

MSE 404 CP – Ceramics Processing Laboratory

Instructor: Laura Nagel
Teaching Assistant: Lawrence Anderson
216-217 Ceramics Building, Monday and Wednesday 2:00-4:50 pm
August 21 – October 13, 2023

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Office Hours: By appointment
Course Website: <https://canvas.illinois.edu/courses/39423>

Text and References (not required):

1. M. N. Rahaman, *Ceramics Processing*, CRC Press, Taylor & Francis Group: New York (2007)
2. W. D. Kingery, H. K. Bowen, D. R. Uhlman, *Introduction to Ceramics*, 2nd Ed., Wiley: New York (1976).
3. Y.-M. Chiang, D. Birnie, III, W. D. Kingery, *Physical Ceramics*, Wiley: New York (1997).

Prerequisites

This course assumes students are working at the senior level in engineering coursework. MSE 307 and 308 or equivalent lab experience is required.

Class Description and Objectives

The objective of this course is to provide students with an understanding of ceramics properties and processing. This course is a practical, hands-on extension of the topics covered in MSE 420 and 421 and will include experiments covering a range of modern ceramic processing methods. These experiments are designed to highlight the relationships between raw materials, processing methods, microstructural development, and physical properties in the diverse class of materials known as ceramics. This laboratory-based practical experience emphasizes the development of an understanding of the underlying physics and chemistry of processing and the design of processing routes to achieve the desired material properties. This will be accomplished through small-group laboratory exercises and written reports and assessments.

As part of this course, a range of practical processing methods will be taught. Students will explore aspects of ceramic powders preparation, powder characterization, forming methods, thermal processing, and physical property characterization. Students will explore the interplay between crystal, electronic, chemical, and microstructural degrees of freedom in ceramics.

The course is a fluid and evolving subject that will be amended throughout the semester as needed. A proposed class outline and schedule are included below.

Lab I – Powder and Slurry Preparation and Characterization (2.5 weeks)

- *Logistics – Laboratory Safety and Expectations Overview*
- *SEM Powder Characterization*
 - Learn basic characterization methods – scanning electron microscopy, helium pycnometry
- *Slurry Preparation and Characterization*
 - Investigate methods for the preparation of stable colloidal ceramic oxide particle suspensions
 - Explore stabilization mechanisms, polyelectrolyte surface coverage, rheology, zeta potential
- *Porosity and Density Characterization*
 - Analyze porosity and density of premade porous samples
- *Deliverable*
 - *Submit as a group*
 - A one-page executive summary
 - A written laboratory report
 - *Submit individually*
 - Theory questions

Lab II – Forming and Thermal Processing of Ceramics (5 weeks)

- *Methods for Forming Ceramics*
 - Study forming methods to prepare ceramic oxide parts by slip casting, tape casting and pressing spray-dried powders
- *Thermal Processing*
 - *Drying, calcining, sintering*
- *Mechanical Properties*
 - Assess the bulk mechanical properties of the green bodies and fired ceramics
- *Deliverables*
 - *Submit as a group*
 - A one-page executive summary
 - A written laboratory report
 - *Submit individually*
 - Theory questions

Class Schedule

Class date		Class Topic	Assignments Due
Mon.	21-Aug	Introduction; Lab I	
Wed.	23-Aug	Lab I	
Mon.	28-Aug	Lab I	
Wed.	30-Aug	Lab I	
Mon.	4-Sept	NO CLASS – Labor Day	
Wed.	6-Sept	Lab I	Theory Questions for Lab I due
Mon.	11-Sept	Lab II	
Wed.	13-Sept	Lab II	Lab I Report and Exec. Summary due
Mon.	18-Sept	Lab II	
Wed.	20-Sept	Lab II	
Mon.	25-Sept	Lab II	
Wed.	27-Sept	Lab II	
Mon.	2-Oct	Lab II	Theory Questions for Lab II due
Wed.	4-Oct	Lab II	
Mon.	9-Oct	Lab II	
Wed.	11-Oct	Lab II	
Fri.	13-Oct		Lab II Report and Exec. Summary due

Laboratory Logistics

- The laboratory will be made available during the above-listed times (i.e., those noted in the official schedule for the class) to support the progress of MSE 404 CP.
- Students can only access the laboratory facilities during business hours and under the supervision of Dr. Nagel, Nicole Robards or the TA, Lawrence Anderson.

