Boston University ENG ME 310: Instrumentation

SYLLABUS FOR SPRING 2020

NOTE: It is your responsibility to read over and be familiar with the policies and dates described in this document. Some dates may be subject to change; changes will be announced in class, via email, and on the edX website. Please check this document prior to emailing me for logistical information.

LECTURE: MW 10:10 – 11:55 AM, PHO 205

LAB: Rm 113A, 110 Cummington Mall
C1 (Tues 5:30 – 9:15 pm), C2 (Thurs 5:30 - 9:15 pm), C4 (F 2:30 – 6:15 pm) depending on registered section

PROFESSOR: Caleb Farny: (farny@bu.edu), 110 Cummington, Rm 207, 353-8664
Office hours: Tuesday 2-4, Thursday 9:30-11, or by appointment

GSTs:	Erfan Aasi (eaasi@bu.edu)	(Tues, Thurs lab sections)
	Ankush Gupta (ag1@bu.edu)	(Thurs lab sections)
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Course description

Designing, assembling, and operating experiments involving mechanical measurements; analyzing experimental data. Safety considerations in the laboratory. Wind tunnel testing. Mechanical and electrical transducers for flow, pressure, temperature, velocity, strain, and force. Electric circuits for static and dynamic analog signal conditioning. Computer use for digital data acquisition and analysis; instrument control. Introduction to frequency domain analysis. Professional standards for documenting experiments and preparing reports, including formal uncertainty analysis involving elementary statistics. Discussion of commercial instrument development. Interpretation of experimental results. Includes lab and design project.

Goals

1. To teach basic techniques for designing experiments and analyzing data
2. To introduce the operating principles and uses of transducers, output devices and signal conditioning elements of measurement systems
3. To introduce the concepts of signals and systems and their interaction in both static and dynamic measurements
4. To provide hands-on experience in professionally conducting experiments in a modern, real laboratory setting with emphasis on safety, documentation, computer use and uncertainty analysis. The uncertainty analysis reflects standardized practice, providing an introduction to professional codes and standards and elementary probability and statistics.

Hub Learning Outcome: Writing Intensive

School, Department, and/or Program Outcomes
ME310 is a required course for the Mechanical Engineering B.S. degree program. Its prerequisite courses are CAS WR150, ENG EK307, EK381/ME366, and ME303.

Course Learning Outcomes
As an outcome of completing this course, students will successfully:
i. Design and implement experimental solutions to engineering problems, including static and dynamic mechanical, electrical and thermal measurements, and justify the tradeoffs between cost, performance and complexity of measurement schemes.
ii. Analyze the uncertainty of experimental results, including identification of sources & types of uncertainty, combination & propagation of uncertainties.
iii. **Hub unit: Writing Intensive**. Demonstrate proficiency in technical writing and documentation of experimental work through use of standardized lab reporting policies and requirements.
iv. Demonstrate the operating principles and justify the uses of transducers, output devices, and signal conditioning elements of measurement systems for flow, pressure, temperature, velocity, strain, and force.
v. Apply the concepts of signals and systems and their interaction in both static and dynamic measurements, including mathematical modeling of such systems' static and time-dependent behavior.
vi. Demonstrate knowledge of the theory and practical application of analog-digital conversion in the context of data acquisition and MATLAB and LabVIEW interface data acquisition control software.
vii. Work efficiently in individual and team settings by performing labs and projects in both self-organized and instructor-organized groups.
viii. Present experimental design and results in an oral presentation.

Reading resources
Due in part to the technical writing component, you will benefit from carefully reading all of the resources that are available to you. These resources consist primarily of the course textbook (see below), the lab manuals, your course notes, and the various digital documents (including this syllabus and embedded lab manual guide!!) that will be posted on the website and described by your instructor. Web resources may also contain helpful written explanation. I strongly encourage you to read through these documents carefully, particularly as you prepare your pre- and postlab reports.
Text: Figliola and Beasley, *Theory and Design for Mechanical Measurements,* 6th ed., 2011. Wiley. ISBN: 9780470547410.

Note: The 4th edition is likely cheaper and is acceptable also.

Optional Text: Taylor, *An Introduction to Error Analysis*, 2nd edition, Univ. Sci. Bks., 1997.

