Measurement Module
Student Guide

There are two goals for the Module.

In PHY131 and so far in PHY132 you have learned how to:

- take careful measurements
- report all measurements with a ± error
- propagate errors when computing results based on measurements
- compute the average and standard deviation of multiple measurements of the same quantity
- distinguish between accuracy and precision

The first goal of this Module is for you to learn to apply these techniques to a general measurement outside of the context of the Practicals. For your convenience, a link to the document on Error Analysis which you used in PHY131 is:

http://www.upscale.utoronto.ca/PVB/Harrison/ErrorAnalysis/

Learning how to communicate the results of your measurement is the second goal of this Module. In the real world, such communication is used for:

- Applying for research grants.
- Reporting to supervisors.
- Communicating to colleagues, either through journal articles or web documents.

Both of these skills will last you the rest of your life as you continue in any scientific, medical or other discipline in which measurements are important.

You will do the measurement and write up the results individually.

As you will see below, you will be discussing each other's Measurement Reports during a Practical. You will need to fill out and bring a form about this to the Practical session where this discussion will happen. The form is available at:

http://www.upscale.utoronto.ca/Practicals/Modules/Measurement/Measurement_Pre_Form.pdf

The Module

There are five related parts to this Module.

1. Doing a measurement. Details of this part are described in **The Measurement** section of this Guide.
2. Writing up the results in a report. Information on how to write a good report is in the **Reports** section of this Guide.
3. Sending an electronic copy of your report to your Teammates well in advance of the Practical where you will discuss each other's reports.
4. Discussing each other's reports during a designated Practical section. Details are in the **Report Discussion** section of this Guide.
5. Submitting a hardcopy of your final report to your Learning Assistants' Drop Box and an electronic copy to turnitin.com by the designated dates. These dates are given in the Schedule of the PHY132 Practicals home page. This page also provides details on how to use turnitin.com.

Details on submitting your report, penalties for late submissions, and some information about turnitin.com are given in the **Submitting Your Report** section of this Guide.

Your Learning Assistants will choose especially outstanding reports, and if yours is chosen you will be invited to prepare your report as a poster which will be displayed in the cases of the hallways outside the Practical rooms. If you accept our invitation you will receive a 1 point bonus. Details on how to prepare a poster are in the **Posters** section of this Guide.

The Measurement

You should choose **one** of the following general questions to answer:

1. How far do you walk during a typical weekday?
2. What is the average density (mass per volume) of your textbooks?
3. How high is the 14-story Burton Tower that is part of the Physics building?
4. The Physics library is on the 2^{nd} floor of the Burton Tower. You leave the library and wish to go down to the 1^{st} floor. On average, how does the time to get to the 1^{st} floor by walking down the stairs compare to the time by taking the elevator? Your calculation should include the average time you need to wait for the elevator.

For each of these questions, you will probably need to re-state it so that it is more specific. For example, for the height of the Burton Tower from what part of the tower to what part of the tower are you doing the measurement?

You are invited to choose a question other than from the above list, but first please obtain permission from the Practicals Coordinators.

Resources

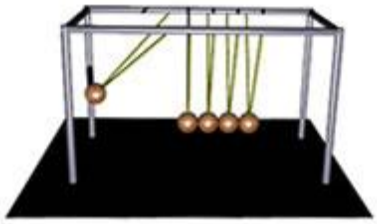
The technologists for PHY132 are Larry Avramidis, Lilian Leung, Phil Scolieri and Rob Smidrovskis. They all share an office in MP127. With their permission you may borrow metre sticks, stopwatches, measuring tape, Vernier calipers, thermometers, and the like from the Resource Centre in MP126. If MP126 is not open you can knock on the door of MP127 during regular business hours M-F 9-12, 1-5.

Reports

The University of Toronto expects all students to be able to write well, and offers extensive resources to help you learn how to accomplish this. You may access these resources at http://www.writing.utoronto.ca/home.

The single most important factor in written communications is to write from the viewpoint of your readers. Here, you should assume that your readers are first year Physics students who have not actually done the measurement that you are reporting. Your goal is to write a report that will inform your readers about the important features of your work and its results. The reader is not interested in going through the details of how you multiplied, divided, etc., and is unlikely to have any interest in long tables of numbers. You will have to use your judgment to determine what to include and what to exclude. For example, most common measuring apparatuses do not have to be described. However, any ingenious or novel method or tool in your experiment should be explained in sufficient detail that the reader can understand what you did.

A common problem with Reports is that students include too much information. You will need to decide what is important and what is not, and include only the important information.



