**Experiment Type: Materials**

**Writing Tips**

* Writing tips – and often graphics tips – follow each section, sometimes on a separate page.
* Use the Tips to remind you of information covered in class or the text.
* Remember to delete the blue boxes after you use them.
* When you are done, make sure your final version is clean. Under the Review tab, click the down arrow under “Accept” and then chose “Accept All Changes and Stop Tracking.”  Be sure to “save” this version. Your final report should be free of any mark-ups or comments.

**NOTE to REVIEWERS**

This template was developed by Celeste Flores and Mary McCall and is based on:

Lab report formats used by DetroitMercy instructors:

* Jim Lynch / Mostafa Mehrabi / Yasha Parvini / Mark Schumack / Jonathan Weaver
* Sigrid Streit (English)

Research into resources provided by other universities and professional associations:

* Boston U / Ohio U / Penn State / U Alabama / U Minnesota
* Wentworth Institute of Technology
* American Society for Mechanical Engineers (ASME)

**Your Name(s)** [use alphabetical order by last name if a group project and add the sections written by each student – see the next page for an example]

**Name of Course**

**Laboratory Section**

**Date**

**Writing Tips: Lab Reports**

* Purpose: You are learning to write lab reports that will be acceptable in an industry setting. Since your report will provide a complete and permanent record of the experiment, it must be thorough, credible, and professional.
* The best lab reports demonstrate the science behind certain engineering choices, which is why your results have to be reliable and repeatable. Well-supported and explained results build credibility for the report, the experiment and the author.
* Audience: Your reader may be technically proficient (a subject matter expert [SME] or a technician) or an executive (some knowledge of the work, but not an SME).

**Formatting Tips: Title and Report Pages**

* Use Calibri for report heads and subheads.
	+ Use UC for MAIN heads, and U&LC for Subheads.
	+ Click on the sample for font sizes.
* Use 12 point Cambria for text.
	+ Line spacing for text: Use single spaced, as is common in professional reports.
	+ Indents: Use 5-space indents for all paragraphs in the document.
	+ Skip lines between paragraphs and subsections for easier reading.
	+ Margins: Use a ragged right margin vs. justified to avoid white gaps in the text.
* Use a two-part title, as noted. Titles use initial capital letters and Calibri 24 pt. boldface font.
* Keep your report title to a maximum of three lines.
* Formatting student names and authorship for group reports:
	+ Angelo, Mark (Introduction, schematic and Appendix A)
	+ Carpenter, Suzanne (Abstract, line graphs, Conclusion)
	+ Harper, Leslie (Lab Set-up and Procedures, References)
	+ Etc.

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**Writing Tips: Table of Contents**

* You will find the Table of Contents formatting function under “References” on the Word Toolbar.
* In this Lab Report template, Appendix A is Instructions, while Appendix B is Sample Abstract and Abstract C is Sample Graphics and Equations.
* In your report, use Appendix titles that describe the contents of your appendices.
* Each section starts on its own page.
* Double check—on the Final Draft—that the pages in the Table of Contents are listed correctly and use the same language as in the text.
* Be sure to delete all the Writing Tips after you have used them.

# **ABSTRACT**

This is a summary that tells the reader what the experiment was about, what was done, and what conclusions were drawn. It should be no longer than 250 words and include the following points in paragraph format:

* Goal of your experiment (Intro)
* A very brief explanation of how you went about conducting your experiment (Procedure)
* What you found in your experiment (Results) [Quantitative results and their uncertainties should be included when possible.]
* Any experiment uncertainties, such as experiment errors and/or future avenues of inquiry (Discussion)

A sample abstract is shown in Appendix B.

**Writing Tips: Sections and Style**

* Reminder: The Abstract is for the busy executive who may not read the entire report. Your job is to present all the key ideas as briefly as possible. Try re-using the topic sentences from each section of your report as a starting point for your Abstract.
* Write in the third person (objective) throughout the report ex., “The materials were tested...”
* Watch your verb tenses:
	+ Reserve the **Past Tense** for all writing about the experiment *that has already happened.* Ex., “The hardness test **was conducted** using the Brinell Hardness Tester.”
* Use the **Present Tense** for writing about *results* and your *general discussion* of the experiment.

