Measurements Laboratory

Mechanical Engineering 4228-005

Professors John W. Daily and Wei Tan

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Class Meets: Daily Section: MW 3:00-4:50 PM, ITLL 1B10
Tan Section: TR 12:30-2:20 PM, ITLL 1B10

Course Website: CU Learn

Prerequisites: PHYS 1140, WRTG 3030, and either MCEN 3017 or ECEN 2250

Office Hours: TBD (posted on Website)
Also by appointment

Catalog description: Fundamentals of measurements: Resolution, frequency response, calibration, digital data acquisition. Uncertainty analysis for design stage, single and repeated measurements, including random vs sytematic, propagation, statistics and outlier rejection. Comparison of measurements with empirical, first and second order models. Written and oral technical communication. Four hours of hands-on laboratory experience per week in teams.

Course description: As mechanical engineers, we are very interested in manipulating the behavior of physical objects, and **in making things work** the way we want them to. Examples range from the design of automobile engines, to artificial hearts, to perfecting the injection system used in making plastic spoons. In this course, you will have the opportunity to learn the pleasure of making things work, as you assemble and/or run a variety of instrumentation devices and manppoIn thiD0 plastic are examples of measurements you will perform this semester.

Measurements are made for several reasons. First, as an integral part of the scientific method, measurements are necessary to determine the validity of models, and to suggest refinements or new approaches. One focus of this course will be on the **comparison of theoretical models** with experimental measurements. You will finally be able to see how some of the theory and analysis you are learning in your other courses can relate to physical reality, to see how some of the models, the mathematical descriptions, can actually predict the behavior of a gadget sitting on a table. Second, measurements are made to **quantify the performance** of devices. Measurements are also used to **control** manufacturing processes. Sometimes, measurements are made just to **get an answer**, such as Young’s Modulus, for example.

In addition, you will learn how to estimate the **quality** of a measurement. What good does it do to measure the weight of an IC chip with a bathroom scale? Or to measure the lifetime of a light bulb with a stopwatch? How many measurements of bolt sizes are needed to get a good average? Knowledge of **uncertainty analysis** is required to properly select measurement tools, and to understand what the measurements mean. Uncertainty is a value that quantifies the ‘goodness’ of a result. Without such a value, it is impossible to judge the fitness of the measurement as a basis for making decisions relating to health, safety, commerce, or scientific excellence.

Another focus of the course will be on **communication skills**, which include input, as well as output. You will learn to prepare formal written research reports/papers and oral presentations. You will also gain some exposure to the vastness of technical literature when you do research for

At the same time, dealing with REAL EQUIPMENT is the best part of this course. Hands-on is fun! Hooking up equipment, twiddling knobs, pumping water, spinning motors, flashing lights, twanging beams and guitar strings... there's no substitute for actually doing it. So make sure you get your turn at the controls, and that your partners do too. Feel free to explore, and play around with the equipment (in a nondestructive way of course). Try things that are not in the lab manual; why not let curiosity guide you. Get involved and you'll get much more out of the course. Let that be your goal.

Learning objectives:

- Hands-on Experience and Context
  - Connect and troubleshoot simple measurement systems.
  - Apply judgment when faced with indeterminate problems.
  - Acknowledge disparity between theory and experimental results in terms of the scientific method.
- Measurement fundamentals
  - Understand the purposes of measurements: comparison with models, performance measurements, process/quality control, physical constant determination.
  - Compute uncertainty, and understand the concept of error
  - Apply standards for calibration
  - Choose and apply appropriate measurement techniques based on linearity and frequency response
- Probability and statistics
  - Compute and apply basic statistics concepts for the analysis of data, including mean, standard deviation, finite and infinite statistics, student t distributions, probability density functions, regression, etc.
- Uncertainty analysis
  - Distinguish between random and systematic uncertainties
  - Compute uncertainty for the following circumstances: design stage, repeated measurements, single measurements, propagation of uncertainty.
  - Apply objective outlier rejection techniques.
- Digital data acquisition
  - Understand modern measurement systems: transducers, signal conditioning, analog/digital data conversion, post-processing
  - Apply concepts of resolution in the choice of measurement systems: amplitude resolution, time resolution
- Modeling
  - Apply mathematical models of physics from other courses to laboratory experiments including first and second order systems and statics models.
  - Empirical modeling including linear regression.

- Fourier analysis
    - Observe and apply concepts of Fourier Analysis to laboratory

reference texts that would be very useful to you!

