

Boston University ENG ME 310: Instrumentation

SYLLABUS FOR FALL 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 Blackboard website. Please check this document prior to contacting your instructor for logistical information.

LECTURE: A1: MW 12:20 – 2:05 PM, OSW 922 (also known as HAR 922)
Prof Elise Morgan, 110 Cummington Mall, Rm 221, 353-2791
Office hours: Fri 8-10 am and 11 am - noon, via [Zoom](#)
A2: MW 10:10 – 11:55 AM, ENG 245
Prof Caleb Farny, 110 Cummington Mall, Rm 207, 353-8664
Office hours: Tues, Thurs 3:30-4:30 pm, via [Zoom](#)

LAB: Rm 113A, 110 Cummington Mall
C1 Mon 2:30 – 4 pm C4 Thurs 5:30 - 7 pm
C2 Tues 5:30 – 7 pm C5 Weds 8:00 – 9:30 am
C3 Weds 2:30 – 4 pm C6 Fri 2:30 – 4 pm

GSTs: Matt Taylor (mtay@bu.edu) (C1 & C5 lab sections)
Jean Soto Aquino (jeansoto@bu.edu) (C2 & C3 lab sections)
Max Cohen (maxcohen@bu.edu) (C1 & C5 lab sections)
Hagen Gress (hgress@bu.edu) (C2 & C4 lab sections)
Sumin Kyoung (sumink@bu.edu) (C2 & C4 lab sections)
Marc Mitjans (mmitjans@bu.edu) (C3 & C6 lab sections)
Saeed Mohammadzadeh (saeedmh@bu.edu) (C5 & C6 lab sections)
Harley Quinn (hjquinn@bu.edu) (C1 & C3 lab sections)
Shahabeddin Sotudian (sotudian@bu.edu) (C4 & C6 lab sections)

Course description

4 Credits. 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.

Instructional Format, Course Pedagogy, and Approach to Learning

Due to the Covid social distancing limitations, we are limited in the number of students who may be in the classroom at any given time. In the face of this extreme restriction, we decided to entirely flip the course. We have made a series of instructional videos that cover the entirety of the course material. Class time will be used to cover active learning exercises based on that week's concepts. You should watch the designated week's set of instructional videos **before** attending your class session. There are engagement questions embedded in the videos, so make sure to answer the questions that appear in the videos **before** your class session. Your answers to these questions will be graded.

The two sections have different room seating capacities and therefore have different in-class arrangements:

A1 (Morgan)

In-person and remote synchronous (including quarantined) students: To ensure distancing

and allow for the extra time that may be required to get to and from the 9th floor of 1 Silbur Way, we will split into two cohorts. The “M” Cohort is for A1 students with last names A-J and the “W” Cohort for A1 students with last names K-Z. Each cohort will attend class for 60-minutes per week. The M Cohort will attend on Mondays 12:30-1:30 pm and the W cohort on Wednesdays 12:30-1:30 pm. Students who are not attending in person should attend their cohort’s class time via Zoom so that they can participate live, albeit remotely. Although you may note that A1 students have more in-class time than A2 students, this extra time is provided to accommodate teaching simultaneously to students in the room and those over Zoom.

Remote asynchronous: The Wednesday class time’s Zoom session will be recorded and made available to watch.

A2 (Farny)

Based on the section enrollment-to-LfA room capacity we are limited to a 45-minute in class session per week. The section roster will be divided into 4 groups: 3 in-class groups and a synchronous remote group. In order to stay on track, the semester is divided into 13 weeks, rather than 27 class sessions.

In class students: You will be in either a “M-I”, “M-II”, or “W-III” class session. The “M” or “W” corresponds to “Monday” and “Wednesday” session, respectively. This assignment will be emailed and posted to Blackboard.

Remote students: You will be in the “W-Remote” session.

A2 Class session timing

M-I: Mondays 10:10-10:55 am, ENG245

M-II: Mondays 11:10-11:55 am, ENG245

W-III: Wednesdays 10:10-10:55 am, ENG245

W-Remote: Wednesdays 11:10-11:55 am, via [Zoom](#)

NOTE that the first class of the semester falls on a Wednesday (Sept 2nd) but is designated for the “M” groups!! October 13th is similarly shifted, as it is a Tuesday but follows a Monday schedule. The course schedule shows the full schedule, and otherwise all other “M” and “W” meetings fall on a Monday or Wednesday as expected.