Ex.,“The Rockwell hardness test results **compare** favorably to those reported in ....” (results)

Ex., “Because the Rockwell Hardness tester **uses** electronic calibration....” (general discussion)

***Usually the tenses are as noted: Abstract=past, Intro=present, Procedures=past, Results and Discussion=present, Conclusion=past tense.***

* **For ease of writing**, write the Report in the following order: Lab Procedures and Set-Up, Results and Discussion, Intro, Conclusion, and then the Abstract. Don’t forget your Title page, Table of Contents, and References.

# **INTRODUCTION**

This section captures why the experiment was done and ties it to similar experiments done in the past to help explain your results. This is why you present research done by others.

To set the stage for your experiment, include more details than in your Abstract. Subheads typically include:

* Background/Theory of the experiment. Include References. On average 5-6 references per lab: Handbooks or Websites for equations, etc.
* Purpose of the experiment.
* Importance of the experiment (you may indicate what the specimens are commonly used for in industrial applications). Ex., “The Bernoulli Equation is one of the fundamental relations in fluid mechanics and is regularly used by practicing engineers in a host of applications.”
* Governing equations (refer to the instructor’s handout) and be sure to use MS Equation Editor for all your equations.
* Inquiry Question—what you are trying to determine (refer to the instructor’s handout).

**Writing Tips: Introductions**

* Be concise. Wordiness will detract from your meaning, not add to it.
* Use Subheads to guide the reader through the text and to introduce new topics. Include two skip lines before a Subhead and one skip line after.
* You must have at least ***two*** subheads under a heading to separate your material in this manner; otherwise, address the information within the section heading.
* Be sure to use ASME style for in-text citations.
* Use diagrams, graphs, charts, and tables. Engineering requires the use of both writing and graphics. Consider it telling a story through graphics that you connect by narrative sentences.
* Do not embed a graph, figure, table, or equation within a paragraph. They need their own space. Set them off with skipped lines before and after.
* See **SAMPLE** of incorporated Equations included in Appendix C.

**Equation Tips:**

* Remember to introduce equations in the text before you present them.
* Include a citation for an equation’s source in the body of the text where the equation is first mentioned [#].
* Equations must be labeled and numbered. When used within a line, they are labeled as “Eq. (1)” and so on sequentially throughout the paper. If the reference to an equation begins a line, it should be spelled out, ex., “Equation (1) shows ....”
* Do not include actual calculations within the body of the text—it is confusing to your reader. Use variable format in the body of the text and keep your actual numerical calculations for the appendix.
* When in variable form, equations are offset and labeled, “Eq. (1)” (justified right margin). See **SAMPLE** included in Appendix C.
* NOTE: In addition to the MS Equation Editor, you will find a helpful handout called “Fundamentals of MS Excel Tips” on the ME Technical Writing webpage at [www.engineeringessentials.com/writing](http://www.engineeringessentials.com/writing).

# **LAB SET-UP AND PROCEDURES**

 This section captures how you used the equipment to test your specimens. Discuss how you answered your inquiry question. Clearly explain how you conducted your experiment so that your results can be duplicated, either by yourself or a reader, to verify your findings. One important way to present numerical results is to show them in figures, tables, graphs, sketches, and photos. In this section, you will use schematics and photos. Tips on graphics begin below with graphing tips on page 10.

These are common subheads in this section:

## Set-up

* Refer to the handout your instructor provided at the beginning of the experiment.
* Name all specimens, the equipment, and the manufacturer and include all serial numbers.

## Procedures

* This section is NOT a set of instructions. Rather, it briefly describes how you used the equipment to test the samples and any significant features of the apparatus (ex., it was electronic vs. manual). The information you provide here should be brief, but complete enough so that an engineering peer could repeat your experiment. Where relevant, present a schematic of the test set-up and supplement it with photos taken of the actual set-up.
* You must report any deviations from expected procedures or equipment performance.

**Writing Tips: Procedures**

* Write out numbers with words when referring to a quantity of something like “three machines or three samples.” When referring to results or weight, use proper numbers like “11 kg.”
* Use transitions between ideas and sections.
* Re: schematics. Do not submit hand-drawn schematics of test set-ups. Use software to create the graphic or use a photograph. Remember to use call-outs to label the parts of the schematic.

# **RESULTS AND DISCUSSION**

This section is a description of your specific findings – not the expected findings as indicated by already published research. Keep your audience in mind, explaining and interpreting the results in the level of detail needed. Present your results using tables, graphs and equations and be sure to refer to them frequently in the text. Address the difficulties that you had and how they could be avoided in the future. You need a minimum of two subheads here:

## Experimental Data and Analysis

* Tell your reader your results using narrative first, then tables, graphs, figures, and equations.
* Refer to the questions provided by the instructor. What were the key ideas your experiment needed to address?
* Be sure to note any experiment difficulties. A discussion of errors and their causes is always useful as it provides context for your results.

