TECHNICAL REPORT WRITING GUIDELINES

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ABSTRACT

This document specifies the recommended format to be used when submitting a formal technical report in a variety of disciplines and purposes. Also, this manual can be used as a guide to compose less formal reports, such as lab reports, that may consist of a subset of the items presented here. It is a useful general guide from which faculty can specify the particular requirements for reports in their courses.

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Introduction

The purpose of a technical report is to completely and clearly describe technical work, why it was done, results obtained and implications of those results. Following the guidelines provided in this document should lead to a well-written technical report that allows the reader to quickly understand what has been accomplished, regardless of the summative or formative nature of the work, and establishes the credibility of the work. The report also provides sufficient detail for the reader to appreciate how the results were collected and possibly recreate the results although the level of detail provided depends heavily on the report's audience and any proprietary nature of the work. Although this document provides guidance for good lab report writing, chronicling work performed for a laboratory assignment as is done for the familiar academic lab report is not the same as producing a report on technical work. For example, technical reports commonly cite sources and include a bibliography often not expected in an academic lab report. However, these guidelines can be used in total to support formal technical report writing or referred to selectively depending on the type of report and level of formality required.

The key to a well-written report is organization. A report that is divided into several sections, occurring in a logical sequence, makes it easy for the reader to quickly obtain an overview of the contents as well as locate specific information. This document provides guidelines for producing a well-written technical report. The next section details what information to provide for the reader in each section of a report. That is followed by a description of how someone in the related technical industry, the likely reader of technical reports, typically peruses a report. This provides important context for recommended organization and content. Additionally, this document presents a list of questions authors should ask of themselves prior to final submission.

The Formal Technical Report

For technical reports, formal and informal, readers are generally most interested in process and results. Clear presentation of results is at least as important as the results themselves; therefore, writing a report is an exercise in effective communication of technical information. Results, such as numerical values, designed systems or graphs by themselves are not very useful. To be meaningful to others, results must be supported by a written explanation describing how results were obtained and what significance they hold, or how a designed system actually functions. Although the person reading the report may have a technical background, the author should assume unfamiliarity with related theory and procedures. The author must consider supplying details that may appear obvious or unnecessary. With practice, the technical report writer learns which details to include.

The formal technical report contains a complete, concise, and well-organized description of the work performed and the results obtained. Any given report may contain all of the sections described in these guidelines or a subset, depending upon the report requirements. These requirements are decided by the author and are based on the audience and expected use of the report. Audience and purpose are important considerations in deciding which sections to include and what content to provide. If the purpose is to chronicle work performed in lab, as is typical for an academic lab report, the audience is typically the professor who assigned the work and the contents usually include detailed lab procedure, clear presentation of results, and conclusions based on the evidence provided. For a technical report, the audience may be colleagues, customers, or decision makers. Knowing the audience and what they are expecting to get out of reading the report is of primary consideration when deciding on sections to include and their contents.

There are certain aspects to all reports that are common regardless of audience and expected usage. Rather than relegate these overarching report-writing considerations to a secondary position, these items are presented before detailing the typical organization and contents for technical reports.

Universal Report-Writing Considerations

The items listed in this section are often overlooked by those new to technical report writing. However, these items set the stage for how a technical report is received which can impact the author, positively or negatively. While in an academic setting, the author's grade could be impacted. While in a professional setting, it is the author's career that could be affected. Effective communication can make the difference in career advancement, effective influence on enacting positive change, and propelling ideas from thought to action. The list that follows should become second nature to the technical report writer.

Details to consider that affect credibility:

- Any information in the report that is directly derived or paraphrased from a source must be cited using the proper notation.

- Any information in the report that is directly quoted or copied from a source must be cited using the proper notation.

- Any reference material derived from the web or Internet must come from documentable and credible sources. To evaluate websites critically, begin by verifying the credibility of the author (e.g. – credentials, agency or professional affiliation). Note that peer reviewed materials are generally more dependable sources of information as compared to open source. Peer review involves a community of qualified experts from within a profession who validate the publication of the author. Open source information may be created by non-qualified individuals or agencies which is often not reviewed and/or validated by experts within the field or profession.

- Wikipedia is **NOT** a credible reference because the information changes over time and authors are not necessarily people with verifiable expertise or credentials.

- Provide an annotated bibliography of reference material to support the use of a source whose credibility may be challenged.

- See Appendix A for information about citing sources.

Details to consider that affect the professional tone:

- Write in an active voice using the third person in most instances. Avoid using "will" before a verb; strive to get to the verb as directly as possible.
  - Passive voice: "The circuit resistance will be measured with a digital multimeter".
  - Active voice: "Measure the circuit resistance with a digital multimeter".

- Avoid using personal pronouns such as "you", "we", "our", "they", "us" and "I". Personal pronouns tend to personalize the technical information that is generally objective rather than subjective in nature. The exception is if the work as a whole is meant to instruct than to inform. For example, technical textbooks whose only purpose is to instruct employ personal pronouns.

- Use correct grammar, punctuation, and spelling. Pay attention to and address spell and grammar check cues from writing software such as MS Word.

Details to consider that affect the professional appearance:

- All diagrams must be neatly presented and should be computer generated. Use a computer software package, such as Paint, Multisim or AutoCAD, to draw diagrams. *Always insert a full-page diagram or graph so it can be read from the bottom or from the right side of the page.*

- Generate all equations using an equation editor and provide each equation on its own line. Under normal circumstances, there is no reason to embed an equation within a paragraph. Depending on presentation and how many equations are involved, number the equations for easy reference.

- If the report is long enough to require a Table of Contents, then all pages of the report after the Table of Contents must include the page number. The title page and table of contents page are NOT numbered pages. Page 1 should be the first page with content after the Table of Contents.
  o Refer to appendix B for information on how to automatically create a Table of Contents and properly number pages.

- If the report includes an abstract, it should be on an unnumbered page after the title page and before the Table of Contents or it can be included on the title page.

- For all paper reports, all pages of the report must be 8 ½" X 11" in size. Any larger pages must be folded so as to fit these dimensions. HOWEVER, in this day and age, an electronic submission may be required. Keep in mind that with an electronic submission, it is easier to provide an appealing look with color since a color printer is not required.

Details to consider that affect readability:

- Every section and sub-section of the report needs to start with an introductory paragraph that provides the context for the section or sub-section.