An example of a good report is a recent article on Newton's cradle, a common toy shown to the right. The article appeared in the American Journal of Physics, and you may access a pdf version at: http://www.upscale.utoronto.ca/Practicals/Modules/Measurement/AJP_Newtons_Cradle.pdf.

The paper is just over 8 pages long in typeset form. This is probably about 16 pages of normal hardcopy text not including figures. You may wish to know that the authors of the above paper estimate that they spent about 600 hours doing programming and data analysis, 250 hours of experimentation and 150 hours of theoretical analysis.[1] Thus they spent a total of about 1,000 hours on the work reported in a 16-page "Report." If you condense the information in your report to the same degree, it will end up about **0.1** pages long! This is not possible or desirable, but does suggest that the text of your report should

[1] Private communication from Gary Delaney, Trinity College Dublin, March 2005.

almost certainly not be more than 800 words (3 pages double spaced not including figures or tables).

Report Structure

Most organizations have *style guides* for written documents, and they can differ from organization to organization. You should use the style and structure that is common in journal articles for your Report.

1. **Title**. This should be short, but precise, and convey the point of the report. It could be either a statement or a question. For example, a title like "Voltage-current relationship of a transistor" is good, as is "Does the transistor obey Ohm's Law?" But simply "The transistor" is too vague and is not a good title.
2. **Your name.** Your student number and email should be given in a footnote to your name.
3. **Your Practical**. Day and time, where, Pod number.
4. **Instructors**. Your Learning Assistants.
5. **Date**.
6. **Abstract**. The abstract summarizes, in a few sentences, the content of the report. It provides a brief outline of what the report is about; it should include a statement of what it is you measured and its value (Warning! -- students often make abstracts too long -- note that an abstract is not an introduction.) The abstract should be indented.
7. **Introduction**. The role of this section is to state why the work reported is useful, where it fits in the bigger picture of the field (or of science in general), and to discuss briefly the theoretical hypotheses which are to be tested.
8. **Experimental Method**. Describe the procedure used in the experiment. Remember that a picture (or simple diagram) is often worth a thousand words! Enough details should be provided for the reader to have a clear idea of what was done. But be careful to not swamp the reader with insignificant or useless facts.
9. **Results and Discussion**. In this section, you present and interpret the data you have obtained. **If at all possible, avoid tables of data.** Graphs are usually a much clearer way to present data (make sure axes are labelled, and error bars are shown!). Please make sure the graphs and diagrams have concise figure captions explaining what they are about! **Do not show the details of error calculations.** The derivation of any formulae you use is not required, but should be referenced. Explain how your data corroborates (or does not corroborate) the hypotheses being tested, and compare, where possible, with other work. Also, estimate the magnitude of systematic errors which you feel might influence your results.
10. **Conclusion**. In a few lines, sum up the results of your experiment. Remember that the conclusion is a summary; do not say anything in the conclusion which you have not already discussed more fully earlier in the text.
11. **Acknowledgements** if any.
12. **References**. In this section of the report list all of the documents that you refer to in your report. We recommend numbering the references sequentially in the text,

in their order of appearance, and listing them in the same order in the references section. Microsoft Word, for example, calls this style an *Endnote*.
13. Tables, if any, each with a caption. Note the caution in Point 9 above: tables of data should usually be avoided.
14. A separate page of the captions of the figures, if any.
15. The figures, one per page.

A sample beginning of a Report is in Appendix 1. In the sample, you will note that I write in the third person ("We devised ...") instead of the first person ("I devised …"). Personally I don't like this convention, but it is part of the standard style for Physics journal articles and you should use it too.

References

You should use the following format for references.

Journal Article: author(s), "title", journal name **volume**(number), pages (year).

Note that the volume number is in **bold** font. For example, one would reference the Newton's cradle article like this:

> S. Hutzler, G. Delaney, D. Weaire, and F. MacLeod, "Rocking Newton's cradle", Amer. J. Phys **72**(12), 1508 – 1516 (2004).

Book: author(s), *title* [,edition if not the first] (publisher, location, year), pp. pages.

Note that the title of the book is in *italic* font. For example:

> R. Knight, *Physics for Scientists and Engineers: A Strategic Approach*, 2nd edition (Pearson Addison-Wesley, Toronto, 2008), pp. 47 – 48.

Web Page: author(s), title, date, Retrieved date2, url.