Website/Digital materials
edX Edge (edx.edge.org): All of the course resources, with the exception of an online grade record, are on the course edge.edx.org website. Developed by MIT and Harvard, edX.org has a superior layout to the Blackboard platform. You are responsible for navigating the website to obtain course documents and watching the assigned videos ("Courseware"). Prior to the beginning of the semester Prof Farny emailed you an invitation to sign up for an account on this website, as it does not have an auto-enroll feature. Please sign up for an (free) Edge account if

you have not already done so. Note that I have not specifically tailored the website or videos for a smart phone platform; the videos are best watched on a computer screen with headphones for properly hearing the audio.

Blackboard (learn.bu.edu): Unfortunately, edX does not provide a means to input grades or submit digital student documents. Please check the course Blackboard site to review your grades and submit digital copies of your lab reports. Note that I do **NOT** use Blackboard to calculate your final grades, so disregard whatever grade assignment or total number of "points" that Blackboard suggests you should have.

Grading:		
	7.5%	Video Worksheets, Class & Lab performance
	20%	Design Project
	15%	Homework Sets
	22.5%	Labs and Lab Reports
	17.5%	Each exam

Nominally, the mean of the overall score across the class will set the dividing line between a B and a B-.

Class

Class will be lively, informative, and PART OF YOUR ASSIGNED GRADED WORK. ME310 is now a "flipped class" to a certain extent; some lectures will involve a chalkboard discussion of new concepts while others will focus on group-based measurement challenges. These challenges are meant to help you explore new concepts and get hands-on experience with the measurement aspect of the course. In order to prepare for these challenges, it is imperative (and required) that you watch the course videos that I've prepared for you on the course Edge website. It is expected that you will have watched the videos and answered the corresponding worksheet questions PRIOR to coming to class, and that you will participate with your group on the in-class measurement challenges. Check the course semester and lab schedule to make sure you are aware of the assignment dates for this course.

Videos

The course has 5 content modules that have an accompanying set of videos that I have written and recorded for you to watch. Each module covers a discrete concept that is central to the course, and understanding the content in the videos is a key step to understanding and passing this course. There are 2 – 4 videos per module, and each ranges from 9 – 14 minutes, depending on the complexity of the topic. Each video has an accompanying time-synced written transcript that appears next to the video; these transcripts are searchable and hyper-linked to the spot of the video that they appear. NOTE that I will not formally cover these topics in class, and that they represent some of the most challenging material in this course! Also note that a few worksheet questions are embedded in most videos. You are responsible for writing these questions down and answering them! These make up your "worksheet questions" and are due in class on the day of the corresponding active learning exercise that accompanies that specific module. Make sure to take notes and post any questions that you have from the videos to the website's Discussion feature.

Why assign videos instead of watching me scribble on the board in class? Pedagogical research has demonstrated that listening to a chalkboard lecture results in low retention of material, not to

Why assign videos instead of watching me scribble on the board in class? Pedagogical research has demonstrated that listening to a chalkboard lecture results in low retention of material, not to mention transcription mistakes from the presented material to your notes. This is why I provide the videos, transcripts, and digital lecture notes for your reference. They are valuable resources that you should reference as you study the course material.

Homework

Homework assignments are given out (roughly) every other week in class. They are due in stapled, printed format at the BEGINNING of class on the due date listed. LATE HOMEWORK WILL NOT BE ACCEPTED unless circumstances merit the exception.

Exams

Your understanding of the class-based material will be assessed via a midterm and final exam. Each will cover a specific section of the material and as a senior-level course, they will be thorough and challenging. The midterm exam will be given in lecture on March 4th. "Make-up" exams will rarely be given. In the case of prior knowledge of a time conflict you must arrange to take the test before you are away. A "make-up" exam will be different from the exam given in the class.

Design Project

You will design and implement a complete transduction system to measure the frequency-dependent displacement of a damped mass on a spring. This will occupy roughly the final 5 weeks of laboratory meetings. Note that it is a design as well as lab project, and as such there will be significant work done OUTSIDE and BEFORE lab.

Drop and Withdrawal Dates

The last day to DROP: February 25th. The last day to WITHDRAW: April 3rd

"Incomplete" grades are reserved for the most extreme of circumstances and are a negotiated contract between the student and instructor.

Collaboration

A. Homework and worksheets: Do it individually. However, you are encouraged to consult with classmates on general concepts.