- Every figure, graph, table, and equation needs to be introduced to the reader prior to being presented to the reader. This introduction provides the context.

- **ALWAYS NUMBER AND PROVIDE A TITLE FOR ALL FIGURES**.

- Make sure that the verb used can actually operate on the noun. For example, stating "the goal for this report is to observe …" implies that the report can observe when it is likely that the goal of the *work* reported on is to make certain observations.

- Check for spelling and grammar errors which are often highlighted with cues by the text editing software. Follow capitalization, punctuation, and indentation norms. Remember to capitalize the names of proprietary items such as licensed software.

- Define acronyms and abbreviations prior to using them.

Finally, always consider carefully the context of information provided. Know your audience. Thoughtfully consider if a statement is clearly supported by the information provided without leaving your reader confused. Remember that by the time you are writing a report, you should know the information inside and out but your reader does not.

Standard Components of a Formal Technical Report

Technical reports should be organized into sections and are typically in the order described in this section. While this is the recommended order, certain reports may lend themselves to either reordering sections and/or excluding sections.

Title Page

The format for this page may vary, however, the following information is always included: report title, who the report was prepared for, who the report was prepared by, and the date of submission. This is not a numbered page of the report.

Abstract

An abstract is a concise description of the report **including its purpose and most important results**. An abstract must not be longer than half a page and must not contain figures or make reference to them. Technical authors are generally so focused on results that they neglect to clearly state the purpose for the work. That purpose is derived from the objectives or goals, most commonly provided by the person who assigned the work. In stating the purpose, it is critical to include key words that would be used in a database search since searches of paper abstracts are commonly used by professionals to find information they need to do their jobs and make important decisions. Results are summarized in the abstract but how much quantitative information is provided varies with report audience and purpose. It is common to include maximum percent error found in the experimental results as compared to theory. Do not use any specific technical jargon, abbreviations, or acronyms. This is not a numbered page of the report.

Table of Contents

Include all the report sections and appendices. Typically, sub-sections are also listed. This is not a numbered page of the report.

The Table of Contents is easy to include if you properly use the power of the software used to generate the report. The Table of Contents can be automatically generated and updated if the author uses built in report headings provided in the styles menu. It is worth the time and effort to learn these tools since their application are ultimately time-savers for report writers. Directions are provided in Appendix B on creating a Table of Contents using section headings.

Introduction

The length of the Introduction depends on the purpose but the author should strive for brevity, clarity, and interest. Provide the objective(s) of the work, a brief description of the problem, and how it is to be attacked. Provide the reader with an overview of why the work was performed, how the work was performed, and the most interesting results. This can usually be accomplished with ease if the work has clearly stated objectives.

Additionally, the introduction of a technical report concludes with a description of the sections that follow the Introduction. This is done to help the reader get some more detailed information about what might be found in each of the report sections included in the body of the report (this does not include appendices). This can feel awkward but providing that information is the accepted standard practice across industries.

Be careful not to use specific technical jargon or abbreviations such as using the term "oscope" instead of "oscilloscope". Also, make sure to define any acronyms or abbreviations prior to using them. For example, in a surveying lab report a student might want to refer to the electronic distance measuring (EDM) device. The first time the device is referred to, the student must spell out what the acronym stands for before using the acronym, as demonstrated in the previous sentence. This practice should be applied throughout the report when the author wants to use an acronym or abbreviation that has not yet been defined within the report.

Background Theory

The purpose of this section is to include, if necessary, a discussion of relevant background theory. The theory included is theory needed to understand subsequent sections of the report that either the reading audience does not already comprehend or is tied to the purpose for the work and report. For example, a report on resistor-capacitor electric circuits that includes measurement of phase shift would likely include a theoretical description of phase shift. In deciding what should or should not be included as background theory, consider presenting any material specific to the work being reported on that you had to learn prior to performing the work including theoretical equations used to calculate theoretical values that are compared to measured values. This section may be divided into subsections if appropriate. Keep the discussion brief and refer the reader to outside sources of information where appropriate.

Design

The purpose of this section is to provide detailed development of any design included in the report. **Do not provide a design section if there is no design aspect to the work.** Be sure to introduce and describe the design work within the context of the problem statement using sentences; a series of equations without description and context is insufficient. Use citations if you wish to refer the reader to reference material. Divide this section into subsections where appropriate. For example, a project may consist of designing several circuits that are subsequently interconnected; you may choose to treat each circuit design in its own subsection. The process followed to develop the design should be presented as generally as possible then applied using specific numbers for the work performed. Ultimately, the section must provide the actual design tested and include a clear presentation of how that design was developed.

Theoretical Analysis

Although a theoretical analysis might be part of a design, the author needs to decide if that analysis should be included as part of the design section or a separate section. Typically, any theoretical work performed to develop the design would be included in the design section but any theoretical analysis performed on the design would be included in a separate section. **Do not provide a theoretical analysis section if the theoretical work is all described as part of background theory and design sections.** However, in most cases, a theoretical analysis section is included to provide important details of all analyses performed. Be brief. It is not necessary to show every step; sentences can be used to describe the intermediate steps. Furthermore, if there are many steps, the reader should be directed to the appendix for complete details. Make sure to perform the analysis with the specific numbers for the work performed leading to the theoretical values reported on and compared to experimental values in the results section of the report. Worth repeating: perform the analyses resulting in the numbers that are included as the theoretical values in the results section of the report. Upon reading the results section, the reader should be familiar with the theoretical values presented there because the reader already saw them in this section.

Procedure

This section varies depending on requirements of the one who assigned the work and the audience. At a minimum, the author *discusses* the procedure by describing the method used to test a theory, verify a design or conduct a process. Presentation of the procedure may vary significantly for different fields and different audiences, however, for all fields, **the author should BE BRIEF and get to the point**. Like with any written work, if it is unnecessarily wordy, the reader becomes bored and the author no longer has an audience. Also, the procedure section should **never** include

specific measurements/results, discussion of results, or explanation of possible error sources. Make sure all diagrams provided are numbered, titled, and clearly labeled.

Depending on the situation, there are two likely types of procedure sections. In one case, a detailed procedure may have already been supplied or perhaps it is not desirable to provide a detailed description due to proprietary work. In another case, it might be the author's job to provide all the detail so the work can be duplicated. The latter is more common in academic lab settings. The writing guidelines for each of these possible procedure sections are provided below.

