Laboratory Reports: Format Details and Scoring Guide

Overall Report Format

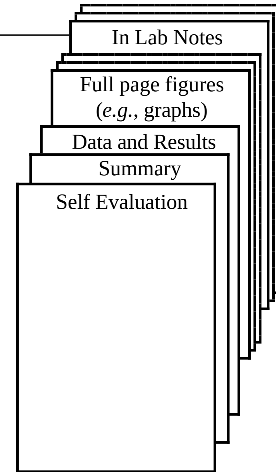

Figure 1: Order for lab report elements

Laboratory reports in this course consist of the following elements in this order (see Fig. 1):

<u>Self-Evaluation</u>: Your brief analysis, on a form I will hand out, of how well you have met the expectations that are detailed in this guide. I expect you to take this evaluation seriously; part of your score will depend on how carefully you have performed your self evaluation.

<u>Summary</u>: A written description—in your own words and based on your own understanding—of the experiment and of your results. It should include:

- a brief and precise description (~one sentence) of the purpose or purposes of the experiment in *your own words*. Do *not* plagiarize the lab manual or the report of another student.
- a brief description (~two or three sentences) of the experimental methods—i.e., what was done and, particularly, *why* it was done in terms of the relevant practical or theoretical considerations. A common problem in this section is describing the procedure in terms that make it sound like you were just following a cookbook recipe—e.g., "We measured this and that and then plugged them into equation 2 ..." Another common problem is going into far too much detail; generally the reader does *not* need to know specifically how you measured things or what instruments you used, but *does* want to understand *what* you measured and why it is *relevant* to the purpose of the experiment. References to *good* figures often help.
- a guide to the experimental data and results—i.e., what you found. Sometimes this will be no more than a few references to the table or tables in which the data and results are clearly indicated, but it is often helpful to comment on certain aspects of the data such as what may have limited the range of any parameters under your control, any important trends that were observed in the measured values, or any unusual problems you may have encountered and how they were overcome.
- *most* importantly, your analysis of the results—i.e., what they *mean*. At a minimum you *must* make clear what your results *are*, whether they are *reasonable*, and what specific conclusions you draw from them. Often you will be comparing two or more values for some quantity. When you know the uncertainties in the quantities, you need to state clearly and directly whether there are any significant discrepancies between them. If you don't know the uncertainties, then you can only make relatively vague statements about "how close" they are, perhaps giving a percentage difference as a low quality figure of merit.

I encourage you to discuss your results with your partners and other students, but your summary must be your *own*. Keep your summaries as brief as possible subject to the need to be clear, precise, and complete. Do not pad them with written repetitions of the data or "feel good conclusions"—*e.g.*, expressions of how much you liked (or disliked) the experiment. Very adequate summaries can easily be written in less than a page. Exceptional summaries may well be longer, but this will be a result of their more detailed and substantial analysis of the results. In *every* case, however, my evaluation of your summary will be *improved* by saying *whatever* you have to say clearly and in as concise a manner as possible.

<u>Data and Results</u> A concise formal presentation of the data and results on *one page* unless that is simply not possible. All notation should be defined either in words or via reference to simple sketches of experimental apparatus. Any important theoretical equations that are used in the analysis should be presented along with a clear indication of how it is to be used. All measured data (*always* with estimated uncertainties) and all calculated results (with uncertainties when necessary) should be clearly indicated with units in tables. Primary results should be *particularly* prominent and easy to compare with each other. There should be *no* "sample calculations," but it must be completely unambiguous how every calculated value was obtained. I encourage you to work with your partner as you analyze your data and produce your tables and graphs, but you must *always* do your own calculations. (The reports of lab partners *will not*, therefore, suffer from the same calculation errors!)

<u>Full page figures</u> Figures that support your data analysis. Most commonly these will be graphs, but some experiments require other kinds of figures like vector diagrams, drawings of fields or optical rays, etc. Each graph should be on its own sheet of quality graph paper with the axes scaled so that the data fills the page. You may use computer produced graphs only if they include all of the elements that are expected on a hand drawn graph.