Note that both the date of the page, if available, and the date you retrieved the page are given. For example:

> J. Harlow, D. Harrison, and R. Serbanescu, "Blackboards, PowerPoint and Tablet PCs in the classroom", December 2005, Retrieved March 14, 2008, http://www.upscale.utoronto.ca/PVB/Harrison/BlackboardPptTablet/BlackboardPptTablet.pdf

Report Discussion

In order for you to benefit from your Teammate's suggestions on your report, you need to get a copy of it to them well in advance of the Practical where you will be discussing it. Similarly, you should read the reports of your Teammates in advance of the Practical: otherwise you will be letting them down by being unprepared to discuss their reports.

If the report is in Microsoft Word, you may turn on `Track Changes` in the `Tools` menu to do an electronic mark-up. If you have Acrobat Pro (not the Adobe Reader) there are similar tools to do electronic mark-up of pdf files. Of course, you may always print the document and do the mark-up on the hardcopy.

During the Practical

During the Practical, the Team will discuss the reports and how they may be improved. A good way to do this is:

1. Choose a member of the Team and discuss his/her report as a group. What is good about it? How may it be improved?
2. Choose another member of the Team and discuss his/her Report. Repeat until all Reports have been read discussed.

The purpose of the Practical is not to *assess* the drafts. Instead, you are being asked to help each member of your Team improve their Report, and they in turn will try to help you improve yours.

The total time in the Practical for this Activity will be 40 minutes. Thus, if your Team has four members you should devote 10 minutes to discussing each Report.

After the Practical

After the Practical, you will individually write the final draft of your Report, incorporating the suggestions and corrections that you think are appropriate.

Since Team members will have read and commented on each other's Reports, we expect that some sentences or phrases of the final drafts will be similar to each other. However, your report is the result of your individual work, and when entire blocks of text are identical between two or more Reports, this becomes a violation of the Academic Code of Conduct.

Submitting Your Report

You will submit your Report in two forms:

1. In hardcopy in the Drop Box for your Learning Assistants by the day and time specified in the PHY132 Practicals home page.
2. In electronic form to turnitin.com by the day and time specified in the PHY132 Practicals home page.

These two papers must be identical.

Late Reports will be penalized at the rate of 10% per day when the University is open. The penalty will be applied to the maximum lateness of either the hardcopy or electronic submission.

The electronic submission may be in Word, pdf, WordPerfect, PostScript, html, text, or rich text formats. Details of course codes, etc. for the electronic submission are given in the PHY132 Practicals home page. **Please be sure to include your name, student number, etc. in both the electronic and hardcopy version.**

Posters

Authors of especially outstanding reports will be invited to prepare the results as a poster, which will be displayed in the cases of the hallways outside the Practical rooms. If you are invited and accept our invitation you will receive a 1 point bonus.

The poster should be 28" tall and 36" wide, and should not have any text on it smaller than 24-pt. There are several good programs for making posters, including Powerpoint, Macromedia Freehand, Adobe Illustrator, Adobe Photoshop and Adobe PageMaker. Posters should include all the necessary information about your measurements and analysis, but should also be eye-catching, colourful and succinct. Posters generally should contain 300 to 500 words, at the most. You may submit the poster in pdf format, and we will attend to getting it printed and posted.

Remember to include your name and the date on the poster.

You can see the posters done by PHY132 students in previous years in the hallways outside the Practical rooms.

This Student Guide was written by David M. Harrison, Dept. of Physics, Univ. of Toronto on December 26, 2010. It is based in part Guides for earlier Measurement projects by Jason J.B. Harlow, Dept. of Physics, Univ. of Toronto. Last revision: February 9, 2012.

Appendix 1 – A Sample Beginning of a Report

A cat always lands on its feet and buttered toast always lands butter side down: which of these sayings is truer?

David M. Harrison*
Thursday Practical Group R2A, Room MP125A, Pod 8
Instructors: Peter Hitchcock and Catherine Robin

March 16, 2008

A well-known saying is that a cat that is dropped onto the floor always lands on its feet. Another well-known saying is that a piece of buttered toast that is dropped onto the floor always lands butter side down. We devised a simultaneous test of both of these sayings by strapping a piece of buttered toast to the back of a cat, butter side out, and dropping the combination. We found that …

Introduction

Common sayings known to our grandparents are often at least partially correct. For example, the saying that cats always land on their feet when dropped has previously been tested and analyzed and found to often be true.[1-4] There has also been some analysis of the saying about buttered toast always landing on the floor butter side down.[5-7] If a piece of buttered toast is strapped to the back of a cat, butter side out, the resulting combination is sometimes called the buttered cat paradox, and has led to speculations of anti-gravity.[8] In this study …

* Number: 000361543, Email: david.harrison@utoronto.ca