Procedure Type 1

Use this procedure type if you have been supplied with a detailed procedure describing the steps required to complete the work. Briefly describe the method employed to complete the work. This is meant to be a brief procedural description capturing the ***intention*** of the work, not the details. The reader should be referred to the appendix for the detailed procedure steps. The following list are considerations for this type of procedure section.

- While describing the experimental work performed from the perspective of the objectives, include important details to appreciate the scope of the work but **DO NOT** describe the procedure as a sequence of steps.
  - Example: For measurements made over a range of input settings, provide the actual range without including the details of the specific input settings or order data was taken (unless order affects results).
- If required by the person who assigned the work, include the detailed procedure in the appendix.
- **MUST** provide detailed diagram(s) of all applicable experimental set-ups (i.e. circuit diagram) that include specific information about the set-up, such as resistor values.
- Provide diagrams and/or pictures that will further assist the reader in understanding the procedural description.
- Provide a detailed procedure of any work performed for which detailed steps were not provided and that the author deems necessary for the reader's comprehension.
- Examples:
  - Acceptable writing:
    - To test the theory of superposition, the circuit shown in Figure 1 is employed. The circuit is constructed on the lab bench and using Multism™, a circuit simulation software. In both settings, a multimeter is used to measure the output voltage, as shown in Figure 1, for the following three cases: (1) Source 1 on and Source 2 off, (2) Source 1 off and Source 2 on, and (3) both sources on. These measurements are compared to the output voltage derived using theory as described earlier. Refer to the appendix for further detail or procedure.
  - Unacceptable writing:
    - In order to test the theory of superposition, first each team member must calculate the output voltage for the circuit shown in Figure 1 for the following three cases: (1) Source 1 on and Source 2 off, (2) Source 1 off and Source 2 on, and (3) both sources on. Then one team member is assigned to build the circuit on the lab bench while the other team member constructs the circuit in Multisim. Once constructed, turn Source 1 on and Source 2 off then connect the positive lead of the meter to the positive end of the output voltage and the negative lead of the meter to the negative end of the output voltage. Record the meter reading. Next turn on Source 2 and turn off Source 1. Again measure the output voltage using the meter ….

Procedure Type 2

Use this procedure type if you have **not** been supplied with a detailed description of the steps required to complete the work. The reader should be able to repeat the work based on the content supplied in this section.

- Describe in detail all necessary steps or processes required to complete the work. This may include, but is not limited to, the following:
    o Equipment use
    o Equipment maintenance
    o Define terms specific to the technology
    o Measurement techniques and/or calibration
- The description should be sufficiently clear so that the reader could duplicate the work.
- Do not assume that the reader has prior knowledge or access to prior reports, textbooks, or handouts.
- If part of the procedure was successfully described in a previous report, either repeat the procedure or include that report in the appendix and refer the reader to it.
- **MUST** provide detailed diagram(s) of all applicable experimental set-ups (i.e. circuit diagram) that include specific information about the set-up, such as resistor values.
- Where appropriate, provide additional diagrams and/or pictures to assist the reader in understanding the procedure.

Results and Discussion

Present the results of the work performed, within the context of the problem statement, using neatly organized and completely labeled tables and/or graphs whenever possible. When comparative data is available, present the data in a way that facilitates the comparison. For example, if theoretical and experimental values are available, present the values alongside one another accompanied by percent error. If it would help the reader understand the results, include a few sample calculations but put lengthy calculations in an appendix.

ALWAYS accompany results with a meaningful discussion. The discussion explains what the results mean and points out trends. In some cases, the results speak mostly for themselves and the discussion may be brief, i.e., "Table 2 shows that the designed variable modulus counter works as expected" along with a sentence or two stating how a variable modulus counter works and referring to parts of the table that verify/justify the statement. In other cases, the meaning of the results may not be as clear requiring more detailed discussion. In most cases, the results will include data from more than one source to be compared to establish validity. With that in mind, meaningful discussion of results includes:

(1) commenting on the percent difference by establishing the comparative size of the difference (negligible, small, large),
(2) cause for the difference (error sources are discussed further in the next paragraph), and
(3) how the results inform the reader as framed by the work's objectives.

All three of the points are important to a meaningful discussion but the third one is most often overlooked. Discussion related to (3) may provide a statement about the theory used to predict the measured data. That statement often includes the theoretical assumptions made to predict the results and what the measured results indicate about the applicability of those theoretical assumptions to the experimental setting.

ALWAYS discuss the possible significant sources of error and how accurate the results need to be in order to be meaningful. Do not include a discussion of possible sources of error that would not add significantly to the observed error. What counts as significant depends on the situation.

For example, if the components used have a tolerance of 5% and the accuracy of the equipment is within 0.5% of the measured value, then the equipment does not add significant error. However, if the components used have only a 1% tolerance then equipment with 0.5% accuracy is problematic. In general, it is impossible to obtain error-free results, therefore when there is 0% error there is still cause for discussion as there is no expectation of obtaining error-free results. Expecting some error is not an excuse for lack of attention to detail when conducting procedures that minimize the error. Errors are different from mistakes. It is **unacceptable** to report mistakes. If a mistake was made, the work must be repeated until acceptable tolerances are achieved before submitting a report. Please find more on discussing percent error or percent difference in the Appendix C.

When working in the industry, it is imperative to know how accurate results need to be. It is worth your time and effort (and in the best interest of your supervisor or client) to provide the appropriate level of accuracy. If that means repetitive measurements to check for accuracy within tolerance, then do it. If it means performing a detailed analysis prior to making measurements, then do it. In the academic setting, the result of laziness or lack of effort may only be a bad grade. In the workplace, you may get fired!

Other information pertaining to writing the Results and Discussion section can be found in Appendix C. This information includes
- How to calculate percent difference/error.
- Typical magnitudes of percent error for courses where circuits are constructed.
- What to consider writing about based on questions posed by the person assigning you to write the report.
- Guidelines for graphs provided in a report.

Conclusion

In this final section of the body of the report, the author should briefly bring everything together. It is similar to the abstract except that now specific results are concluded upon in a quantitative way. Therefore, the conclusion should be a concise description of the report including its purpose and most important results providing specific quantitative information. The conclusion should not contain figures or make reference to them. As with the abstract, the reader should be able to read this section on its own which means that there should be no specific technical jargon, abbreviations, or acronyms used.