Lab kits and lab section

Due to the LfA mode we can no longer rely on a single set of on-campus laboratory equipment. You have been contacted by the ME Department regarding your location and plans for distributing a ME310 lab kit. We have worked throughout the summer to completely redesign the ME310 labs. ~~Assuming no supply issues, we are planning on 4 new lab exercises. You should ultimately receive the following LfA Lab kits:~~

~~—— Scope pack: PicoScope 2204A (and cabling)~~
~~—— EK307 pack: Circuit components, breadboard, etc~~
~~—— EK301 pack: Mechanical support (clamps, wooden meter stick, etc)~~
~~—— ME310 course pack: Sensors (vibration, thermocouple, force), thermocouple chip, thermometer~~

~~On campus (and nearby remote) students will pick up their full kit from their lab section. Remote students outside of the Boston area will receive theirs via a shipping service. A full list will be~~

~~posted on our Blackboard site. Contact Prof Farny if you are missing something by Sept 14th or haven't received your shipment.~~

~~With this kit you will tackle the lab procedures in your home workspace. We have designed the labs to be safely completed in a home, dorm room, or apartment. You will still make use of your registered Cx lab section, however!~~

9/28/20 UPDATE: The vendor for the oscilloscope has not been able to fulfill our order as initially promised. We are looking for replacement suppliers and will update you on the status once we learn more.

Each lab is scheduled to take place over a 2-3 week time frame, and is split up as follows:

1. Prelab: A formal document that you write, comprising the first few sections of your overall report. Your prelab should be submitted to TurnItIn. Your GSTs will run a set of Zoom-hosted office hours during your normal lab section time slot to address questions about lab procedures.
2. Lab procedure: Over the course of a week you, either alone or with partners from your lab section, will work through the lab procedure using the lab manual and lab kit.
3. Lab troubleshooting session: The next scheduled lab section will be held in person and/or via Zoom, as a troubleshooting session with your GSTs. This will be your chance to bring your equipment to the lab and receive direct feedback from the GSTs on any questions you might have. One GST per lab section will be reserved for students attending remotely via Zoom.
4. Lab report: Your full and compiled lab report will be due by the following week, via TurnItIn.

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. We 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

Blackboard (learn.bu.edu): All of the course material will be hosted on Blackboard. We have transitioned to a Blackboard Ultra website, so the format may look different from what you're used to seeing.

Please check the course Blackboard site to review your grades and submit digital copies of your lab reports. Note that we do **NOT** use Blackboard to calculate your final grades, so disregard whatever grade assignment or total number of "points" that Blackboard says you have.

Grading	10%	Video questions, Class & Lab performance
	15%	Design Project

15%	Homework Sets
20%	Labs and Lab Reports
20%	Each exam

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

Class

ME310 is now a fully “flipped class”. Each class will involve a measurement and/or analysis challenge that is designed to help you explore that week’s video concepts. In order to prepare for these challenges, it is imperative and required that you watch the course videos that we’ve prepared for you. It is expected that you will have watched the videos and answered the corresponding video questions PRIOR to coming to class, and that you will participate in class with the in-class exercises. Check the course semester and lab schedule to make sure you are aware of the assignment dates for this course.

Videos

Note: We have not designed the website or videos for a smartphone platform; the videos are best watched on a computer screen with headphones for properly hearing the audio.

The course has 11 major concept areas that have an accompanying set of videos organized within that week’s video playlist. Each playlist covers a discrete concept that is central to the course; understanding the content in the videos is a key step to understanding and passing this course. There are 3 – 5 videos per module, and each ranges from 9 – 16 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 we will not formally cover these topics in class! Also note that a few questions are embedded in most videos. You are responsible for submitting your answers to these questions. These make up your “video questions” that will appear within the videos and should be submitted by the day you have class, for that week’s video playlist schedule. Make sure to take notes and post any questions that you have from the videos.

Pedagogical research has demonstrated that listening to a chalkboard lecture can result in low retention of material, not to mention transcription mistakes from the presented material to your notes. This is why we 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 will accompany the major concepts and will be administered most weeks of the semester. They should be uploaded to Gradescope by the BEGINNING of class on the due date listed. LATE HOMEWORK WILL NOT BE ACCEPTED unless circumstances merit the exception.

Exams

There will be 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. Both exams will be administered online. The midterm exam will be given online on **Wednesday Oct 21st**. "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

The details for the project will be announced later in the semester. This will be a group project.

Drop and Withdrawal Dates

The last day to DROP: November 6th. The last day to WITHDRAW: December 1st

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

Community of Learning: Class and University Policies

A. **Homework and video questions:** Individual assignments. However, you are encouraged to consult with classmates on general concepts.

B. **Lab reports:** Everything you write needs to be your own work. 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.** 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 may **and are encouraged** to consult with your lab partners to discuss findings and results. Screen sharing your results to facilitate a discussion via Zoom or a similar web conferencing application is **OK** -- just don't use screen shots as part of your report. Take this guidance **very seriously but PLEASE feel free to come talk to us if you're unsure about boundary lines!**

C. **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/>

D. **COVID-19 & BU Community Health Expectations:** Masks must be worn over the mouth and nose at all times when in public spaces on campus, including classrooms. You should be prepared to show proof that you are compliant with health attestations and testing in order to attend class. You are expected to follow all university guidelines with respect to daily symptom checks, testing, social distancing, and mask wearing when you leave your dorm or home. For a detailed description of the allowable types of masks and other official BU policies regarding COVID-19, please visit:

<http://www.bu.edu/dos/policies/lifebook/covid-19-policies-for-students/>.

