

**ENGINEERING COURSE STANDARDS**



**Fall 2002  
Revised 2013/14**

**College of Engineering  
Arkansas State University  
Jonesboro, Arkansas**

# **ENGINEERING COURSE STANDARDS**

for  
**Undergraduate Engineering Students**  
College of Engineering  
Arkansas State University

Prepared by  
**Engineering Standards Task Group**  
College of Engineering  
Arkansas State University

Fall 2002  
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## I - EXECUTIVE SUMMARY

Virtually all engineering organizations have similar standards and guidelines for the various types of work that they perform. Many of these standards concern the details for performing and implementing engineering investigations and designs, but standards also exist for how engineers communicate and document their work. The College of Engineering at Arkansas State University (Astate) has developed standards and guidelines, consisted with industry standards, for the various types of documents that students must complete as part of their engineering education. The purpose of this document is to present these engineering course standards and guidelines.

Performing calculations and completing homework assignments are a necessary part of most mathematics, science, and engineering courses. By working through assignments, students develop a better understanding and an ability to practice the theory presented in lectures. Most companies require that engineering calculations be checked by others for accuracy, so a logical, systematic approach is essential. In many instances, tables and figures are also incorporated into calculations as well as engineering reports to help explain complex subjects and summarize data and findings. If a checker cannot follow and verify an engineer's work independently, the work is meaningless. Thus, the standard formats and guidelines for presentation of calculations, tables, and figures are described in Chapters III and IV.

Engineers are rarely judged solely by the quality of their technical knowledge or work. Many engineering employers and clients have nontechnical backgrounds and routinely judge engineers by how well they communicate orally and in writing. Thus, report organization, proper punctuation, correct spelling, choice of words, and writing style are very important. The steps for report planning and implementation; rules and guidelines for manuscript mechanics including punctuation, abbreviations, numbers and units, equations, spacing and indenting, and others; and general guidelines for good technical writing are including in Chapter V.

The type of written documents that are addressed in detail here are those that will be required by coursework in the Astate College of Engineering. Engineering faculty will frequently communicate with students using e-mail, and students will frequently be required to submit homework and lab assignments using business letters or memos. The standard format, guidelines, and content for these forms of written communications are presented in Chapter VI. Most of the engineering lab courses require that laboratory reports be submitted, and many of the upper-level courses involve design projects that require periodic progress reports. These reports have typically been labeled as "informal", but perhaps a more descriptive term might be "short reports" since all engineering reports should be formal in the sense of content and organization. The proper format and content for these short reports are discussed in Chapter VII. Formal written reports are required for many of the upper-level courses as well, and a group-written formal report is required for Senior Design I and II. Chapter VIII describes the content, organization, and format for formal engineering reports and also provides some helpful writing tips. Logs books and notebooks are also required for some labs and courses, and the format and guidelines for these documents are provided in Chapter IX.

## II – INTRODUCTION

### Background

All engineering organizations have similar standards and guidelines that have been developed for the various types of work that they perform. For example, a consulting engineering firm might use standard construction specifications from the *International Building Code (IBC)* for concrete work, structural steel, mechanical piping, electrical controls, and so on. Standard specs are helpful to the contractors who bid and perform the actual work if all engineering firms use similar standards and the contractors become familiar with them. Also, engineering design firms usually have standards and guidelines for various kinds of design work, such as the method for calculating natural vibration frequency and the procedures for estimating rainfall runoff. Engineering organizations also have standards for how information is to be presented, particularly calculations, tables and figures, and most types of written communications. Although some variations and preferences do exist in the way practicing engineers present their work, there are many more similarities than differences.

The College of Engineering at Astate is an engineering organization devoted to undergraduate and graduate engineering education as well as engineering research and service. As such, the engineering faculty has always required certain standards for engineering coursework although some requirements may be slightly different for individual faculty members. During the 2001/02 academic year and again in 2013/14, an Engineering Standards Task Group was formed to gather input from the faculty, to determine what types of standards were appropriate for engineering coursework, and to establish a broad set of standards and guidelines for the work required by engineering students at Astate. The efforts of the task group's work are presented in this document.

## **Purpose and Scope**

The primary purpose of the *Engineering Course Standards* document is to provide general standards and guidelines for various types of assignments that students will be required to complete as part of their undergraduate engineering education. Much care has been taken to ensure that these standards are consistent with industry standards and those commonly used by practicing engineers while realizing that some variations and preferences exist. The importance of these standards will become evident to the student as they advance through the engineering curriculum. The standards and guidelines should be beneficial to students by saving time and minimizing frustration caused when trying to make decisions about the format or mechanics of an assignment and the specifics required by a particular engineering professor. This document will also be beneficial to the faculty by reducing the amount of class time devoted to these topics since this document will be introduced to students in their freshman year and should be retained for subsequent use.

For the most part, the *Engineering Course Standards* addresses only the types of documents that will be assigned by the engineering faculty, but other important topics are also covered. Chapter III is devoted to guidelines, format, and presentation of engineering calculations and homework, and Chapter IV covers standard figures and tables. Chapter V discusses the basics of all forms of written communications and provides numerous guidelines on such topics as punctuation, abbreviations, equations, and manuscript mechanics. Chapter VI covers letters, memoranda, and e-mail; Chapter VII addresses the specifics of laboratory and progress reports; Chapter VIII provides details on format and content of formal technical reports; and Chapter IX discusses log books and notebooks. Numerous examples of implementing the standards and use of proper format are given throughout the major chapter sections as well as in the appendices.



### **III - HOMEWORK AND CALCULATIONS**

#### **Background**

Practicing engineers are required to apply learned theory and experiences toward problem solutions. Regardless of the particular engineering discipline, basic problem solution techniques must be applied. These basic techniques are designed to allow the solution process to be viewed as a logical, systematic approach to the desired outcome. As a professional engineer, one might be required to work on a multi-disciplinary team. One might also be required to present their problem solution for evaluation by peers, superiors, and/or clients. Even if the solution process is not to be presented to others, it is helpful to the engineer to have the process laid out in a format conducive to easy interpretation. Engineering students are expected to learn and develop these problem presentation skills while learning the theory behind problem solution. For these reasons a basic standard has been adopted for problem solution presentation.

#### **Calculations**

The Astate College of Engineering has adopted the following standardized procedures for representing calculations on assigned work. These procedures are considered acceptable by all instructors, but each instructor reserves the right to make specific requirements of their students in addition to those specified here. Calculations appearing on homework assignments, tests, reports, or any other student work should follow these guidelines:

1. Begin all calculations with the theoretical formula where applicable.
2. Substitute numerical values with proper units for variables into the formula.
3. Show clearly all unit conversion factors necessary for problem solution.

4. Identify the solution derived from calculations with the proper units clearly shown. A numerical value without units is meaningless.
5. If the numerical value is a final answer, report that value with the proper significant figures and units and identify it according to the wishes of the instructor (box around it or underline).
6. When possible, simplify mathematical expressions algebraically as much as possible before utilizing a calculator and reducing the result to a decimal approximation. For example, retain fractional expressions and cancel common factors.

Calculation formats must be adhered to in order for full credit to be given on any and all assignments.

For an example of proper calculation representation, see Appendix A. Proper format for calculations and homework representation is demonstrated in the examples found there.

Students are expected to understand and follow the calculation guidelines for all work. For calculations appearing in reports, variables used in formulas must be clearly defined. Variable definition is generally not necessary for homework assignments and tests, but it is up to the individual instructor's discretion of this requirement. For trigonometric and basic algebra work, formulas are generally not required. However, the proper identification of units within the calculations is necessary for such work.

Questions regarding calculations format should be addressed to the student's instructor. Severity of point deduction for improper calculation representation is up to the discretion of individual instructors. Students are advised to inquire as to point deductions from each individual instructor on the first day of class to prevent problems later in the semester.

## **Homework**

Homework assignments are a necessary part of most science and mathematics courses. Since engineering is a combination of both science and math, students should expect to have homework

assignments in all engineering courses. Homework assignments are made in order for students to practice applying theory and principles that may seem abstract during their introduction. The homework should reflect the material covered in lecture and reading assignments. The importance of homework cannot be overstated. By working through assignments outside of class, students develop their own understanding and comprehension of the material discussed in lectures.

Academic dishonesty will not be tolerated on homework or any other assignments given by the Astate College of Engineering. See the student handbook for a copy of Astate's policies on academic dishonesty. Those policies will be strictly enforced. Homework assignments are to be completed by individuals. Having said that, it is prudent to note that studying and working in groups is extremely beneficial to engineering students. A fine line exists between helping and receiving help and cheating. Taking credit for someone else's work is cheating. Receiving help from a fellow student so that one can finish his homework assignment, however, is not cheating. The instructor of the class might just as easily provide that help. The ethical issues will not be discussed here, but a student cannot expect to succeed if they do not do their own work.

The Astate College of Engineering has specified the following criteria for all homework assignments. The general format for engineering homework assignments is well documented (1), and that general format will be adhered to by Astate's engineering faculty. All homework assignments are to be done on engineering paper unless otherwise specified. Engineering paper has horizontal and vertical rulings on the *reverse* side, with only margins and headings ruled on the front. The horizontal and vertical rulings on the reverse side show through to the front to assist in lettering and diagram construction, but they do not disappear with erasures. All work should be completed within the margin and header rulings. All work should be done neatly and legibly in pencil. Only one homework problem should be placed on a single page unless otherwise instructed. If a problem

requires more than the front of a single page, it should be continued on the front of a separate sheet. Never use the back of a page for writing out solutions. While exact format may vary with each instructor, the following procedures should be followed for all engineering homework assignments:

1. Across the top of each page in the header areas, identify the problem number, class title, name, date, and the sheet number along with the total number of sheets being submitted for the assignment.
2. Print all letters (no cursive writing). Use of all CAPS is generally preferred, but not always required.
3. Beside the left margin just below the header, write the word GIVEN. The upper part of the page is reserved for all information given in the problem that is to be solved. If necessary a diagram of the given information should be drawn here. All information needed to completely understand the problem statement and solve it should appear in the GIVEN section.
4. Below the GIVEN section, write the word FIND beside the left margin. This section of the page is reserved for identification of all values which are to be determined for complete problem solution.
5. Below the FIND section, write the word SOLUTION beside the left margin. The SOLUTION section is where all work towards problem solution begins. Proper format for calculations must be followed. Additional diagrams required for problem solution should appear in this section. If any assumptions are made about the problem, they should be clearly stated in this area using complete sentences. Put all calculations in a single, vertical column; do not work back and forth across the page. Final answers should be clearly identified upon completion of the problem per the instructor's directions.

The above format procedures are commonly referred to as "Given, Find, Solution" (GFS) format. The GFS format provides a skeleton outlay for all engineering homework assignments. Appendix A provides examples of GFS format. A slightly modified format can be found in the *Engineering Fundamentals & Problem Solving* textbook (1).

The basic format for homework assignments is easy to use once the student learns it. By starting out with the correct format, it will quickly become habit to set up the problems correctly. The solution process for each homework problem should follow in logical order. Neatness is also essential. The student is also reminded to print all work, preferably in all CAPS. By following these procedures, the student will continue to develop their problem-solving skills through application of logical thought processes. Since the homework must be set up in a logical manner, the student must think in the same manner. Logical thought processes are essential to engineering problem solution.

## IV - STANDARD FIGURES AND TABLES

### Background

The use of figures and tables in engineering practice is common. Few reports can be prepared without using at least one figure or table, and it is not unusual for a single report to have several of both. Figures are used primarily to provide one with a visual representation of mathematical equations or objects being discussed. Tables are used to represent how specific inputs affect outputs or to demonstrate variation in values as related to changes in materials or other factors. These generalized categories for information found in figures and tables are by no means inclusive of all possibilities, and the engineering student will obtain a better idea of when to use figures and tables with experience.

Two basic rules exist which apply to the use of both figures and tables in engineering reports. Of primary importance to the engineering student is identifying figures and tables in the body of the report. A general rule of thumb states that a figure or table should not appear in a report unless it is specifically referenced in that report. Furthermore, the table or figure should appear immediately after it is first referenced. If a table is to appear in an appendix, it may or may not be directly referenced in the report body, but the appendix should be referenced in the body. When numbering tables or figures which are to appear in an appendix, the letter of the appendix must appear in the figure or table number (Table A-1, Figure A-1 for those appearing in Appendix A). Never place a figure or table in a report before it has been referenced. Proper placement avoids confusion on the part of the reader. The second basic rule states that figures and tables should appear in the report in numerical order. Discussion about numbering figures and tables can be found later in this chapter.

## Tables

Tables are used to present data in engineering reports. Data included in the body of a report must be relevant to the material being presented and is usually a summary of the important results. If the material is primarily raw data, it can be included in a table in an appendix to the report as opposed to the body of the report. A proper table includes a title at the top which describes the data contained therein (2). Tables are generally numbered with Cardinal numbers (1, 2, 3, and so on). Consistency within a report is the most important thing. See Table 1 for an example of proper table format.