B. Lab reports: Also to be done individually. All pre-labs are also to be done individually. This policy extends to **ALL** components (text, plots, tables, etc) of the document. **Do NOT share digital files other than whatever raw data needs to be shared within your group.** For some experiments, there will only be one copy of your raw data/results, which you must copy later for inclusion in your own reports. Your lab report should be a stand-alone document, and therefore you may not ‘reference’ any section in one of your lab partners’ reports. However, you must consult with your lab partners even after the lab period to discuss findings and results. Take this guidance **very seriously but PLEASE feel free to come talk to us if you’re unsure about boundary lines!**

C. Design project: This is a group collaborative project, and I expect to see some division of labor here; there will only be 1 report per group, so each group member will receive the same grade. Despite the division of labor each member of the group must understand the other member’s contributions.

Academic Conduct Statement
Cheating on homework, quizzes, exams, project reports, or any form of assignment, may be a form of plagiarism and is an infringement of every code of engineering ethics. Plagiarism is a serious academic offense and should not be taken lightly. Understanding your ethical responsibilities is an integral part of becoming a professional. A copy of the Code of Ethics of engineers, promulgated by the Accreditation Board for Engineering and Technology (ABET) and the National Society of Professional Engineers, can be found on the main course web site.

Recall that when you enrolled at Boston University, you agreed to an Academic Honesty Pledge. The Academic Conduct Code details your responsibilities as well as the results of code violations, and is posted at: *https://www.bu.edu/academics/policies/academic-conduct-code/*

Accommodations for students with documented disabilities: If you are a student with a disability or believe you might have a disability that requires accommodations, please contact the Office for Disability Services (ODS) at (617) 353-3658 to coordinate any reasonable accommodation requests. ODS is located at 19 Deerfield St, on the second floor. I will make every effort to accommodate such requests but (a) please notify me at the beginning of the semester if you've received approved accommodations in previous semesters (even if you haven't received your paperwork for this semester yet!) and (b) my policy is that I need at least one week's notification prior to each exam so we can make the necessary arrangements.

Religious accommodations: I am aware of and in agreement with Boston University's Policy on Religious Observance, whereby absences for any religious beliefs are understood and missed assignments on such occasions will be given a chance to be made up. I require notification at least a week in advance, particularly if an accommodation must be made, for such occasions.

Matlab Access
I **highly** recommend the use of MATLAB for analysis and plotting for ME310 and will require it for some of the homework analysis. You can download Matlab to your personal computer:
http://www.bu.edu/tech/services/cccs/desktop/distribution/mathsci/matlab/
Most of you have taken EK125 and were familiar with MATLAB at one point, and it's not difficult to learn the basics if you studied a different programming language. I am more than happy to give assistance and guidance if you need help.

LAB AND LAB REPORT POLICIES AND PROCEDURES

1. **Groups**
   Organize yourselves into groups of no more than 4 students each. There will be no more than 4 groups per each lab period. Lab reports are individual assignments.
2. **Notebooks and Reports**
   a. Lab Notebook: I no longer require the use of a notebook for labs 1-4, but I do encourage it, particularly for the design project. I recommend a version that is page numbered and square-ruled.
   b. Lab Report: Each student will generate a lab report for each experiment, the elements of which are spelled out in the sections below. These reports will be generated on a word processor with inclusion of tables and plots (typically generated in a spreadsheet or other computational analysis program).
   c. All entries must be in permanent ink. Do not erase or 'white-out' mistakes. Instead, cross out with ONE mark and explain.
   d. Format, content and neatness will be graded. Your writing or typing must be legible, intelligible, and concise but complete. As mentioned above, these reports are stand-alone documents. Do NOT assume that 'everyone knows that'.
   e. If you use information from a previous class or from some textbook (even our own) or even use pictures, plots, text, etc. from the lab manual handout, or from the web, you MUST document such with a citation. A standard point deduction of 10 points will be applied for missing citations (when relevant).
   f. The pre-lab section of the report is due at the beginning of the lab. The GST will check, sign and date the prelab or you will receive no credit.
3. **Lab preparation**
   The lab component for this course bears considerably more responsibility than other lab exercises you've had. You will be in charge of connecting the instruments and collecting the data – not the GSTs! Their role is primarily to help you troubleshoot whatever problems may arise. In order to complete everything, you'll need to be adequately prepared. To help you stay organized, you're expected to carefully read through the lab manual and prepare a thorough prelab document (see below).
4. **Due dates**
   Based on the schedule below, you are required to submit a printed copy of your report to your GST at the **beginning** of your lab session, AND a digital copy to Blackboard SafeAssign **before** your lab session. LATE LAB REPORTS WILL NOT BE ACCEPTED OR GRADED unless dire circumstances warrant the exception; see me if you are unable to complete your report on time. The GSTs take attendance, and failure to show up for a lab session will result in an Incomplete for the course. See me as far in advance in possible if you have a scheduling issue and we'll arrange for you to make up the lab. Most lab reports are handled slightly differently:

   Lab 1: This lab does not have a required post-lab analysis but the pre-lab document will be collected in lab and graded.