- Theory and Design for Mechanical Measurements, Figiola and Beasley, Wiley and Sons Pub. 1995. This book has a good explanation of uncertainty calculations as well as general instrumentation information. T50.F54 1995
- Experimental Methods for Engineers, J.P. Holman, 6th edition, McGraw-Hill, 1994. A classic text in this area. Not as great with uncertainty information, but good concise descriptions of experimental techniques. TA152.H6 1994
- Measurement Systems, Application and Design, E.O. Doebelin. McGraw-Hill, 1990. An excellent, in-depth reference for a wide range of sensor types and measurement techniques. QC100.5.D63 1990
- Measurement Uncertainty, Methods and Applications, Ronald H. Dieck, Instrument Society of America (this is the professional society for people who make measurements for a living) 67 Alexander Drive, PO Box 12277, Research Triangle Park, NC 27709 1997. T50.D53 1997

Other useful texts:

- Learning with LabVIEW, Robert H. Bishop. National Instruments, 1999. A tutorial introduction to LabVIEW, which is a computer data acquisition software package used in both Measurements and Senior labs. It is becoming popular in industry as well. Knowing LabVIEW is a marketable skill, but is not required for this course.

Professional behavior:

Professional behavior means carrying your weight in the teamwork efforts, AND treating your classmates, TAs, instructors, and ITLL staff with **professional courtesy**. We appreciate professional behavior in the classroom. Because we think this is so important in the classroom, we will be evaluating you subjectively at the end of the semester and will award points according to whether we viewed your behavior as below average, average or outstanding professionally.

Turning in lab reports:

All work should be typed in a professional manner and turned in on time. Late assignments will not be accepted. Lab reports handed late will be graded at the discretion of the instructor and may not receive full credit.

If you have a documented illness or family emergency, arrangements can be made for late assignments with no penalty. Note: **computer viruses or disk crashes do not constitute a valid excuse**. That's what backup copies are for. You will not be allowed to 'drop' an assignment.

In the case of individual assignments, **evidence of dishonesty** will not be tolerated. The miscreant will receive no credit for the assignment, and an entry will be placed in the student's Deans folder. However, helpful interaction between students is encouraged. *The key difference is that helping each other means communicating concepts. Cheating means using/copying another's work as your own.*

Extra credit:

We do not give extra credit assignments.

Grading:

Categories	*Weight*
Written Questions Lab 1	10%
Written report	20%
Oral presentation	20%
Poster Session	20%
Project Leadership	20%
Industry Visit	5%
Professional behavior	5%

There are always a number of questions about grading. The fact that there are different people grading your homework and exams, makes it seem difficult to fairly assign grades. We do recognize these problems and strive to ensure that the grades are fairly assigned. The most important thing we can do is to normalize the grades in a way that compensates as much as possible for such variability.

At the end of the semester, your homework, exams, projects, etc. scores will be normalized by the total points possible and weighted as described above. The breakdown of grades will be assigned such that the class average plus one standard deviation **or more** approximately encompasses A – B grades, and the class average minus one standard deviation **or more** approximately encompasses B – D grades. The actual percentage breakdown of grades depends on the performance of the entire class. The boundaries between grades are selected to achieve the desired overall class GPA, which is about 2.7 – 2.9 for an undergraduate class.

In addition we will be handing out peer evaluation forms after each lab. If we find significant differences in the contributions of individual team members over the course of the semester final grades will adjusted accordingly.

Grades will **not** be changed after they have been assigned at the end of the semester, except in extenuating circumstances. So, if you have any questions about your scores on assignments, professional conduct, quizzes, etc., that may affect your final class grade, you must ask/address them before the end of the semester.

Typically the following performance criteria will be rewarded with the grade as described below:

- A: EXCELLENT - Work performed in excess of requirements, consistently throughout the semester. Homework, labs, and projects successfully completed and scored a very high percentage of the possible course points.
- B: COMMENDABLE - Performed and produced more quality work than minimally required. Homework, labs, and projects successfully completed and scored a high percentage of the possible course points.
- C: SUCCESSFUL - Work completed. Achieved minimum requirements. Homework, labs, and projects completed and scored a reasonable percentage of the possible course points.
- D: MARGINAL - Work partly completed and/or turned in late and scored a minimal percentage of the of possible course points. Did not effectively contribute to the team projects.

Course Policy and Important Information:

If you qualify for accommodations because of a **disability**, please submit to your instructor a letter from Disability Services in a timely manner so that your needs may be addressed. Disability Services determines accommodations based on documented disabilities. Contact: 303-492-8671, Willard 322, and www.Colorado.EDU/disabilityservices.

Campus policy regarding **religious observances** requires that faculty make every effort to reasonably and fairly deal with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. Please notify your instructor of any obligations that conflict with your fulfillment of the course requirements.
See full details at http://www.colorado.edu/policies/fac_relig.html

Students and faculty each have responsibility for maintaining an **appropriate learning environment**. Students who fail to adhere to such