Researching the Literature

Writing Professional Lab Reports

A Researching the Literature

<u>Reference books</u>

In your lab reports you will have to refer back to accepted actual values or behaviors (data trends) of properties. You will need to discuss these in the context of their actual model limitations, accuracies, etc.

Our lab library has a number of such current reference texts. When you quote them, you will have to use a proper citation system. Web sources are generally not accepted for reports. Exceptions are described in the syllabus.

<u>Databases and online journals</u>

Web of Knowledge

task: search for the publications of Robert Millikan

In which journals has he published?

How many publications does he have?

Online Journals, UW

Task: go to prola archive (via the Physical Review publication series), find the journal home, and repeat the previous search.

How many times were the articles you find cited?

Q: How many physics related journals does the UW library subscribe to?

Some compiled information of interest from the Web of Knowledge:

Output in scientific papers by country, 1998-2008

USA	2,798,448
Japan	757,586
Germany	723,804
England	641,768

10 Most Cited Journals of 2006

J Biol Chem	410,903
Nature	390,690
Proc Nat Acad Sci USA	371,057
Science	361,389
J Am Chem Soc	275,769
PRL	268,454
Phys Rev B	212,714

10 Most prolific journals 2008

1. Lecture Notes in Comp Sc	87,567
3. Phys Rev	53,354
4. Appl Phys Lett	39,056

5. PRL	34,128
6. J Appl Phys	32,502

Physics Journal Impact Factors

1999		1995-99		1981-99	
Rev Mod Phys	16.8	Rev Mod Phys	25.1	Rev Mod Phys	125.3
J Phys Chem D	9.9	Rep Prog Phys	16.0	Rep Prog Phys	47.7
Phys Today	7.4	PRL	12.2	Phys Rep	45.6
Rep Prog Phys	7.1				
Phys Rep	6.1				
PRL	6.1				

Impact factor = no. of times article published cited in indexed journal the next year / total no. published in year of article publication

Which journal to choose?

Our course: Physics Today

Amer J Phys

(some hard copies in lab: Rev Mod Phys)

Bibliography, Citing, Quoting

At the end of a paper or report a section called 'bibliography' is attached. In this section, all cited material appears. There are a number of common styles practiced. In our course the following rules apply:

- Add a section 'Bibliography to a full report
- In this section, list all cited material in the order of occurrence in the report

  e.g. [1] RA Millikan 'The Electron' 1924, page 90-94

  [2] JI Kapusta Amer J Phys 43(9), 1975, page 799-800

  n/b The Electron is a monograph

  The pages of Kapusta's article refer to an ongoing numbering in a journal

  List cited items one per row and with increasing integer reference number

  Add the exact page(s) you are referring to. This is not common but helps me to find what you are talking about.
- Do not make changes to the material you quote. The only exception occurs when some grammatical pointer is missing in the quoted text because you quote only a part of the whole (e.g. in the quoted text appears a 'he' but the noun that the 'he' is referring to is not included in the quoted text). In that case, add the missing part that is required to make the text fully intelligible in square brackets: he [Millikan] said ...

  Do not use square brackets for anything else but these interjections and bibliography itemizing.
- When you use a quotation from a cited source, ALWAYS

  Use quotation marks around the quoted text

  Write [n] right behind the quotation in the report main text, where 'n' refers to the actual number in your bibliography

  Embed the quotation into a reasonable and meaningful context of your own writing

For example, say we want to use the following quote from Millikan:
"In the theoretical derivation of Stoke's Law the following five assumptions are made: (1) that the inhomogeneities in the medium are small in comparison with the size of the sphere. ...(5) that the velocity with which the sphere is moving is so small ..." [1]

And later in the bibliography: [1] RA Millikan 'The Electron' 1924, page 95

The above example may or may not be a good quote, depending on the context in which it is set. For example, Context 1 When analyzing the fluid dynamic situation in the Pasco Millikan experiment one assumes that in good approximation the oil droplets are spherical and they drift due to gravity and buoyancy in an equilibrium through the medium, air. In that case, one applies the Stoke's Law analysis.

The question arises whether the Stoke's Law is valid. According to Millikan, there are a number of assumptions made and for which the Stokes Law is only applicable: "..." [1].

Here, the quote is put to good use and ads perspective and authority to one's analysis of the applicability of Stoke's Law.

Context 2 We want to analyze the Millikan experiment with respect to Stoke's Law: "..." [1].

