Sensors and Instrumentation for Biological Systems
Biological Engineering 420, Spring 2009
Course Syllabus

Instructor: Daniel M. Jenkins
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TA: N/A

Meeting Times and Locations (subject to change pending consensus of participants)
Tuesday & Thursday, 10:30 to 11:45 AM; Agr. Sci. 204
Thursday, 1:30 to 4:00 PM; Agr. Sci. 315

Grading:

Lab Reports:	30% †
Final Project:	15%
Attendance/ Participation:	10%
Preliminary Exams (2) and/or quizzes (?):	30%
Final Exam:	15%

† Note that this is a Writing Intensive (WI) course. There will be a series of six lab topics and a final project to write reports about. You must submit reports for the first lab (Calibration, Errors, and Uncertainty) and for at least two of the other lab topics chosen at your discretion. For your final project report you may choose to give a verbal presentation or write a final report (note that if you submit more than three preliminary reports, the extra(s) with the lowest score(s) will not count towards your grade).

Textbook: *Experimental Methods for Engineers (7th Ed.)*. J. P. Holman. 2001. McGraw Hill. ISBN # 0073660558

References: *Instrumentation for Engineering Measurements (2nd Ed.)*. Dally, J. D., W. F. Riley, & K. G. McConnel. 1993. John Wiley & Sons.

Medical Instrumentation (*3rd Ed.*). Webster, J. G. 1998. John Wiley & Sons.

Chemical Sensors and Biosensors. Eggins, B. R. 2002. John Wiley & Sons.

The Art of Electronics (2nd Ed.). Horowitz, P. & W. Hill. 1989. Cambridge Press.

Course Website (Laulima): Notes, handouts, and supplementary readings from various references including those above will be posted on Laulima:
https://laulima.hawaii.edu/portal
(Log on with your UH username and password, then click the tab "BE-420-001 [BE-420-001 [MAN.88772.SP09]]")

Prerequisites: BE 350 and EE 211; or consent

Catalog Description: 4 units. Principles of common physical and chemical sensors. Interfacing sensors to different electronic circuits and data acquisition systems. Electronic detection and quantification of biomolecules (biosensors). Applied control for biological processes.

Syllabus (Tentative)

Week	Lecture	Lab
1	Introduction. Standards, errors, uncertainty…	1. Calibration and uncertainty analysis.
2	Calibration; least squares analysis; fundamental system dynamics.	2. Fundamental dynamics of sensor and instrumentation systems.
3	Transfer functions; second order systems; introduction to temperature.	3A. Environmental sensors I: thermocouples and RTDs.
4	Operational amplifiers; more temperature sensitive devices; capacitive sensors (humidity and vapor).	3B. Environmental sensors II: thermistors, semiconductor devices, psychrometry, capacitive probes.
5	Seismic mass transducers: principles, applications, instrumentation, low frequency response.	4A. Force I: Strain gage and piezoelectric load cells; excitation (electrical and mechanical); resonance; DC response.
6	Piezoelectricity; **Exam I (tentative)**.	4B. Force II: Acceleration and pressure; acoustic devices.
7	Optical sensors, principles and applications: Current sources, LED's, photoamplifiers, optoisolators. Advanced optical systems- optical filters, gratings, photodiode arrays, fiber optics, gating circuits.	5. Displacement and Light: Linear Variable Differential Transformer (LVDT), optical encoders, photodiodes- operation and application.
8	Basis of electrochemical potential. Redox reactions and ion-permeable membranes. Operation of potentiometric and amperometric electrodes. Impedance buffering. Temperature compensation.	6A. Electrochemical Sensors I: Potentiometric electrodes for cations and pH. Impedance buffering with instrumentation amplifiers. Amperometric electrodes for O_2.
9	Origin and measurement of bioelectric potentials. Active filters.	6B. Biopotentials, Biosensors: Design and application of EKG; amperometric biosensor.
10	Biosensor principles and design: challenges of specificity, sensitivity, durability, and miniaturization. Enzyme and chemical binding kinetics.	7A. Programming tutorial (relay ladder logic, programmable logic controllers) no report; program due at end of lab.
11	Introduction to applied systems for data acquisition and control- PC or programmable logic controllers.	7B. Programming tutorial II- (Dynamic C microcontroller) no report; program due at end of lab.
12	Fundamentals of computer architecture and digital interfacing. Timers and counters. **Exam II (tentative).**	Work on final design project.
13	Digital interfacing to power circuits.	Work on final design project.
14	Basics of (applied) control systems.	Work on final design project.
15	Open for contingencies, exams, review, and student evaluations.	Final project presentations.

* Note that some topics above will require more or less than 1 week to cover, and the syllabus should not be considered an absolute guide to the amount of time spent on each topic.

Important Dates:

January 12- First Day of Class (class starts on January 13 for BE 420).

January 19- Martin Luther King Day (No class- no effect on BE 420).

January 20- Last day to drop classes and switch sections (without a 'W').

January 21- (4:00 PM) Last day to add classes.

January 30- (4:30 PM) Lab 1 report due.

February 16- Presidents' Day (No class- no effect on BE 420).

February 19- Preliminary Exam #1 (tentative).

March 6- (4:30 PM) Second lab report due.

March 13 (4 PM)- Last day to withdraw from classes (with a 'W').

March 26- Prince Kūhiō Day.

March 23 - 27- Spring break (no classes).

April 3- Third lab report due.

April 9- Preliminary Exam # 2 (tentative).

April 10- Good Friday (No classes- no effect on BE 420).

April 30- (1:30 PM) Final design presentations (tentative).

May 6- Last day of class (May 5 is last day for BE 420).

May 14- Final Exam; 9:45-11:45 AM.

