

DEPARTMENT OF NUCLEAR ENGINEERING
University of California
Berkeley, California

C. M. Lederer/ K. Vetter

How to Write a Laboratory Report for NE-104A

Most of the effort to produce an NE-104A laboratory report should be spent *analyzing your results correctly*, and on *presenting the data and results of the analysis clearly*. A large part of this effort involves calculating derived quantities and presenting the results in tables and graphs, including the *correct handling of uncertainties*. Until about 1998, students were required to structure a report like a short research paper. This entailed writing a considerable amount of text, a time-consuming, unpopular, and sometimes hazardous exercise. More recently, two changes have simplified the job of writing lab reports:

1. Much of the text-writing has been eliminated. The text still required includes a brief (one or two paragraph) introduction and answers to specific questions (*if* the question calls for a written explanation). Some suggestions for writing text are given below.
2. The write-up for the laboratory spells out explicitly what to include in the report. See the last section of the write-up. Most of the required items will be in the format of tables (sometimes just a single number) and/or graphs. Proper presentation of data in tabular and graphical formats is very important; tables and graphs are discussed at length below.

Reports (including figures and tables) should be printed with your computer or done neatly *in ink*, not pencil.

Writing an Introduction

The introduction should describe the *purpose(s) of the experiment* and the *method(s) used*. An example for the first experiment follows. You are welcome copy or paraphrase this example; for future experiments you must write your own introduction. A circuit diagram or sketch of the apparatus should be included if it helps to describe the experiment. If one is available in the write-up provided to you, it can be copied and pasted onto the report.

Introduction (example for experiment 1)

In this experiment I investigated the characteristics of nuclear pulse-processing electronics. Units studied included a preamplifier ("preamp"), linear amplifier ("amp"), single-channel analyzer (operated as a lower-level discriminator), counter, timer, and count-rate meter. A triggered oscilloscope was main diagnostic tool and was used in most measurements to determine voltages and time intervals; a secondary purpose of the experiment was to gain proficiency in the use of an oscilloscope. A square-wave pulser provided input signals in lieu of a radiation detector. Measured properties included the gain of the preamp and of the combined preamp and amp—equal to the output voltage divided by the input charge (in units of volts per picocoulomb), the voltage gain of the preamplifier when a pulse is applied to the test input,

and the system noise. The RC time constant of the preamp was also measured. The charge sensitivity of the preamplifier and the preamp-amp combination (the linearity of v_{out} vs. q_{in} , or the constancy of the gain, which is equivalent) was investigated over an input pulse width ranging from 0.1 to 4.0 μs . These measurements enabled me to estimate the charge equivalent of the noise, the charge equivalent of a test input voltage, and the electrical properties of several important preamplifier components (C_F , R_F , C_{test}). The count-rate meter was investigated to determine its accuracy for several values of the count rate and to understand the effect of the time-constant setting.

Reporting Data in Tables

Most often the data to be reported consist of multiple numbers. These should be collected and presented in tables and/or graphs. An example of a partial table for gain measurements is:

Table 1. Gain of the Preamplifier

Pulser Voltage ^a (V)		Pulse Width (μs)		Output Voltage (V)		Gain (V/pC)	
10.00	± 0.20	4.00	± 0.20	3.29	± 0.08	0.86	± 0.05
10.00	± 0.20	2.00	± 0.10	1.53	± 0.05	0.80	± 0.05
10.00	± 0.20	1.00	± 0.05	0.87	± 0.04	0.91	± 0.06
8.00	± 0.20	0.400	± 0.020	0.250	± 0.020	0.82	± 0.08
6.00	± 0.20	0.400	± 0.020	0.200	± 0.020	0.88	± 0.10

a) Input voltage is pulser voltage \div 10.

Note that:

1. The data (the first three columns) are given together with the analysis (column 4). In a student lab report it is a good idea to state the equations used to calculate the derived quantities (the gain and its uncertainty) and perhaps show one calculation with numbers substituted in the equations. (This may earn you partial credit if you make a mistake.) Do not show the calculation for each set of data; give the results in a table as above.
2. **Every** experimental number, and **every** number calculated from an experimental number(s) should have an **uncertainty**. If there is an applicable formalism for calculating the uncertainties, it should be used. This will always be the case for calculated numbers, and for some data values (counting number and averages of multiple measurements, for example.) If all uncertainties in a column are the same, the uncertainty can be included in the column heading rather than repeated for each value. In the above example, the first column could have been headed

Pulser Voltage (V)
(± 0.2 V)

and the uncertainties omitted.