<u>In-Lab Notes</u>: The physical pieces of paper on which you recorded data and notes on the procedure while doing the experiment in the lab. It is important that these notes be understandable and complete, but they need not be particularly neat or concise and I will generally only glance at them when evaluating your report. They are important only when you forget to include necessary data on your data and results page.

Format Details

The prime directive when writing *any* report is to make the reader's job EASY. *Every one* of the following items is intended to support this single overriding goal. Furthermore, you are specifically encouraged to ignore anything I say below and do it some other way IF (and *only* if), by doing so, you increase the likelihood of achieving the prime directive. Keep the following general principles in mind:

GP1 *Remember your audience*

Your audience—the person you are writing the report for—is an intelligent peer, someone who is at about the same point in their study of physics as you are; who knows the physical principles you are exploring; knows about lab equipment, measurement, and error analysis; but who has *not* performed the specific experiment you are describing. You are *not* trying to tell this person exactly how to do the experiment; but you do want him or her to understand what you did, why you did it, what you got, and what it means.

GP2 *Be logical and orderly*

The reader should be able to read your report starting at the beginning and never have to wonder where something came from. Each statement in the summary should receive whatever support it needs in terms of *previous* statements or references to the data and results. There should not be any question about what any symbol stands for or how any calculated value was obtained; the reader should be able to precisely reproduce your results from your data and your explanations of how they were processed.

GP 3 *Avoid lazy writing*

Lazy writing can be the result of writing for a reader who knows the subject matter as well as or better than you do. In such situations you may assume that a few poorly chosen words will be sufficient to "get the idea across." We engage in lazy speech in everyday conversations and it is often perfectly adequate. It is not, however, acceptable in reports. Be precise and specific.

GP 4 *Avoid redundancy*

Almost any time you can find a way to avoid writing something twice, do it. The point is to reduce unnecessary distractions so that the reader's job is made as simple as possible.

The sample lab report is intended to serve as a model for you to emulate. The following is a list of specific items to notice on the sample report and to pay attention to as you write your own reports:

1 Units determined correctly and indicated for *every* measured and calculated value

This may be the single most common problem and it is why it is shown here first and in bold face. It is not simply "a good idea" to include units on physical quantities; it is *absolutely essential*. A failure to indicate the units on a physical quantity is a *complete* failure to provide the value of that quantity. This failure often leads to further mistakes and, eventually, to results that are total nonsense and that destroy almost all value to having done the experiment in the first place. Few mistakes are easier to avoid and *none* will be more destructive to the score you receive on a lab report.

2 One page for data and results

Except in the rare situation where it is not possible, all data and results—including any sketches of experimental apparatus, explanation of notation or other explanatory notes, and theoretical equations used in the analysis—should be presented on a *single page*.

3 Brief presentation of relevant theory and equations

Provide the reader with a brief summary of the relevant theory used to process and analyze your data in the form of a few words and equations.

4 All notation is well-defined

Make sure that the reader knows precisely what each symbol you use represents physically.

5 Precisely one symbol per quantity

Never use two *different* symbols to refer to the *same* thing. Never use the *same* symbol to refer to two *different* things.

6 Figures (meaning drawings *and* graphs) numbered sequentially and titled

... e.g., "Figure 3: The dependence of the ball's final speed on the ramp height"

7 Sketch of experimental apparatus—e.g., "Figure 1: Experimental apparatus"

Usually you will want to include a simple schematic diagram of the experimental apparatus. Nevertheless, do so *only* if it is genuinely useful. Often such a figure is most useful in clearly defining measurements you have made. Label the figure clearly with the same symbols used elsewhere in the report to refer to any important distances, masses, angles, velocities, etc.

8 Equations numbered sequentially—e.g., "Eq. 4"—and referred to elsewhere by number.

9 No sample calculations but unambiguously obtained results

You need to provide the reader with all of the data and any equations or other information that are necessary to precisely reproduce your results, but do not clutter your report with sample calculations.

10 All numerical data and results in tables

The *only* exception to this rule occurs when a physical quantity is needed for certain calculated results but is held constant throughout the experiment. In this case, its value should be presented either where its symbol is defined or in the title of the table in which its value is used.