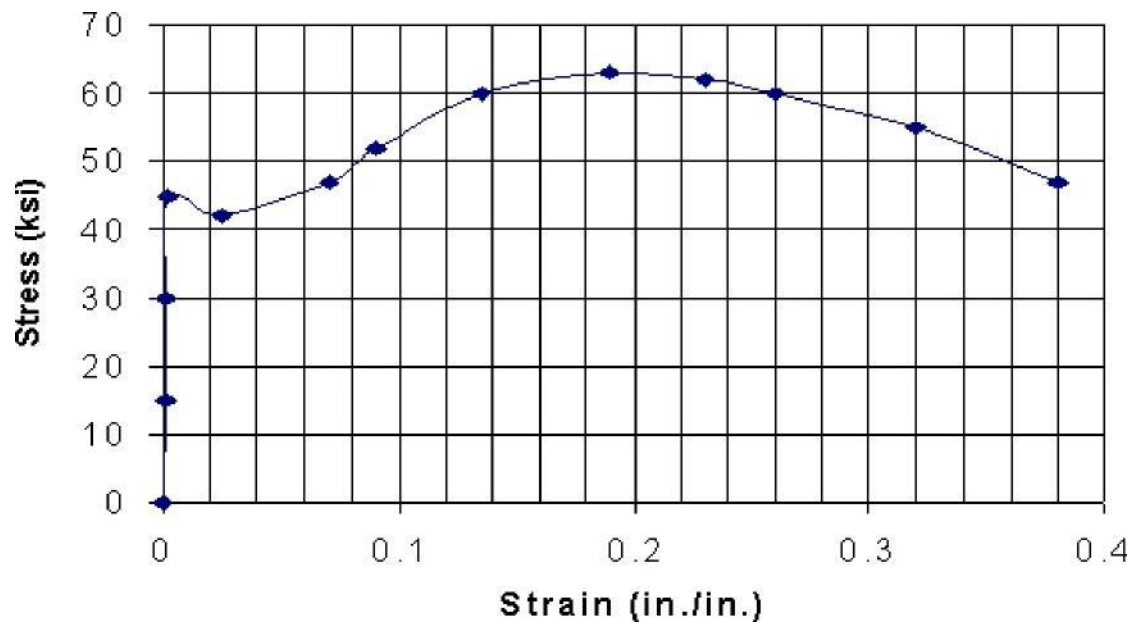
**Table 1 Typical Values for  $\mu_s$**

<b>Contact Materials</b>	<b>Coefficient of Static Friction (<math>\mu_s</math>)</b>
Metal on ice	0.03 - 0.05
Wood on wood	0.30 - 0.70
Leather on wood	0.20 - 0.50
Leather on metal	0.30 - 0.60
Aluminum on aluminum	1.10 - 1.70

## Figures

Figures are used in engineering reports to provide a visual representation of objects or mathematical relationships. Proper figures include a title at the bottom of the figure which briefly describes the figure. Figures should appear in a report in numerical order just as tables. Cardinal numbers (No. 1, No. 2, No. 3) are used for figure identification (2), but the “No.” descriptor may be omitted by some. See Figure 1 for a proper figure example. Most any textbook can be used as a reference for proper figure and table usage. Engineering texts are preferred since they are most

likely to follow the guidelines presented in this document.



**Figure 1 Stress-Strain Diagram for Mild Steel**



## V - WRITTEN COMMUNICATIONS

### Importance

Engineers are rarely judged solely by the quality of their technical knowledge or work. People also form opinions by what one says and writes. When an engineer writes a memo or report, talks to members of a group, deals with vendors on the phone, or attends meetings, the image others get is largely formed by how a person communicates. Even if an engineer works for a large company and does not see high-level managers very often, upper management can still gain an impression of an engineer by the quality of written reports as well as by what the immediate supervisor tells them. Richard C. Levine, Manager of Hardware Planning at Bell Northern Research, once told a group of engineering students the following:

*Another fundamental is the ability to read with comprehension and to write clearly and correctly....I can't emphasize enough that both of these skills are extremely important. I am not a picky person when it comes to spelling and grammar, but when I see a report or memo that has repeated errors, I immediately question the ability and dedication of the person who wrote it. Why didn't they take the time and effort to do it right? Most of the successful engineers I know write clear, well-organized memos and reports. Engineers who can't write well are definitely held back from career advancement.*

Many engineers spend nearly half of their time writing and usually find that the time devoted to writing increases as they move up the corporate ladder. It does not matter that some writing is now sent through electronic mail (e-mail); the need for clear and efficient prose is the same whether it appears on a computer screen or sheet of paper. Much written material first read on a screen ends up being printed out on paper anyway, and the possibility of a paperless office seems pretty remote.

Engineers interact throughout their career with a variety of other engineering and non-engineering colleagues, officials, and members of the public. Even if an individual does not do the actual engineering work, they may have to explain how something was done, should be done, has to be changed, needs to be investigated, and so on. The list of all the possible engineering situations and contexts in which communication skills are needed is unending. The following list identifies just some of the documents that engineers are responsible for writing:

Memos	Contracts	Articles
Abstracts	Specifications	Executive Summaries
Weekly Reports	Progress Reports	Investigation Reports
Policy Manuals	Training Aids	Maintenance Manuals
Annual Reports	Lab Reports	Repair Manuals
User's Manuals	Newsletters	Safety Instructions
Proposals	Tutorials	Letters
Patents	Procedures	Standards

Many public and private organizations have style-guides and procedural manuals for writing reports and other documents. That is exactly the purpose of this document: to present a standard for typical writing assignments for engineering students at Arkansas State University. These helpful guidelines address topics such as abbreviation, capitalization, citation of references, gender-neutral writing, punctuation, timesteps, graphics, common mistakes, and overall report format. Inasmuch as technical reports are often written as a team effort, style-guides and procedure manuals help achieve internal consistency within any given report. They also contribute to inter-report consistency for the organization. Finally, writing guides save time and minimize frustration by reducing the need to make decisions about the mechanics of a report and the specifics required by a particular engineering professor at Astate. At minimum, refer to these guidelines and other available guides such as those of Beer and McMurrey (3) and *The Chicago Manual of Style* (4).

The type of engineering documents addressed here will only be those that will be required by the College of Engineering coursework. These documents can be classified as letters, memoranda, and e-mail; laboratory and informal reports; formal technical reports; and log books and notebooks. The format, examples, and some rules for each type are presented in later chapters.

### **Planning and Implementation**

This document has been developed as if it were a formal technical report. The objectives are to present and demonstrate the techniques of effective communications for Astate engineering students. As with most worthy endeavors, the planning and implementation stages are important in order to produce high quality work. The following sections on this topic are taken directly from Martin (5).

Very simply stated, the purpose of written or oral communications is to present *specific* information to *specific* audiences for *specific* purposes. To accomplish this, the development of all communication methods requires two phases: exploratory and implementation. When these two phases are completed, a third, improvement, is needed to ensure the best quality product. The usual steps are gathering information, planning the report/speech, writing, and then revising. The first two steps, gathering and planning, constitute the exploratory phase; the last two, writing and revising, are (respectively) the implementation and the improvement.

**Exploratory Phase: MAPS.** The acronym MAPS helps define the exploratory phase. The letters stand for message, audience, purpose, and scope. These words serve as guides in this creative phase of gathering information and planning. The message directs the selection of information from three major sources: personal and professional experience, library/internet sources, and original research/experiments/tests performed. For example, the message of a progress report will be the progress made on a project. The audience will be higher management, maybe the course instructor,

or possibly a client. The purpose of a progress report is to keep management/your client informed, a very important part of project management. The scope of a progress report should include a brief introduction, summary of work completed, work in progress and work yet to be done, any problems (technical, costs, or timing), and attachments like man-hour summaries and a Gantt Chart.

**Procedures: PWRR.** The procedures for the implementation phase are correlated with the acronym PWRR which stands for plan, write, relax, and revise. One of the most important aspects of any project is to prepare a plan to serve as a guide and to prevent wondering what to do next. So, the first step in preparing a report or talk should be to make a plan or an outline. The initial outline may only be simple phrases that are expanded and revised as the work develops. In the case of a written report, it eventually becomes the table of contents.

When preparing a written report, the next step is to write a rough draft of each section using the topical outline. The idea is to get information on paper as quickly as possible without worrying about spelling, grammar, and punctuation. Ideas easily slip away when distracted by the few seconds needed to check punctuation or synonyms. These aspects can always be corrected later, and with modern word processing software, this is not a problem. This approach is easier said than done, but when engineers finally learn to write in this manner productivity increases dramatically. After the rough draft is finished, the manuscript should be put aside for a day or a week, if possible. Relaxing after completing a task is satisfying and motivating, but of greater importance is that a more objective, critical review can be made of a written report at a later time.

The last implementation step is revise, revise, revise. Revising is the most important aspect in producing top-quality reports. Conciseness in writing is an outstanding virtue, greatly appreciated by

the busy engineer and manager. But, writing that is too terse can cause problems for the reader. It can require extra time to analyze and supply what was left out in an attempt to save reader's time. In revising, check the rough draft for technical accuracy. Check closely for misleading statements; truthfulness is the soul of science and engineering, the essence of professionalism. Strive for clarity; write so that statements are not misunderstood. Make sentences as simple and concrete as possible; avoid implications and jargon not generally known to the intended readers. Avoid writing sentences which have more than 20 words. Revise for good organization and logical development. Liberal use of headings and subheadings can lead the reader through the thought processes desired. To achieve conciseness, delete unnecessary words that do not affect the reader's understanding, needs, or ease of assimilation. Correct errors in grammar, punctuation, and spelling. There is no excuse for these errors. Finally, have a competent colleague review the report and suggest improvements.

### **Manuscript Mechanics**

Accuracy and clarity are of vital importance for technical reports, but first impressions often depend on appearance. Some people that review technical reports, particularly those in upper management, may have little technical background, and their overall evaluation can be influenced by how well the report is written and its appearance. Thus, it is advantageous to produce a report that is free of typographical mistakes, grammatical errors, and misspelled words and is also professional-looking. There are no set rules for manuscript mechanics, but the following recommendations are good practice and assure a professional look.

**Spelling and Punctuation.** The effect of poor spelling is a sense of annoyance for the reader, and it distracts their attention from the topic that is being communicated. Spelling errors can bring readers to a stop and cause them to seriously question the writer's ability to write. They may even suspect that a person who is careless with spelling could also be inept in more critical technical matters.

To reduce or eliminate any noise in writing caused by incorrect spelling, use a spell checker and also have a standard dictionary nearby. Also, it is good practice to have others read your work to check for spelling mistakes and misuse of words.

The flow of meaning in written sentences is controlled by punctuation marks much the same as in spoken language by means of pitch, pauses, and emphasis. When punctuating written sentences, speak the sentences aloud as in normal conversation. Pay careful attention to where natural pauses occur within the sentence; that is likely where some punctuation is needed. Many detailed books on proper punctuation exist, and they should be used if a lot of queries exist in this area. The following suggestions taken from Beer and McMurrey (3) and Martin (5) are often the most common problems many engineers tend to have with punctuation.

Commas. Confusion sometimes exists about commas because their use is frequently optional. To decide if a comma is important, determine if adding or omitting a comma in a given sentence creates noise. In general, if no possible confusion or strain results, the tendency in technical writing is to omit unessential commas. Often, omitting a comma after introductory words (such as the first word of this sentence) or phrases in a sentence will cause the reader momentary confusion. One more point about commas: most technical editors prefer what is called a “serial comma” when a list of words or phrases is presented in a sentence. For example, *the serial comma has become practically mandatory in most scientific, technical, and legal writing*. Some believe that the *and* joining the last two terms replaces the need for a comma, but this is not the case in standard, technical writing.

Parentheses. Parentheses are used to set off facts or references within a sentence. An example is given in the paragraph above. If the words within the parentheses are not a complete sentence, put any required comma or period outside the parentheses. If the parenthetical material forms a complete

sentence, put the period inside the parentheses. It is best not to use parenthetical material too frequently since these marks force the reader to pause, and are likely to distract them from the main intent of the writing.

Dash. A dash makes a sentence seem more emphatic by calling attention to the words set aside or after it: *Staying up all night to finish a lab report is not so terrible—once in a while.* Since the dash is considered less formal than other parenthetical punctuation marks, try to avoid using it in formal writing. Also, overuse of dashes will cause a loss of their effect. Notice that the dash discussed here is the “em” dash—the dash used between words that practically touches the letters at each end of it.

Colon. Colons are used to separate the hour and minute in a time notation and to divide parts of the title of a book or article. The most common use of the colon within a sentence, however, is to introduce an informal list. For example, several items will be needed for the final exam: a pencil, a calculator, and three sheets of graph paper. A colon can also be used to introduce an illustration or example, but in both cases, an independent phrase comes before the colon.

Hyphens. Hyphens have been called the most underused punctuation marks in technical writing. Unfortunately, apart from the general rule that hyphens should be used to divide a word at the end of a line or to join pairs of words acting as a single descriptor, there is no clear consensus on when to use them. Here are some suggestions:

1. Do not hyphenate prefixes such as *pre-*, *re-*, *semi-*, and *sub-* unless leaving out a hyphen causes an eyesore or possible confusion. For example, distinguishing between recover (regain) and re-cover (to put a new cover on) is good.
2. Do not hyphenate compound words before a noun when the first one ends in *ly*. For instance, *early warning system* needs no hyphen since it is clear that *early* modifies *warning*, not *system*.