## Data Discussion

Share your final results having factored in the initial expectations and any errors. Often, the data obtained during the experiment is used to calculate other quantities.

* This is the transition to the Conclusion, which follows.

**Writing Tips: Results**

* There is no need for introductory information here. Get to the point, and share your results. Ex., “Efforts to find the tensile strength for cast iron and steel generated the results shown in Fig. 5 and Fig. 6, respectively.”

**General Graphics Tips**

* Before writing, decide which data is best displayed graphically and which in text.
* Be sure to refer to the graphic in the text before presenting the graphic. Ex., “The initial question was to determine the stress and strain of the steel and cast iron specimens shown in Fig. 1.” (If a reference to a figure begins a sentence, the word figure should be spelled out, ex., “Figure 1...”.) Then Figure 1 will be placed close to where you refer to it and have a clear title. Ex., “Figure 1: Steel Sample (top) and Cast Iron Sample (bottom).” DO NOT separate the discussion of your figure from its graphic.
* Use Calibri (11 pt. font) for titles and graphic captions to distinguish them from the report text, which uses Cambria.
* Use white space to make your tables, figures, graphs, and equations easy to read.

**See more tips on graphics on the next page with graphing tips on page 11.**

**General Graphics Tips (continued)**

* Keep all parts of the graphic together (DO NOT split figures or tables between pages). If needed, start the graphic on a new page to keep it together.
* Include units of measurements with all numbers (ex., 11 kg or 7,500 psi).
* Similarly, keep all numbers and their units of measure on the same line (ex., 25 mm, 13 cycles, ¼ inch). ASME style leaves a space between the number and the unit.
* Lists of repetitive information may be presented in a table, but the table must be explained.
* DO compose titles for figures and tables that are **informative** (can be complete sentences, with more than one line of text when necessary) and show your results.
* **Figure and Graph Titles** ALWAYS appear BELOW the graphic. Be sure to number them sequentially beginning with 1 through the end of the report (figures and graphs in appendices are labeled separately). Skip a line between the figure and its title. Center the title.
* **Table Titles** ALWAYS appear ABOVE the graphic. Be sure to number them sequentially beginning with 1 through the end of the report (tables in appendices are labeled separately). Table headings appear above tables so that there is room underneath them to note unusual details in the footnotes. Skip a line between the table and its title. Center the title.
* Be sure all your tables have headings for each column and your figures and graphs have labels for both axes.
* Include equations in variable form (see Appendix C).
* See **SAMPLES** of figures, graphs and tables included in Appendix C.

**See more tips on graphing on the next page.**

**Graphing Tips**

* Do NOT rely on different colors to distinguish between different series (your report may be photocopied in black and white).
* DO identify different curves with a legend or callouts.
* Do NOT provide a legend for a plot with only one data series (warning: Excel will provide this automatically, so if you have only one series, delete the legend).
* Do NOT use grid lines (unless you have a particular reason to do so).
* In Excel, DO use the “scatter” chart for graphing experimental data. Only use the “line” chart if you are showing data that requires categories along the horizontal axis.
* DO include points and lines on graphs:
	+ Do NOT connect data points with straight line segments unless there is significance to the straight lines.
	+ If you’re going to draw a curve to fit the data (a “trendline” in Excel), identify the fitted curve on the graph.
	+ DO remove extraneous data points that clearly come from noise.
* DO include, if appropriate, a measure of uncertainty on your graphs (for example, error bars).
	+ Do NOT show individual error bars for points on a graph **when doing so would crowd the plot and obscure the data points** (instead, use few representative error bars or use labeled lines that show the range of uncertainty).
* DO use axis labels, tick marks, and divisions to indicate units in labels (in parentheses).
	+ DO use proper subscripts and symbols in labels if required.
* DO consider whether to start your vertical axis at zero or another number. For instance, if your data really starts at 10,000, consider using what is called a “suppressed zero.” You will need to indicate that to the reader. List zero and then insert an axis break (2 parallel bars on a slant ⸗). This broken axis symbol indicates some of the increments on the scale have been left out. This technique helps you create a more readable graphic because numbers and text can be larger.