11 Tables numbered sequentially and titled—e.g., "Table 3: Results from the graphical analysis"

12 Tables constructed with ruled divisions

13 Meaningful column headings

All columns are headed with words and/or notation that has been unambiguously defined elsewhere.

14 Units, uncertainties, and any common powers of ten in table headings

This is an important element in reducing redundancy and making tables easier to read. The only exceptions are when the uncertainty varies within the column or when the column has a single entry.

15 Logical progression of table columns

The first column(s) should contain any independent values (i.e., the values of physical quantities that you *select*), the next column(s) should contain the dependent values (i.e., the *measured* values of physical quantities that are associated with your independently selected values), the rest of the columns should be filled out in logical order with values that are calculated from the data in previous columns

16 Logical progression of table rows

Values should be presented in numerical order so that trends in the data are easily discerned.

17 Estimated uncertainties indicated on all measurements and on results whenever required

Remember that *every* measurement requires *two* values—the value of the quantity *and* an estimate of the uncertainty in that quantity. You may or may not be required to find uncertainties in results.

18 All numerical quantities in "proper format"

The process of putting a value in proper format goes as follows:

The raw result (possibly with many insignificant figures):	3258.2394 N ± 45.72 N
1. Factor out the units:	(3258.2394 ± 45.72) N
2. Factor out an appropriate power of ten if necessary:	(3.2582394 ± .04572) x 10^3 N
3. Round the uncertainty to one significant figure:	(3.2582394 N ± .05) x 10^3 N
4. Round the value to the *same* decimal place as the uncertainty:	(3.26 ± .05) x 10^3 N

In this format there are no redundant powers of ten, no redundant units, no extraneous digits, and it is easy to see at a glance that the value is about one and a half percent uncertain—*i.e.*, 0.05 is between 1 and 2% of 3.26. If this value were one of several entries in the column of a table, only the "3.26 ± .05" would appear in its row; the power of ten and the units would appear in parentheses in the column heading—e.g., "(10^3 N)". If, in addition, all the entries in the column had the same uncertainty, then only the "3.26" would appear in its row and everything else would appear in the heading in the form "(units, uncertainty)"—e.g., "(10^3 N, ± 0.05)".

Notwithstanding the above, it is O.K. and even a good idea to keep *one* extra digit in the uncertainty and one extra digit in the value of *intermediate* results to guard against round-off error in the final result.

If you do not determine an uncertainty for some value, make sure that it has an *adequate* but not *excessive* number of significant figures. In most cases 3 or 4 sig figs is appropriate,

19 Primary results presented *clearly* and *prominently* in *one place*

20 Graphs numbered (as "Figures") and titled meaningfully

Graphs are "Figures" and should be numbered sequentially along with any other figures. They should be titled with a few meaningful words that serve to explain the contents of the graph and not, for instance, with a cryptic and redundant phrase like "*v* vs. *t*" that merely repeats the labels on the axes.

21 Graphs presented on graph paper with major and minor divisions or produced properly with a computer.

You may use any kind of quality graph paper as long as it has major and minor divisions with major divisions every five or ten lines and at least 10 minor divisions per inch. One of the best graph papers has minor divisions every mm, major divisions every cm, and semimajor divisions every 5 mm. You may also use a graphing program as long as the graph that is produced meets the other requirements listed here.

22 Each axis labeled with words, associated symbol, *and* units—e.g., "speed of ball, v (10^{-2} m/s)"

23 Axes scaled appropriately

Use a scale that allows your data to fill the page as completely as possible *without* resorting to the use of awkward intervals. For instance, when using graph paper with 10 minor divisions per major division, the major divisions should represent intervals like 1, 2, 4, or 5—and definitely *not* 3 or 7. Awkward intervals require you to interpolate values, often lead to grossly misplotted data, and make the reader's job difficult.

24 Data plotted precisely and enclosed in small, neatly drawn circles, triangles, or squares

Use *different* symbols to distinguish different data sets when they are plotted on the same graph.