3. With really complex technical terms, such as *direct-axis transient open-circuit time constant*, there may be very little to go on, and the best solution may only be found in a technical dictionary.

Quotation Marks. Use quotation marks to set off direct quotations in the text, and put a needed period or comma within them, even if the quoted item is only one word. British publishers use different guidelines, but the American practice is to always put commas and periods inside quotes, and semicolons and colons outside. For example: “The correct answer is 18.2 Joules,” he told me. If the quoted material takes up more than two lines, set it off from the text by a space and indent it from both right and left margins. Some other distinction, such as italics or font size, might be used, and the quotation marks should be omitted in this case.

Semicolon. The semicolon seems to be disappearing from much engineering writing. Often it is replaced by a comma, which is an error according to traditional punctuation rules. More frequently, a period is used and a new sentence is started, but the psychological closeness implied by a semicolon is lost. For example, examine the correctly punctuated sentence: *We wanted to finish the computer program yesterday; however, the network was down all afternoon.* There are plenty of examples of similar sentences where the semicolon has been replaced incorrectly with a comma. Semicolons should also be used to separate a series of short statements listed in a sentence if any one of the statements contains internal punctuation. The semicolon will then divide the larger elements.

**Punctuation of Lists.** If the lead-in to a list ends with a verb, no colon is necessary. For example, *The five priorities established are* would not require a colon after *are* since the list is needed to logically and grammatically complete the sentence. A lead-in like *We have established the following five priorities* would be followed by a colon. If the items in the list are complete sentences, each item



should conclude with a period. If the items are parallel phrases, they should be concluded with a comma, or if internal commas exist, then use a semicolon. The *and* should be placed after the comma/semicolon prior to the last item in the list. The first letter of the first word in each item should be capitalized. For lists of phrases, some prefer that the first letter of each word be capitalized, but either way is acceptable as long as the text is consistent. Another concern when writing lists is to maintain grammatical parallelism between entries. This means if some entries begin with a verb, all entries should do so.

**Sentence Length.** When dealing with highly technical subjects, sentences should rarely be over 20 words long. Technical material can be difficult enough to follow without being presented in long, complex sentences, particularly if the audience is not familiar with the topic. Nobody wants to be left breathless at the end of a mile-long sentence. If sentences tend to be lengthy, look for ways to break them into two or more separate ones. The readability of text is determined partly by the length of the sentences; however, too many short sentences may leave the reader feeling like a first grader.

**Abbreviations.** Abbreviations are necessary in technical communication; they refer to concepts that would take a great deal of time to spell out fully. It would be time-consuming and boring for an engineer to read *Computer-Aided Design/Computer-Aided Manufacturing* several times when CAD/CAM would do. However, confusion may occur when abbreviations are used that the reader does not understand. Always spell abbreviated words the first time unless this would insult the intelligence of the reader. Once the abbreviation has been defined, the reader can be expected to remember it. Occasionally, some highly complicated or unusual abbreviations may need to be defined more than once to remind the reader, or a glossary can be provided as a reference for the reader.

Abbreviations can be subdivided into initialisms and acronyms. Initialisms (sometimes called initializations) are formed by taking the first letters from each word of an expression and pronouncing them as initials: GPA, IBM, ASU. Acronyms are also created from the first letters or sounds of several words, but are pronounced as words: FORTRAN, NASA, ROM, JAVA. Some acronyms become so well-known that they are thought of as ordinary words and are written in lowercase: *bit*, *radar*.

Use the correct form of *a/an* before an initialism. No matter what the first letter is, if it is pronounced with an initial vowel sound (for example the letter M is pronounced “em”), use *an* before the initialism. Form the plural of acronyms and initializations by adding a lowercase *s*: for example, CRTs. Only put an apostrophe between the abbreviation and the *s* if indicating a possessive form.

**Numbers.** Engineering reports usually involve a great deal of numbers which can result in a lot of confusion due to typographical errors, incorrect or inexact numbers, and inconsistencies. This type of noise can be avoided by making certain any number is written correctly. The way that numbers are presented is an indication of the degree of precision: know that 53.235235 implies an accuracy of 0.000001 and that 53.2 may be more representative of the accuracy of the value presented. Numbers can be expressed as words (twelve) or numerals (12). The ordinary practice is to present numbers from one to ten in word form and to present all other numbers as figures. Use numerals rather than words when citing time, money, or measurements: 1 AM, \$43.45, 14 feet. Spell out ordinal numbers only if they are single words. Write the rest as numerals plus the last two letters of the ordinal: second verse, fifteenth time, 21<sup>st</sup> attempt. If a number begins a sentence, it is good practice to spell it out regardless of any other rule or rewrite the sentence so that the number does not begin the sentence. Form the plural of a numeral by adding an *s* with no

apostrophe such as 1960s. Place a zero before the decimal point for numbers less than one, and omit all trailing zeros unless they are needed to indicate precision. Write fractions as numerals when they are joined by a whole number, and connect the number and the fraction by a hyphen: 2-1/2 gallons. When expressing large or small numbers, use scientific notation such as 4.35E-06.

**Units.** The general public in the United States is still not committed to the metric system, but the engineering profession is generally committed and prefers the SI system (from French *Systeme International*). Be consistent by not mixing the English and metric units unless it is required. Depending on who the readers might be, it may be necessary to show both types of units. In this case, use one of the unit systems (primary) in the text following by the other (explanatory units) in parentheses. Sometimes similar symbols can stand for more than one thing, and confusion can result unless an explanation is given. For example, consider G (gauss, measure of magnetic induction), G (gravity), and G (giga-). Units of measurement derived from a person's name usually are not capitalized, even if the abbreviation for the unit is. For example, consider newtons, N. Refer to a recent dictionary of scientific terms to determine the correct spelling/symbol for the units.

**Equations.** At times, equations can communicate ideas far more efficiently than words. However, formulas and equations slow down the reader, so use them only when necessary and when certain the audience can follow them. Most word-processing programs now make it easy to write equations in text, but make sure the equations are noise free and easily understood. Equations should be centered on the page and numbered sequentially in parentheses to the right for reference. Leave several spaces between the text and any equation, and leave a space between lines of equations. Also, space on both sides of operators such as =, +, or. For text with several equations, try to keep the equal signs and reference numbers parallel throughout the text. Every symbol used in equations should be defined in the text or below the equation as illustrated below.

$$P = I * E \quad (1)$$

where:

- P = Power, measured in watts
- E = EMF (electromotive force) in volts
- I = Current in amperes

**Spacing and Indenting.** Generally, the text of a technical report should be double-spaced, but sometimes exceptions do occur. Consistent spacing and indentation make for a professional-looking report. Some guidelines are

1. Triple-space above and below centered headings, quotations, listings, and equations. Double-space above and below subheadings set at the margins.
2. Single-space inset or center listings, such as definitions of the terms of equations, and number them if they are numerous.
3. Single-space long quotations (more than three lines).
4. Single-space individual footnotes, entries in a bibliography, or items in a list of references; double-space between the individual items. For items in a bibliography or list of references, indent the second and succeeding lines three spaces.
5. Single-space the summary and abstract sections of a formal report. Limit the length of a summary to one page if possible; otherwise, double-space the summary.
6. The beginning of a paragraph should be indented five spaces when using double-spacing. If text is single-spaced, no paragraph indentation is necessary, but double-space between paragraphs.
7. Single-space material in an appendix.

**Paper and Margins.** Reports should be printed on one side of good-quality white sheets, 8-1/2 by 11 inches. Company policy might require colored or boarder sheets for some reports; however, black print on white paper generally gives a neater appearance. Use of colored sheets is good practice for long reports to separate major sections such as appendices.

The left margin should always be either one or 1-1/2 inches; all others should be one inch. The greater left margin ensures that the reader will not have difficulty reading the report after it is bound. Different word lengths will cause the right margin to vary, but it should not be less than 3/4 inches. Some people prefer to use full justification for margins for a neater appearance, but this sometimes crowds words and makes reading difficult with small fonts. Where quotations or other insets are included in the text, an additional 1/2 inch should be used on both the left and right sides.

**Page Numbering.** The general rule is to locate page numbers at the bottom center of the page, but some exceptions do occur. Use Arabic numerals for the main body of the text, and use lower-case Roman numerals for prefatory pages (transmittal letter, title page, table of contents, list of figures, list of tables, and abstract). The transmittal letter and title page are counted, but the page numbers are omitted for these sheets so that the table of contents would be iii. Pages of appendices should be numbered using different notation to distinguish them from the main body. For example, for Appendix A, use page numbers of A-1, A-2, and so on.

**Headings and Subheadings.** Use of major section headings and subheadings will help organization of the report and will help the reader follow ideas and retrieve information. Headings signal the main points of the report and should have the same wording as the topical entries in the table of contents. The main headings name the major divisions, sections, or chapters of a report. These main headings should always be centered at the top of a new page, all-capital letters, and either underlined or placed in bold lettering. Main headings and subheadings can be numbered; for example, **1.0 INTRODUCTION** is a main section heading, **1.1 Background** is a second-order subheading, and **1.1.1 Prior Studies** is a third-order subheading. Use of numerals is optional, but the format should be consistent throughout the report.

Two levels of subheadings (second- and third-order) are usually adequate. Second-order subheadings should be placed flush with the left margin; the words are in lowercase letters with the first letter of each word capitalized; and the subheading is either underlined or placed in bold lettering. Double-space above and below second-order subheadings, but put no text on the same line and no punctuation after the subheading. The third-order subheading is treated exactly as the second-order except for three details: indent it five spaces (1/2 inch) or same as paragraph indentation, put a period after it, and start the text on the same line after the subheading. Again, an alternative is to use numerals along with the subheadings as illustrated in the previous paragraph.

### **General Guidelines**

A basic rule of technical communications is to give the reader the most information of value while requiring the minimum time and effort. Probably the most important step in meeting this objective is to revise, revise, revise. The following guidelines should be kept in mind while doing these revisions:

1. Engineering reports are generally written in the third-person which means an observer rather than the doer of the work. Also, past-tense is preferred since the writing is usually about something done in the past. For example, a report is prepared about some experiment or investigation that was done. However, using present-tense makes more sense for describing such things as designs which are proposed. Mixing of past- and present-tense is acceptable in some instances, but the writer should take care to minimize this practice.
2. Most people reading written documents are likely to be in a hurry. Just as the sentences need to be concise and direct, the document needs to have the most important information at the beginning. For example, a long report should give the main points through an informative title followed by a summary section.
3. Even the clearest writing is useless when the information it conveys is wrong. If the report text refers to Appendix B when the information is in Appendix C, the error may confuse the reader and cause them to lose confidence in the report. Inaccurate statements and references will cause the reader to be suspicious of the reliability of the entire report.

4. Not only should it be easy to access the document's essential message, but all information should be in the right place. This means the report should be organized so that each idea, point, and section is clearly and logically laid out within an appropriate overall pattern. Use headings and subheadings liberally.
5. The word *ambiguous* comes from a Latin word meaning to be undecided. Ambiguity primarily results from permitting words like *they* or *it* to point to more than one possible referent in a sentence, or from using short descriptive phrases that could refer to two or more parts of a sentence. In either case, the reader becomes confused and may interpret a sentence differently than intended. Strive to be so clear that sentences cannot be misunderstood.
6. Abstract or subjective words are not inherently wrong, but they fail to provide the precision needed for effective technical writing. Avoid abstract words and phrases like *pretty soon*, *substantial amount*, and *corrective action*, and replace them with concrete, objective terms that have exact meaning, preferably numerical or "either/or" descriptors.
7. Coherence in paragraphs can be achieved by making sure that each sentence clearly relates to the one before it and after it. This means opening with the main point or topic sentence, repeating key words where needed, and using transitional words and pronouns to link sentences as they build up the paragraph.
8. Using an unnecessarily pompous word instead of a straightforward one can cause the reader to slow down. Choose the simplest and plainest word whenever possible. Readers can be distracted or even confused by words that call attention to themselves without contributing to meaning. Check the writing for phrases and words that can be removed without reducing the reader's understanding, and delete them. Never use big words to impress the reader, or five words when two would be better.

## **VI - LETTERS, MEMORANDA AND EMAIL**

A variety of communication methods are at the disposal of professionals today. The method used for communications depends on what will be said, the urgency of the message, required formalities, and where the person is located. Business letters are written communications to recipients who are external to the organization of the sender. Memoranda are written communications that stay within an organization (a business firm or a government agency, for example). Of course, some internal communications may also be in the form of a business letter, for example, those sent by a CEO to all employees. If the matter is urgent or informal, a telephone call or e-mail may be appropriate.

### **Business Letter**

A hardcopy letter should be used when it is important to ensure that the recipient receives the message and takes it seriously, when the recipient needs time to study the message at length and act appropriately upon it, when the communication is long and packed with information, or when a permanent record of the communications is desired. Traditionally, business letters have used one of two standard formats: the block and the semi-block formats. Figure 2 shows a letter formatted using the block design. The semi-block format is similar to the block format except that the heading, subject line, complimentary close, and signature block are moved to the right-of-center. Either of these formats is acceptable for course requirements in the Astate College of Engineering, and the particular style will be selected by the course instructor. The formats vary strictly according to where various components of a letter are placed on the page (for example, is the heading on the left margin or right-of-center?).