Here, the quote replaces any analytical insight or synthesis the student should have produced. The quote replaces student work instead of enhancing it. The student wanted to avoid doing the work himself and receives no credit for the section, which is hardly anything but Millikan's work.

A The lab report

Why to learn technical report writing:

The American Institute of Physics, AIP, has conducted research into which aspects of their undergraduate education in physics students appreciate most 5 years after graduation. Technical writing skills consistently fair high in the appreciation. Employers agree with these findings too.

How to write reports (according to Linton)

"Good literature research:

Two things need to be known by a good researcher: where to look and for how long

Deciding how long to look is the more delicate and complex task.

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A good research report is one which contains just enough authentic and pertinent information to accomplish the job designed. The writer's problem is one of compromise and adjustment, judicious selection and judicious omission. He is expected to know a great deal more than he tells and to tell exactly as much as his reader needs to know."

In undergraduate reports, we assume that the audience is built of peers of equivalent knowledge. Material, which we find in the general physics textbook (here: University Physics, Sear s/Zemansky), need not be explained 9although it may need to be listed).

"<u>Identifying and dividing the problem</u>

Very few projects are so limited and precise in their statement, that the researcher knows exactly what he must look for first. In fact, an advanced undergraduate lab is often designed to the end *to hone the student's ability to identify what is important and in which sequence a complex task must best be approached."*

The first step is to come up with a rough outline, which must then be divided into a detailed outline; preferably a tree at least three braches deep. The headlines of the tree build the skeleton of the final report. An experienced report writer will find that his headline statements are the topic sentences of the paragraphs, which will build the final text.

"Two attitudes at this initial stage account for a large percentage of subsequent failures: The inexperienced writer wastes his energy in an endless reordering of preliminary detail. The second failing attitude is the reverse of the above. The writer knows that he can turn out a barely acceptable report with very little effort and declines to undertake the extra labor necessary to turn up significant material. His reports are usually one long cliché."

The basic structure of a report

"The basis is always the body of fact, the foundation upon which the rest of the structure is built, the theoretical background and data results. Upon that is constructed the critical interpretation of the facts or discussion; and at the top the lines meet and resolve themselves into a program for the future or a conclusion."

As a consequence, the report is often written backwards: an example of such a backward structure

First: Results and Discussion ~*condense the data to not waste space, show the main calculations, analyze errors and meaning of the results*

(Then: Conclusion)

Then: Experimental Detail ~ *write down what is needed to understand exactly the experimental constraints so that the reader could reconstruct your experiment in its essential parts*

Finally: Introduction ~ *write down exactly what is needed to understand the context of the report and what is needed to grasp the Results section*

Add the lab book. Do not make any changes here in the recorded data.

Guidelines for lab reports in Phys 3650

Do not use personal voice anywhere in the lab report.

Introduction/Background: This section contains all theoretical information

necessary to follow the discussion section, but not more (wordiness is not awarded, conciseness is desirable).

Audience. The same material will have to be presented at different depth and difficulty levels when written for school kids or professional audiences.

For professional audiences, skip trivial steps, which can be found in every textbook.

Special content: Motivate why a study was done and how it relates to the current level of knowledge.

Undergrad lab particulars: Arrange material to be consistent with order of appearance in the result and discussion section. Present core equations and concepts, whether trivial or not. Skip intermediate steps, which should be clear to all your peers. Always include the final equations, which will be applied in a later section.

Always lay out the model or approximation restrictions for which the theory applies.

Motivate experiment by explaining briefly how it fits into the course section. Go from the general to the specific. Point out what one had hoped to learn or to demonstrate. Do not add any conclusions, which were drawn from the experiment.

Do not add any description of the apparatus beyond the most general of statements ('a compound microscope was used').

Experimental Detail: The apparatus is described in its entirety but without excessive reference to company makes or names. The apparatus is first described in its function and setup, usually accompanied by a sketch of the setup.

This is followed by a description of parts of the apparatus or the apparatus setup, which limit the range of detection in some way. It includes anticipated sources of systematic error (see below). Without doubt, not all errors can be anticipated or be known beforehand. You can deal with such errors in the Results section, especially operator error.

All relevant parameters, which can affect the performance of the experiment, should be shown here, if they are not already part of the accompanying lab book.

Results/Discussion: This section contains a tidy summary of the main data and

results of all main calculations. The format of presentation builds a line of thought , which is easy to follow: Why did I do something? How did I do it? What did I find? What does it mean? (When things are obvious they may be skipped.)

We discuss the impact of the important sources of error on the data and whether and how we minimized or corrected them. Data are usually presented within standard deviation and/or with graphical error bars.