Grading Policies

Student learning and growth will be assessed based on the following assignments:

- **Laboratory Safety, Best Practices, Peer Evaluations (10% of total grade)**
 - Students will be expected to follow appropriate laboratory safety and best practices. Failure to do so will result in a loss of points.
 - Laboratory work carries with it a number of safety protocols designed to protect you and your fellow students. These protocols include, but are not limited to, adhering to the dress code, the use of personal protective equipment (PPE), and other experiment-specific safety requirements.
 - Students **cannot** work on an experiment alone. Your laboratory partner must be present or you must arrange to work with another group. Additionally, at least one instructor must be present in the laboratory during your work.
 - Attendance of all laboratory sessions is not mandatory but is strongly recommended. Please communicate with Dr. Nagel and your groupmates if you will not be able to attend a lab session.
 - Laboratory cleanliness is very important. Students are to leave the laboratory looking better than they found it. This means cleaning up after yourself, returning items to where you found them, and generally maintaining a clean and orderly work environment. The instructors, the TA, and Ms. Robards will be noting any failures herein.
 - Students are required to provide and maintain a neat, orderly, and comprehensive laboratory notebook. These notebooks are extremely important and can be used in litigation to establish intellectual property, the design of multi-million dollar processes, and much more. Laboratory notebooks will be subject to period inspection by the instructors. Details on the expectations for your laboratory notebook are provided in **Appendix A** below.

- **Post-Lecture Quizzes (5% of total grade)**

- **Theory Questions (20% of total grade)**
 - Each student must answer a set of theory questions relevant to the topics covered in the module. Theory questions are **individual** assignments.
 - Lab I – Due Wednesday, Sept. 6, by 2:00 PM (Electronic Submission)
 - Lab II – Due Monday, Oct. 2, by 2:00 PM (Electronic Submission)

- **Laboratory Reports and Executive Summaries (65% of total grade)**
 - Each group must produce a written report for each lab. Details of the requirements are provided in **Appendices B and C**. Because each lab includes multiple experiments, care must be taken to organize the report appropriately.
 - Lab I – 25% of total grade, Due Wednesday, Sept. 13, by 2:00 PM (Electronic Submission)
 - Lab II – 40% of total grade, Due Friday, Oct. 13, by 5:00 PM (Electronic Submission)

Late Assignments

- **Late submission of assignments must be discussed with the instructor.**
- If you have concerns, I am happy to discuss your situation with you.

Absence Policy

Attendance of all laboratory sessions is not mandatory but is strongly recommended. Please communicate with Dr. Nagel, the TA and your groupmates if you will not be able to attend a lab session.

Academic Integrity

The University of Illinois at Urbana-Champaign Student Code should also be considered as a part of this syllabus. Students should pay particular attention to Article 1, Part 4: Academic Integrity. Read the Code at the following URL: <http://studentcode.illinois.edu/>.

Academic dishonesty may result in a failing grade. Every student is expected to review and abide by the Academic Integrity Policy: <https://studentcode.illinois.edu/article1/part4/1-401/>. Ignorance is not an excuse for any academic dishonesty. It is your responsibility to read this policy to avoid any misunderstanding. Do not hesitate to ask the instructor(s) if you are ever in doubt about what constitutes plagiarism, cheating, or any other breach of academic integrity.

Mental Health

Significant stress, mood changes, excessive worry, substance/alcohol misuse or interferences in eating or sleep can have an impact on academic performance, social development, and emotional wellbeing. The University of Illinois offers a variety of confidential services including individual and group counseling, crisis intervention, psychiatric services, and specialized screenings which are covered through the Student Health Fee. If you or someone you know experiences any of the above mental health concerns, it is strongly encouraged to contact or visit any of the University's resources provided below. Getting help is a smart and courageous thing to do for yourself and for those who care about you.

- Counseling Center (217) 333-3704
- McKinley Health Center (217) 333-2700
- National Suicide Prevention Lifeline (800) 273-8255
- Rosecrance Crisis Line (217) 359-4141 (available 24/7, 365 days a year)

If you are in immediate danger, call 911. *This statement is approved by the University of Illinois Counseling Center

Community of Care

As members of the Illinois community, we each have a responsibility to express care and concern for one another. If you come across a classmate whose behavior concerns you, whether in regards to their well-being or yours, we encourage you to refer this behavior to the Student Assistance Center (217-333-0050 or <http://odos.illinois.edu/community-of-care/referral/>). Based on your report, the staff in the Student Assistance Center reaches out to students to make sure they have the support they need to be healthy and safe.