E. **Inclusion:** We consider our classrooms to be a place where you will be treated with respect, and we welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, gender identities, gender expressions, national origins, religious affiliations, sexual orientations, ability – and other visible and nonvisible differences. All members of this class are expected to contribute to a respectful, welcoming and inclusive environment for every other member of the class.

F. **Accommodations for students with documented disabilities:** If you are a student with a disability or believe you might have a disability that requires accommodations, requests for

accommodations must be made in a timely fashion to Disability & Access Services, 25 Buick St, Suite 300, Boston, MA 02215; 617-353-3658 (Voice/TTY). Students seeking academic accommodations must submit appropriate medical documentation and comply with the established policies and procedures <http://www.bu.edu/disability/accommodations/>

We will make every effort to accommodate such requests but (a) please notify us 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) our policy is that we need at least one week's notification prior to each exam so we can make the necessary arrangements.

G. Religious accommodations: We are 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. We require advanced notification at least a week for such occasions.

Matlab Access

We **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. We are more than happy to give assistance and guidance if you need help.

LAB AND LAB REPORT POLICIES AND PROCEDURES

1. **Groups**
You are encouraged (but not required) to work with a group of your peers as you work through the lab procedure. We recommend organizing yourselves into groups of no more than 4 students each. Lab reports are individual assignments.
2. **Notebooks and Reports**
 - a. Lab Notebook: You should keep and maintain an organized set of notes for documenting data, observations, and general experimental setup notes. Any bound notebook is fine but we recommend finding a version that is page numbered and square-ruled (available from multiple vendors).
 - 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 lab notebook 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 prelab session, to be submitted via TurnItIn.
3. **Lab preparation**
The lab component for this course bears considerably more responsibility than other lab exercises you've had. This has historically been the case in ME310 and is now even more so in the LfA environment! The GST-led Prelab session will provide feedback on the lab goals and procedure, and they will provide troubleshooting assistance in the subsequent Lab session. 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 posted earlier in the syllabus, you are required to submit a digital copy of your prelab, in-lab data and spot check results, and full report over a course of 3 weeks during which you're engaged with a lab exercise. **LATE LAB REPORTS WILL NOT BE ACCEPTED OR GRADED** unless dire circumstances warrant the exception; see your instructor if you are unable to complete your report on time.
5. **Uncertainty Analysis**
Certain labs will require a formal uncertainty analysis, as described at the top of the lab manual. Lab 1 will **not** require a formal uncertainty analysis.
6. **Lab Report Content**
A section by section breakdown of what is expected appears below. The first homework assignment involves the critique of an old lab report and is meant to familiarize yourself with the format involved with ME310 reports.

7. **Academic Honesty**

These labs 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. It **IS** permissible to discuss your data and results via Zoom. **Do NOT share digital files other than whatever raw data needs to be shared within your group.**

8. **Safety**

Safety is paramount. You only have the one set of equipment that was delivered to you at the beginning of the semester. Treat it carefully, since there will not be a replacement readily available. Make sure to keep liquids away from your lab equipment!!

9. **Equipment**

Two bad things happen to lab equipment: An instrument fails or is made to fail via an accident. Do your best to prevent the latter (set your power connections carefully and handle with care!). Please report broken equipment directly to your instructor and GST as soon as possible, so we can diagnose and fix or replace as necessary.

ME 310 LAB REPORT CONTENT

GENERAL INFORMATION

- Include page numbers for your report.
- A full report will consist of a prelab document, in lab notes and data, and a postlab document, combined into one complete document. All 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 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 $\neq$ better! We 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
- 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 working through the lab procedure. 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 $\neq$ 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. 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.

6. Equipment List

Next should come a tentative list of equipment. It is a tentative list because you may need to add to the list once you work through the procedure. You should include information on the **equipment manufacturer and model number**. You should construct this list in the form of a table.

Data Sheets: You'll need these for your Uncertainty Analysis. It is your responsibility to go to the manufacturer's website for this information.

7. Procedure Checklist

The lab manual provides the goals and the main procedural steps for accomplishing those goals. You should transcribe these steps into a single bulletized checklist of steps for you to follow, referred to as that lab's Procedure. 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 your Prelab session.

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 power on a circuit, 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 23% of your lab grade.

INLAB REPORT SECTION: To be done during lab

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

1. 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.

2. 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.

3. 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.

4. Perform Spot Checks

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. All ME310 labs include spot checks to help you identify problems relating to faulty data, incorrect analysis, lab technique or faulty equipment.

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.

5. Note general observations

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

6. 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 certain labs (at the time of publication, labs 2 – 4). The lab manual will clearly specify whether uncertainty analysis is required.

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	7%
	Equation summary	2%
	Data needs	5%
	Equipment list	2%
	Procedure checklist and safety	3%
Inlab	Data	5%
	Spot checks, block diagram	5%
Postlab	Analysis	14%
	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, we 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). We 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! A lab report template is posted on Blackboard 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>