3. Round numbers correctly and consistently. For a number with no uncertainty, rounding should show its approximate precision. When rounding a number with an uncertainty:
 - a. Decide how you want to round uncertainties. Common methods are to round the uncertainty to one or two significant figures, or to round to two figures if the error digits are $\leq nn$, to one figure if $> nn$. (The above table was rounded this way, with $nn = 25$.)

- b. Round the value to the same number of decimal places as the uncertainty.
 - c. In most cases, a number with zeros for place holders (e.g., 3000 ± 500) should be converted to an exponential [$(3.0 \pm 0.5) \times 10^3$] or cast in different units (see d.)
 - d. Use unit prefixes to give reasonable values. For example, note the use of V/pC (volts per picocoulomb) to avoid giving numbers like 8.64×10^{11} in column four of the example.
4. The table should have an *appropriate title and column headings*. When there is more than one table in a report, the titles should include running table numbers.

Reporting Single Measurements or Calculations

Single values (numbers that are not part of a series, thus don't belong in a table) should be set off on a separate line, preferably in a box. E.g.,

The half-life of ^{108}Ag calculated from the slope of the decay curve in Fig. 1 is

2.4 \pm 0.2 min.

Do not bury data in text.

Graphs^a

The attached "Fig. 3" is an example of a properly drawn graph. Note the following:

SCALE: Proper scaling of graphs is important, not only so that the data fits in the space allocated, but, more importantly, so that the information is clearly conveyed in a visually pleasing manner.

Size: determined by the precision of the information to be conveyed and by the space available.

Type of scale: The two most common scales are linear and logarithmic. As a rule of thumb, when the range of interest of a variable extends over two or more orders of magnitude, then a log scale is used in preference to a linear scale. Log scales are also used to demonstrate an exponential (log-lin) or power (log-log) relationship between two variables. (Conversely, use a linear scale if you want to show a linear relationship.)

DATA POINTS

Size and form: Data points should be large enough and clear enough to be distinguished easily, but not so large as to blot out significant information. When several relationships or several data sources are shown on a single graph, each type of point should have a unique symbol. Some commonly used symbols are \circ , \bullet , \triangle , \blacktriangle , \square , \blacksquare , \diamond , \blacklozenge , $+$, and \times .

¹ From a handout on graphs prepared by S. Kaplan, Fall 1982.

Error bars: When the experimental uncertainty of a value is larger than the size of the data point, it ***must have an error bar***. (If there are many data points and the uncertainties vary slowly, it is sufficient to give error bars on every n^{th} point.) Error bars in one dimension are usually sufficient, but occasionally error bars in both dimensions are required.

TEXT AND LABELS: If the graph is not drawn by a computer program, the text should be printed neatly or typed.

Grid: For non-computer drawn graphs, use a good-quality graph paper with appropriate grid type and size. For most computer-drawn graphs (and graphs prepared for publication) it is preferable to show only tick marks along the axes and omit the grid. (An exception is a graph from which the reader is expected to extract precise values.)

Axes: Each axis must be labeled with its variable name, its dimensions, and the scale.

Data points and curves: All data-point symbols and curves should be clearly identified. A convenient way to do this is with a symbol table or "legend" printed in a vacant region of the graph. An alternative is to identify the data points and curves in the figure caption. For hand-drawn (non-computer) graphs, lines should be positioned carefully. Straight lines should be drawn with a straightedge, curved lines with a French curve or, carefully, freehand.

Figure caption: Every figure should have a title, or figure caption that describes briefly the subject of the figure. When there is more than one figure in a report, the captions should include running figure numbers.

