University of California, Berkeley
Department of Mechanical Engineering

ME 103 – Experimentation and Measurements (4 units)

Undergraduate Required *Syllabus*

Lectures (1 section, 2h/wk): M&W 10:10-11a, 105 North Gate
Discussion (1 section 1h/week): F10:10-11:00a, 105 North Gate
Labs (6 sections, each 3h/wk): T&Th 8-11a, T&W&Th&F 2-5p

INSTRUCTOR

Asst. Prof. S.A. Mäkiharju
6119 Etcheverry Hall, Office hours: M&W 9-10a or by appointment
Email: makiharju@berkeley.edu
(For course related questions, preferably come to office hours or first post them on Piazza in bCourses.)

Writing and presentation instructor

Lecturer Marcel Kristel, marcelk@berkeley.edu
6173 Etcheverry, Office hours: M1-2p, W2:30-3:30p and by appointment.

GSIs

Jason Parker, jtparker@berkeley.edu, office hours: TBD
Nicole Neto Godry Farias, nfarias@berkeley.edu, office hours: TBD
Sangjoon Lee, sangjoonlee@berkeley.edu, office hours: TBD
Daniel Grieb, djgrieb@berkeley.edu, office hours: TBD

CATALOG DESCRIPTION

This course introduces students to modern experimental techniques for mechanical engineering and improves students' teamwork and communication skills. Students will work in a laboratory setting on systems ranging in complexity from desktop experiments with only a few instruments up to systems such as an internal combustion engine with a wide variety of sensors. State-of-the-art software for data acquisition and analysis will be introduced and used throughout the course. The role of error and uncertainty, and uncertainty propagation, in measurements and analysis will be examined. Design of experiments will be addressed through examples and homework. The role and limitations of spectral analysis of digital data will be discussed.

COURSE PREREQUISITES

MEC85, ME40, ME100/EE 49/EE16A, ME 106 (can be taken concurrently), ME 109 (can be taken concurrently.

TEXTBOOK(S) AND/OR OTHER REQUIRED MATERIAL

Mechanical Measurements, 6/E (students can also use 5th edition), Marangoni, Lienhard & Beckwith
Additional lecture slides and handouts will be provided. *Note: 5th ed. has been available for <$10!*

COURSE OBJECTIVES

Introduce students to modern experimental techniques for mechanical engineering; provide exposure to and experience with a variety of sensors, including those to measure temperature, displacement, velocity, acceleration and strain; examine the role of error and uncertainty in measurements and analysis; exposure to and experience in using commercial software for data acquisition and analysis; discuss the role and limitations of spectral analysis of digital data; provide experience in working in a team in all aspects of the laboratory exercises, including set-up, data collection, analysis, technical report writing and oral presentation.

DESIRED COURSE OUTCOMES

By the end of this course students will have experienced the many stages in designing, planning and conducting experiments, and eventually reporting the results both orally and in writing in a team environment. They will have also have seen the importance of fundamental science and complex engineering skills that are needed in engineering. Equally important, they will work in a team environment where the success of the team depends on the success of every team member. Specifically, by the end of the course students should: Know how to use, what can be measured with, and what the limitations are of the basic instruments found in the laboratory; know how to write a laboratory report and communicate their results in the form of an oral presentation; understand the relevance of uncertainty in measurements, and the propagation of uncertainty in calculations involving measurements; know how to program effectively using LabVIEW for data acquisition and analysis. In brief: Prepare students for experimental work, or its management, in academy or industry.

TOPICS COVERED

- Data acquisition and control software: LabVIEW
- Sensors: I/O requirements, calibration, limitations
- Dynamic analysis of signals: spectral analysis, bandwidth, frequency response
- Elementary statistics: normal and t-distributions, confidence intervals
- Uncertainty analysis: techniques for propagation of uncertainty
- Teams: forming, expectations, potential problems
- Technical communication: written, oral
- Design of experiments
- Measurements for complex systems

CONTRIBUTION OF THE COURSE TO MEETING THE PROFESSIONAL COMPONENT

Provides a platform where students work on increasingly complex measurement systems as teams, make formal oral presentations and submit complete technical reports. Provides the flexibility and structure to implement experiments designed by the students testing varying configurations and setups.

ASSESSMENT OF STUDENT PROGRESS TOWARD COURSE OBJECTIVES

Students will perform a set of five laboratory experiments and will report their findings both in writing and orally 70% of the grade, (*L1&2 8%, L3&4 12%, L5 30% [including 2, proposal, 3 for initial presentation, 5 for final presentation)).* Homework will count for 25% of the grade (each of 7HW is 3 or 4 points). 5% lab practical. (Should attend all labs, but regardless of reason, to pass 9 of 12 required.)

Schedule

Ok to discuss individual assignments and show your codes etc. to classmates, but no sharing of code or other individual products (see student code of conduct).
All HW are individual, but some lab reports are done partly or entirely as a group.

Subject and order of lectures is subject to change based on pedagogical needs, but labs and homeworks will follow the schedule.
…in this class we talk a lot about uncertainty, let us begin by eliminating uncertainty about what comes next!