25 Best fit straight lines or curves

Best fit straight lines are *only* drawn for data that support a linear relationship. Draw the line accurately using a straight edge and skipping over data points. If a curve is a better fit, draw it smoothly, making sure that it shows the *trend* in the data; *never* play "connect the dots!"

26 Slopes and intercepts of any linear best fits shown directly on the graph *and* on the data and results page

Yes, this is a little redundant, but the reader wants to be able to see these values both when looking at the graph *and* when looking at the data and results page. **Make *sure* that you include units!**

27 Use the first person in your summary

It is clearer to use phrases like, “We measured the height...”, then to engage in passive voice constructions like, “The height was measured ... .” Science writing has long proscribed the use of the first person out of some mistaken belief that it implies a lack of objectivity. Fortunately, this absurd taboo is beginning to disappear.

Scoring Criteria

Report Format (Weight 30%)

1 Not acceptable—This score will be given to reports that do not show proper attention to basic format requirements in general and, *especially*, to the proper formats for data presentation and graphs. I want you to examine the sample lab report and emulate its format closely unless deviating from that format serves the prime directive—making the reader’s job easier. This should be an easy score to avoid since it simply requires paying a little attention. The surest ways to earn this score are to

a) **omit or give incorrect units especially on results** (**See #1 above**),
b) omit uncertainties on measurements and on any calculated values for which they are required, (See #17)
c) report numbers in improper format, (See #18),
d) fail to present data and results in tables, (See #10 and #19)
e) use multiple pages for data and results when it is clearly not necessary. (See #2)
f) display a general lack of familiarity with the expected format as detailed here and as exemplified by the sample report,

2 Not quite satisfactory—This score will be given to reports that show a good faith effort to meet the basic format requirements, but which still fall short in one or two important places.

3 Satisfactory—This highest possible score will be given to reports that meet the basic format requirements.

Experimental Data and Analysis (Weight 30%)

NOTE CAREFULLY: Any report that is submitted without a completed data analysis will simply be returned with the single remark “incomplete, resubmit when finished.” When you resubmit the report it will be marked as “late” and graded as would any other late lab report

1 Not Acceptable—This score will be given to reports that display grave errors either in collecting experimental data or in its subsequent analysis. The most common problem leading to this score is a failure to check one’s data and calculations when a seriously flawed result is achieved. This is often the result of not performing basic analyses before leaving lab so that any mistakes in the collected data can be rechecked. Unfortunately, it is all too common—and particularly heartbreaking—to see good data lead to wholly improper conclusions as a result of simple calculation or unit errors that go uncorrected. Please understand very clearly: You are not graded on how well your results work out, but you are graded on how carefully you collect and analyze your data. The simple fact is that seriously flawed results are almost always the result of mistakes that are easily avoided or remedied if you simply pay attention.

2 Not quite satisfactory—This score will be given to reports that show a good faith effort to gather accurate data and to perform a proper analysis, but which are marred by errors—in collection or analysis—which might have been harder to catch or which are not so consequential as to call attention to themselves. Mistakes in error analysis are a common cause of this score.

3 Satisfactory—This highest possible score will be given to reports that display reasonable data along with complete and essentially mistake-free analysis.

(Note: Particularly thoughtful analyses of data and results that go *beyond* that which the lab manual and/or I have specified will be evaluated and rewarded as appropriate in the “Summary” score.)

Summary (Weight 40%)

1 Not acceptable—This score will be given to summaries that have evidently *not* been proofread and corrected and to summaries that could *easily* be improved with revision—*e.g.*, reports that are needlessly awkward, confused, long, or illogically presented; that make redundant statements; that have irrelevant or incorrect information; that are missing important information; etc.

2 Not quite satisfactory—This score will be given to summaries that show a reasonably good faith effort to meet the basic requirements of proofreading and revision, but which still fail to meet the more demanding and subtle requirements for brevity, clarity, precision, and completeness.

3 Satisfactory to Good—This score will be given to summaries that meet or exceed basic requirements. Such summaries will clearly take into account the needs of the intended audience—another student like yourself who is taking this course, but who has not yet performed this experiment. If you can honestly answer “yes” to the question, “Would you understand the purpose, general methods, data, and results of this experiment if you had *not* done the experiment and had *only* this report to read?”, then you have succeeded.