References

Anywhere within your writing that you have either copied or paraphrased another source, you must cite that source. This entails two steps. One is to provide a parenthetical citation at the location in the report where the material that is not your own resides and the other is to provide the complete bibliographic information in a References page following the Conclusion section of the report.

Using the APA style, the parenthetical citation at the location in the document where the copied or paraphrased material exists includes: the author, the publication date, and the page number(s). For sources with no author, the name of the reference material is used. All this information is included within parentheses thus being referred to as a "parenthetical citation".

The full bibliographic information for all reference material cited within your writing is collected on the References page. In technical papers, the referenced sources are usually listed in the order they are referred to in the body of the report and, in fact, many published engineering

papers will simply number the references and then use that number in square brackets to replace the parenthetical citation within the body of the report. Those new to this form of technical writing, often ask about how and where to list references used but not explicitly cited in the body of the report. However, if the reference is important enough to list, that generally means that there is an appropriate place to cite it in the body of the report, perhaps in the introduction or background theory. In Appendix A you can find further information about creating citations using citation generators available on the internet that will create a properly formatted citation for you when provided with the relevant information. Although citation generators are readily available, the one I recommend is from Calvin College called KnightCite and can be found at http://www.calvin.edu/library/knightcite/.

The References section begins on a new page; not on the same page with the conclusion. Refer to Appendix A for information on preparing the References section. A wealth of information about citation styles, including lengthy guides and short handouts, can be found at http://libraryreference.sunydutchess.edu/citations.htm.

One final note on references and providing bibliographic information concerns use of sources that may appear to be questionable. There is no doubt that information from a wiki is questionable since, by definition, it can be changed by users including unqualified users. Although most wikis are reviewed and erroneous or misleading information corrected, at any given time there could be erroneous and misleading information. However, depending on the work presented in the report, internet sources including .com sites that have industry bias and .org sites that have policy bias may have valuable information. Even .edu sites can be problematic if the page is from an individual rather than an educational group within the institution since the former is likely not to have any editors and the latter is likely to be monitored and curated by the group. In order to establish credibility or usefulness of a source, especially a questionable one, provide an annotation to the bibliographic information that provides further information as to why the source was included and perspective on its application to the work reported. Information about annotated bibliographies is provided in Appendix A.

Appendix

This section may not always be present. Materials included in an appendix may include lab sheets, parts list, diagrams, extensive calculations, error analyses, and lengthy computer programs. Introduce numbered or lettered appendices rather than putting different items in one appendix.

Why You Should Know How a Reader in Industry Peruses a Technical Report

For obvious reasons, the reader will first read the title page and abstract. Therefore, it is imperative that the abstract be clear and well written. It should tease the reader into looking further into the paper. The conclusion is often the next section to be read. All valuable readers, politically speaking, will jump directly to the conclusion making it important to provide a table of contents to ease document navigation. If the conclusion, relative to the title page, sounds interesting and conclusive they will read the other sections to learn more.

The introduction is read next. It should provide the reader with enough information about how the report progresses so that the reader can pick and choose which sections are most applicable to their interests. Based on this, some or all of the subsequent sections may be read.

In light of understanding how a technical report is read, there are several general guidelines to consider:

- A professional looking and well-organized document sets the tone for the reader.
- If you use acronyms, describe them first then include the acronym in parenthesis, i.e. Digital Multimeter (DMM). Do not use acronyms in the abstract and conclusion sections.
- DO NOT be judgmental in your writing; "I felt that ...", "the results were great ...", etc. Present the work clearly and validate the work with data accompanied by meaningful discussion.
- Give your report to someone to proofread. Note where they had questions or couldn't understand your discussion. Then see if you can improve how that information is presented.
- Remember that the reader can't understand what you are "thinking". Know your audience and write your report for that audience. Ask questions of the person(s) who assigned the work to you if you are unsure of the comfort level of the identified audience with the material as that will establish the level of detail required in the content.
- Write your reports independent of other reports. Referring to a "Lab 3 Part 1" does not mean anything to a general audience. If the current work is based on prior work, then provide an overview of that work and include explicit citations.

Questions to Ask Yourself Prior to Submitting Any Report

Before submitting any report, ask yourself the questions listed below and follow the suggestions to improve your report if the answer to any of these questions is NO. Even though not all the questions pertain to every report, it is still a good practice as it will likely help you produce the best report possible in the time available to you.

Does every section of the report focus on providing information to support meeting the objectives of the work?
When you sit down to outline or write each section, you need to think about how that section can be used to provide information that supports the objectives. For example, if there is an objective to understand filters and their characteristics then (1) the background theory section must explain what filters are and derive or present their characteristics, (2) the procedure section must explain what tests are performed to observe and record the filters' characteristics, (3) the result section may present information on the recorded filter characteristics, and (4) the conclusion section must comment on filter characteristics. This reasoning must hold for EVERY objective.

Did I present all the results obtained?
Make sure to look back at your work to see if you have included all results. ***If you took measurements of something, there should have been a good reason and therefore the results of those measurements should be included somehow.*** Also, the results should be displayed in either tabular or graphical form making it as easy as possible for the reader to understand them. Use Insert ... Table in MSWord or create the table or graph in MSExcel. Do ***NOT*** use tabs and the space bar to create a table.

When presenting results, did I include percent difference?

In most cases, you should plan on including percent differences. Percent difference provides useful comparison of data. It provides a standard for how large or small differences are. The only time NOT to include percent difference is when you are making a qualitative comparison or a comparison of items that you did not necessarily expect to come out the same. In those cases, explain the difference in an appropriate context such as "the measured current did not exceed the manufacturer's specifications".

Are all results accompanied by a meaningful discussion?

Whenever discussing results, make sure that the actual results being discussed are contained within the discussion or are clearly presented (perhaps in a table or graph) within less than a page of the discussion. A discussion loses its meaning quickly if the reader is struggling to find the supporting data. ALL results presented MUST be accompanied by meaningful discussion. Meaningful discussion includes (1) commenting on the percent difference by establishing the comparative size of the difference (negligible, small, large), (2) cause for the difference (error sources), and (3) how the results inform the reader as framed by the work's objectives. Note, even if percent difference is very small, you are still expected to include a meaningful discussion. For example, when comparing theory with simulation you may have a very small or even 0% difference. The comment in this case is that you would conclude that the theory used on paper does an equally good job of predicting the results as the simulation software. ***Typically, meaningful discussion of results includes a statement of theoretical assumptions made to predict results and what measured results indicate about the applicability of those theoretical assumptions to the experimental setting***. As your work becomes more complex, it is more likely that simple theoretical assumptions will not accurately predict results.