# **CONCLUSION AND RECOMMENDATIONS**

This section states only conclusions that can be verified by data from the experiment. While the “Results and Discussion” section reported the particular results of your experiment samples, your “Conclusion” will discuss these results and their significance in a broader research context. Offer your observations in the body of the report – use the Conclusion to describe the “take-aways” based on evidence.

Include two subheads for this section:

## Conclusion(s)

* State what your conclusions are after conducting the experiment.
* Answer the Inquiry Question you posed in your Introduction.
* Show key results.
* List errors you discovered during experimentation.

## Implications for Further Study

* Suggest future ideas for study. If you don’t have recommendations for further study, drop this sub-section and don’t use subheads for this section.

**Writing Tips: Conclusion**

* This is the most important section of your report because it tells your reader the implications of your experiment and possible next steps. It answers the questions: Are the results reliable? and What decisions can we make based on this data?
* Make your Conclusion brief and write in clear, concise sentences.
* Conclusions are *related* to the Results and Discussion portion of your report, but whereas your Results and Discussion section deals with the specifics of the experiment, your Conclusion deals with the experiment’s underlying general principles. Ex., either steel is more brittle or iron is. That means either steel is better for Application A or iron is.
* Edit for clarity, conciseness, organization, and attention to audience.
* Group Report Edits: During group lab reports, blend multiple author styles into a single voice (students can upload their assigned sections to One Drive, and a selected student will edit the sections into a coherent whole). This task should be shared throughout the semester.
* Proofread carefully.

# **REFERENCES**

Place all sources here and use The American Society of Mechanical Engineers (ASME) style.

You can find ASME citation resources on the course BlackBoard site, the ASME site (<http://www.asme.org/shop/proceedings/conference-publications/references>), and the University of Missouri at <https://libraryguides.missouri.edu/mae/asmecitation>.

For example:

[#] Lastname, F. M., Lastname, F. M. and Lastname, F. M., Year of Publication. *Title of Book.* Publisher, City, ST or City, Country of publication.

[1] Stalnaker, J. J. and Harris, E. C., 1980, *Structural Design in Wood*. Van Nostrand Reinhold, New York. (book)

[2] Wright, W. J., Fulay, P. P., and Askeland, D. R., 2010, “Title of Chapter 5,” *The Science and Engineering of Materials*, 6th ed. Chegg Books, Santa Clara, CA, pp. xx-xxx. (chapter in a book)

[3] Green, D. W., Winandy, J. E., and Kretschmann, D. E., 1999, “Chapter 4: Mechanical Properties of Wood,” *Wood handbook—Wood as an engineering material*. Forest Products Laboratory, Gen. Tech. Rep. FPL–GTR–113. U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, WI, pp. 4-1- 4-45.

<https://www.fpl.fs.fed.us/documnts/fplgtr/fplgtr113/ch04.pdf> (handbook)

**Writing Tips: References**

* Keep a list of your sources as you use them.
* Remember, ASME uses a number vs. alphabetical order listing for References.

**In-text Citations:**

* References should be cited in numerical order according to their order of appearance and the author should be named.
* The numbered reference should be enclosed in brackets [1]. “**I**t was shown by Prusa **[1]** that the width of the plume decreases under these conditions.”

**References:**

* ASME style lists references by number and then includes all authors by last name then First Initial and Middle Initial. Ex., Smith, J. A.
* Use n.d. if no dates are available.

# **APPENDIX A: Instructions for Appendices**

Before you begin to write your lab report, you must make decisions:

* what information is best displayed in text format?
* what information is best displayed graphically?
* what information is critical to the reader’s understanding of the project – and which can be offered as supplemental material in an appendix?

Appendices are particularly useful when you have a mixed audience. The primary reader might be an executive, while the secondary reader is an SME (Subject Matter Expert) who will appreciate the additional data you provide in an appendix.

Your first appendix is titled Appendix A: Topic of Appendix. Your second appendix is called Appendix B: Topic of Appendix, and so on. If you include graphics in your appendix, label them as Figure A-1, Figure A-2, Table A-1, Table A-2, and so on. Label graphics in Appendix B in the same way, Figure B-1, Table B-1, and so on.

Note that each appendix begins on a new page. Also note that each appendix should be introduced somewhere in the text portion of the report. Ex., “Detailed lab results are provided in Appendix A on page x.”

**Writing Tips: Appendices**

* Note the different size fonts in the header.
* Remember: The singular is appendix, but the plural is appendices.