**CEB Engineering Associates, Inc.**  
115 West Central Drive  
Little Rock, AR 72340

January 12, 2014

Mr. David Thomas, Director  
Craighead County Regional Solid Waste Authority  
P. O. Box 1995  
Jonesboro, Arkansas 72403

RE: General Engineering Services Agreement

Dear Mr. Thomas:

Enclosed are two copies of the General Engineering Services Agreement covering the work that CEB is presently doing for the landfill. This agreement establishes general scopes of work for different types of projects we might complete for the Authority, administrative procedures for the work, compensation provisions and rates, and general and special conditions. The actual projects we perform will be established by approved, individual-project scopes of work.

If this is acceptable to the Authority, both copies of the attached Agreement should be signed, attested, and dated by the Authority. One executed copy should be returned to us. If you have any questions, please do not hesitate to contact me.

Sincerely,

David R. Reed, P.E.  
Project Engineer  
CEB Engineering Associates, Inc.

DRR/ms  
Encl.:

**Figure 2 Block Format for Letters**

The following describes standard components for business letters, but all these components may not occur in an individual letter:

1. Company or Personal Logo. If company stationery is used, letters should begin a full inch below the logo. Company logo stationery should not be used on following pages; there should be a matching stationery without the logo.
2. Heading. The heading portion of the letter contains the sender's address and the date. If letterhead stationery is used, only the date is needed.
3. Inside Address. This portion of the letter includes the name, title, company, and full address of the recipient of the letter. Make this the same as it appears on the envelope.
4. Subject/Reference Line. Most engineering companies make use of a subject or reference line. This line is used to announce the topic, purpose, project, or account number. Project numbers are frequently used, and this notation on a letter is helpful for filing purposes.
5. Salutation. This is the "Dear Sir" element of the letter. In some contexts where there is no clear recipient or the recipient does not matter, the salutation is omitted. If a salutation is used, make sure the recipient is addressed properly (Mr., Mrs., Ms., Dr.). If the salutation is for a group, select an appropriate name, such as "Dear Faculty". Notice that the salutation for business letters is punctuated with a colon. A comma implies a friendly, nonbusiness communication.
6. Body of the Letter. The body of the letter begins just after the salutation and continues until the complimentary close. Typically, the text of business letters is single spaced; the first line of paragraphs is not indented; and double spacing is used between paragraphs.
7. Complimentary Close. This is the "Sincerely yours," element of the letter. In letters where interpersonal action is irrelevant, this element is sometimes omitted. If there is more than one word in the complimentary close, capitalize only the first word. Notice that the complimentary close is punctuated with a comma.
8. Signature Block. This element includes a blank space for a signature, the sender's name and title, and the name of the sender's organization. In professional correspondence, include the letters after the sender's name that identify earned degrees or registration, and include the sender's title and the name of the organization below the sender's name.

9. End Notations. These elements are the “Cc:” and “Encl. :” abbreviations that are often used below the signature block. The first set is the initials of the sender and typist, respectively (for example, “JMC/rbs”). Because many engineers now prepare their own letters, use “ms” for manuscript instead of the typist initials. “Cc:” followed by one or more names indicates to whom a copy of the letter is sent. Abbreviations like “Encl. :” or written-out versions such as “Enclosures” or “Attachments” indicate that other documents have been attached to the letter.
  
10. Following Pages. If letterhead stationery is used, use the matching quality and style of paper for the following pages but without the letterhead. On following pages in professional correspondence, use a header like the one shown below and located it on the left margin. Triple space below the heading to continue the body of the letter.

Dr. David Beasley  
August 19, 2013  
Page 2 of 4

## **Memoranda**

A memorandum can be used for most communications internal to an organization with the exception of possibly a full formal report. A memo might contain a status or progress report on a project; it might be a request to an employee to provide information; or it might be the employee’s response to a request for information. Thus, a memo can be very much like a business letter, or it can be very much like a short report. The key is the memorandum format. The memo format is commonly used for progress reports that are required in some engineering courses at Astate. These progress reports in memo format may have attachments as with a business letter. If longer than one page, memo progress reports should have subheading to help organize and present the information. For example, a progress report on a design project might have subheadings for an introduction, accomplishments, future work, and problems. An example progress report for Senior Design I and II is included in Appendix B.

Memoranda use a format that is much simpler than that of business letters. While formats vary somewhat, Figure 3 illustrates the standard components.

### **M E M O R A N D U M**

**DATE:** August 23, 2013

**TO:** Mr. Joe Murphy, Chair  
Engineering Computer Committee

**COPIES:** Dr. Brad Edgar  
Dr. Tom Parsons  
Dr. Paul Mixon

**FROM:** Dr. R. C. Clift, Engineering Program Director

**SUBJECT:** Computer Facilities for Engineering

Please prepare an updated list of all computer facilities and software packages that we currently have for engineering. Indicate all items that are currently being used, where/who is using the items, and those that are no longer in use. Also, make a list of future needs for the College of Engineering for the next three years.

I have attached copies of the lists from last year. Some of these items have been purchased and some items on the IF list still remain to be purchased. Please submit the updated lists to me by the end of October. Thanks.

Attachments:

### **Figure 3 Example of Memorandum Format**

The main header words in the memorandum format are usually in all capital letters and are now commonly shown in bold type for appearance.

1. MEMO Heading. In most cases, the word “MEMORANDUM” is placed at the top, center of the first page. The font size is usually slightly larger than that of the text and other header words, and some provide a space between each letter of the word.

2. DATE Heading. The date used for the memo should be somewhere in the header. The example shown by Figure No. 3 shows the date as the first line, but in some designs, it may be a subsequent line.
3. TO Heading. The name of the recipient or the group name is shown following the TO: heading. Use appropriate names and titles, such as “Susie”, “Susie Jacques”, or “Mrs. Susie Jacques, Executive Secretary”, depending on your familiarity with the recipient and the formality of the situation.
4. COPIES Heading. If copies are sent to others, this heading should also be used. List the names and titles of those receiving copies of the memo.
5. FROM Heading. The sender’s name or the name of the group is placed on this line. The familiarity with the recipient and the sense of the formality dictate how the sender is addressed. In many organizations, the writer of the memo places their initials or first name just after the typed name.
6. SUBJECT Heading. A brief phrase that encapsulates the topic and purpose of the memo is placed in this space. Generally, the first letter of each word in the phrase is capitalized, and there is no punctuation at the end. The actual label for this element varies; some styles use “RE:” or “SUBJ:”.

Most of the rules that apply to business letters also apply to the body of a memo. For example, text should be single spaced with double spacing between paragraphs. In more formal styles of memoranda, writers actually insert the same kind of complimentary close and signature block as used for business letters. For continuing pages, some type of header is appropriate with the name of the recipient, date, and page number shown.

### **Electronic Mail**

Once a person gets comfortable with e-mail, it may seem like the only communication method needed. However, written media are preferred and necessary in many cases as previously described. In many ways, e-mail messages are formatted and look similar to memos. Most of the e-mail heading portion is quite simple, most of it being handled by the e-mail program itself. The address of the recipient is filled in; addresses for those to receive copies are filled in; and a brief phrase

indicating the contents or purpose is added. After typing in the body of the message, an additional formatting element to add to a professional e-mail communications is a “signature”. Construct a signature containing your full name, title, company name, e-mail addresses, regular mailing address, telephone number, and other such detail. As for style in e-mail messages, here are some suggestions:

1. Typos and Mistakes. There is some controversy about how much to worry about writing mistakes in e-mail. Except for very formal electronic communications, most people disregard or even expect occasional writing glitches in the e-mail they send or receive. However, e-mail messages can be proofread and edited as easily as most other written documents. Sloppiness in writing can become a bad habit.
2. Formality. The tone of e-mail communications is generally informal. E-mail messages are normally rather short, for example, under a dozen lines, and the paragraphs are short as well. No one likes having to do a lot of extended reading on a computer screen.
3. Specific Subject Lines. If you want your e-mail to be read and have the impact you intend, make the subject line specific and compelling. It is not uncommon for people to log-in and find 50 messages waiting.
4. Format. Whenever possible, break the message into paragraphs of less than six or seven lines and skip an extra line between them. Use only the characters on the keyboard; anything else may not format properly when the recipient views it. Use headings to identify and mark off the various subtopics. If there is a series of points, use the various forms of lists that are available.
5. Automatic Replies. The reply function in e-mail is a wonderful time-saver. However, e-mail is often addressed to multiple recipients. Know for sure that you want all listed recipients to receive the message. Particularly be careful with replying to group list-serves. It can be highly embarrassing for a sensitive message to go to unintended parties. Thus, sensitive topics probably should not be discussed via e-mail. Remember that e-mail can be quickly forwarded to a huge audience.

## VII - LABORATORY AND INFORMAL REPORTS

### General

This section describes some of the common types of informal reports that are written by engineers, particularly in terms of their typical content and organization. Traditionally, these reports have been labeled as “informal” to distinguish them from formal technical reports, but perhaps a more descriptive term might be “short reports” since all engineering reports should be formal in the sense of content and organization. A few examples of informal reports are listed below:

1. Inspection or Trip Report. These reports describe the inspection of a site, facility, or property; summarize a business trip; or report on an accident, describing the problem, discussing the causes and effects, and explaining how it can be avoided.
2. Laboratory Report. These reports discuss an experiment, test, or survey; present the data collected, discuss the research theory, method, or procedure; discuss conclusions, and possibly, explore applications of the findings or possibilities for further research.
3. Progress Report. These reports summarize how a project is going, what has been accomplished, what work lies ahead, what resources have been used, and what problems have arisen.
4. Proposal. A proposal seeks a contract, approval, or funding to do a project; functions as a competitive bid to get hired to do a project; promotes an organization as a candidate for a project; or promotes the project itself, showing why it is needed, methodology to complete the work, personnel requirements, and time and funds needed for the project.

As part of the engineering coursework at Astate, students are required to write many different informal reports. Most reports will involve laboratory work and some may be considered progress reports for projects. Thus, the following sections are devoted to these two types of informal reports.

## Laboratory Reports

A laboratory (lab) report presents not only the data from an experiment and the conclusions that can be drawn from that data, but the report should also discuss the theory, methods, procedures, and equipment used in the work. As much as practical, a lab report should enable readers to “replicate” the work so that the results can be verified independently. The term *laboratory report* is actually a bit restrictive. Any report to describe the collection of original data through an experiment, field research, or survey and then to draw conclusions from those findings can use the content and organization plan discussed here. The contents may include only a few or all of the following sections:

1. Introduction. In the introduction, an idea of the overall topic and purpose of the report as well as an overview of contents may be given. Avoid diving into the thick of the discussion; orient readers to the topic first; do not place tables/figures or references to them in this section. Good subheading topics for an introduction are Background, Purpose/Objective, Literature Review/Theory, and Scope of Work.

The Background section provides a discussion of the background leading up to the project. Typically, this involves discussing a research question, the problems or incidence that caused the question, the persons/organization requesting the work, the dates involved, and the samples or materials submitted for testing.

Often included in the introduction of the lab report is a discussion of the research literature or theory related to the project. If this information is lengthy, it may justify a separate section from the introduction or it may be placed in an appendix. Summarize the findings of other work, give and define applicable equations and diagrams, and define terms unfamiliar to the reader. Provide citations for the sources of information using the standard format for a List of References (see Chapter VIII).

2. Methodology. The next major section of a lab report should give the reader an idea of the approach used to collect data. Actual data should not be presented here, but the focus should be on the methods and procedures used as well as the equipment and facilities involved. If standard methods are used, references should be given, and it may be appropriate to include a copy in an appendix to the report. A separate subheading should be used for each different test performed. Generally, test methods are described in paragraph



format although some procedures may be better presented in a list format. This part of the report in particular enables readers to replicate the work performed.

3. Results. A laboratory project normally involves collecting data and organizing and presenting the information in a section of its own. The common approach is to present the data first, often formatted into summary tables, figures, or charts, without interpretive discussion. After presenting the data and maybe some statistics, a separate subheading can be used for a discussion or explanation of the results (variations of data, potential errors, unusual observations). Only a summary of the data should be presented in the results section of the report, but all data, including original data collection sheets, should be included in an appendix so that the reader can verify the tables and figures of the main text.
4. Conclusions/Recommendations. The conclusion section of a laboratory report summarizes the major findings and conclusions based on the data collected and explains why those conclusions are valid. A common part of this section involves exploring the implications of the data and conclusions, considering how they can be applied, and outlining further work that may be needed.
5. Information Sources. At the end of most laboratory reports is a section, usually one page, that lists information sources used in the project. For entries in the list, use the List of References format given in Chapter VIII.

The laboratory report can be presented in memorandum format if it is short and addressed internally within an organization. However, laboratory reports prepared for engineering courses at Astate should be presented in the style of a formal report, with covers, title page, table of contents, and appendices. An example of an Astate engineering laboratory report is shown in Appendix C. For reports over three or four pages, the formal report format should always be used. The same general guidelines as given in the Manuscript Mechanics section of Chapter V should be used.