Discuss the experimental average within error (numerically and graphically, where possible) and compare it to, sometimes various and not directly related, accepted experimental values (as you can find them in the Handbook of Physics and Chemistry, eg speed of sound in air may be found for T=0°C and T=20°C, but you may work at an intermediate temperature) and theoretical predictions or values (for graphical analysis: (eg) the theory predicts a straight line through zero, your experiments show a straight line which does not go through zero – where does the offset come from, can it be explained? ...corrected?).

Use comparative figures where possible to visualize how well or how poorly your data fit with the accepted theory. What do your data mean with respect to the important equations *within* the field . If the theoretically expected behavior is not found, what fit line does describe the data best? Is there more than one regime, eg with respect to temperature (eg the low temperature behavior deviates from the predicted exponential behavior, but the mid- and high temperature range agrees with the theory)?

Conclusion: Final evaluation with respect to the ***overall*** meaning of the experimental result. Did it confirm theoretical expectations?

If not, what do we think why it did not? If yes, how well did it agree? Do we have non-trivial suggestions how to improve the experiment for better results?

Do not present new results in this section.

Do not do calculations in this section.

Do not present new figures in this section, unless it is for the purpose of comparing your results to accepted theory in the greater picture, which goes clearly beyond what the previous sections could deal with in the context of the lab.

Use this section to interpret your results *in the bigger picture*: What do your data mean with respect to the lecture super-topics light, electrons, nuclear, etc.?

For example, could you confirm Snell's Law well enough for the context of an undergraduate lab (error < 10%)? If you found deviations between experiment and theory, what are the main error sources which would likely have caused the disconnect between data and theory? As your last resort, does the theory need to be changed or did you simply violate the region of validity for the model assumptions under which you were working or analyzing?

<u>Lab Book</u>: We attach the raw data and the lab book to the end of the report.

The lab-book does contain all raw data of an experiment plus the observation of relevant parameters which might affect the reproducibility of an experiment.

Entries in a lab-book are never erased or made unreadable. If you have reason to decide why a certain data is wrong or irrelevant, mark it as such and explain below why you concluded that the data is obsolete and can be excluded from further treatment.

n/b Often, the results and discussion chapters appear as separate sections. For instance, that is what I have done in the example report below (it was written for a different course). In our course, you may choose what seems to work best for every case, but you need to be consistent within each report.

Appendix Example Lab Report (Phys 2310) with commentary

Lab 3 – Telescopes and microscopes

<u>General</u>

Commentary: The lab report is much like a scientific paper. In fact, most scientific papers which are based on experimental work are extended versions of lab reports with somewhat more emphasis on the discussion part than is customary in most lab reports.

Below, I distinguish at times between an experiment that has gone well and one that produced seriously flawed data. At times, I have added commentary and notes to the section, which would not appear in an actual report or would go into footnotes.

<u>Introduction</u>

Commentary: The purpose of an introduction to a lab report is to supply a reader with all necessary theoretical background to follow the report content.

For the telescopes/microscope report, we need to tell the reader about the model limitations we are working in (thin lens approximation, geometrical optics, paraxial rays, and perhaps add a cautionary note about lens aberrations). Secondly, we need to inform the reader about the type of telescope and microscope we will be dealing with and what the relevant equations (ie the one's used in 'results') are. We may add examples where it seems helpful (for instance, in the refraction report it could be useful to add information about specific cases of refractive indexes relevant to the report and what major dependencies on physical parameters, which might change or have unusual values for our experiment, they have). In general, we should also think about who is going to be our audience and what level of information is trivial for that audience.

Example:

When one combines two or more lenses to build an optical instrument, proper choice of distances and resulting vergences enable us to build equipment which can lead to the magnification of details of nearby objects ('microscopes') or the magnification of far away objects ('telescopes').

(note below: purpose is to explain what telescopes and microscopes do)

In this work, we employ the thin lens approximation for paraxial rays and consider light to travel according to the laws of geometrical optics. The lenses in use will not be of the highest quality and consequently serious lens aberrations are a factor to be kept in mind.

(note below: purpose is to explain the limits of the meaning of our data)

(note below: check backward that every topic has its own paragraph)

An astronomical telescope consists of two positive lenses which are spaced such that the distance between the lenses equals the sum of their focal lengths. Such a telescope will magnify an object to an image size of

$$M_T = -f_{objective}/f_{eyepiece} \qquad (1)$$

For objects at distance s = infinity, the image distance s' can be found for known lens focal length using the thin lens equation:

$$1/s + 1/f = 1/s' \qquad (2)$$

Note, that there will be an intermediary real image built by the objective lens and that the final image, which is observed through the eyepiece lens is virtual and inverted.