Did I explain percent differences?

When it is appropriate to include percent differences, those percent differences must ALWAYS be explained. When the experimental data is derived from a qualitative study rather than an accurate quantitative study or when the experimental data is being compared to a manufacturer's typical value, a percent difference might not illuminate the points being made. Otherwise, your explanation of the percent differences must be included and provide the required content for meaningful discussion. To inform this discussion, establish the relative significance of the difference based on the limitations of the experiment and/or theory. Specifically, establish the percent difference considered inconsequential or negligibly small as opposed to consequential but within reasonable tolerance based on the components, the experiment, and the equipment used or the limitations of the theory applied. ***You MUST include in your explanation the expected tolerances of each of the components used in the experiment.*** Error beyond the accepted range based on experimental tolerances or theoretical limitations is unacceptable, indicating a gross error by the experimenter. Never leave lab with errors that large unless you have confirmed with a knowledgeable third party that no gross errors have been committed. You should also never leave lab without a valid explanation of any percent differences larger than the component tolerances. Never include data in a report for which you do not have a valid explanation (gross error by the experimenter is not valid). Further details and various formulas for percent difference are provided in Appendix C.

Did I introduce every report section, subsection, figure, or table with an introductory sentence or paragraph?

Check throughout the report to make sure that you are leading the reader rather than providing context at a later point. It is always easier on the reader if the context is supplied first which is why you lead with an introduction for *EVERY* report section, sub-section, and figure or table.

Did I check to make sure there are no personal pronouns?
Rewrite any sentences that include personal pronouns. Remember to maintain an active voice.

Did I use a font color other than black?
Carefully consider when using font colors other than black. Many font colors do not provide enough contrast against white for easy viewing on an electronic device. Yellow, green, and orange may cause some eye strain on the part of your reader. Bolding the text may alleviate the color problem but look critically before finalizing a report with these font colors. Red is a bad choice for font color as it implies a problem and is most often the color used for editing text.

Did I perform a spell check and grammar check?
MS Word highlights possible spelling errors with a red underline and possible grammar errors with a green underline. Right click on word or phrase being underlined for suggested corrections.

Did I remember to spell out any acronyms when they are first used in the report?
Never assume the reader is familiar with all the same acronyms you are such as KVL for Kirchoff's Voltage Law or EDM for Electronic Distance Meter. Read through the report and make sure that anywhere an acronym is used, it was spelled out prior to that use.

Are there page numbers?
Page numbers should be inserted in the header or footer of each page. The header can be accessed by double clicking on the top margin, and double clicking on the bottom margin opens the footer. Another way to access the header and footer and to insert page numbers is by accessing the Header & Footer under the "Insert" menu. Also, if you end up with page numbers on the Title page and Table of Contents page, you need to remove them. This is done by inserting a section break before the desired Page 1. It is then possible to have different headers and footers for different sections of the document by making sure that "Link to Previous" is not highlighted within the navigation section of the Header & Footer toolbar. Further details are provided in Appendix B.

Did I number and title all the figures?
EVERY figure must include a caption that provides a figure number and a title. Microsoft Word makes it easy to insert captions. If you right click on the figure, one of the options given is "Insert Caption". Using this feature, Microsoft Word will automatically increase the figure numbers. Alternatively, if you click on the References menu, there is a button for "Insert Caption".

Am I sure that I don't need a Table of Contents?
Reports longer than ten pages generally should have a Table of Contents (TOC). If you wrote the report using Heading Formatting supplied by MS Word or wrote the report outline in outlining mode, then it is as simple as a couple of clicks to insert a TOC that can automatically be updated as you make changes in the report. See Appendix B for directions on automatically creating a TOC.

Did I remember to provide a citation for ANYTHING that was directly quoted, copied, or paraphrased from a source?
Remember that this doesn't only include statements but also figures that were copied. What is required is that in every place in the report where material was either directly quoted, copied, or paraphrased, you need to provide a parenthetical citation which provides the author's name, the publication year, and the page number from which the information was taken. Then, in the References section, provide the full bibliographical information. The reader should be able to tell which work is being cited by the information provided in the parenthetical citation. Refer to Appendix A for further details on references and parenthetical citations.

Conclusion

Technical Report Writing Guidelines provides a recipe for writing technical reports for a variety of disciplines and applications. If all of the information contained herein is studied and applied, the result will be a report worth reading. Considering that most technical jobs require accurate communication through written material, developing good technical writing skills can only improve your career status. Be aware that most jobs in a technical field require a significant amount of technical writing, from informal memos to formal proposals for presentation to customers. It is worth your time to read this material carefully and practice your writing skills.

APPENDIX A: "How To" Guide on References and Citations

Students have learned in multiple courses since high school about proper research techniques and citing sources. Here, you will find the answers to some basic questions about research and citing sources followed by an activity to perform for writing citations. Answering questions about providing citations also addresses questions related to information literacy. Specifically, how do you decide if a source is providing reliable and valuable information?

How do you decide on the quality of a source?

1. The highest quality sources have an editorial board or are peer-reviewed in some way. This includes books and most articles from periodicals (magazines). Do not assume that all magazines, including online magazines, have a significant review process.
2. Information from the internet likely to change, such as information on any wiki page or information provided by a ".com" site, may be useful but may not be high quality or reliable.
3. Information from a ".com" or ".org" site may be biased and may be prone to change over time. The better the reputation of the owner of the site, the more reliable the information provided.
4. Cannot assume that information from a ".edu" site is of high quality. The site may be from a single faculty member with no reviewer. It is more likely to be of higher quality if the site is sponsored by an educational department within an institution (such as a library or an institute).

Which citation style should you use?

The preferred style for scientific writing is the APA style.

Why provide citations?

1. If you do not provide a citation where you should and you are found out, you may be accused of plagiarism which can lead to negative consequences such as diminished or destroyed reputation, failing grades, and dismissal.
2. Citations add to the credibility of the information you are trying to communicate.
3. Citations provide a path to more in depth information for your audience.