   Lab 2: The full report is due in 1 week, even if have a free period on the next week.

   Labs 3 & 4: Since the analysis is significantly more complex, you will be given 2 weeks to submit the report for labs 3 & 4.
5. **Error Analysis**

An estimate of your errors, their sources, and impact on results is required in every lab report. Additionally, Labs 3 & 4 require a full formal uncertainty analysis (see details below). Both these reports have two weeks prior to their due date to ensure adequate time for preparation of the longer and more extensive lab report.

6. **Engagement**
   5% of your course grade will be based on your in-lab attendance and engagement. Half of this credit will be lost if you arrive later than 10 minutes and you may be asked to attend a different lab section. Your GSTs will base the other half on your relative engagement with your group on the lab exercise. These are easy points to earn and participating with the experiment is the best way to learn the hands-on material in this course! Only in the most extreme of circumstances will you be allowed to be late or miss a lab and schedule a makeup. These labs require a large amount of overhead in terms of equipment, prep, coordination and manpower, and it is not fair to anyone to reschedule without compelling cause.
7. **Lab Report Content**
   I have sample reports available in my office for your perusal. A section by section breakdown of what is expected appears below.
8. **Academic Honesty**
   Labs 1 – 4 are meant to be individual efforts. While discussion of the analysis with your peers is ok (and encouraged), 'sharing' of ANY written/digital content among your current peers (or those who have already completed the course) is plagiarism and will result in an Academic Misconduct investigation. Distribution of *data* within your lab group is permissible and expected, for certain labs. **Do NOT share digital files other than whatever raw data needs to be shared within your group.**
9. **Safety**
   Safety is paramount. Never work alone. Tie up loose ends (hair, clothing and jewelry). Keep workspaces free of clutter. NO FOOD OR DRINK IS ALLOWED IN THE LAB!
10. **Equipment**
    Two bad things happen to lab equipment:
    a. An instrument fails or is made to fail via an accident. Do your best to prevent the latter (set your power supply levels carefully and handle with care!), but my MAIN priority is to ensure a smooth lab experience for the next group that comes along. Please report broken equipment directly to me and your GST as soon as possible, so we can diagnose, and fix or replace as necessary. I promise I won't get upset!
    b. The tools necessary to set up the experiment aren't available. This scenario typically occurs because mechanical engineers love tools and try to procure them with all means possible. Please fight this temptation and leave the ME310 tools for future students (this includes yourself). The toolbox lives in the GST office, and has a sign-out sheet. It is your responsibility to sign out all tools that you need throughout your lab session, and to return them accordingly. If a tool is missing after a lab session, the GST will come looking for YOU! Please keep the lab environment neat and in working order.

ME 310 LAB REPORT CONTENT

GENERAL INFORMATION

- Include page numbers for your report. Please print double-sided whenever possible.
- A full report will consist of a prelab document and a postlab document, combined into one complete document. Both are written by you, based on the sections detailed below. The goal of the prelab is to familiarize yourself with the lab procedure and goals so that you can better understand and complete the lab in the allotted time.
- You should take notes during the lab and include them as part of the report, by writing them in your prelab document. Include at least 4 extra blank pages stapled onto the end of your prelab document to allow space for these notes. If you prefer to maintain a separate lab notebook for your in-lab data and notes (as you would do in an industry or academic research setting), be sure to include a photocopy of your lab notebook and include it in your report.
- Longer ≠ better! I absolutely do not expect 40-50 page reports. As a technical report, communicating the relevant information in a clear & **concise** manner should be your main goal. The theory section has a maximum page length but do your best to keep the overall length of your report to a minimum length as well.

PREPARATION BEFORE LAB (Prelab Report Section)

- Title page
- Objectives of lab
- Theory and preparation for analysis
- Appropriate tables of symbols and equations
- Spot check preparation
- Listing of data needs
- Tentative equipment lists
- Procedure checklist

1. Title Page

This should include only the title of the experiment, the date the experiment was actually done, your name, and all other students who did the experiment with you, using your apparatus.

2. Objectives

First, the objectives of the lab should be stated. This should be a **brief and concise** statement of what the scientific and/or engineering goals of the experiment are (e.g., investigate a phenomenon and/or demonstrate a theorem).