The compound microscope in its most basic form consists also of two positive lenses. However, these lenses are spaced and arranged differently than for the telescope. A so called tubular length separates the two lenses inward focal lengths. The resulting magnification is the product of the two individual lenses magnifications:

$$M_{mic} = -s_1'/s_1 * -s_2'/s = 25cm*s_1/(f_1*f_2) \quad (3)$$

(note below: note that there are many versions of and omissions made of some subjects in this variant of necessary background. I did, for example, not comment on whether the objective or the eyepiece has to be the stronger lens. That would certainly make a possible addition to my text.)

Parallax is a problem that affects the accuracy of distance measurements with optical instruments. It is the shift of an object relative to its background and is particularly bad when the object distance is very different from infinity.

Experimental detail

Commentary:

Do not write this in cookbook recipe style but make a cohesive and coherent text out of it. Tell all details that would be needed to reproduce your results.

Example:

An astronomical telescope was built from two positive lenses (fill in your lenses f's). The stronger lens was used as the eyepiece. A sheet of mm-paper was used as object on a screen. The object distance was smaller than 1m, thus it was necessary to correct for severe parallax.

(add figure which shows the setup and geometry)

To correct for parallax, the image was brought into focus. Then the object and the image were watched simultaneously and if small movements of the head resulted in relative changes between object and image, the image was not built in the plane of the object, and, therefore, parallax was not completely corrected for.

Replacement of the position of the eyepiece changed the placement of the image relative to the object plane and corrected for parallax.

With parallax eliminated, s and s' and the image magnification were measured directly. The procedure was repeated with an object on the room wall which served as a reasonable enough approximation of s = infinity.

Next, a compound microscope was built from the same lenses in reversed order. With the image focused and parallax removed to first order, the magnification was measured and all distances recorded.

(add figure which shows the setup and geometry)

Results

Commentary:

Add ALL experimental *results* and analysis in this chapter. Do not refer to results in 'experimental detail' and do not introduce results or analysis in 'discussion'.

Example:

An array of measurements for object and image positions for the astronomical telescope described in 'experimental detail' is presented in table 1. The experimental averages and data dispersion are recorded as arithmetic average and standard deviation.

(fill in table 1)

The average image distance was calculated using f= 150mm and s = 4 ± 0.25 cm by employing the thin lens equation. The error in s'_{avg} is found through error progression using the formula: ... (fill in as appropriate, consult webpage info if needed)

Using equation 1 the telescope magnification was calculated (see table 2). The average magnification is 2.64 ± 0.15. The theoretical value for the magnification is x and is known within the manufacturers accuracy specifications of y.

(fill in table 2)

Table 3 and 4 summarize the analogous data for the compound microscope described in section 'experimental detail'. The magnification was found as x ± y and compares to the manufacturer data of z ± k.

(fill in table 3 and 4)

As major sources of systematic error must count:

The fact that there were no apertures limiting the light that could enter into the optical pathway. Stray light could easily have entered. The effect could either have increased or decreased the image distance and consequently the observed magnification and would have contributed to image blur and related uncertainty in the data.

The fact that the operator was wearing eye glasses: It is uncertain what effect this could have on the observations. It is to be suspected that the distance from the eyepiece lens at which the operator would have taken his observations would affect the impact of the extra lens. This was not realized at the time and there are no records of the exact circumstances. In the future, any such effect could be studied, if the observer uses eyeglasses with two different strengths.

(n/b an exception was made to the rule where to discuss improvements because the subject seemed to fit here and may have taken focus off the truly important conclusions later on)

Other factors include the precise and perfectly flat positioning of the object (mm paper) and the rotation of experimenters, each of which could have introduced systematic error.

Discussion

Commentary:

In this section you shall first evaluate your final results within error and compare them to theoretical data or expectations (within accuracy, if available).

Based on this you comment on the validity of models and equations as introduced in the introduction and evaluate the observed impact of errors. For systematic errors, you try to estimate their magnitude by common sense reasoning and predict whether a particular error would increase or decrease the averaged experimental result.

(note below: I did deviate from this concept by adding some error estimate in my results chapter. How you should handle this depends on each case.)

