MECH 305/306 Data Analysis and Mechanical Engineering/Mechatronics Laboratories 2021

Instructors

Dr. Ahmad Mohammadpanah, amohammadpanah@mech.ubc.ca,
Dr. Steven Rogak, rogak@mech.ubc.ca,

Why we are here

Thoughtful observation of the physical world is the foundation of Engineering and Science. All theories and practice are rooted in measurements; this is the way we learn about the world. It is therefore essential for both researchers and practicing design engineers to be skilled in obtaining *meaning* from physical observations. This task is not trivial and involves several steps, from formulating a question to be answered (and helps your engineering task if you answer it), to selection of the physical measurement systems and operating procedures, through to the interpretation of your data and observations.

The famous rocket scientist Wernher von Braun once said “Research is what I am doing when I don’t know what I am doing.” This insight reveals a fundamental characteristic of true research, which is that at the start of the work the outcome at the end is not known. Typically, in research, initial observations provide insights for subsequent more detailed investigations.

Course-based experiments typically focus on demonstrating various physical principles, but they are not “research” according to the von Braun definition because the underlying theory and expected results are already well established. The academic need to provide an experimental activity that can be successfully completed within a compact timeframe means that the experimental procedures and associated equipment need to be prepared well in advance. All that is left for the student is to obey the instructions, “crank the handle” and turn out the desired numbers and graphs. We aim to break out of this pattern in this course.

Learning Objectives

The objective of this course is to enable you to improve your skill in developing, conducting and interpreting experiments. The Laboratory and Data Analysis portions of the course includes several specific activities to help you develop these skills.

Laboratory Experiments

MECH 305/6 has been designed with the objective of giving you a laboratory experience that is closer to true research by using a more open-ended experimental format. The course will include two types of experiments:

I) “Familiarization” experiments where equipment (lab-in-box kit) and procedures are provided for you, where the purpose is to learn about the capabilities and use of the equipment. This experience should enable you to explore a question or questions asks in the lab user manual and develop your own measurement and analysis procedures. You may also conduct more experimental tests to answer your own questions.

II) A "Capstone Experiment", where you develop your own research question and procedure for one of the experiments done earlier. Here you will go more deeply into a chosen area and seek to explore in more detail an important research question that you have identified in the Introductory experiments, or in your activities outside the classroom. You may focus on one of the experimental systems covered in one of the Introductory labs propose a question to be answered with the system, then carry out the experiment. Alternatively, you may propose an experiment to investigate an experimental question from a broader field. You will work in a team (3 or 4 students) on this project. You may use the Arduino and sensors you have already in your lab-in-box kit to build a new apparatus for your experimental tests or purchase new sensors (the cost of new things will not be covered.)

Data Analysis

To get useful answers from experiments, you need to understand both the physical systems that produce the numbers, i.e., your measurements, and the analytical methods that can be applied to the numbers. The course covers analysis of data within the course lectures and biweekly tutorials. Why analyze data? Often, we want to understand patterns within the numbers; data visualization is particularly important here. In other applications, we might understand the basic patterns fairly well, but we need to determine whether one population of objects, say a shipment of grade F bolts with fine threads, is different from another population or shipment, or strong enough to keep the passengers in an airplane safe. Here, the variability of the measurements is critical, and the methods of statistics are essential.

The methods of data analysis and the experimental design go hand-in-hand. After this course, in major projects, graduate research, or engineering practice, you most likely will consider the measurements and the analysis together. Each topic is important and challenging in its own right. Therefore, the lab and data analysis components will run parallel and mostly independently for much of the course, later to merge in various activities later in the term.

Lab groups and Tutorial Schedule

Prelab exercises, tutorials and all examinations are completed and marked for individual students. Some lab reports are individual and some are to be completed by teams. Most of the students will complete the part I labs and their reports around Reading Week, leaving time to develop and carry out the Capstone Experiment. The work will include a number of deliverables through the term, such as a proposal. Mech306 students are not required to complete the National Engine Lab (you may choose to work on it voluntarily; but there will not be any credit for completing this lab for Mech 306 students), consistent with the credit level in this course, but still follow the guiding principles discussed above.

Note: Teams and Lab Schedule on a separate document ("Schedule" on Canvas, and refer to MS Team for your team and labs).

Lecture Topics:

- Data presentation, Description of data, mean, sample vs population variance, histograms, scatter and bubble plots, a brief intro of FFT
- Introduction to Uncertainty, Errors and Error Bars, how to report Error
- Determining the Uncertainty and Errors in Measurements
- Error Propagation
- The normal distribution
- Review of Probability and Bayes Theorem
- Basic Hypothesis Testing
- Comparison of Samples and Rejection of Data, Student t-Test, Binomial Distribution

- Introduction to DOE (Design of Experiments) with Fractional Factorial,
- The ANOVA and F-test
- Machine Learning
    - This course also provides a brief review of core issues necessary for understanding the application of ML (Machine Learning), including the fundamental techniques in ML: Classifiers, Support Vector Machine, Decision Tree, Naïve Bayes, Linear Discriminant Analysis, Clustering, Principal Component Analysis, Deep Learning (ANN (Artificial Neural Network) and CNN (Convolutional Neural Network))

As you can see from these topics, this is a rather full course and as your instructors we would be remiss in our duty if we neglect to underscore the fact that learning the concepts in each topic in this course is demanding and takes time. One key to true and lasting knowledge in this course is practicing through applying various techniques to different sets of data. Luckily, there are a plethora of examples available in your textbook and we will also provide you a manifold of examples to practice. Examples from industry will also be used to show how these theories and concepts may apply in practice.

Textbook

Required: J.R.Taylor. "An Introduction to Error Analysis", 2nd ed. University Science Books, 1997 (available at the bookstore).
Optional Reference: Montgomery, Runger and Hubele, Engineering Statistics, Fifth edition, John Wiley, 2011 (either 4th or 5th edition is suitable; this was the text used in past years and you might get a copy from a senior student)

Grading

Please note the Mech 305 students have one extra labs (National Gas Engine), and the weight distribution for each lab will be allocated accordingly.

1. Lab-in-Box 20 %
   • *Prelab Quiz (individual) 4*%
   • Part I reports 16%

2. Capstone Experiment 20%
   • Proposal Abstract 3%
   • Full proposal with plan 5%
   • *Conduct (individual) 2%*
   • Report 10%

2. Tutorials (individual) 10%

3. Two Midterms 20%

5. *Final exam 30%*

Students must have a passing average on the individual marks (sum of prelab, tutorial, quizzes and final) before the team marks are included to compute the overall average. The individual conduct marks will be based on assessments of TA's and instructors throughout the term. We will be looking for evidence of good effort, commitment and good team contributions.

A & S