4 Very good to Excellent—This score will be reserved for the very rare summary that goes beyond “simply” explaining the results of doing what was asked and demonstrates that you have paid particularly close attention to the experimental procedure and devoted some thought to what was really going on while you were in the lab. Such close attention and thought invariably reveals minor flaws in the suggested theoretical analysis, in the experimental design, in the measurement procedures, in theoretical assumptions that are inadequately realized in the experimental apparatus, etc. Accordingly, you are encouraged to modify procedures when doing so seems likely to yield better results, to measure or otherwise check on things that might simply be taken

for granted in the written procedures, and to perform simple "what if" calculations to determine the impact of effects that are assumed to be negligible in the theoretical analysis.

(Note: This kind of thoughtful analysis is simply essential in scientific research, but it is hard to learn how to do; that's why I don't expect it and why I reward it, when I see it, with an exceptional grade. I will try to give examples from time to time throughout the quarter.)

Decoding my Cryptic Marks

Circled words, ends of words, or spaces between words in summary

Spelling, improper tense, plural/singular errors, missing articles, etc. *You* figure it out. If you really can't, then ask.

Circled numerical values

Improper format, incorrect or missing units, things that should be in table headings, etc. Figure it out.

amb (ambiguous)

awk (awkward, see GP3)

CB (cookbook)

A passage that reads like a cookbook. Usually happens when describing a procedure in too much detail and/or without providing any sense of *why* you are doing what you are doing.

exp (Explain, see GP2)

GWS (goes without saying)

Don't waste the reader's time saying things that are always true or that follow obviously and directly from something else you've just said.

IDF (I don't follow)

IO (illogical order of presentation)

Something that should have been said before or should be said later. (See GP2)

MEI (missing essential information)

The reader has not been given some information that is necessary to make sense of this. (See GP2)

mistake(s)

You have made mistakes in your data collection or analysis. If I am questioning a measurement, think about it yourself and see if you don't agree. If I am questioning a calculated result, go back and see where you made your mistake.

notation

Notation used in a table heading, an equation, or elsewhere is either inconsistent or not defined. (See #4 and #5.)

NAF (needs a figure, See GP1 and GP2)

NAS (not a sentence)

Either an incomplete sentence or two or more sentences separated by commas.

NC (no content)

The sentence doesn't really say anything.

NI or NEI (nonessential information)

NP ("not proofread" or "needs proofreading")

A mark to avoid at all costs! You should *never* turn in a report without having carefully proofread it. Remember: After the second lab report, I will not grade reports with summaries that are evidently not proofread. (See p. 5)

NR (needs revision)

The passage is needlessly confusing. The thoughts being expressed can easily be said more clearly. More than a few instances of this remark will likely result in a score of 1 for the summary. (See p. 5)

red (redundant, see GP4)

RIC (the reader is confused)

Remember your audience. (See GP1)

ROE (round-off error)

You have rounded off too much and lost significant figures as a result. (see #18)

RTA (read this aloud)

If you read this passage aloud I think you'll see just how much it needs revision.

RWU (the reader won't understand)

Similar to "RIC." (See GP1)

sig figs (significant figures)

Too many or too few significant figures. (See bottom of p. 3)

sp (spelling)

SSR (See sample report)

Another term to shudder at for it means that you have not paid attention to the most simple matters of format. Remember: After the second lab report, I will not grade reports that do not meet basic format requirements. (See p. 4)

ugh

An expression of distaste. Probably the result of my having just read a lazy or slangy expression. (See GP3)

units (UNITS!!)

Missing or incorrect units. This is another *really* bad one; units are *always* essential. (See #1)

UYOW (use your own words)

Sounds like a passage I've read somewhere else

vague

Needs to be more specific

WDTM? (What does this mean?)

Often I *do* know what you mean or I at least have some vague idea, but you have certainly not *said* what you mean. Take a look yourself; read it out loud and see if you don't agree. If you don't, be sure to let me know.

WDYGT or HDYGT? (Where or how do you get this?)

X (an "x" mark—indicates a factual error)