Do not just copy the handout. In the conclusion section at the end of your lab you should return to the objectives to ascertain how well the objectives were realized. Since the conclusions depend on the results of the experiment, what is included in the results section will also depend on the objectives, so check what is asked for (or what will be obtained) in the results section before writing your objectives.

3. Theory

Next, a **brief** summary of pertinent theory or established empirical evidence related to the experiment should be given. You should base (and cite!!) your explanation off the lab manual, class notes, and textbook, so read these sources carefully. The purpose is to understand the basis of the experiment and how these data are to be reduced and analyzed to meet the lab's objectives prior to arriving to lab. It is your responsibility to understand the theory well enough to know what measurements need to be made (e.g., if a Reynolds Number is required, then you need to measure temperature, which will allow you to look up the fluid's viscosity). All derivations or dimensional analyses requested in the lab manual be done in this section.

Longer ≠ better! You will be graded, in part, on conciseness. The Theory section should be no longer than 5 pages, double-spaced (this is a limit, not a goal!).

4. Equation Summary

This is a listing of the equations you will need to find your results from your data and the theoretical values to which you will be comparing them. Be sure to list the meaning of all the symbols used in your equations and their units.

5. Spot Check Preparation

It is almost always desirable to do an analysis of some data points in the lab while the experiment is running. This is called a spot check. A spot check permits you to see if the results make sense, or if the experiment is generating data that is obviously erroneous and either the experiment or your method of analysis needs correcting. As an example, in the Bernoulli experiment performed in ME303, you were looking for the Re that corresponds to the laminar to turbulent transition region. Were this lab done in ME310, you would outline in your prelab how to do this (such as viscosity tables and a calculator). Then, during your lab you could check that your results were consistent with the expected values for flow transition.

All ME310 labs include spot checks to help you identify bad data, bad analysis, bad lab technique or faulty equipment. **Your prelab preparation should identify the relevant equations, along with the necessary unit conversions & constants to reduce in-lab time.** Then in the lab, you will only need to plug in your experimental values.

6. Data Needs

This section should include a list of data needs, including the range of variables the data will include. The purpose of this is to simplify in lab the construction of neat data tables that are easy and informative to read. It also allows you to determine a complete list of the data you'll need in lab, to reduce the chance you'll forget or miss a measurement.

Headings for table rows and columns should be devised as well as tentative unit assignments. In this section your tables should be "skeleton" tables containing no actual data. For example, if your data is to be voltage as a function of frequency, then you'll need to specify the min, max, and increment for the frequency. Once in lab, you will write these values directly into these skeleton tables, so be sure to leave sufficient room in the empty table for the data to be written.

7. Equipment List

Next should come a tentative list of equipment. It is a tentative list because there will be probably be some additions to the list to be made in the lab and for information on **equipment**

manufacturer, model number, and serial number. Also, you will wish to record **stated accuracy** (with calibration data if available) and **instrument resolution** (smallest increment, or least count). Accuracy information can be found in the equipment manuals in the lab for the electronic instruments. You should construct this list in the form of a table (with plenty of blank spaces) and are permitted to fill it in with the unknown information during the lab.

Data Sheets: You'll need these for your Uncertainty Analysis. Instrument data sheets will be posted on the edx website for obscure instruments only; otherwise it is your responsibility to go to the manufacturer's website for all other instruments.

8. Procedure Checklist

With the exception of Lab 1, a comprehensive description of the lab procedure AND a detailed and bulletized list accompanies the lab manual. You should attach a photocopy (or re-typed) printout of this procedure to the end of your prelab. Note that while you are not asked to re-write the procedure in your own words for the prelab, you are still expected to have read through and familiarized yourself with the procedure BEFORE coming to lab. You'll notice that the bulletized checklist contains some blank spaces where the proper settings for certain steps are left out. **You should fill in these setting values yourself as part of your prelab preparation.** *Note that for Lab 1, the bulleted procedure list does not exist; you'll need to write you own for this particular lab.*

These steps should be your direct guide to completing each step involved in the lab exercise. This is to help you to remember when to turn crucial valves so the lab doesn't flood out and when to take crucial data or perform spot checks so you don't have to repeat portions, or all, of an experiment. The labs can become somewhat confusing while in progress and it is not difficult to forget a procedure step, so pay close attention to this section. You may find that you will need to revise or add further steps to this list during the lab.

There is a fair amount of work involved in prelab preparation. It is a very significant part of doing an experiment and should not be raced through just prior to lab. The prelab comprises 25% of your lab grade.

