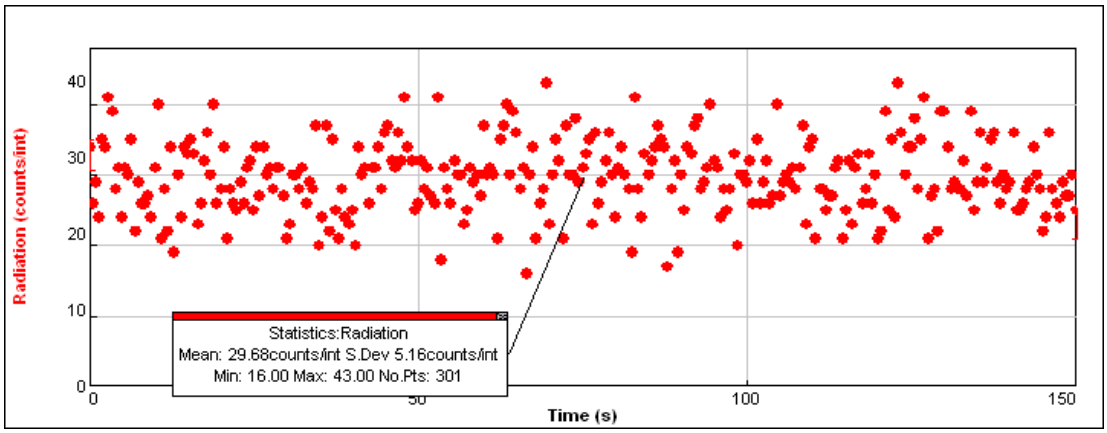


High count rate results with symmetric histogram:









ANSWERS TO PRELIMINARY QUESTIONS

1. The time between flashes (events) is not uniform; sometimes it is long, and sometimes it is very short. There is apparently no way to predict when the next event will occur.

2. There are now more flashes each second, but they are still irregular.

DATA TABLE

Logger *Pro* (computer)

Average count rate (1 s interval)	33.7

	Low count rate (~1/interval)	High count rate (~30/interval)
Interval length (s)	0.017	0.9
Average rate (counts/interval)	0.98	28.9
Square root (average rate)	0.99	5.4
Standard deviation (counts/int)	0.97	5.1
Fraction within ± std dev		70%

DataRad (calculator)

Counts/interval (100 s interval)	2710

	Low count rate (~1/interval)	High count interval (~30/interval)
Interval length (s)	0.04	1.11
Average rate (cpm)	1504	1550
Average counts	1.00	28.7
Square root (average counts)	1.00	5.3
Standard deviation (cpm)	1612	263.9
Standard deviation (counts)	1.07	4.9
Fraction within ± std dev		80 %

Bin max	Number
1105	11
1237	12
1369	49
1501	38
1633	69
1765	28
1897	30
2030	15
2162	8
2294	5

214/265 or 80% of the measurements are within one standard deviation of the average.

ANSWERS TO ANALYSIS QUESTIONS

1. No, the low-count rate histogram is not symmetric. This is apparent from the peak that is left of center on the distribution. The asymmetric shape is different from the Normal distribution, so these data are not distributed like the Normal distribution.

2. The second, high-rate, histogram appears symmetric since the peak is in the middle. This shape is qualitatively similar to the Normal distribution.

3. (4 for calculator) The square root estimates are very close to the actual standard deviations. This is consistent with the count data following the Poisson distribution.

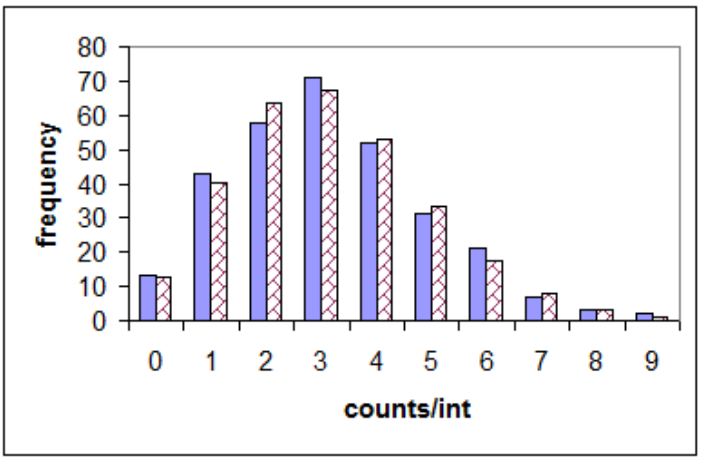
4. (5 for calculator) The estimated standard deviation of a set of measurements with a 900-count average would be $900^{0.5}$, or 30. That 200 (or 2000) measurements are to be made is not relevant.

5. (6 for calculator) The fraction of measurements within one standard deviation of the average is 70%, which is very similar to the expected two-thirds of values within that range for the Normal distribution. The calculator histogram bins are broader than are the computer bins, so the higher 80% fraction is due to over counting in the broader bins.

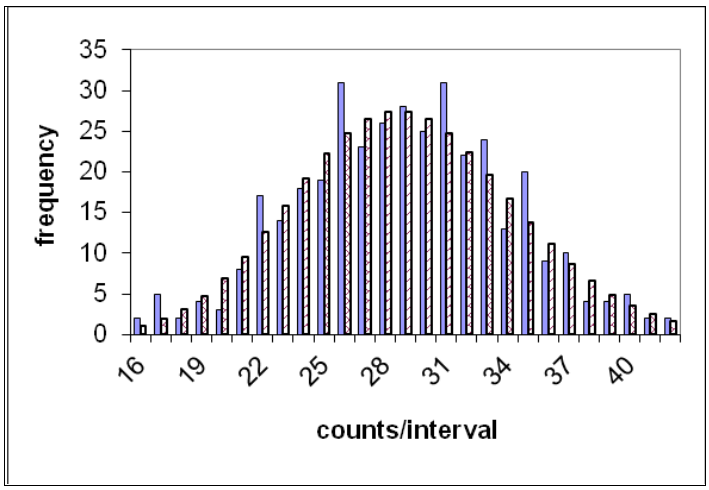
ANSWERS TO EXTENSIONS

1. Below is a histogram of low-count rate data of average rate three (solid bars) with Poisson distribution (hatched bars) of same average and area. This graph was created using a spreadsheet. The distribution of the experimental data and the Poisson distribution are very similar; both are asymmetric. The expression used to calculate the unit-area Poisson distribution, where x the counts/interval and μ the average, is

$$P\left(x;\mu\right) = \frac{\mu^x}{x!}\, e^{-\mu}$$



2. Below is a histogram of high-count rate data (solid bars) with Poisson distribution (hatched bars) of same average and area. The distribution of the experimental data and the Poisson distribution are very similar; both are nearly symmetric as expected for data with an average count rate near thirty.



3. Approximately 90% of the measurements fall within an interval two standard deviations on either side of the average. This is consistent with the Normal distribution.

4. Essentially all of the measurements fall within an interval three standard deviations on either side of the average. This is consistent with the Normal distribution, where 99.7% of the measurements fall within this range.