Further, as a Community of Care, we want to support you in your overall wellness. We know that students sometimes face challenges that can impact academic performance (examples include mental health concerns, food insecurity, homelessness, personal emergencies). Should you find that you are managing such a challenge and that it is interfering with your coursework, you are encouraged to contact the Student Assistance Center (SAC) in the Office of the Dean of Students for support and referrals to campus and/or community resources.

Students with Disabilities

To obtain disability-related academic adjustments and/or auxiliary aids, students with disabilities must contact the course instructor as soon as possible and provide the instructor with a Letter of Academic Accommodations from Disability Resources and Educational Services (DRES). To ensure that disability-related concerns are properly addressed from the beginning, students with disabilities who require assistance to participate in this class should apply for services with DRES and see the instructor as soon as possible. If you need accommodations for any sort of disability, please speak to me after class, or make an appointment to see me or see me during my office hours. DRES provides students with academic accommodations, access, and support services. To contact DRES, you may visit 1207 S. Oak St., Champaign, call 217-333-1970, e-mail disability@illinois.edu or visit the DRES website at <http://www.disability.illinois.edu/>. Here is the direct link to apply for services at DRES, <https://www.disability.illinois.edu/applying-services>.

Disruptive Behavior

Behavior that persistently or grossly interferes with classroom activities is considered disruptive behavior and may be subject to disciplinary action. Such behavior inhibits other students' ability to learn and an instructor's ability to teach. A student responsible for disruptive behavior may be required to leave class pending discussion and resolution of the problem and may be reported to the Office for Student Conflict Resolution (<https://conflictresolution.illinois.edu>; conflictresolution@illinois.edu; 333-3680) for disciplinary action.

Emergency Response Recommendations

Emergency response recommendations and campus building floor plans can be found at the following website: <https://police.illinois.edu/em/run-hide-fight/>. I encourage you to review this website within the first 10 days of class.

Religious Observances

Illinois law requires the University to reasonably accommodate its students' religious beliefs, observances, and practices in regard to admissions, class attendance, and the scheduling of examinations and work requirements. Students should complete the Request for Accommodation for Religious Observances form should any instructors require an absence letter in order to manage the absence. In order to best facilitate planning and communication between students and faculty, students should make requests for absence letters as early as possible in the semester in which the request applies.

Sexual Misconduct Reporting Obligation

The University of Illinois is committed to combating sexual misconduct. Faculty and staff members are required to report any instances of sexual misconduct to the University's Title IX and Disability Office. In turn, an individual with the Title IX and Disability Office will provide information about rights and options, including accommodations, support services, the campus disciplinary process, and law enforcement options.

A list of the designated University employees who, as counselors, confidential advisors, and medical professionals, do not have this reporting responsibility and can maintain confidentiality, can be found here: wecare.illinois.edu/resources/students/#confidential. Other information about resources and reporting is available here: wecare.illinois.edu.

Anti-Racism and Inclusivity Statement

The Grainger College of Engineering is committed to the creation of an anti-racist, inclusive community that welcomes diversity along a number of dimensions, including, but not limited to, race, ethnicity and national origins, gender and gender identity, sexuality, disability status, class, age, or religious beliefs. The College recognizes that we are learning together in the midst of the Black Lives Matter movement, that Black, Hispanic, and Indigenous voices and contributions have largely either been excluded from, or not recognized in, science and engineering, and that both overt racism and micro-aggressions threaten the well-being of our students and our university community.

The effectiveness of this course is dependent upon each of us to create a safe and encouraging learning environment that allows for the open exchange of ideas while also ensuring equitable opportunities and respect for all of us. Everyone is expected to help establish and maintain an environment where students, staff, and faculty can contribute without fear of personal ridicule, or intolerant or offensive language. If you witness or experience racism, discrimination, micro-aggressions, or other offensive behavior, you are encouraged to bring this to the attention of the course director if you feel comfortable. You can also report these behaviors to the Office of the Vice Chancellor for Diversity, Equity and Inclusion:

<https://diversity.illinois.edu/diversity-campus-culture/belonging-resources/>.

Family Educational Rights and Privacy Act (FERPA)

Any student who has suppressed their directory information pursuant to Family Educational Rights and Privacy Act (FERPA) should self-identify to the instructor to ensure protection of the privacy of their attendance in this course. See <https://registrar.illinois.edu/academic-records/ferpa/> for more information on FERPA.