**APPENDIX B: Sample Abstract from Lab Report: Uncertainty Analysis**

**ABSTRACT**

 The conservation of mass was applied to a centrifugal blower. The mass flow rates of air at the inlet and outlet were determined from measurements of area, pressure, temperature, and air speed. The ideal gas law was used to determine air density. Uncertainties with single-point and multiple-point measurements were determined, and then used to report the inlet and outlet mass flow rates as ranges. The mass flow rate at the inlet was determined to be 0.25 ± 0.02 kg/s and that at the outlet was calculated as 0.31 ± 0.04 kg/s, implying that mass was, indeed, conserved.

# **APPENDIX C: Sample Graphics and Equations**

## Sample of Figure and Title

“The equipment schematic in Fig. 1 shows…” (this is the text lead-in)



**Figure 1. Schematic of blower showing measured dimensions**

## Sample of Table and Title

“As seen in Table 1, all measurements…” (this is the text lead-in)

**Table 1. Single-point measurements and uncertainties**

|  |  |  |
| --- | --- | --- |
| **quantity** | **measurement** | **uncertainty** |
| pressure, *p* (kPa) | 102.3 | ± 0.1 |
| temperature, *T* (°C) | 23.6 | ± 0.1 |
| diameter, *D* (cm) | 13 | ± 0.1 |
| height, *H* (cm) | 13.2 | ± 0.1 |
| width, *W* (cm) | 10.6 | ± 0.1 |

## Sample of Graph and Title

“The calibration of the drag sensor and the equation of the best-fit line and R-squared value are shown in Fig. 2.” (this is the text lead-in)



**Figure 2. Calibration of the drag sensor. The equation of the**

**best-fit line and R-squared value are also shown.**

## Sample of Incorporating Equation Description and Variable Form into the Text

The conservation of mass [1] for a control volume is: (this is the text lead-in)

$$\frac{dm\_{CV}}{dt}= \sum\_{}^{}\dot{m}\_{in} - \sum\_{}^{}\dot{m}\_{out} Eq. 1$$

where *mCV* is the mass of air inside the control volume and $\dot{m}$ is mass flow rate. Assuming steady flow, and recognizing the blower has a single inlet and outlet, Eq. (1) reduces to:

$$ \dot{m}\_{out}= \dot{m}\_{in} Eq. 2$$

The mass flow rate can be expressed as:

$$ \dot{m}= ρVA Eq. 3$$

where *ρ* is fluid density and *V* is the average velocity across the cross-sectional flow area *A*. The air density for this experiment was determined using the Ideal Gas Equation from measurements of pressure and temperature:

$$ρ= \frac{p}{RT} Eq. 4$$

where *p* is the absolute pressure, *R* is the ideal gas constant, and *T* is the absolute temperature. Substituting this expression for density into Eq. (3) leads to the following expressions for (circular) inlet and (rectangular) outlet mass flow rates:

$$\dot{m}\_{in}= \frac{p}{RT} V \frac{πD^{2}}{4} Eq. 5$$

$$\dot{m}\_{out}= \frac{p}{RT} VHW Eq. 6$$

Uncertainties for the mass flow rates were estimated using the following formulas for the inlet and outlet (see reference 2 for an explanation of these formulas):

$$ u\_{\dot{m}\_{in}}= \left[\left(\frac{∂\dot{m}\_{in}}{∂p}u\_{p}\right)^{2}+ \left(\frac{∂\dot{m}\_{in}}{∂T}u\_{T}\right)^{2}+\left(\frac{∂\dot{m}\_{in}}{∂V}u\_{V}\right)^{2}+ \left(\frac{∂\dot{m}\_{in}}{∂D}u\_{D}\right)^{2}\right]^{1/2} Eq. 7$$

 $ u\_{\dot{m}\_{out}}= \left[\left(\frac{∂\dot{m}\_{out}}{∂p}u\_{p}\right)^{2}+ \left(\frac{∂\dot{m}\_{out}}{∂T}u\_{T}\right)^{2}+\left(\frac{∂\dot{m}\_{out}}{∂V}u\_{V}\right)^{2}+ \left(\frac{∂\dot{m}\_{out}}{∂H}u\_{H}\right)^{2}+ \left(\frac{∂\dot{m}\_{out}}{∂W}u\_{W}\right)^{2}\right]^{1/2} Eq. 8$

where *u* is measurement uncertainty.

The objectives of this experiment are to gain experience with uncertainty analysis and practice with identifying sources of error and their anticipated effects on results.

Note: The discussion of this equation was split over two pages – but the break occurred between text explanations, not between the equation itself.