What information needs to be cited?

1. Anything that is a direct quote.
2. Any content that is paraphrased from a source.
3. Any graphic image, including photographs, copied from a source.

What information does not need to be cited?

1. Commonly known information (i.e. Ohm's Law).
2. Graphic images designed for public use, such as images provided in the Clip Art Gallery by Microsoft.

What is your first and best resource for help?

The library provides primary support for research work. College libraries across the country provide a wide range of resources to help their students. Many of these sites are available without a login.

The Dutchess Community College library's web site provides links to research resources and guides and can be accessed publicly at http://sunydutchess.libguides.com/home. For DCC students:

1. Sign in to myDCC.
2. Click on the library icon on the Student tab.
3. Channels of interest:
   a. Getting Citations from a Database
   b. APA Guidance
   c. Tutorials & Other Resources
   d. Citation Generators – recommend Knight Cite to generate your citations for your work

How should you collect bibliographic information?

As you are researching information, **every time** you find a source that you think might be useful, use a citation generator to generate the proper bibliographic information (highly recommended site: http://www.calvin.edu/library/knightcite/). Also include an annotation; a short description of the source's relevant contents. Annotations can be included as part of the References section thus providing what is called an "annotated bibliography". Further detail is provided in a subsequent sub-section. See the examples provided here for generating citations using the KnightCite link.

Figure 1 KnightCite entries for Electronic Design article

The entries in the KnightCite form shown in Figure 1 generated the following citation:

Yang, C. E. (2016, September 16). What is the Piezoelectric Effect?. In *Electronic Design*. Retrieved from http://electronicdesign.com/power/what-piezoelectric-effect

Figure 2 KnightCite entries for Arduino knock sensor article

The entries in the KnightCite form shown in Figure 2 generated the following citation:

Knock Sensor. (n.d.). In *Arduino*. Retrieved March 17, 2017, from
https://www.arduino.cc/en/Tutorial/KnockSensor

__Note__: All lines following the first line in a citation are indented. Use paragraph formatting and/or the formatting controls provided with the ruler in your text editor. Refrain from using TAB for standard indentation.

Hopefully, these examples help illuminate how to use the citation generator although confusion commonly occurs when citing web sites distinguishing between the web site's title and the document title (see form above). The web site's title is the name of the web site's "owner" as opposed to the name of a particular page within the site. For example, if looking at a web page online about "Solar Energy Basics", which is a page provided by the National Renewable Energy Lab, then "National Renewable Energy Lab" is the web site title and "Solar Energy Basics" is the document title.

Annotated references – what they are and when to use them

Although not generally required, annotating references is a useful research technique during the process of collecting sources. However, requiring annotated references may become more common with the expectation that people regularly pull their information from internet sources. Thus, for reports submitted to me it is my expectation that an annotation is included for sources whose credibility is questionable. Annotated references include one to three sentences describing relevant, useful information about the source. Annotated bibliographic entries for the sources cited above are provided here.

Knock Sensor. (n.d.). In *Arduino*. Retrieved March 17, 2017, from
https://www.arduino.cc/en/Tutorial/KnockSensor
Arduino is a well-established company that provides microcontrollers. Hardware and software
technical support and tutorials for many peripheral devices that can be attached to the
microcontroller are available on their site. This page provides information about using the
knock sensor to detect sound including a suggested sketch.

Yang, C. E. (2016, September 16). What is the Piezoelectric Effect?. In *Electronic Design*. Retrieved
from http://electronicdesign.com/power/what-piezoelectric-effect
Electronic Design is a magazine available in print as well as on the internet. This article
provides a lightly technical explanation of the piezoelectric effect. A PDF file of the full article is
available from this site.

As mentioned above, annotated references are especially useful and important if citing a source
whose veracity may be questioned in some way as is often the case for internet sources. A source of
reference material is suspicious if it isn't clear who is responsible for the content. But even if the
author or authors are clearly stated and their expertise can be objectively verified, the material can
still be questionable if there isn't a paid editorial review board that assures the accuracy of the
information provided in some regular and structured way. In such a case, you can use the
annotation to establish the credibility of the source and/or to point out questionable standing while
establishing the usefulness of the source for the purpose of the report.

An example of this would be the HyperPhysics site. When looking at "About HyperPhysics", you
will find this statement: "The intellectual property rights and the responsibility for accuracy reside
wholly with the author, Dr. Rod Nave." It is clear there is no paid editorial review board but there is
good reason to trust the information. A sample annotated reference for this site might be:

Nave, R. (2017). Filter Circuits. In *HyperPhysics*. Retrieved from http://hyperphysics.phy-
astr.gsu.edu/hbase/electric/filter.html#c1
HyperPhysics is an educational site written and updated by a professor at Georgia State
University in the Department of Physics and Astronomy. The source has been selected as an
endorsed tool for physics teachers by the National Science Teachers Association. It also won a
Merlot Classic Award in 2005 and is reviewed by the Physical Science Information Gateway and
PhysicsWorld.

Note how the annotation helps establish the veracity of information culled from this site.
Another possibility for the annotation, although all efforts should be made to avoid it, might be to
describe why a source is referenced even if the credibility cannot be established. For example,
there can be well-stated simple explanations of complex material on a site such as "How Stuff
Works". Although not considered a credible source of information, it might be the best source for
the simple explanation and this could be stated in an annotation. Keep in mind that if references
are provided, such as is commonly done on Wikipedia, all efforts should be made to use the primary
source.

Creating a references section for a written report

The final page of a written report, before any appendix, is the References section. If you have
collected the citations as recommended, then all that is left to do is put them either in alphabetical
order or the order in which referred to from the body of the report. Selecting either the
alphabetical listing of the sources or citation order depends on the standards of your field.

Alphabetical listings are most common in the sciences, both social and physical. Citation order is common in engineering. Either way, the list with annotations provides all the content for the References section.

Parenthetical citations

In the body of any report, wherever information is presented that is derived from a source, the source needs to be identified. The way that is done is by using a parenthetical citation. **The parenthetical citation provides (1) the name of the source, (2) the year the source was published (n.d. if no date given), and, (3) when applicable, the page number within that source**. The name of the source must be the name used in the References page. Here are some guidelines as to what to provide for the "name":

1. If there is one author, then that author's last name is the "name" of the source.
2. If there are multiple authors and there won't be confusion with another source, then the first time the source is cited, list all authors' last names using "and" between the second to last and last name as the "name" of the source. Subsequent times the source is cited, can use the first author's last name followed by a comma and "et al." as the "name" of the source.
3. If there is no author as may often by the case for an internet source, then use the name of the web page as the "name".