APPENDIX A – Laboratory Notebook Overview

In an attempt to bring uniformity and consistency to your laboratory experience, we will be adopting a uniform laboratory report format and procedure. The following is adapted with permission from the new electronic book produced by Matt Sherburne, Nicole Robards, and Angus Rockett for use in MSE 307.

The following outlines the expectations for the laboratory notebook in MSE 404 CP.

The Laboratory Notebook

The purpose of a laboratory notebook is to record what you did in sufficient detail that you can reproduce what you did (for example through a detailed description of the apparatus and the procedures used to acquire the data), explain problems with the data based on information you recorded in the lab notebook, record any events that might have affected the data, record things that went well, etc.

Suppose that the data looks good but the values change suddenly in the middle of the experimental run. You find that if it were not for the sudden change, your data would have explained the behavior you observed very well. What caused the sudden change? Referring to the lab notebook, you find that you bumped the lab bench between those two measurements. Conclusion: the change in the data was due to bumping the table. You may be able to correct for that change and show that the data works.

Suppose that the position of the sample in the apparatus matters? If you write down where you placed the sample in the apparatus you can reproduce the behavior. At least all samples will be measured at the same position.

Suppose that you and another group run the same experiment but get different results. How do you account for the difference? You refer to your lab notebook and they refer to theirs and you find that the difference was the heating rate (so the experiments in fact were not the same). So the difference in the results may be due to the different heating rate. Now you have learned not only what you set out to learn but also what the effect of heating rate is.

NOTE: the purpose of the lab notebook is NOT to record only your successes. Indeed, it is most important to record the things that went wrong as these are most likely to affect your results. Experiments almost never go completely right. Consequently, you are often faced with how to deal with bad data. If you always insist that all data agree with a trend you will never succeed. You also cannot just ignore data points that do not fit your idea of what the trend should be. However, if you can sort through your data and figure out what the problem was, you may be able to correct for it, determine what to change about the experiment, and possibly show which data is reliable and why.

Elements of the Laboratory Notebook

The following outlines the expectations for your laboratory notebook and what should be included in it for each laboratory portion of the course:

- Your laboratory notebook needs to be either of a stitched or glued type of binding. A three ring binder and/or loose paper will not be acceptable for this class, nor are they acceptable in the real world once you are employed. The three ring binder and loose paper will get you a 0% on the lab notebook portion of your grade.
- The size of the notebook you use is a personal choice; just remember that if you choose a notebook that is small, drawing detailed figures will not be easy. A notebook that is standard page size allows you to easily print out figures or data and go back and glue it into your notebook next to the original figure or data.
- Your pages will need to be numbered; whether you number them or the notebook comes numbered is up to you.
- Every page should be dated. If you start a new experiment or start a new day of work begin a new page in the notebook.
- A sketch or photographs of the apparatus should be included in the notebook along with a description of how the apparatus was connected together (as appropriate). If you measured out a sample, record how the sample was prepared.
- For example, 10 mg of camphor was measured out from the reagent bottle onto a glass slide. Next 15 mg of succinonitrile was measured out from the reagent bottle onto the same glass slide. Both materials

were white powders. The two measured samples were mixed on the glass slide with a spatula. After mixing the combined sample weighted 24 g (1 g apparently was lost, perhaps due to adhesion to the spatula).

- On the outside of your notebook you should put your name, course number, instructors name and your email address.
- If your laboratory notebook does not have a prelabeled section for the table of contents then you should reserve several pages at the front of your laboratory notebook for your table of contents.
- Electronic/digital notebooks are not acceptable for this course. The main reason for this is that their veracity has not been tested in patent litigation cases. Until a legal standard exists for the use of digital notebooks they will not be allowed.
- All writing should be done using permanent ink. What tends to work best is the classic ballpoint pen, as these cannot be erased and do not smear. Other pens work but tend to smear either by your hand running across the writing prior to its drying or from an accidental spill. Pencil is never acceptable.
- If you make a mistake, and you will, do not attempt to ease or apply white out to the mistake. Simply put a line or an "X" through the error and continue on from that point. Draw an "X" in any large empty are of your notebook. This way data cannot be inserted into the space later.
- Your notebook needs to be recorded in chronological order.
- Make notes with small written sections about anything that is odd, out of place, or could potentially impact the outcome of the experiment. For example, note that you bumped the table or something of this type.