Since this is an undergraduate lab, we also expect that things can go wrong. If you failed to make measurements correctly or you forgot to do an experiment, mention it here. Add a comment as to what impact your error or omission would have on the validity of the overall data.

Do not use evasive or excusatory language, just be factual about it. If you made grave omissions or mistakes it could affect the lab grade. Being not factual about it will affect the lab grade even further.

Add comments for how to improve the experiment if you can see non-trivial ways. For example, do not recommend to make a better data statistic by adding more repetitions. Also do not comment on using better protractors, meter sticks etc. Focus on sources of systematic error and how to remove them.

Example 1: (positive experiment outcome)

The good quality of the data (less than 5% error) suggests that geometrical optics is a very viable tool when used with paraxial rays for simple (here: two-lens) optical instruments. Even the use of relatively unsophisticated lenses and the lack of a protective box, which would have inhibited the sideway entry of stray rays into the processed beam, did not obfuscate the validity of the thin lens algebra.

The problem of parallax is serious for small object distances and is difficult and subjective to be corrected for.

In principle, a change of experimenters should give rise to partial removal of data offsets due to individual incorrect observation habits. On the other hand, it introduces possible new sources of observation bias. Since the overall data are quite reliable it is to be assumed that the only serious problem with systematic error stems from a remaining parallax, perhaps in combination with an object paper sheet which was slightly out of plane.

Example 2: (negative experiment outcome)

While the data for the telescope gave reasonable results (magnification of 2.64 ± 0.15 as compared to a theoretical magnification of 3.1), no satisfactory or reasonable correlation was found for the microscope. The experimental average for the microscope magnification was found to be 8 ± 4 times, while the theoretical value is 20 times.

The large error in the data analysis suggests that a key part of the experiment was either conducted with large operator error or with a significant systematic error in effect. It seems possible that the strong eye glasses, which the operator was wearing, might have served as this un-identified source of error. In addition, it was found very difficult to judge whether parallax had been removed correctly for the very small object distance. This in itself should lead to an offset of data.

In hindsight it also has to be rendered possible that there could have been unrecognized effects from gazing through the lenses at an angle because such rays are not paraxial. (add statement about whether such rays would increase or decrease the magnification)

Typically, one considers rays with up to 6 degrees above the optical axis as paraxial. The lenses in use had a diameter of x and a distance between them of y, allowing easily for non-paraxial geometry. Since the lenses in use are material for under-graduate laboratories, it is to be suspected that the lenses are not of the very best quality and, therefore, likely suffer from significant aberrations for off-axis rays.

Coma could thus have contributed to a mis-judgment in the parallax removal and distortion could have affected the judgment of magnification.

It is impossible to judge with certainty what has gone wrong. For the future, we suggest a protocol, which lists explicitly to watch out (and note in the lab book) for positioning of the eye and to consider calculations to correct for worn eyeglasses.

(note below: It is not evident that eye glasses should cause a problem. The answer would depend on further details which our hypothetical report writer did not document, such as what distance the observer had to the lens when he or she gazed through the eyepiece or whether the observer was short- or far-sighted and whether he/she wore glasses which corrected for astigmatism as well. What matters here is that the report writer thought about reasonable causes for systematic error, even if he did not get it all quite right.)

Conclusion

Commentary:

In conclusions no new facts are being introduced. Instead, the relevance of the results is emphasized in the bigger picture. Here that could mean that discussion deals with the relevance of the experiment in terms of the optics of optical instruments, while in conclusions we could point out the meaning of the experimental results in terms of the whole of geometrical optics.

Example 1: Positive outcome

The use of paraxial rays and thin lenses allows for well determined experimental conditions when one deals with simple two-lens optical instruments like telescopes and microscopes. After these first experiments it is feasible to say that with diligently careful and precise experimental methodology results can be obtained that allow for correction of manufacturers specifications of magnifications of optical instruments.

Example 2: Negative outcome

Even the confirmation of basic laws of geometrical optics can easily turn problematic when one combines lenses to build optical instruments. Many uncertainties add into the experiment and it is necessary to keep extremely precise track of experimental conditions to make results reproducible.

One class of possible complications involves the validity of standard assumptions like paraxial rays and thin lens approximations for the actual experimental conditions. The other relevant class of problems is systematic errors, which are very easily introduced and come in many disguises.

In conclusion one has to consider the impact of such systematic error sources as stray light, the wearing of corrective lenses, parallax, or the contribution from various forms of lens aberrations to the ray paths in order to improve the experiment such that one will obtain results which are in agreement with the fundamental laws of geometrical optics.