See the paragraph below to demonstrate how to use the bibliographic entries created above to provide parenthetical citations.

> The program code used in the project was modified from the code provided for the Arduino knock sensor (Knock Sensor, n.d.). The knock sensor operates off the principle of piezoelectricity. The piezoelectric effect is a physical phenomenon observed when pressure is applied to certain crystals which results in electrical charge generated (Yang, 2016).

Providing citations in a presentation

In a presentation, include the bibliographic entry in small writing at the bottom of any slide that includes information requiring a citation. Also, provide a parenthetical citation at the location on the slide where the information is provided.

If the information cited is a graphic image, you may include the full citation in small writing just below the graphic image instead of using a parenthetical citation with the full citation at the bottom of the slide.

If you do a good job of providing the full citations on the slides where they are needed, then it may be unnecessary to include a "References" slide at the end of your presentation.

APPENDIX B: Page Numbering and Table of Contents using MS Word

Proper page numbering and a useful table of contents are important features of a professionally presented technical report. The directions provided here apply to Microsoft's Word but are fairly common and universal.

PAGE NUMBERING

The key to proper page numbering is in the headers and footers of the document. To insert automatic page numbering, first position cursor to be able to edit the header or footer. This can be done from the Insert menu where you can select "Edit Header" from the pull-down menu visible when clicking on "Header". If you want to place the page number in the footer, the directions are identical except you want to edit footer rather than header. Once in the header (or footer), click on "Page Numbers" to view the pull-down menu that provides the various choices for page numbering. Select the choice that suits you and the document will automatically insert those page numbers on all pages.

Although most students know how to add an automatic page number in either the header of footer of the document, few know how to control how that looks throughout the document. All pages before the first content page of the report (the introduction), should not include page numbers. To control which pages have the page numbers on them, follow these steps:
1. Put the insertion point at the end of the page right before the introduction.
2. Click on the Page Layout tab.
3. Click on the pull down arrow next to "Breaks" in the Page Setup section of the Page Layout tab.
4. Then click on "Next Page" under Section Breaks. This will create a new section starting on the next page.
5. Enter in the Header and Footer of this new section and click on "Link to Previous" if it is already selected. Removing the link to the previous headers and footers means that you can create headers and footers in this new section that are disconnected from the previous section. In this case, you want nothing in the header or footer for the title page and table of contents page but you want to insert an automatic page number in either the header of footer of the new section.

TABLE OF CONTENTS

To create an automated table of contents, you need to have used "Styles" to select the style for report section headings such as "Introduction" and "Background Theory". If you haven't done that, it is not too late. Just go to each heading, select that line and select what heading level it is in the Styles section of the Home tab. If you like the look of your headings, you can change the heading style to that look by right clicking on the heading, click on "Styles", and then select the choice that says "Update Heading '#' to match this selection".

Once all your headings have been assigned a heading level, then go to the page where you want to insert the table of contents, click on the "References" tab, then click on Insert Table of Contents …. Word will automatically create the table. If you need to update page numbers due to edits, just right click on the Table of Contents and select "Update Field". You can update the whole table or just the page numbers. If you made changes to heading names, then you need to update the whole table, but otherwise, just updating page numbers does the job.

APPENDIX C: Writing Tips for Discussing Results

The information provided in this section is applicable to discussing results regardless of for a formal technical report, an academic lab report, or just responding to technical questions. The information includes:

- How to calculate percent difference/error.
- Typical magnitudes of percent error for courses where circuits are constructed.
- What to consider writing about based on lab questions.
- Guidelines for graphs provided in a report.
- Considerations for technical responses.

Percent Difference/Error

The percent difference or percent error is necessary to fully comprehend the magnitude of the difference or error being evaluated. For example, if in discussing results I read "The voltage difference is 0.02V" and no percent difference analysis was provided, I could conclude this is a negligibly small difference. However, if the theoretical voltage was 0.085V and the measured value was 0.065V then the percent difference would be –31%! Whereas if the measured value was 0.58V and 0.6V was the expected value, then the percent difference is only 3.4%. Yet, both cases are for a 0.02V difference.

There are various ways to consider and calculate percent difference or percent error. Even how we refer to it varies! When comparing two values that are expected to be different, such as when comparing a theoretically derived value to an experimentally measured value, it is logical to refer to "percent difference". When the discussion is focused on error, then it makes sense to refer to "percent error". We certainly expect a difference when comparing theory to experiment because we expect the real world of the experiment to introduce variables not found in theory. Considering these variables as "errors" is more a point of view than a point of fact. For example, the tolerance of resistors in a circuit is a point of fact that introduces a potential difference between the theoretical resistor value and the actual resistor value. Thus, which phrase is used implies a bias on the results. When using "difference", the implied bias is that the differences are all explainable and justifiable whereas using "error" implies fault. For the sake of this discussion, I will use the phrase "percent difference" demonstrating my particular bias as an engineer.

There are various ways of calculating percent difference that depend on the value that is perceived to be most valid and thus the one being compared against. Each of those ways is presented below. In a report, it is good practice to show a sample calculation of percent difference which serves to demonstrate to the reader the equation used.

Equation (1) provides the formula most commonly used in academia. It is used when the purpose of the experiment is to validate a trusted theoretical principle used to calculate the theoretical value. In this case, the percent difference is an indication of how different the measured (or experimental) value is from the expected value based on theory.

$$\% \: difference = \frac{measured \: value - theoretical \: value}{theoretical \: value} X 100\%$$
Eq. (1) Testing a measured value against trusted theoretical value

Equation (2) provides the formula used when the purpose is to compare two values without judgment as to which value is the most trusted or believable. That is generally not the case when

comparing experiment to theory as the experimenter, more often than not, has evidence to justify trusting one of the values more than the other. Equation (2) is commonly used when comparing two experimental values determined using two different methods.

$$\% \ difference = \frac{value1 - value2}{average \ of \ value1 \ and \ value2} X100\%$$

Eq. (2) Testing for difference between values when uncertain which is more trusted or believable

Equation (3) is used when the purpose is to test the theory's validity, a more advanced prospect. This equation is used when the experimental observations are trusted but there is a question as to how accurately the theory employed predicts those observations.

$$\% \ difference = \frac{measured \ value - theoretical \ value}{measured \ value} X100\%$$

Eq. (3) Testing a trusted measured value as compared to an uncertain theoretical value

In all these equations, the measured value is used interchangeably with the experimental value. This value is determined through experimentation. The theoretical value is determined from an analysis and does not depend on any measured value.