Practical Aspects

The following outlines some practical aspects that should be kept in mind when working on your experiments and filling in your laboratory notebook.

- Record your raw data immediately, do not wait and get distracted, or think that I will remember it. You can very easily transpose digits or just forget the correct number if interrupted. Without the correct data it will be much more difficult to write up your lab report.
- Your lab notebook is not to try to carry lab equipment on and should not be used to carry anything around the lab. It is too easy for you to drop and break the items you are carrying.
- Make every effort to keep your lab notebook away from any liquid such as the sink, or other spills which may occur in the lab. While water may not make your ballpoint pen ink run it does make it difficult to write on wet pages.
- Include more detail in your notes than you think you actually need. This will help when you are attempting to write up your lab report. This means record anything and everything you observe in your experiment.
- If it matters in what order devices were connected or turned on then you should record that. It is better to write too much than too little.
- Record how you did the experiment. In what order did you make measurements? What were the values you set the apparatus controls to and in what order? Did you observe any effect of this sequence? Record as much of what you did as reasonable. The more you write down the more likely you are to be able to diagnose problems with the results.
- Any experimental values not recorded by a computer should be written in the lab notebook. (What was the gas flow rate? What voltage did you set the power supply to? Etc.)
- If possible/reasonable, capture your results in a printed form and incorporate them into the lab notebook. When practical, print out the data and tape it or glue it into the notebook. Paper can always be read somehow. Electronic data gets lost, deleted, or becomes obsolete.
- Make notes of things that did or might have gone wrong. If you don't notice anything go wrong during the measurement write that down. That way you know that you did not notice anything strange about the measurement.
- Remember: there are few things in science more annoying than trying to write up an experimental result and realizing that the observation does not fit the theory but you did not write down some key experimental procedure that would have allowed you to at least know why the results did not agree with expectations.

APPENDIX B – Executive Summary Overview

Overview

An executive summary is typically required for business, engineering and scientific reports or proposals. Writing and perfecting these documents will be an aspect of your future career in pretty much any field you pursue. The executive summary is a fully developed mini-version or overview of the report – it is not merely an introduction. The executive summary aims to provide a brief overview of the whole report so that executives or managers (who are very busy) could read the executive summary alone without the accompanying report. It should allow the reader to quickly understand the information contained in the report and should persuade the reader that the document is worthy of being read in detail. It should provide concise, complete, specific, and self-sufficient information such that it can be understood in isolation from the rest of the document. The executive summary should briefly outline the subject matter, the background problem, the scope of the investigation, the method(s) of analysis, the important findings and important issues raised in the discussion, and provide the conclusion and recommendations in just one page. The executive summary should not just be an outline of the points to be covered in the report with no detail of the analysis that has taken place or conclusions that have been reached.

Overall the executive summary stands as an overview at the front of the report but it is also designed to be read alone without the accompanying report (this would often occur in the workplace). The executive summary should be no more than 1 page long and achieve all of these goals.

Writing an Executive Summary

The executive summary should be written in your own words, using a formal writing style. Avoid using jargon and informal language. Early in the document, *clearly articulate the purpose/aim/goal of the report* – using emphasized text as needed. Briefly provide a context for why this work is timely, important, and necessary. Throughout the executive summary one might:

- Describe the procedure that was used including the methodology or analytical process used to process the data collected.
- Provide a clear, concise summary of the results of the study. The summation of the major findings may include a number of sentences or bullet points.
- Include recommendations for improvement, aspects that were particularly challenging, and roadblocks that kept one from achieving an overall goal as needed.
- Edit the summary to remove minor points. Use your judgment to ensure that the summary is concise and to the point.
- Remove unnecessary words and sentences. Check the accuracy of grammar, spelling, sentence and paragraph structures so that things flow nicely.
- Use formatting and graphics to highlight the message as needed. Clarity of the summary can be improved through usage of bullet points and subtitles in the organizational structure. This will also make it easier for the reader to skim read.

Process involved in writing an Executive Summary

The executive summary is normally not more than a page in length and should provide an adequate representation of the entire document in a shortened form. The executive summary is provided on a separate page at the beginning of the report. An impersonal writing style is used so as to ensure that the report remains formal especially if the audience is your manager or supervisor. At least one sentence is provided for each main section of the report. The key points in the executive summary should be presented in the identical order as they appear in the report so as to encourage logical flow and cohesion. It may be useful to write the executive summary after you have written the whole report so that it more accurately reflects the content of the report. Avoid recycling sentences or paragraphs from the body of the report as this can be repetitious for the reader.