### **Progress Reports**

Another common type of informal report is sometimes called the progress report, status report, interim report, quarterly report, monthly report, and so on. The purpose is to present the status of the work on a project to management or a client. The report supplies the details to enable

management/clients to act as manager or executive of the project and to enable them to modify it or even cancel it if the need arises. The writer of the report is the one doing or overseeing the work being performed, and the recipient is the individual or organization that requires the work. For example, the recipient may be internal management (work supervisor) or an external client with whom the writer's organization has a contract.

To understand the function of progress reports, an understanding of the nature of most engineering projects is helpful. In a project of any size, length, or importance, there are usually changes, new and additional requirements, problems, and miscommunications. Management/clients may worry that the work is not being done properly, on schedule, or within budget. Those performing the work may worry that management/clients will not like how the project is developing, that new requirements jeopardize the schedule and budget for the project, or that unexpected problems affecting the schedule and outcome of the project have arisen. A progress report should ease a client's concerns about the schedule, quality, and cost of their project; it helps the providers stay in touch with their clients, maintain a professional image, and protect from unreasonable expectations and mistaken or unwarranted accusations. Most management/clients are understanding of problems if they are kept informed, but do not expect a client to pay for out-of-scope work at the end of a project if they were not kept informed of problems and reasons for the extra work.

Progress reports typically have the following content and organization (see example progress report in Appendix B):

1. Introduction. The introduction should indicate the purpose and topic of the report, its intended audience, and provide a brief overview of the contents. Sometimes much of this information can be deleted from the body of the report since it will be provided by the header if using memo or business letter format.

2. Project Description. Briefly describe the project to refresh the memory of management/clients and in case the progress report is routed to readers who are not familiar with the project. Summarize details such as purpose and scope of the project, project start and completion dates, and names or organizations involved in the project.
3. Progress Summary. The main message of the progress report is the discussion of what work has been completed, what work is in progress, and what is yet to be done. Appropriate subheading may be accomplishments and future plans. This discussion can be handled in two ways:
  - a. Summarize *work* completed in the previous period, *work* under way in the current period, and *work* planned for the immediate future period.
  - b. Summarize which *tasks* in the project have been completed, which *tasks* are currently under way, and which *tasks* are planned for future work.

The later approach is preferred and the one recommended for use in Astate engineering coursework. Normally, a list of tasks to be performed, man-hours to complete each task, and time schedule for each task will be prepared for management/clients at the beginning of the project in the formal proposal. Thus, it is appropriate to attach this information to the progress report showing the initial plans along with the actual man-hours/time required for each task to date. As the work completed for each task is summarized, the percent complete should be given along with a discussion to indicate whether the task is on schedule or behind schedule.

4. Project Summary. In this section the writer should go on record about the problems that have arisen in the project, problems that may jeopardize the quality, cost, or schedule of the project. The writer should give a general opinion as to how the project is going but resist temptations to say that everything is going well or to complain about every minor annoyance. Remember, the writer's job is to provide management/clients with the details they need to act as managers or executives of the project as a whole.

For large projects, progress reports can be lengthy, 100-pages, bound, formal reports.

The formal elements include a cover, title page, table of contents, summary, appendices, and so on. It is more likely that the progress report can fit easily into a business letter or memo format.

## VIII - FORMAL TECHNICAL REPORTS

### General

Engineers are often involved with projects that require formal written reports. Engineering reports have standards or specifications just as do other types of engineering projects. Standards for technical reports involve the layout of the report, the organization and content of the sections, the format of the headings and the lists, the design of the graphics, and so on. The American National Standards Institute (ANSI) has defined and published specifications for engineering reports entitled *Scientific and Technical Reports: Organization, Preparation, and Production* (6). The discussions in this chapter are based on those guidelines and details provided by Beer and McMurrey (3). The format for this entire document follows the guidelines so as to serve as an example for Astate engineering students.

The advantage of having a standard structure and format is that when other engineers review a report, it will be designed in a familiar way, and the reader will know what to look for and where to look for it. Many recipients of engineering reports do not read the entire report and are most interested in the key facts, the conclusions, or other such essentials. Thus, engineers familiar with a standard format know where to find the information. This is also a major reason for preparing a well written executive summary for the report. Also, as an engineering student at Astate, the content, organization, and format for written reports prepared for the engineering faculty will be known. However, this standard for engineering reports is not intended as the “one and only one” standard, but as a focal point to enable engineers to maintain a familiar “look and feel” to reports. Many companies, professions, and organizations have adopted their own standards for reports, and while their standards may have some unique features, the basic organization and format will be similar.

The standard sections of a formal engineering report are listed below and are discussed in the following sections of this chapter:

- Transmittal Letter
- Report Cover
- Title Page
- Table of Contents
- List of Tables and Figures
- Executive Summary
- Introduction
- Body of Report
- Conclusions
- List of References
- Appendices

### **Transmittal Letter**

The transmittal letter is a cover letter that follows the standard format of a business letter as described in early parts of this document. Many times, it is attached to the outside of the report, but may be bound as the first page inside the cover. It should be addressed to the person who requested the report and should be signed by the person responsible for completing the report. Basically, the transmittal letter should be brief, note that the report is attached, and should cover the events that led to preparation of the report. The letter contains information about the report that does not belong in the report.

The first paragraph should cite the name of the report, putting it in italics, underscores, or capital letters. It should also mention the date of the agreement to write the report. The middle paragraph should focus on the purpose of the report and may give a brief overview of its contents. This should not be a summary of the report since a summary section is included in a formal report. The final paragraph should encourage the reader to get in touch if there are questions, comments, or concerns. It closes with a gesture of good will, expressing hope that the reader finds the report satisfactory.

## **Report Cover**

Good covers give reports a solid, professional look as well as protecting the internal pages. There are many types of covers, some more acceptable than others. Unacceptable for all but the shortest reports are the clear (or colored) plastic slip cases with the plastic sleeve on the left edge. These are aggravating to use since readers must struggle to keep them open and a hassle with the static electricity they generate. The most preferable covers are those that allow reports to lie open by themselves, such as spiral bindings. These sorts of bindings are inexpensive, use a plastic spiral for the binding, and a thick, card-stock paper (front and back) that comes in a range of colors for the covers. For added protection and a glossy look, the covers can be laminated after printing.

All report covers should show identifying information in a pleasing design, otherwise the report may be ignored. As a minimum, the report cover should show the title, name of organization requesting the report, name of organization or individual preparing the report, and the date. There is no standard requirement for the identifying information, but some companies might have a specific format. Some companies will also have a logo designed specifically for report covers. Identifying information and layout for the cover are best created using word processing software, and then the file can be directly printed on card-stock paper.

## **Title Page**

The title page will generally have about the same information as the report cover but will have a little more detail. The title page should contain the full title of the report, name and address of the organization requesting the report, the author's organization and address, and the full date or month the report is completed. Other information may be required on the title page of certain reports. If it is part of a contract, the contract number may be required. If the report has a tracking or job number, that number may be needed both on the title page as well as on the report cover.

The placement of information on the title page can vary, but mostly the information is centered horizontally on the page and carefully spaced vertically so that a nice, roomy design is achieved. Do not cram all of the information at the top, bottom, or middle of the title page. Also, some slight changes in font, capitalization, and boldness of lettering makes for a pleasing appearance. Font sizes of more than 14 are usually considered too large.

### **Table of Contents**

A table of contents (TOC) shows the reader what topics are covered in the report and the page number where each of the major sections/chapters start. For some reports where the second- or third-level subsections are short and several subsection titles may be on one page, page numbers on the TOC may be omitted. If this is done for one section on the TOC, it should be done for all other subsections of the same level so as to be consistent. One of the most important design features of a TOC is how many of the headings and subheadings to include. Generally, all headings/subheadings given in the report should be shown in the TOC exactly as they appear in the report. A common mistake is to select heading titles when preparing the draft TOC and to use different heading titles when writing the text.

Critical to a TOC is indentation, spacing, capitalization, and use of bold lettering. Review the TOC for this document. The first-level headings should be all aligned with each other; the second-level sections should be aligned with each other; and so on. The page numbers are right-aligned with each other so that the last digit in a number is always in the same column. Main chapter or section headings should be in all caps, and the use of bold lettering seems to add to the appearance. Second- and third-level subheadings should use headline caps; lower-level sections should use sentence-style caps. The TOC should be spaced-out on the page, but avoid just two or three lines on the second

page. Adjust the spacing between lines to make this come out right.

### **List of Tables and Figures**

Do not confuse tables and figures. Tables are rows and columns of words and/or numbers. If the illustration does not consist strictly of rows and columns, it is a figure. Figures are any illustration, drawing, photograph, graph, or chart that cannot be classified as a table. As a general rule, lists of tables and figures are only placed in a technical report when there are 10 or more total illustrations in the main body, but some faculty at Astate may take exception to this rule. The two lists can be combined under the heading, “Lists of Tables and Figures”. For long reports that contain more than 10 figures and tables, separate lists of figures and tables should be used. The lists can be put on the same page if they fit, otherwise use separate pages.

The lists of tables and figures have many of the same design features as the table of contents. The idea is to enable the reader to find the table or figure of interest with ease. The title of the table or figure should be exactly as it appears in the text. However, in cases where the title is lengthy, some use shorter titles for the lists to give something meaningful that the reader can scan quickly, or use the first few words of the title followed by “. . .”.

### **Executive Summary**

Some technical reports may have a one or two paragraph abstract which provides an overview of the purpose and contents of the report, but an executive summary or synopsis is most common. An executive summary is a condensed version of the entire report covering the background information, summary of the important details, and the findings and recommendations. It is as if someone used a highlighter to mark key sentences and then copied them all onto a separate page and edited them for readability. Typically, executive summaries should be limited to one page with single-spaced text and double spacing between paragraphs. For long reports the executive summary may



not fit this format, but if longer than one single-spaced page, the executive summary should not exceed three double-spaced pages of text.

The executive summary, introduction, and conclusion sections may seem to be repetitive, but readers do not necessarily start at the beginning of a report and read page by page to the end. Readers skip around. They may scan the table of contents; they usually read the executive summary for key facts and findings; and they may only read a section or two from the body of the report. For these reasons, reports are designed with some apparent duplication so the reader will be sure to see the important information no matter where they go to read. However, the writer should be careful that instances of duplication are justified, phrased differently, and do not unnecessarily increase the report's length. Also, since the executive summary may be the only section read by some people, a significant amount of time should be devoted to make sure that it is well written.

## **Introduction**

An essential element of any report is the introduction. In an engineering report, the introduction prepares the reader for the information that is given in the main body. It does not dive into the technical subject, although it may provide some theoretical or historical background. Some subjects that might be covered include the specific topics of the report; situations that brought about the need for the report; purpose of the report; contents or scope of the report; and other background information such as concepts, definitions, history, and statistics that will enable the reader to understand the context.

## **Body of Report**

The body of the report is the main text and will probably include a number of chapters or main sections that cover the topics. The chapters that are necessary for a report vary significantly and

depend on the type of report and the audience. Earlier sections of this document describe what information should be included for many of the different types of reports that engineers write. For the final report in Senior Design II, which is a comprehensive report on a design project, the typical chapter titles of the body include Fabrication and Testing, Final or Component Design, and Design Implementation. The fabrication and testing chapter includes a description of what was fabricated, detailed procedures for testing, and analysis and interpretation of data. The final design chapter provides an overview of the design; the final design specifications; and details of the structural, mechanical, and electrical components. Design implementation covers topics such as cost estimates, safety features, and operation and maintenance of the design.

Most engineering reports involve the explanation of investigations, laboratory exercises, or detailed designs. When writing these reports, be sure to review the guidelines provided in Chapter V of this document as well as the rules in Chapter IV for standard figures and tables. When explaining work that has been done in the past, write using the past-tense and the third-person, divide the subject matter using subheadings, use footnotes for definitions if needed, be clear and complete, and finally, write so as to not be misunderstood. For detailed descriptions of systems, devices, and their function, first describe the overall system or device in terms of the components and how the parts work together. Then, describe each component and their parts and how they function. Use graphical illustrations and analogies that will help the reader understand.

When reviewing the rough draft, look for ways to strengthen the organization and flow of the ideas. Do this kind of review at the level of whole paragraphs and whole groups of paragraphs. Strengthen transitions between major blocks of thought, such as between paragraphs or groups of paragraphs. Add topic sentences (particularly the overview kind) to paragraphs where appropriate. Check the logic and sequence of paragraphs. Break up paragraphs that go on too long, challenging

the reader's attention span. Consolidate clusters of short paragraphs that focus on essentially the same topic. Put in short overview paragraphs at the beginning of sections and subsections.

Drawings, diagrams, tables, and charts are very important components of a technical report. They are useful to convey certain kinds of information more effectively and also give the report an added look of professionalism. When graphics are used, keep these guidelines in mind:

1. Add labels to identify the parts of a figure being illustrated, and a pointer from each label to the part being identified.
2. Figure titles should be added and should appear at the bottom of the figure to indicate the subject of each figure and its subsequent number in the report. Table numbers and titles should appear at the top of the table.
3. Position graphics just after the first position in the text where they are referenced, if not on the same page, then at the top of the next. However, paragraphs should be finished prior to placement of graphic inserts.
4. Insert graphics into pages with text rather than appending them at the end of the report. For readers, it is pleasing to have text broken up with graphics.
5. Do not just pitch graphics into the report without referring to them and explaining key points about them. If a graphic is not mentioned in the text, then it is probably not needed. Remember, graphics serve as aids to help with complex explanations.