Significance of Difference

You must provide reasoned discussion whenever a significant percent difference exists. What is considered significant depends on the work undertaken and the associated accuracy requirements. The degree of accuracy is likely limited by factor(s) beyond control of the experimenter. For any given experiment, the sources of error must be identified and quantified so that an acceptable range of percent difference is specified. Associating a percentage difference with an error source can be straightforward, in the case of manufacturer-supplied component tolerance, or may need to be estimated based on experience, past practice, or theory.

A common limitation that sets the acceptable range of percent difference is the tolerance of components as compared to their nominal values. For example, standard resistors have a tolerance of 5% from the nominal value. Therefore, a percent difference less than 5% can be attributed to the resistor tolerance. There may be other error sources but if those add a fraction of a percent, then those other error sources are considered comparatively small and insignificant. There is no reason to present to the reader insignificantly small error sources. If there are multiple significant error sources, each must be specified and the expected impact of the combination of error sources on the acceptable tolerance for results. Continuing with the example, many capacitors have a tolerance of 10%. Therefore, in circuits with standard resistors and capacitors with 10% tolerance, worst case error adds up to 15% so that all results within 15% of expected value are acceptable due to the combined tolerances of the resistors (5%) and the capacitors (10%). Keep in mind that components with tighter tolerances lead to a smaller acceptable range for the percent difference between measured and expected values.

If the percent difference between measured and expected values for a particular experiment is greater than the accepted percentage as determined from evaluating the error source, then one of three possible reasons should be considered. First, the percent difference could be an indication that the theory is not predicting the results as generally expected. In this case, there must be a reason to suspect flawed theory and it is important to determine any theoretical assumption(s) at fault. Second, an error source considered insignificant may, in fact, be introducing significant error.

In this case, the error source must be identified and explained. If possible, action should be taken to mitigate the source of error. Third, a significant (and unacceptable) human error was made during experimentation in which case the experiment needs to be redone.

Recognizing that lab preparation always includes performing theoretical predictions first and may also include computer simulation, the experimenter MUST be in a position to judge the data as it is being recorded. If a large percent difference is noted during lab, **do not proceed** until the problem is resolved. Depending on the setting, this may include seeking assistance from the instructor, colleagues, or supervisor, and may require obtaining permission to proceed. Be aware that the most common source of error leading to percent differences outside the acceptable range is gross error in the lab which must be identified WHILE in lab.

Writing Discussion Based on Questions

When writing results and discussion section, pay close attention to all questions posed by the instructor in an academic setting or by colleagues or customers in a work setting. Generally, questions indicate aspects of the work considered most important and must be discussed along with the presentation of results.

Guidelines for Graphs

Always refer to graphs and tables when discussing results. Construct graphs using the following guidelines:
1. Create the graph using a computer software package such as Microsoft Excel. If computer access is not available, use grid paper.
2. Clearly label axes, including quantity plotted and its units.
3. Use a smoothed line to produce the best-fit curve. Only use a trendline when you are looking to provide a polynomial equation to approximate the observed behavior.
4. Clearly indicate data points using a circle, triangle, or square. Use different shapes for different curves plotted on the same axes.
5. Label different curves plotted on the same axes.
6. Number and title every graph. "Figure 1: V vs. R" is NOT an acceptable title whereas "Figure 1: Measurement of Voltage (V) as a Function of Varying Resistance (R)" is.
7. Place all graphs in the report so that the bottom of the graph is either along the bottom of the paper or the right side of the paper.

Considerations for Technical Responses

The list provided below supplies guidelines for answering technical questions as opposed to writing a formal technical report. Keep in mind that this a "short list". You should also make sure to ask yourself the questions posed in the "Questions to Ask Yourself Prior to Submitting Any Report" section of the guidelines.
- **First type the question, then type the answer**. In other words, always provide the question with the response. It is important for the reader to have the question being answered in front of them when considering your response.
- Make sure the underlying objectives are understood as they are the indication of what to focus on in answering questions and writing reports.
- Use full sentences and make sure all parts of the question are answered. If asked to explain, make sure to provide adequate explanation.

- When comparing data, supply the data AND the percent difference along with a meaningful discussion. The question need not explicitly ask for a meaningful discussion; that is implied when asked to make a comparison.
  - When comparing data, make sure the type of data is clearly indicated. Data that is obtained completely from theory with no use of data collected in the lab is theoretical data. Data obtained from experimental measurements is experimental data. If theory was used to derive data, such as using current to calculate voltage using Ohm's Law, the result is still experimental in nature since it is based on experimental information. Finally, data can be computer generated or simulated data.
  - Tables or graphs should allow for easy comparison between numbers. Indicate the type of data and its units, and supply a percent difference where appropriate. All types of data should be included.
- If the responsibility of answering questions is a team responsibility, it is expected that ALL team members contribute to the discussion and writing of the answers. Ineffective teams will often default to assigning individuals to certain portions or questions just to copy them all together to form a single report. However, the result is often not a cohesive report and doesn't take advantage of the varied skills and perspectives of the team.
  - The recommended method of answering questions as a team is to organize a team meeting at which the team discusses what is needed to provide the responses and a plan for preparing a first draft. If a meeting is not possible, the team should engage in an electronic discussion (texting or email). Individuals could be assigned to respond to particular questions and then several days before the team report is due, each individual shares their work with the rest of the team. This allows time before the due date for everyone to review and revise the supplied responses.
  - Considered using Google Docs that allows a team to jointly work on a document, simultaneously adding content and editing existing work. Google Docs also allows editors to leave comments thus providing communication between team members concerning plans and feedback.
- Make sure to read over what you have written to see if it actually answers the question at hand. You may not be getting straight to the point, you may not be backing up your answer with meaningful information, or you literally may not be answering the question. It is not unusual to provide a response based on what you thought the question was asking and a critical re-reading of the question and the response can assure you don't make that mistake.