INLAB REPORT SECTION: To be done during lab

- Complete equipment list
- Make and record a safety inspection
- Follow procedure checklist
- Take data
- Perform spot checks
- Note general observations
- Draw experimental setup

1. Complete Equipment List

Include the manufacturer, model number, and accuracy information (if known). Put this information into the table in your prelab section or record it directly in your notebook.

2. Perform Safety Inspection

Before beginning the experiment, consider and document the safety issues related to this experiment. Include both issues that were addressed and also those that were not addressed. For those issues that were not addressed, comment on how the safety of the experiment might be improved in the future. Note that this includes safety FOR the equipment, not just FROM it – you should be aware of the limitations of all equipment you use and take appropriate steps to ensure no input or output loads exceed those limits.

3. Follow Procedure Checklist

Check off each step as you proceed through the checklist. You should write in procedure changes if they become necessary. If there is extensive revision of the procedures necessary, you should record the revised procedures in your prelab or notebook.

4. Take Data

Record data in the data tables you developed in your prelab. Be sure to include appropriate units and other comments (e.g., which of several instruments you were using or which scale you were using on your instrument). Be sure to record the **raw** data before you make **any** calculations. All data must be recorded neatly and be **easily** legible to the graders (including the units of the data) or else loss of credit will result. The 5% credit given for this section is primarily given for format, presentation, and completeness. More credit will be lost if the data is faulty, leading to poor analysis and results.

5. Perform Spot Checks

Usually you will be told what spot checks to do, but for some labs you are expected to come up with some of your own. Regarding spot checks, it is not enough to simply do them. Comment on what information they supply, e.g. "demonstrates a linear relationship", or , "corresponds to a theoretical expectation", etc. Spot checks should be performed in the data section, near the relevant data. The goal here is to prevent you from wasting time taking bad data.

6. Note general observations

In addition to taking data, general observations that relate to the lab, such as problems and inconsistencies, should be recorded.

7. Document experimental setup

Finally, in order to make sure you understand and remember how the experiment was set up, draw a block diagram of the measurement and instruments involved. Nothing fancy is necessary, but it should show the electrical connections between the instruments and the basic idea of how the instruments were positioned relative to the phenomena that they're measuring.

ANALYSIS AFTER LAB (Postlab Report Section)

- Analysis
- Uncertainty analysis
- Results
- Discussion and Conclusions

1. Analysis

The chief purpose of the analysis section is to show the calculations ("analysis") that you performed to transform the data into results. The analysis should appear in the lab report following the data pages from the lab. It is very important that your analysis be clear to someone who did not do the lab. Therefore, you should describe it with text to orient the reader. Sample calculations for each unique analysis must be included. Specify which data point is being used in each sample calculation and identify the source (including the page number in the lab notebook) of the data and reference data you use (e.g. viscosity values). Use and check units. Hint: sometimes it is easier to convert all data into SI units and then do your calculations.

Following the sample calculations, analysis of all of the data points should be summarized in tables, including intermediate as well as final results. The data points used in the sample calculations should also be included in these analysis tables as a check that the analysis behind the tables is working properly. All tables must have a name (e.g., Table 1) which you should use in your text (eg. "Table 1 lists the intermediate calculations performed for determining the mass"), clearly labeled columns and rows (variable names and units), and an explanatory caption. The name and caption are usually combined, for example, "Table 3a. List of relevant acoustic and thermal properties for tissue-mimicking gel. All values are experimentally determined as described in Section 2, except where citation indicates another source for the values".

Calibration curves and other curves needed for the analysis of data should also be included in the Analysis Section, however, all results plots belong in the Results Section only. All plots must have name (e.g., Figure 1), which you should use in your text (e.g. "Figure 1 plots the output gain as a function of frequency"), and an explanatory caption below the plot which describes the features and parameters of the plot. The name and caption are usually combined, for example, "Figure 5. Light emission as a function of duty cycle for 5 different pressures with symbols as indicated in the legend. Frequency = 1 MHz, DC = 0.03"). If there is more than one curve on a plot, clearly distinguish them by different symbols, line types, and/or colors in a legend included somewhere on the plot. The scales of the x- and y-axes must be clearly shown and labeled with variable names and units. Be sure to use the appropriate plot axis type in your plotting application: log-log, semi-log, etc. Plots should be sized so that they take up most of a report page width.