## **Conclusions**

For most reports, a final section called a "conclusion" or "conclusions and recommendations" is necessary. Like the introduction, this section should emphasize the most important ideas or the conclusions of the report. The three main functions are to (1) summarize or review the key points, key facts, and major findings of the work; (2) draw logical conclusions from the discussion that has preceded; and (3) generalize by moving away from the specific topic to a discussion of such things as implications, applications, and future developments. If recommendations are expected, they can also be listed in this section, but new material should not be introduced in the conclusions.

## **Back Matter**

The back matter of a technical report consists of a bibliography or a list of references and the appendices. A bibliography is an alphabetized list of references according to the last name of the first author, and it is not necessary that they all be cited in the text of the report. A bibliography, however, is seldom used for engineering reports; a list of references is much more common. The works in a list of references are listed in the order in which they are cited in the report and are numbered accordingly. Appendices are used to supply information that is necessary for the report's completeness but would distract the reader's train of thought if included in the text.

**List of References.** The list of references is placed at the back of the report, usually immediately after the conclusions section. The references are arranged and numbered according to their occurrence in the report. The way entries in the reference section are constructed may look complex. The best approach is to follow the example given in this document, although all the different types are not shown. Names of books, journals, and magazines should be shown in italics, but this is not universal. Titles of articles in journals are put in double quotation marks. For books, list the city of publication, followed by a colon, the name of the publisher, followed by a comma, the year of publication, and a period. For each article, provide the date, volume number, and issue number that the article appeared in and the beginning and ending page numbers of the article. For unusual sources not discussed here, consult *IEEE Information for Authors* (7).

When a reference is being cited in the text, the corresponding number in the list of references is generally enclosed in parentheses. If two or more references are being cited at one location, the reference numbers are enclosed in parentheses and separated by a comma. The citation numbers are placed after the word, paragraph, section, or quotation to which they refer. Documenting the information sources has a lot to do with establishing, maintaining, and protecting your credibility in

the profession. Borrowed information must be documented regardless of the shape or form in which it is presented; whether directly quoted, paraphrased, or summarized, it is still borrowed information and must be documented.

**Appendices.** The appendices are those extra sections following the list of references in the report. Important information that does not fit (usually because it is too long) in the main body of the report should be placed in an appendix. For example, appendices may be used for detailed development of theory, large tables of data, fold-out maps and detailed drawings, manufacturer's literature, or other necessary documentation that does not fit in the main body. Do not place all the information in one appendix, but group like materials and place in separate, appropriately named appendices. Remember that appendices should be considered as "stand alone" documents that are appended to the main text for added information. Thus, appendices should be self-explanatory, and it is usually common practice to include some introductory paragraphs. Do not just begin with table after table of information without some explanation of the material.

## IX - LOG BOOKS AND NOTEBOOKS

### Log Books

The engineer's log book is intended to serve as a record of daily activities, reference documentation, new ideas, engineering research, and project developments whether or not the work materializes into practical use. Because of legal necessity, many companies require their engineers to keep a daily log of activities regardless of the type of work they are doing. In order to obtain a patent, the dates of certain activities must be documented, and this is best done using an engineer's log book. Keeping and maintaining a log book is also a requirement for Senior Design I and II and most engineering laboratory courses at Astate. Remember that a log book is not just a diary which *summarizes* daily activities. A log book *documents all* of the important details, findings, sketches, and references related to each day's activities.

For engineers involved in product development, the primary purpose and reasons for maintaining a complete log book are that it will serve as evidence to prove inventorship, to establish the date of conception of an invention and reduction to practice, and to show that the inventor has used diligence in advancing the invention to completion. In order for these objectives to be accomplished, the following should be noted:

1. Ideas, calculations, experiments, and tests which may have a bearing on developments should be entered in the log book.
2. All entries should be in ink and should include the project work order, objectives, problems worked on, possible and actual solutions, trade-offs considered, calculations made and tests made (including procedures used). Avoid characterization of tests as "successful" or "not successful" since the facts will speak for themselves.
3. Margins should be maintained in order to provide for ease of reproduction.

4. Each page should be signed and dated on the day of entry with the pages being used in consecutive order.
5. All entries should be periodically and routinely witnessed by at least one witness, preferably two. The witnesses should be persons capable of understanding the entries. The witnesses should endorse each sheet as “read and understood”.
6. Where tests are made or models are constructed or operated, the witness must have observed what was done and not merely read the log book entry. Preferably, the witness should note the following on the document: witnessed tests, read, and understood this page.
7. Do not leave any pages blank. If a page or part of a page must be left blank, draw a line down through the blank portion.
8. Use a log book with bound pages and hard covers such as those that can be purchased from the Astate Bookstore. Do not tear out any pages.
9. Photos, graphs, drawings, and sketches should be used liberally. They must be dated and signed by the owner of the log book and the witness. Preferably, these are inserted in the log book and attached with stapes.
10. If a change is made, draw a line through the original entry and add the new material so as to clearly indicate what the change is and why it was made. Also, note the date when made and who made it. Where possible, make a new entry rather than alter an existing entry.

Samples for a log book cover sheet, a blank log book page for Senior Design I and II, and a completed log book entry are given in Appendix D.

### **Lab Notebooks**

The technical notebook is one of the basic tools for any experimental work, whether it is basic research, product development, or engineering design. It is primarily for the experimenter's own use, but another person with similar technical background should be able to understand and duplicate any experiment, data, and conclusion, or to prepare a technical report by following only the lab notebook details. There are many reasons to keep an accurate and complete record of

experimental work. Among these are

1. To establish the authenticity of the work,
2. To defend patents,
3. To act as a basis for technical reports and articles,
4. To avoid duplication of effort, and
5. To avoid repetition of erroneous procedures.

The nature of the work and the purpose of the experimenter will influence the content and format of the laboratory notebook. Many companies have rigid internal requirements tailored to their specific needs. The notebook format, which is shown on the following pages, should not be interpreted as an "industry standard". Rather, it is intended to suit laboratory work in the College of Engineering courses, particularly Electrical Engineering labs, and provide experience in following an acceptable format. Student notebooks should follow these guidelines unless otherwise directed by the course instructor. The notebook should be bound, never loose-leaf, and the pages numbered consecutively, preferably by the word-processing program being used.

A neat, organized, and complete lab notebook record is as important as the investigation itself. The lab notebook is the record of what was done. A hard lead pencil should be used so that the writing does not smear. Make corrections of any mistakes after making a clean erasure of incorrect text. Neatness is a basic requirement. Each person will keep his or her own notebook even though you might have lab partners.

In industry, lab book entries are expected to be in ink and to be made directly in the notebook as the experiment is done. Also, each entry must be dated and signed. Sometimes engineers may be required to make an entry of no progress made today just to show that work was being done on the



project. If a mistake were made, the error would be “Xed-out” and the entry started over. This leaves the original entry readable and keeps a permanent record of all the work which can be used as evidence in a patent court.

**General Format.** Use all pages and avoid leaving any of them blank or leaving blank spaces on any page. Date and initial each page at the top as it is used. Where possible use the left-hand, even numbered pages for wiring diagrams, sketches, graphs and calculations (placed opposite your text). In industry it is very important to sign and date all work and leave no spaces where additions might be added later in order to preserve the legal integrity of the notebook.

Use the first page of the notebook for a table of contents with a format as shown below.

### TABLE OF CONTENTS

<u>EXP. NO</u>	<u>TITLE OF EXPERIMENT</u>	<u>PAGE</u>
1	Electrical Measurements	3
2	Kirchoff's Laws	9

**Experiment Record Format.** For each experiment, following the seven-part format which is described here. Each experiment is to be started on a new page with the following information at the top of the first page, and each subsequent page. On the first page of each experiment, list the names of any partners that worked on this experiment.

DATE      EXP. NO.      EXPERIMENT TITLE      YOUR NAME

The seven-part format for the experimental record includes the following:

1. Objectives. Briefly state the major goals of the experiment.
2. Preliminary. State the approach to the experiment, that is, how the objectives are to be achieved. This may include a brief summary of theory, a few important equations, and/or a reference to some relevant text.
3. Equipment List and Wiring Diagrams. *Be sure another person can tell exactly how the experiment was constructed.* Include ratings and nameplate data. Identify the device tested and instruments used by some unique method (serial No., inventory No., or other). NOTE: Items 1 through 3 can be completed prior to the lab work if the class is given information ahead of time.
4. Procedure. Give essential details on how the experiment was conducted. DO NOT recopy the hand-out material.
5. Data. This section may be combined with 4 above, so that it appears near the corresponding procedure. Make a record of data taken during the experiment. Tabulate data wherever possible.
6. Calculations and Results. Work out one example for each type of calculation. Start with the equation, then substitute in the values with the correct units, and then calculate the answer. If the same equation must be used repeatedly, tabulate the results. Include percent errors and percent deviations. Be aware of the precision of your data and watch the significant digits of the final results. *Do not round the intermediate calculations, this only adds extra round-off errors.*
7. Conclusions. Write scientific conclusions about the results of the experiment. Base the conclusions on what was actually done, and not on what should have been done. Be factual and concise. *Do not conclude something unless the results actually support that conclusion.* Remember a scientific conclusion is a statement about the behavior of some physical system based on the observation of facts.

**Content Requirements.** The laboratory notebook must answer the following questions in at least one part of the seven-part format.

1. WHAT WAS DONE? This includes the approach to the problem or project, as well as the experimental procedure. If tests are conducted on some device, clearly identify that device and give theoretical or nameplate characteristics. Include wiring diagrams and identify measurement equipment. Another person should be able to repeat the experiment using only the information in the notebook.
2. WHO DID IT? List all members of the lab group, including yourself, at the beginning of the write-up.
3. WHEN WAS IT DONE? It must be obvious to any reader when the experimental work was performed. Date all entries in the notebook. It is possible that a single experiment may have 2 or 3 different dates. Do not leave blank spaces and never "back-date" notebook entries.
4. WHAT WERE THE RESULTS? Data must be distinguished from calculated values. It should be obvious which measuring instrument yielded which data. Examples for each type of calculation must be given. Figures for graphs must have titles and labels, and scales are required for both axes of graphs. Do not "freehand" curves.
5. WHAT DOES IT MEAN? Make observations and draw conclusions *from the results of the work*. Be *precise* and *concise*. Compare the results to the theoretical (give reference). Specifically why are the results believed or disbelieved? Discuss errors relative to the accuracy of the measurement equipment.

The laboratory notebook MUST contain all the information that would be required for anyone to completely reproduce the experiment. For convenience in the lab, record all the data on a data page at the beginning of each experiment. The actual lab report may then follow the data pages. However, as the procedures and results are described, the appropriate data, graphs and calculations MUST be included at the point where they are discussed. Graphs and computer printouts MUST be taped or glued into the notebook at the appropriate point in the description. Figures and tables should be placed such that they can be read from the *bottom* of the page or from the *right hand edge* of the page. When there are questions specifically asked in the lab manual or experiment handout, write the question followed by the answer. The conclusions must include logical

inferences drawn from the observed facts and supported by the observed data. All statements must be complete sentences and be written using correct English grammar and spelling.

Figures must be large enough to be easily read and follow the guidelines presented in Chapter IV of this document. If values are to be interpreted from a graph, then the graph should usually be full-page size. Most graphs should be computer generated. All figures and tables should have appropriate titles and labels. If a figure has multiple curves, each one should be clearly identified. Identifying a curve as "ch1" for an oscilloscope output is not acceptable. It must be clear which physical variable each curve represents. Scales on graphs should be identified including the proper units. The scale increments should be multiples of 1, 2, or 5. One exception to this is scales for angles measured in degrees where multiples of 15, 30, 45, or 90 may be more appropriate. The scale should be adjusted so that few if any leading or trailing zeros are required in the printed scale values. For example, plot in kA, mA or  $\mu\text{A}$  instead of A to fit the range of values to be plotted.

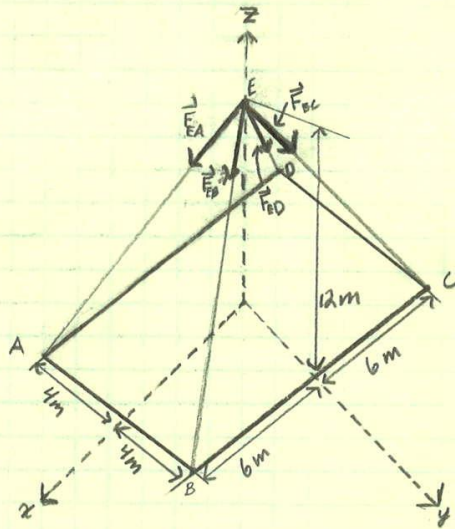
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## APPENDIX A

### Sample Calculations

GIVEN



FIND

EXPRESS EACH FORCE AS A CARTESIAN VECTOR AND DETERMINE THE RESULTANT FORCE

SOLUTION

$A(6, -4, 0)$   $B(6, 4, 0)$   $C(-6, 4, 0)$   $D(-6, -4, 0)$   $E(0, 0, 12)$

$\vec{r}_{EA} = \{6\hat{i} - 4\hat{j} - 12\hat{k}\}m$   $\vec{r}_{EB} = \{6\hat{i} + 4\hat{j} - 12\hat{k}\}m$   $\vec{r}_{EC} = \{-6\hat{i} + 4\hat{j} - 12\hat{k}\}m$   $\vec{r}_{ED} = \{-6\hat{i} - 4\hat{j} - 12\hat{k}\}m$   $r_{all} = \sqrt{6^2 + 4^2 + 12^2} = 14m$

$\vec{F}_{EA} = F \cdot \frac{\vec{r}_{EA}}{r_{EA}} = \frac{F}{r_{EA}} \cdot \vec{r}_{EA} = \frac{29}{14} \cdot \vec{r}_{EA} = 2kN \{6\hat{i} - 4\hat{j} - 12\hat{k}\} = \{12\hat{i} - 8\hat{j} - 24\hat{k}\}kN$  APPLY SAME LOGIC TO ALL OTHER VECTORS...