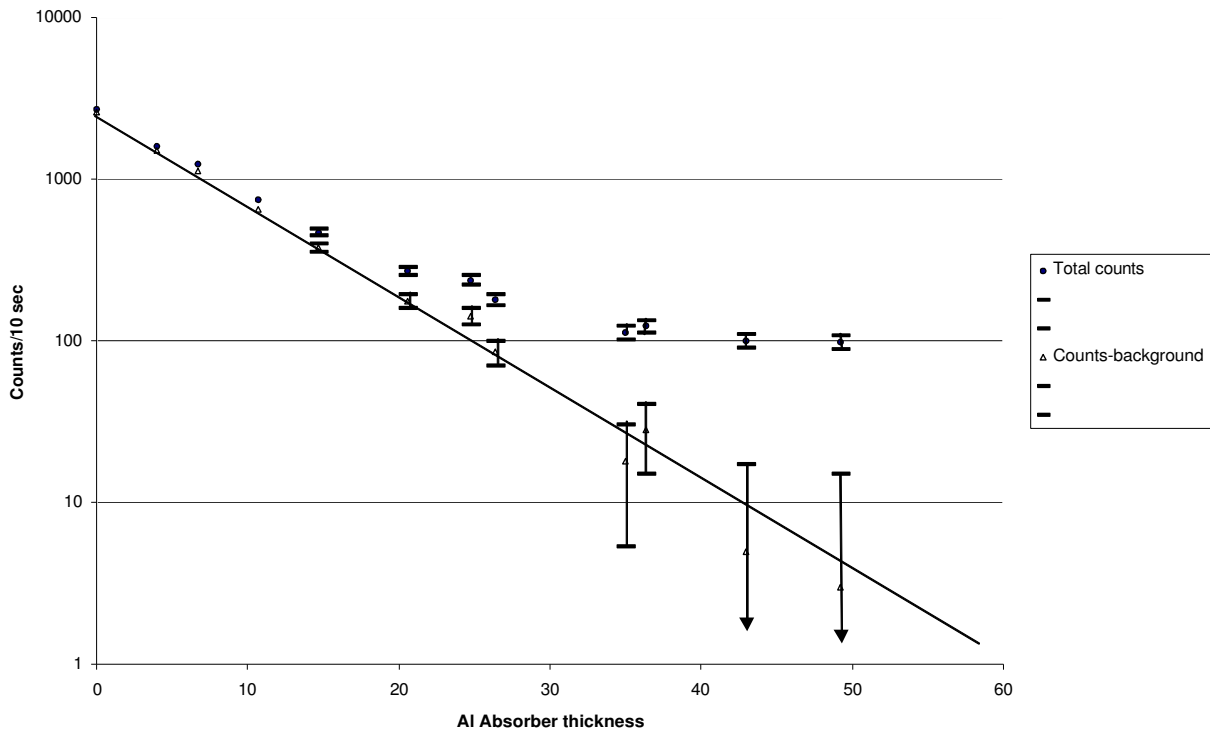
Text in answers to questions

First consider whether written text is the best way to answer a question. I have attempted to indicate where text is required and approximately how much to write ("one or two sentences," "a paragraph," for example). If the question does not call explicitly for a written answer, consider whether a number, a calculation, a formula, or a single term or phrase is more appropriate. Even when text is appropriate, remember that the grader usually looks for a key term or terms used correctly in context. Try to anticipate this and keep the answer short. A rambling discussion that gets off the point may lose some of the credit for an otherwise correct answer. Think through the meaning of what you are writing carefully and try to reduce it to one or a few concepts.

Use of Computers—or not?

Word processors, spreadsheets, and graphics programs can be extremely helpful for writing reports, and most students write their reports with them. The alternative requires a typewriter (or neat handwriting) and graph paper (often semilog or log-scale), all of which are becoming endangered species. However, the use of a computer does not excuse you from the requirements of a proper table, graph, or a clear layout on the page. This means that you must use programs that are capable of doing the job (most are) and use their formatting features to control the output.^b As an example, the graph on p. 5 was prepared with Microsoft Excel. (Something is missing on the graph—what?) Sometimes you may decide that the spreadsheet or graphics program is not worth the trouble, especially if you are not familiar with all of its formatting features. A neat handwritten table or graph is a perfectly acceptable alternative, as is hand-edited computer output, cut-and-paste, or any combination of computer output and manual composition that yields the desired result.

Fig. 3. Beta-ray count rate vs. Absorber thickness



^{II} An obvious example of misuse of a program is a calculated number with 12 significant figures. Very few physical numbers are known to this precision, certainly none that you will measure or calculate from your data in NE-104A. Other examples of misuse of a program are “default” graph or table titles like “XLS0003”, and point-to-point lines connecting points on a graph when a fitted straight line or curve is more appropriate.