Sample calculations may be done by hand or using a *symbolic* manipulator program (such as Mathematica or Maple), but the rest of analysis, as well as uncertainty analysis and plots should be done with a computer. Hand-written sample calculations may be done in the lab notebook for convenience, then photocopied for the report. Alternatively, you may simply leave space in your report pages for the appropriate hand-written calculations.

2. Uncertainty Analysis

The uncertainty analysis should include your estimated elemental experimental uncertainty in each measurand (both systematic and random, identified as such, as well as total uncertainty), statistical analysis of data where appropriate, and uncertainty propagation for equations and results using partial differential root sum square propagation equations, and sample calculations. Discuss the uncertainties introduced by all relevant instrumentation and combine & propagate with the random uncertainty for all results, as relevant.

Sample calculations must be shown for a single point for each unique analytical equation and a single example for each type of resultant. Following the sample calculations, uncertainty in ALL values and results must be calculated and displayed in tables. Uncertainty analysis counts for 20% and is **only** required for labs 3 and 4.

3. Results

This section is where you show the result of the experiment's objectives, in terms of tables and plots whenever possible (refer to above paragraph on plots for format). Interpretation and explanation of the results belongs in the Discussion section but you should include at least **some** guiding text so that the reader can understand what is being presented. **Do not include intermediate calculations (those belong in the analysis section), only final results in the results tables**. Data points should have error or uncertainty ranges indicated, where appropriate, in both tables and plots (on plots it should be represented as error bars when possible). **If a plot will convey the same information as a table, then just use a plot.**

4. Discussion and Conclusions

Were the lab's objectives met? In the discussion section you should evaluate your results and discuss the physical meaning of the numbers and plots. If there are relevant theoretical or empirical results available, compare your results with them, and attempt to explain any discrepancies. Answer any and all questions asked in the procedure section of the lab handout. Mention experimental limitations and ways the lab might be improved. Remember to include uncertainty in this discussion. If results or experimental objectives were unsuccessful, try to provide a coherent discussion as *why* this was the case. Because it is important to think about and communicate experimental results as well as get them, this section comprises 16% of your lab grade.

ADDITIONAL GRADING

Presentation

The presentation quality of your lab report will, at a minimum, be graded for readability, conciseness, completeness, and placement of items in the proper section.

SUMMARY OF LAB REPORT ORDER AND CREDIT

For each experiment, the report should consist of:

	Section	Max. Credit
Prelab	Title page	1%
	Objective	3%
	Theory	6%
	Equation summary	2%
	Spot check preparation	4%
	Data needs	5%
	Equipment list	2%
	Procedure checklist and safety	2%
Inlab	Data	5%
	Spot checks, block diagram	5%
Postlab	Analysis	12%
	Uncertainty analysis	20%
	Results	12%
	Discussion	16%
All Sections	Presentation	5%

Some thoughts on lab report word processing…

You are free to use whatever word processor you prefer when you go about typing up your weekly lab reports. HOWEVER: Personal experience and lots of student feedback has shown that Microsoft Word can make your life very difficult when it comes to assembling long documents that contain both embedded figures and equations. It can be done, but you might have gained some bags under your eyes and lost a few hairs by the time you're finished. As a less stressful alternative, I recommend learning how to use LaTeX. It's an open source platform (so its name was clearly not generated by a marketing team!) and it has a short learning curve, but it will be your best friend after the initial time investment. Also, it's (virtually) free, in that the package for the Mac platform (TeXShop) is free and the Windows platform (WinEdt) has a recommended payment reminder that can be ignored if you've got the patience.

So what's LaTeX you ask? LaTeX is a document formatting software that relies on a user-programmable typeset language that makes embedding figures, figure numbers, equations, equation numbers, tables, table numbers, and section headings, etc, all much easier to update and position within your document. It performs all this and produces a slick-looking report that's sure to get you an A based just on its appearance! (if you were still in high school, that is…)

In a nutshell, the program consists of an editor window, where you write your text, provide links to your figure files, and program your equation symbols, and a window where it displays the typeset document in PDF format.

The only downside is that proofreading can be difficult, since the editor window is not always formatted in a well-presented manner (depending on the particular software package you're using). I highly suggest carefully proofreading the PDF version, and then making notes where you'll want to make changes on the editor window side.

There are many versions available, so feel free to search online yourself, or you can use either of these links:
Mac download:
http://pages.uoregon.edu/koch/texshop/

Windows download:
http://www.tug.org/protext/
or
http://www.winedt.com

Don't be surprised if it's a large download! I've posted a lab report template on the edx website for your reference. Feel free to use it as a basis for your reports.