$\vec{F}_{EB} = \{12\hat{i} + 8\hat{j} - 24\hat{k}\}kN$   $\vec{F}_{EC} = \{-12\hat{i} + 8\hat{j} - 24\hat{k}\}kN$   $\vec{F}_{ED} = \{-12\hat{i} - 8\hat{j} - 24\hat{k}\}kN$

$\vec{F}_R = \vec{F}_{EA} + \vec{F}_{EB} + \vec{F}_{EC} + \vec{F}_{ED} = \{(12+12-12-12)\hat{i} + (-8+8+8-8)\hat{j} + (-24-24-24-24)\hat{k}\} = \{-96\hat{k}\}kN$

$\vec{F}_{EA} = \{12\hat{i} - 8\hat{j} - 24\hat{k}\}kN$   
 $\vec{F}_{EB} = \{12\hat{i} + 8\hat{j} - 24\hat{k}\}kN$   
 $\vec{F}_{EC} = \{-12\hat{i} + 8\hat{j} - 24\hat{k}\}kN$   
 $\vec{F}_{ED} = \{-12\hat{i} - 8\hat{j} - 24\hat{k}\}kN$   
 $\vec{F}_R = \{-96\hat{k}\}kN$

## APPENDIX B

### Sample Progress Report



## MEMORANDUM

**DATE:** October 16, 2013  
**TO:** Dr. R.C. Clift, Mr. David Handwork, Design Team Advisors  
**FROM:** Student Name, Design Team Member  
**SUBJECT:** Progress Report No. 1, August 29, 2013 through October 8, 2013;  
Pedestrian Transport System

### INTRODUCTION

The group was given the task of developing a pedestrian transportation system for the campus of Arkansas State University. The master plan for 2030 shows that many current commuter and faculty parking areas will be the building sites of new academic and residential buildings, providing the university with a new problem to handle such growth. With the current enrollment, the student to parking space ratio is 1.28, which is drastically lower than the 2.8 national average for university campuses. The expected enrollment in 2030 is 30,000 students with an additional 2000 faculty and staff if the student to faculty ratio stays the same at 19:1. With the increase of students and the decrease of current parking spaces, new parking expansion further from the center of campus will be necessary, creating a need for students to move quickly from these points.

The past few weeks have been spent with the group working both collectively and individually on tasks 1-6. The tasks include Develop Proposal, Further Define and Develop Constraints, Brainstorm for Alternative Solutions, Develop Selection Criteria, Narrow Solutions to Four Designs, and Progress Report. Table 1 shows the man hour schedule for the team, and Figure 1 shows the updated Gantt chart for the group.

### ACCOMPLISHMENTS

#### Task 1: *Develop Proposal*

The writing for Task 1 was divided equally among the members into the problem statement, methodology, and project management. Each member prepared their resume. The tables and figures required for the proposal were created by the member completing the corresponding section. Each member completed their portion of the proposal and a group meeting was held to assemble the draft. The title page and table of contents were also created. The draft proposal was then discussed in a group meeting with the project advisors and submitted to Dr. Clift. After the submission, Dr. Clift returned the proposal with suggested changes, and the group members

edited their sections and met to assemble the final proposal. This task is 100 percent complete but required 16 more hours than the estimated 30.

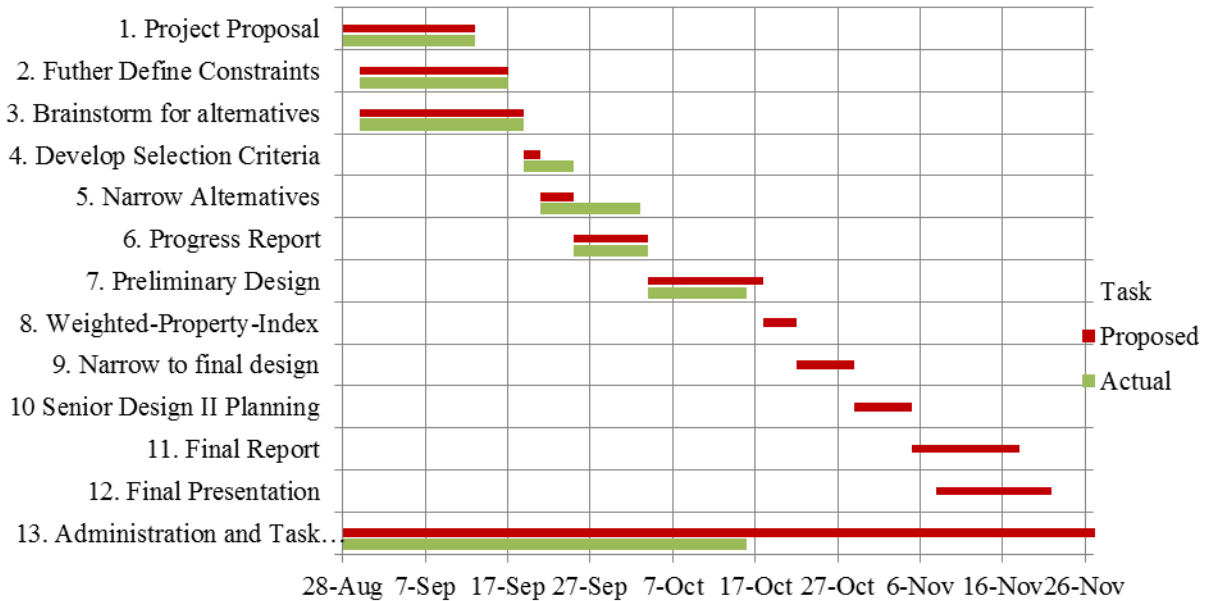
**Table 1. Man Hour Schedule**

Man Hour Schedule					Individual Hourly Breakdown					
No	Tasks	Estimated Hours	Actual Hours	% completed	Estimated Hours Per Person	Actual Hours Per Person	Student No. 1	Student No. 2	Student No. 3	Student No. 4
1	Write proposal	40	56	100	10	14	10	13	20	13
2	Define and develop constraints	12	11	100	3	2.75	3	2	3	3
3	Brainstorm For Alternative Solutions	12	19.75	100	3	4.94	7	4.25	5.5	3
4	Develop selection criteria	4	5.5	100	1	1.38	1	2	1	1.5
5	Narrow Alternative Designs	4	4	100	1	1	1	1	1	1
6	Progress Report	12	10	100	3	2.5	3	3	1	3
7	Preliminary Design	80	9		20	2.25	6		3	
8	Weighted Indices	4	0		1	0	0			
9	Narrow To Final Alternative Design	4	0		1	0	0			
10	Plan For Senior Design II	12	0		3	0	0			
11	Final Report	80	0		20	0	0			
12	Final Presentation	16	0		4	0	0			
13	Administration and Task Management	60	32	50	15	8	8	8	8	8
	Total Man-Hours	340	147.25		85		39	33.25	42.5	32.5
	Total Man-Hours Per Team Member	85								

*Task 2: Further Define and Develop Constraints*

An acceptable design requires the solution to adhere to all constraints. In order to obtain a better understanding of the problem and requirements for design, the group looked over the master plan and constraints relevant to the situation. The group researched requirements of a pedestrian transportation system as well as ADA regulations. Further constraints applicable to the project were also researched, and a list containing all constraints was prepared. Some of the more important constraints included the travel time between stations, continuous run time, access to

resident halls and athletic facilities, and the amount of people the system is able to carry at any given time. This task is 100 percent complete, and the group spent one less hour than estimated.



**Figure 1. Gantt Chart for Pedestrian Transport System**

*Task 3: Brainstorm for Alternative Solutions*

After the constraints were fully defined, the group met to brainstorm for alternative solutions. To begin this process, the group had a meeting and discussed general solutions. The group recorded these ideas and the final list of alternatives included a bike program, bus system, gondola, monorail system, moving sidewalk, shuttle cart, and tramway. During the process of generating ideas, the group followed the rule that a feasible alternative is any solution that solves the problem completely and satisfies all of the constraints.

Once all ideas had been discussed, the group assigned each member several of the ideas for further development. The group members then drafted one-page summaries of each idea which included a description and sketch of the alternative. When this was complete, the group compiled all sketches into one document. Pros and cons of each alternative were compiled to aid later in Task 5. The pros and cons were included in the document to present to the project advisors. This task is 100 percent complete and required 7.75 hours more than expected.

#### Task 4: *Develop Selection Criteria*

The selection criteria were initially discussed in an advisor meeting, and the group obtained some ideas of what to include. The group met later to develop a complete list, and a survey was made and conducted on the campus. The survey was given to 60 people including facility, staff, and students to determine the relative importance of each selection criteria to the survey participants. The survey asked the public to rank the selection criteria on a scale of 1 to 7 with 1 being the most important. A table was made in an advisor meeting in which the data from the survey was analyzed. The four selection criteria that ranked highest by the public were selected, and a fifth criterion, public acceptance, was added by the group to combine several other important criteria.

The top selection criteria were cost, reliability, ease of operation, maintenance, and public acceptance. Cost included the cost of system development and construction as well the total cost of operation and maintenance. Reliability was defined to be the ability of the system to perform and maintain its function at all times. Ease of operation was defined as the time and staff required to manage the daily responsibilities to allow for efficient performance. Maintenance encompasses the staff and skills required to keep the system performing efficiently and to fix the system quickly if problems occur. The public acceptance aspect deals with how environmentally friendly and how aesthetically pleasing the system will be, while allowing for ease of travel between destinations. After defining each criterion, the group developed a list of pros and cons for each alternative for use in the narrowing stage. This task is 100 percent complete and needed 1.5 more hours than originally planned.

#### Task 5: *Narrow Solution to Four Designs*

Task 5 was performed using the “narrowing” technique described in the proposal to narrow the feasible alternatives that were developed during brainstorming. This was done during an administrative meeting. The group entered the meeting with one-page summaries and pros and cons with respect to selection criteria for each alternative. At the end of the process, the alternatives were narrowed to four designs. Table 2 displays the results from the narrowing process.

One alternative was initially chosen as the base for comparing all alternatives. Each alternative was given a value indicating how it compared to the base. A positive value indicated better for the selection criteria, and a negative value indicated worse. The base alternative was assigned a value of 0 for each selection criteria since it is neither better nor worse compared to itself. The four alternatives with the highest score at the end of the narrowing process were a bus system, shuttle cart, moving sidewalks, and bike rental program. This task is 100 percent and was completed within the time specified in the proposal.

**Table 2. Narrowing Alternative Solutions**

Selection Criteria	Gondula	Tramway	Monorail	Bus	Shuttle Cart	Moving Sidewalk	Bike Rental
Reliability	0	0	2	1.5	3	1	2
Cost	0	0	-2	0.5	1.5	1	3
Ease of Operation	0	0	0.5	-2	-2	3	-1
Maintenance	0	0	0.5	1.5	2	1	3
Public Acceptance	0	0	0.5	3	2	0.5	2.5
Sum Total	0	0	1	5	6.5	6.5	9.5

*Task 6: Progress Report*

For Task 6, each member was required to create a progress report summarizing all completed work on the project. The progress report included future plans for the design process and any problems encountered. This task is 100 percent complete while requiring two less hours than estimated.

*Task 13: Administration and Task Management*

This task takes place throughout the duration of the project. This task included the weekly meetings the group had with project advisors and log book entries that document all work completed on the project. This task is approximately 50% complete.

**FUTURE**

Future plans for the project include completing tasks 7-13 in the design process. During task 7, each member will complete a preliminary design of one of the four alternatives determined from the narrowing process. When the preliminary designs are completed, the selection criteria will be weighted in Task 8. Using these weighted selection criteria, the preliminary designs will be narrowed to one final design in Task 9. Task 10 will be used to plan fabrication and testing for

Senior Design II. The final report and presentation will be prepared in Task 11 and 12 and Task 13 continues weekly as it has been throughout.

## **PROBLEMS**

The group has not encountered many problems at all. Group meetings have been easily set up and all members have been present. David Handwork has not been able to attend advisor meetings regularly due to his work schedule and advisor meeting times have change throughout the process, but this is not a problem, and the team keeps having full attendance from members. The team has had effective communication and production thus far. Preliminary designs will be completed October 31<sup>st</sup> which is one week behind schedule, so the team needs to put in extra time later to make up for this delay.