An example layout and formatting instructions for the executive summary are provided on the next page.

FirstName1 LastName1 & FirstName2 LastName 2 (Group #)

Month Date, 2019

Experiment and Document Title

Project Overview

For all executive summaries, the text should be Arial size 10 or Times New Roman size 11 font. In all cases the text should be single-spaced and fully justified. There should be a simple heading like that provided here including the names of your group members and your group number, the date, and the document title.

This section should be a short, concise paragraph that establishes and summarizes the work that was done, the context in which this work is important, what the major goals/aims/objectives of this work are, and briefly summarizes the philosophy of how it was done and what was achieved.

Project Methodology

This section should describe the work that was done, the specific techniques, why those approaches are used and appropriate, and any deviations or important aspects the reader needs to know about your approach to the experimental work.

Project Findings and Implications

This section subsequently summarizes the major findings of your work and the implications of your work for the overall course goals and your developing understanding. In this section one can also include a summary of challenges or roadblocks that kept you from achieving your goals, recommendations or how to improve the work in the future, and context for how your work informs the design and processing of future materials.

The document should be self-contained and no more than 1 page long. It should be attached in front of your main laboratory report.

APPENDIX C – Laboratory Report Overview

In an attempt to bring uniformity and consistency to your laboratory experience, we will be adopting a uniform laboratory report format and procedure. The following is adapted with permission from the electronic book produced by Matt Sherburne, Nicole Robards, and Angus Rockett for use in MSE 307.

The following outlines the expectations for the laboratory reports in MSE 404.

The Laboratory Report

In this section a general style guide is given along with a detailed discussion of the parts of the lab report. This is the style that the TA will be using for grading.

Your Laboratory Report must:

- Be typed using a word processing software such as Microsoft Word, LaTeX, or otherwise.
- Be double-spaced.
- Use an appropriate professional font and font size
- Have 1-inch margins on all sides of the page.
- Have numbered pages.
- Have a header that includes the names of your group members and the experiment title (smaller fonts are allowed here to keep the margins at 1 inch).
- Not be longer than it needs to be.

In addition to these formatting requirements, your laboratory report must also include the following structural sections in this order:

- **Title & Cover Page**
 - Your Title should briefly describe the contents of the report and be one line in length if possible. Avoid fluff, qualitative words and acronyms. It is best to use descriptive words that lets the reader know what your reports contents are to be. The cover page should include the due date of your report, the lab group you are in and your lab partners' names. You and your lab partners should have their institutional affiliations listed, double-spaced from and centered below the title. When more than two authors, the names are separated by commas and "and" as necessary.
- **Executive summary** – see Appendix A above
- **Introduction**
 - The introduction establishes the context of your experiment and gives any background information that might help the reader understand the importance of this work. Also included is a statement of the purpose of the work, such as, your hypothesis or at least the questions you investigated. Explain the rationale and approaches and the outcomes your study revealed. When writing the introduction you should use the active voice as much as possible. Avoid first-person references if possible.
 - In general you would like the introduction to answer the following set of well-established questions:
 - What did you study?
 - Why is it important to understand this topic?
 - What did you know about this before you studied it?
 - How has the study advanced your knowledge?
 - The introduction section should be well referenced – including appropriate texts and peer reviewed and review literature.
- **Materials and Methods**
 - In this section you explain "clearly" how you carried out the experiments in your study. Describe your experimental design clearly, including the actual experimental procedures you used. In this section you should also discuss how your data was analyzed. How the data is summarized and how you are reporting the data: means, percentages, standard deviations, etc. Any statistical tests