For group projects, you may want to take advantage of a good online resource for sharing Latex code: http://www.sharelatex.com

ME310 Spring 2020 Semester Schedule						
L	Dates	Topics/Classroom Activities	Video	HW	Video/WS	Labs
1	1/22	Course, lab & report overview				
2	1/27	Measurement methodology				1: Overview of Instrumentation
3	1/29	Measurement methodology; error analysis		#1 due		
4	2/3	Analog-digital conversion; sampling theory	Yes		#1	2: Strain gauges
5	2/5	Uncertainty overview	Yes		#2	
6	2/10	Prec vs Bias Uncertainty				3: Drag & pressure; 4: Temp calibration
7	2/12	Uncertainty, linear measurement systems		#2 due		
8	2/18	Measurement overview: Temperature sensing				No labs this week
9	2/19	Measurement systems: response functions, sensitivity, linear regression	Yes	#3 due	#3	
10	2/24	Regression, weighted fit; Instrumentation error				Labs 3 (Drag and pressure) and 4 (Temperature calibration)
11	2/26	Measurement overview: Filters				
12	3/2	Exam 1 review		#4 due		
13	3/4	**Exam 1**				
14	3/16	Project descriptions				
15	3/18	1st order systems	Yes	#5 due	#4	
16	3/23	1st order systems continued				Project
17	3/25	2nd order systems	Yes	#6 due	#5	
18	3/30	2nd order systems continued				
19	4/1	Quality factor, experimental methods for time-dependent systems		#7 due		
20	4/6	Continue time-dependent analysis				
21	4/8	Continue time-dependent analysis				
22	4/13	In-class project work		#8 due		
23	4/15	In-class project work				
24	4/20	In-class project work				
25	4/22	Final exam review				
26	4/27	Project presentations		Design report due		
27	4/29	Project presentations				

Concept	Textbook (Chapter: section)
Overview	Ch 1
Uncertainty Analysis	Ch 4: 1-4, Ch 5: 1-6
Temperature sensing	Ch 8: 2, 4, 5
Regression	Ch 4: 7
Analog filters	Ch 6: 8
Digital filters	Ch 7: 7
General signal conditioning	Ch 6: 9
Amplifiers	Ch 6: 6
Aliasing	Ch 7: 2
Dynamic inputs	Ch 2
System response to dynamic input	Ch 3

SPRING 2020 ME 310 Lab Schedule

Note: Each lab group should have a minimum of 3 students and a maximum of 4

Holidays	Section >	C3	Tues @ 5:30 pm			C1	Thurs @ 5:30 pm			C4	Fri @ 2:30 pm		
	GSTs:	Erfan, Peco, Levent				Erfan, Ankush				Peco, Levent			
		Group #				Group #				Group #			
	Week of	1	2	3	4	1	2	3	4	1	2	3	4
	20-Jan	f	f	f	f	f	f	f	f	f	f	f	f
	27-Jan	1	1	1	1	1	1	1	1	1	1	1	1
	3-Feb	2	2	2	2	2	2	2	2	2	2	2	2
	10-Feb	3	f	4	f	3	f	4	f	3	f	4	f
President's day	17-Feb	x	x	x	x	f	f	f	f	f	f	f	f
	24-Feb	f	3	f	4	f	3	f	4	f	3	f	4
Spring Break	2-Mar	4	f	3	f	4	f	3	f	4	f	3	f
	9-Mar	x	x	x	x	x	x	x	x	x	x	x	x
	16-Mar	f	4	f	3	f	4	f	3	f	4	f	3
	23-Mar	P	P	P	P	P	P	P	P	P	P	P	P
	30-Mar	P	P	P	P	P	P	P	P	P	P	P	P
	6-Apr	P	P	P	P	P	P	P	P	P	P	P	P
	13-Apr	P	P	P	P	P	P	P	P	P	P	P	P
	20-Apr	P	P	P	P	P	P	P	P	P	P	P	P
	27-Apr	No meeting											

Possible pts	Experiment number and title
33	*1 Intro to scope, MM/DMM, and DAQ (Prelab due but no analysis!)*
80	2 Strain Gauges (1 week for report)
100	3 Flow Over a Sphere (2 weeks for report)
100	4 Temperature Measurement and Calibration (2 weeks for report)
100	P DESIGN PROJECT: Mechanical 2nd Order System and Digital Data Acquisition
	Labs 3, 4 and the Project require formal error analysis
	f Free lab period for your group
	x MW Schedule/Holiday
	* Presentations will be held during last week, in class