APPENDIX C

Sample Laboratory Report

ENGR 2421-002

Electrical Circuits I Lab

ASU College of Engineering

Lab Exercise 2

[Name of Experiment]

[Student Name]

Experiment performed on: September 9, 2013

Report submitted on: September 11, 2013



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## 1.0 INTRODUCTION

### 1.1 Background

In 1862, Gustav Robert Kirchhoff developed two theories in electrical engineering involving electrical circuit theory. He proved what he called Kirchhoff's laws that were derived from Maxwell's equations to show how current and voltage act in a circuit. Kirchhoff's Current Law (KCL) states that the sum of the currents in all paths leading into or out of a node will be zero [1]. This is shown mathematically in Equation 1.

$$\mathbf{i}_1 + \mathbf{i}_2 + \mathbf{i}_3 + \dots + \mathbf{i}_n = 0 \quad (1)$$

where:

$$\begin{aligned} \mathbf{i}_1 &= \text{Current in 1}^{\text{st}} \text{ path} \\ \mathbf{i}_2 &= \text{Current in 2}^{\text{nd}} \text{ path} \\ \mathbf{i}_n &= \text{Current in n}^{\text{th}} \text{ path} \end{aligned}$$

Kirchhoff proved another law for any closed loop which states that the sum of voltages around the loop in either a clockwise or counter-clockwise fashion will be zero. This statement can be expressed mathematically as shown below in Equation 2.

$$\mathbf{v}_1 + \mathbf{v}_2 + \mathbf{v}_3 + \dots + \mathbf{v}_n = 0 \quad (2)$$

where:

$$\begin{aligned} \mathbf{v}_1 &= \text{Voltage across 1}^{\text{st}} \text{ path} \\ \mathbf{v}_2 &= \text{Voltage across 2}^{\text{nd}} \text{ path} \\ \mathbf{v}_n &= \text{Voltage across n}^{\text{th}} \text{ path} \end{aligned}$$

### 1.2 Purpose

The purpose of this lab exercise is to use and illustrate Ohm's law along with Kirchhoff's current and voltage laws. In doing so, a better understanding of the theory behind Kirchhoff's laws should be acquired as well as how to apply the laws to real circuits in order to obtain experimental data. A further understanding of how to take basic electrical measurements should also be obtained.

## 2.0 METHODOLOGY

### 2.1 Equipment

The following equipment was used in the lab in order to obtain the original data:

<u>Digital Multimeter (DMM):</u>	EXTECH 3822, SER#:M99009902
<u>Adjustable DC Power Supply:</u>	Hewlett Packard E3630A Triple Output DC Power Supply SER#:KR51307144
<u>Circuit Bread Board:</u>	Elenco Digital/Analog Trainer Model: XK-150, SER#: NA
<u>Resistors:</u>	10 k $\Omega$ $\pm$ 5%, 18 k $\Omega$ $\pm$ 5%, 33 k $\Omega$ $\pm$ 5% (for Circuit 1) 820 $\Omega$ $\pm$ 5%, 1.5 k $\Omega$ $\pm$ 5%, 2.7 k $\Omega$ $\pm$ 5% (for Circuit 2)

### 2.2 Procedure

For this lab, all resistors were small carbon-film resistors. The theoretical resistance values for the resistors were verified based on band color from a website that was accessed through Dr. Engineer's home page. After the resistors were verified by color band, the resistance values were measured with the digital multimeter (DMM). The values measured by the DMM were then compared to the theoretical values to check if the resistors fell within the  $\pm 5\%$  range as specified. The percent error between theoretical and actual resistance was calculated by using equation 3.

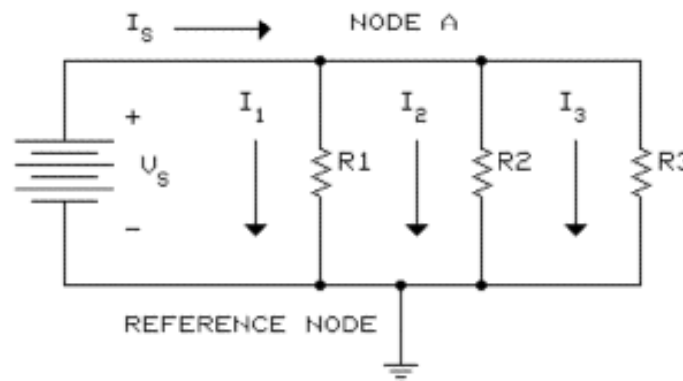
$$\left| \left( \frac{\text{measured} - \text{theoretical}}{\text{measured}} \right) * 100 \right| = \% \text{ error} \quad (3)$$

Table 1 shows the theoretical, measured, and percent difference for the respective resistors. As can be seen in Table 1, the resistors were well within the  $\pm 5\%$  range specified by the band color (gold) on the resistor. After the resistors were verified, the next process was to set up the power supply for the experiment. Since this experiment was performed immediately after experiment 1, the voltage output from the adjustable DC power supply was not verified again with the DMM.

**Table 1**  
**Resistor Values**

Theoretical (kΩ)	Measured (kΩ)	% Difference
10.00	9.91	0.91
18.00	17.77	1.29
33.00	32.67	1.01
0.820	0.86	1.74
1.50	1.49	0.94
2.70	2.68	0.75

The first circuit for this experiment was setup using the adjustable DC power supply as the 16 V DC voltage source ( $V_s$ ) along with three resistors, 10 kΩ ( $R_1$ ), 18 kΩ ( $R_2$ ), and 33 kΩ ( $R_3$ ), in parallel with the source. Figure 1 shows the schematic of the circuit.

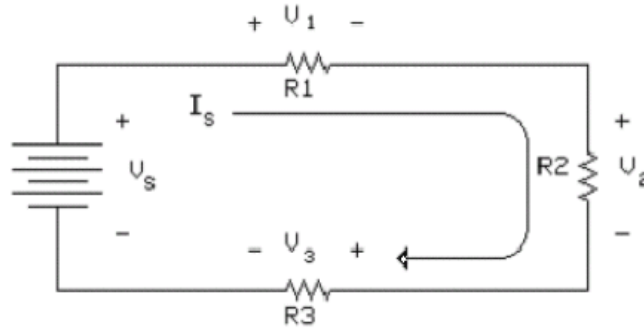


**Figure 1 Circuit 1 Schematic**

In order to measure the desired currents, one end of resistor  $R_1$  was removed from the circuit, and the DMM was attached in series with the resistor in the circuit. The measured current value was recorded and the resistor was placed back in the circuit. This was repeated until all three resistors had a recorded value for their respective current.

The actual voltage across each resistor in circuit 1 was also desired in the experiment for calculation of current values. Since voltage across a parallel circuit is the same, measuring the voltage for each resistor was not necessary. Thus, the voltage across each resistor in circuit 1 was the same as the output voltage from the power supply which was 16 V DC.

In the second circuit, the power supply once again acted as the voltage source except this time it was set to create 18 V DC. The same three resistors were used in the circuit, but this time they were all placed in series with the voltage source. The schematic for the circuit is shown in Figure 2.



**Figure 2 Circuit 2 Schematic**

In order to measure the desired voltages, it was necessary to measure across each of the resistors in the circuit with the DMM. This process was repeated until the voltage across each resistor had been measured and recorded. The source current was obtained by breaking between  $R_3$  and the common in the circuit and placing the DMM in series between the break. Because this is a series circuit, this was the only current that needed to be obtained. Using the current and the values of the resistors, the theoretical voltage across each resistor was calculated and compared to the measured value from the DMM.

### **3.0 RESULTS AND DISCUSSION**

This lab was divided into two tasks. The first task was to show an understanding of Kirchhoff's Current Law (KCL). A parallel circuit was given, and the task was to evaluate the circuit by comparing theoretical and measured current values. The second task was devoted to Kirchhoff's Voltage Law (KVL). A series circuit was given, and the task was to evaluate the circuit by comparing theoretical and measured voltages.

Table 2 lists the values of measured and calculated current for all three resistors in circuit 1 along with the percent difference between the two.

**Table 2**  
**Measured and Calculated Current Values**

Resistor Value	Measured Current	Calculated Current	% Difference
10 K $\Omega$	1.61 mA	1.6 mA	0.9
18 K $\Omega$	0.90 mA	0.88 mA	1.3
33 K $\Omega$	0.49 mA	0.48 mA	1

Table 3 shows the measured and calculated voltage values along with the percent difference for the voltage values.

**Table 3**  
**Measured and Calculated Voltage Values**

Resistor Value	Measured Voltage	Calculated Voltage	% Difference
10 K $\Omega$	2.95 V	2.95 V	0
18 K $\Omega$	5.37 V	5.31 V	1.18
33 K $\Omega$	9.85 V	9.74 V	1.18

The data in Tables 2 and 3 show that both KCL and KVL are viable tools in circuit analysis. In regards to the percent difference, there are several factors that should be considered. One source of error for the KCL evaluation was voltage source drift from the initial set value. Another source of error was the percent difference for the resistor values. The  $\pm 5\%$  tolerance on the resistors gave some propagation error to the total value. Probably the biggest source of error is the human factor. The difference in applied pressure when trying to measure a value can add to the total error. One way to help diminish the human error is to use spring clips to give a more consistent pressure during measurements. Another way to improve the percent difference is to periodically check the voltage source to ensure that it has not drifted from the set value.

#### **4.0 CONCLUSIONS**

With reference to question 1, all measured data was within the required tolerance of  $\pm 0.5\%$  of the DMM. However, the amount of difference because of the DMM could add to why some of the values for current, resistance, and voltage were different when measured and

theoretically calculated. With reference to question 2, the differences between the measured and calculated values for the resistors were within the tolerance of  $\pm 5\%$ . Most of the differences between the theoretical and measured were minimal and could be due to many factors including impurities in the material and the DMM used for measurement. Finally, with reference to question 3, the differences between the measured voltages and calculated ones were all within the tolerance of  $\pm 1.5\%$ . Once again, the voltage calculation that did not fall within the tolerance could be due to such factors as the tolerance of the DMM, the tolerance of the resistor, and the human error involved in the process.

### **LIST OF REFERENCES**

1. Hayt, W.H., Kemmerly, J., and Durbin, S., *Engineering Circuit Analysis*, 8th Edition, McGraw-Hill, 2008.

**APPENDIX D**

**Sample Log Book Forms**



ARKANSAS STATE UNIVERSITY

COLLEGE OF ENGINEERING

PROJECT: \_\_\_\_\_

\_\_\_\_\_

ENGINEER'S LOG BOOK

NAME: \_\_\_\_\_

MAJOR: \_\_\_\_\_

FROM \_\_\_\_\_ 20\_\_ TO \_\_\_\_\_ 20\_\_

This book is intended to be used for recording ideas, calculations, experiments, tests and other data related to experimental, developmental, research or engineering work.

GRADING

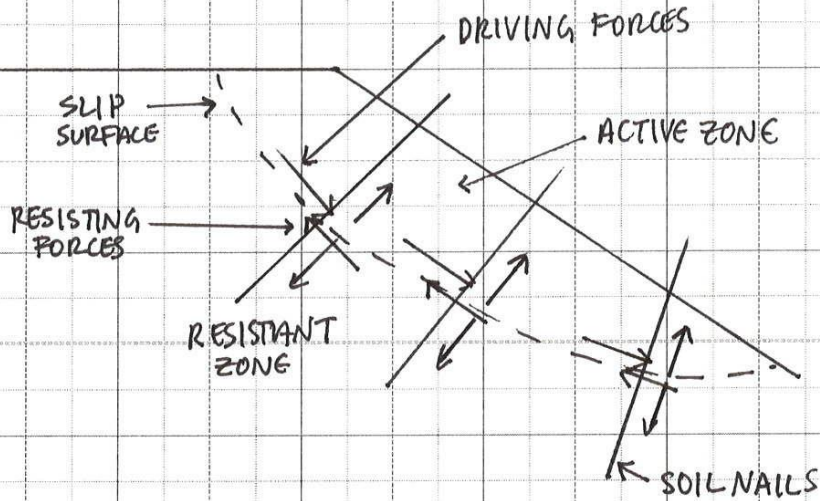
<u>FACULTY ADVISOR</u>	<u>GRADE</u>	<u>DATE</u>



Name Student Name	Date 2/8/11	Task #3	Start: 11:45	Hours
			End: 12:30	0.75

- CONTINUATION OF READING THROUGH INFORMATION FOUND ON 2/7/11

### SOIL NAILING IN A LANDSLIDE



- PROS:
- CAN BE USED IN TIGHT + IRREGULAR PLACES
  - LESS TRAFFIC OBSTRUCTION + IMPACT ON SURROUNDING AREAS
  - ELIMINATES TIME + EXPENSE OF USING PILES
  - REDUCES RIGHT-OF-WAY REQUIREMENTS

- CONS:
- SOIL MIGHT BE OVEREXPOSED PRIOR TO INSTALLATION OF NAIL
  - SOILS MAY NOT BE COMPATIBLE FOR NAILING
  - NAILING IN SENSITIVE SOILS + EXPANSIVE SOILS FOR PERMANENT LONG-TERM APPLICATIONS IS NOT RECOMMENDED
  - SHOULD NOT BE USED W/ CLAYS

Witness Oldom

Date 2-8-11

Witness JAMES MORRIS

Date 2/8/11