- you used to analyze your data need to be discussed here as will any other numerical or graphical techniques you applied to your data.
- Ideally this should read as if you are verbally describing your processes for the experiments. Using the active voice is allowed, but the third person, passive is the preferred approach. Avoid writing in the first person in this section. Also remember to write in the past tense.
- **Results and Discussion**
 - In this section you need to write concisely and objectively. This section's function is to present your results in an objective manner. The presentation should be in a logical manner, generally sequentially using both Tables and Figures along with the text. If you take the time to generate high quality Tables and Figures the results section can be organized around these. You should (in this course) report your negative results as well. In writing this section you will most likely notice the passive voice dominating, use the active voice as much as you can work it into your write up. Again you have already done the work so this should be written in the past tense. It is easy to start writing paragraphs that all look and sound alike in the section, make an effort to avoid repetitive paragraph structures.
 - Some common mistakes to avoid:
 - Do not reiterate each and every value from your Tables and Figures. Only the key results need to be presented.
 - Do not make a Table of data and then plot this same data in a Figure. You need to make a decision on the best way to present the data. I would generally represent things as graphs, given enough data and that it makes sense to do so.
 - Do not tell your reader all about the raw data. You went through the time and effort to do the statistics so this is what you need to present.
 - You should compare your results to know actual values and determine the % difference. Just presenting the two numbers without any thought to how your results compare to the real world is not sufficient. Include what may have caused the difference and how you can improve the experiment if you were to redo it. Discuss any potential applications of these materials.
 - Figures and tables should be incorporated into the text at this point and aligned in professional, non-intrusive manner. All figures and tables MUST have a caption.
 - **Conclusion**
 - Start by restating the objectives of your experiments, generally from your introduction and relate these to your results. Summarize the content of your report and highlight any successes or failures of your experiments. It is also appropriate to suggest future experiments or improvements to you would recommend.
 - **References**
 - Referencing is a standardized way of acknowledging the sources of information and ideas that you have used in your document. A list of ALL the references used in the text must be written. Do not use footnotes in your report. List the references in chronological order as they appear in the text.
 - References should be done in the AIP Format. Here are some examples:
 - Generic: A. B. Author1, D. C. Author2, E. F. Author3, *Journ. Title Abb.* **Vol#**, PageStart (Year).
 - Specific: Z. W. Shan, G. Adesso, A. Cabot, M. P. Sherburne, S. A. Syed Asif, O. L. Warren, D. C. Chrzan, A. M. Minor, A. P. Alivisatos, *Nature Mater.* **7**, 947 (2008).

Producing Tables

Tables are one of the most used objects in scientific publications. Tables are assigned numbers independently from figures and are assigned the numbers in the order in which they appear in the text. The first Table is Table 1, the next Table 2.... The legends go above the Table; tables are read from the top down. The typeset of tables should be based on the following rules: 1) Never use vertical lines; 2) Avoid double lines; 3) Place the units in the heading of the table (instead of the body); 4) Do not use quotation marks to repeat the content of cells.

Producing Figures

Figures help you relay your message to the reader and are often easier to understand for a reader than the actual text, for these reasons you should take some time and care when generating your figures. Figures are numbered chronologically as they appear in the text. The first figure is Figure 1 and the next is Figure 2.... The caption for a figure goes below the figure.

Further Stylistic Points

Avoid the use of First or Second person to describe what occurred in the lab – such as “I did” or “You did.” Instead say “This was done.”

The Passive Voice – The passive voice is used to describe the experiment. This is done to reinforce that the experiment and results are ultimately what the report is about. “The sample was heated for 15 minutes at 200°C.” instead of “The investigator heated the sample for 15 minutes at 200°C.”

Lab Report Grading Rubric

Required components (contributions to the lab report grade shown in red). At a minimum start a new section for each item in red. The title page and executive summary should be on separate pages. Double space your report, margins one inch, figures must be clear and readable, references sufficient to determine sources.

- **Title page – 5%**
- **Executive summary – 10%**
- **Introduction and background – 15%**
 - Motivation for the experiment
 - Background theory
- **Materials and Methods – 15%**
 - Description of apparatus
 - Procedures used to conduct the measurements
 - Experimental variables tested (and not tested, as appropriate) and why
- **Results and Conclusions – 40%**
 - The 40% is divided evenly by the measurement descriptions. There should be a separate measurement description for each variable tested.
 - Discuss the results of your findings. Compare your values with the actual values (these values you can find online) and determine the % error. Include what may cause this error and how you can improve the experiment if you were to redo it.
 - Discuss (potential) applications of these materials and implications of your findings for applications or processing routes.
 - What information did you obtain from the data
 - How does this relate to the motivation & theory
- **Writing, Formatting, and Professionalism – 15%**
 - Spelling, grammar, organization, use of space, references, formatting, figure quality, etc.
 - Overall effectiveness and clarity of the report.
 - Poor or inadequate references, failure to reference the right types of materials, etc.
 - Use concise and proper language.
 - **Do not plagiarize – this includes reproducing text from papers, texts, other class members, etc.**