Wk	Date	Primary lecture topic	Week's lab/other task	Assignments and reading for the week
5	9/23 9/25 9/27	M: Sensor physics, part 2, linear encoder W: Sensor physics, part 3, inc. LVDT F: Discussion – review past labs	Lab 3 week 1 of 2 Vibrating beam, get all sensors working. VI provided	~~Lab 2 **individually** completed assignment. **DUE 9/30 11:59pm.**~~ ~~**Read:** 6.7, 6.10, 11.13, 17.10, 8.6~~
6	9/30 10/2 10/4	M: Theory for HT lab 4 and HW3 W: HT lab, and sensors used. F: Disc. – lab report expectations	Lab 3 week 2 of 2 Measure natural frequency with different masses on end of beam.	HW 3: Students using theory of cylinder in cross-flow to predict cooling of Lab 4 resistors. **DUE 10/6 11:59pm.**
7	10/7 10/9 10/11	M: Image based measurements 1 W: IR measurements, PIV, part 1 F: Discussion – Design of experiments 1	Lab 4: Heat Transfer lab – resistive heating and convective cooling. Analyze VIs and instrumentation used. Characterize flow field approximately with lab hotwire. Discuss, troubleshoot and understand.	**Custom lab proposal due 10/11 11:59pm. Must include bill of materials, Gant-chart, etc. 1-3 pages.** **Read: TBA**
8	10/14 10/16 10/18	M: Group **presentations**, custom lab plan. W: Group **presentations**, custom lab plan. F: Group **presentations**, custom lab plan.	Lab 4: Heat Transfer lab – resistive heating and convective cooling. Find equilibrium points. Compare thermocouple and IR camera.	Lab 3 **individual** report **DUE 10/18 11:59pm.** **Read: TBA**
9	10/21 10/23 10/25	M: Uncertainty and Monte Carlo W: PIV, part 2 F: Discussion – PIV examples and HW	Custom labs following **approved plan**. Week 1 of 5 Pick from list below.	HW4 Image Processing. **DUE 10/25 11:59pm.** **Read: TBA**

10	10/28 10/30 11/1	M: Design of experiments 2 W: Discuss uncertainty with special guest F: Discussion – topics from ongoing labs.	Custom labs. Week 2 of 5 *(Come to lab, make most of the time, use GSIs and instructor as resources. Come to OH as needed – do not leave your resources unused!)*	**Lab 4 individual report due 11/1 11:59 pm.** **Read: TBA**
11	11/4 11/6 11/8	M: Technical writing part 2 – M. Kristel W: Presentation prep. lecture – M .Kristel. F: Disc. Feedback on past HW and labs.	Custom labs. Week 3 of 5	HW 5 – some design of experiments with uncertainty budget using Gauss and MC methods & Matlab. **DUE 11/8 11:59pm.**
12	11/11 11/13 11/15	M: Academic holiday. W: Temperature, pressure and flow meas. F: cont.	Custom labs. Week 4 of 5	**Read: TBA** HW 6: PIV from sample data **DUE 11/15 11:59pm.**
13	11/18 11/20 11/22	M: Rev.of sensor physics relevant to HW7. W: Real life experiments – lessons to learn F: Let's discuss your remaining questions!	Custom labs. Week 5 of 5	HW 7: Sensor physics **DUE 11/22 11:59pm.**
14	11/25	M: Discussion – review expectations for custom lab reports and presentation.	Week of Thanksgiving. No labs!	No assignments. Enjoy the break!
15	12/2 12/4 12/6	M: Group **presentations** of report. W: Group **presentations** of report. F: Group **presentations** of report.	Lab practical tests. Individual, 12 minutes per student. **Sign up before the break to secure a time slot that works for you!** Only enter lab when it is your turn.	**Custom group lab report due 12/8 11:59pm!**

Custom lab topics to choose from (you propose what your goals will be, what you will measure and how – GSIs will instruct on how to sign up):

- Image based measurement and control of ball (max. 12 groups)
- Vertical OR Horizontal axis wind turbine model in wind tunnel – *discuss with GSI which tunnel of three to use* (max 12 groups, i.e. max two from each lab section unless you find a time outside regular lab hours that coincides with GSI OH and enables a third group to do this whilst still having tunnels for ~1.5h/wk.) (IF CHOSEN, ACT EARLY TO GET IN 3D PRINTER QUE AND NOTE THIS MAY FILL UP FAST)
- Field strain measurements
- PIV e.g. of a laminar flow in a pipe (max three groups can choose this – anyone with laser training has priority, but first to pick gets the slot)
    - May need to be done outside Hesse, talk with GSI Parker before signing up for this
- PTV of spray/other (max three groups can choose this)
- LDV of spray/other (max three groups can choose this)
- Material characterization with the vice setup (bending beams and using displacement and load cell, max 12 groups.)
- Measure linear waves in a wave tank (max two groups, lab in Etch 2115) [talk with GSI Parker before signing up for this]
- Combustion lab (max. 1 group per section, max. 6 groups total)