Course Policies:

1. ***Safety***: Any student observed willfully engaging in activities hazardous to any of the course participants will be summarily dismissed from the lab with no credit for attendance, will not be allowed to submit the corresponding lab report for a grade, and depending on the severity of the offense may be referred for disciplinary action. Specific safety precautions will be listed at the start of each lab handout, and in general you should not touch or use any equipment that is not explicitly called for in the lab handout without the expressed consent of the instructor. Those committing minor and/or unintended infractions of safety protocols or misuse of lab equipment will be given a warning; the second offense will be cause for removal from the lab. You may not attend the lab if you do not have shoes covering your entire feet, including toes.
2. Accidents in the lab are to be reported to the instructor immediately.
3. Lab reports are due as noted in the "important dates" section above (Lab 1 report due on January 30; second and third "discretionary" reports due on March 6 and April 3, respectively). Late penalties will be assessed at 20% per week or fraction thereof up to a maximum of 60%. The final project report must be turned in at the start of the final lab period for the course (April 30, 1:30 PM). You are encouraged to revise lab reports returned to you with instructor feedback for a higher grade, but revisions will not be allowed for reports that are submitted late. Note that copies of your reports will be made

to include in portfolios of student work for assessment of the program's progress towards achieving the program outcomes which are listed at the end of this document.

4. Students with unexcused absences from labs will be marked absent, and not allowed to submit lab reports for them. Absences will only be excused for extreme circumstances such as serious injury or illness, death in the family, participation in varsity athletics or other university sponsored activities, or observation of religious holidays. A confirmatory note from the relevant authority will be required, and advanced notice should be given if possible.

5. Unscheduled quizzes may be administered during some lecture times. You may not make up a quiz that you miss due to an unexcused absence.

6. While most of the labs will be completed in small teams, you are required contribute meaningfully to the execution of the experiment, submit your own written reports, and be capable of performing all of the calculations and analysis required for the report.

7. Up to 25% of the grade for written work may reflect the quality of grammar and spelling, and another 25% may reflect technical organization.

8. The participation grade is largely determined by lab attendance, and to a lesser extent by lecture attendance. Note, however, that the participation grade is awarded entirely at the discretion of the instructor and will be severely impacted by habitual tardiness, disrespectful behavior towards your peers or other course participants, and lack of engagement/ contribution in the experiments.

9. All pertinent work must be shown on exams and papers to receive credit. Unintelligible work will not be graded.

10. Questions are encouraged. The instructor should always make himself available to you during scheduled office hours, and to the extent that his schedule permits he will answer questions by e-mail or phone, or arrange for meetings outside of class.

11. Grading: if the overall class average is greater than 75%, those above 90% will receive an A, those above 80% will receive a B, those above 70% will receive a C, and those above 60 will receive a D. If the class average is less than 75%, the grades will be "curved" to make the average 75%, and letter grades will be assigned as described above. Note that the grade thresholds may arbitrarily be made lower than described above, but they will not be made higher (e.g., if you fall in a given range you may receive a grade higher than the nominal value of the range), though the instructor reserves the right to suspend the curving policy of he judges that students are generally not making a sincere effort to meet the course expectations.

12. Students are expected to be attentive in lab, and to learn from the execution of the coursework. To encourage this, a discretionary amount of extra credit will be awarded to students who identify errors in lectures or labs distributed by the instructor, or who offer simpler or more elegant proofs and derivations or analyses used in lab. Up to 3% may be added to the students final grade per incidence, depending on the severity of the error and/or the astuteness/ analytical rigor of the student's observation/ proof. All extra credit will be added after adjustment of the final averages so that other students' grades are not affected.

Course Learning Objectives

Upon completing this course, the student will be able to:	Level[†]	BE Outcome[‡]
i) apply principles of mass/energy/charge conservation and force balance to derive differential equations for a system;	D	a)
ii) formulate systems of differential equations through coupled/ interdependent variables;	D	a)
iii) formulate and apply appropriate boundary/ initial conditions;	D	a)
iv) apply analytical techniques for the solution of ordinary differential equations;		
v) understand basic principles of how light and electromagnetic radiation interact with materials;	M	b)
vi) understand how molecular structure relates to material properties;	M	b)
vii) understand reduction and oxidation processes, and their relationship to chemical energy;	M	b)
viii) understand the concept of pH, buffering, and protonation/ deprotonation;	M	b)
ix) understand the relationship between free energy, entropy, internal energy, and enthalpy;	D	c)
x) demonstrates understanding of the thermodynamic constraints for energy conversion;	D	c)
xi) recognize and define the problem to be solved;	D	d)
xii) recognize the role of environmental conditions on cell/enzyme survival/ activity;	D	d)
xiii) demonstrate the ability to engineer a system to control or monitor a biological process;	M	d)
xiv) use models of a process to identify the most salient characteristics governing system behavior;	D	e)
xv) design a simple experiment, with effective controls, to quantitatively measure relevant parameters;	D	e)
xvi) fundamentally understand accuracy and precision of a measurement, and how these relate to uncertainties in the performance of a design;	M	e)
xvii) use appropriate statistical tools to determine the power/ reliability of an experiment;	D	e)
xviii) logically interpret data from experiments;	M	e)
xix) write structured code to interface a computer/ controller with a system or process;	M	f)

xx) implement simple fabrication/ manufacturing processes;	I	f)
xxi) prepare appropriate engineering plans, including drawings and circuit diagrams, to implement an engineering design;	M	f)
xxii) design simple circuits for signal processing and measurement;	M	f)
xxiii) share responsibilities and duties with team members;	M	g)
xxiv) objectively discuss the problem and the merits of possible solutions;	M	g)
xxv) formulate an effective strategy for action;	M	g)
xxvi) maintain constructive dialog with team members with different tasks;	M	g)
xxvii) organize the content of a document according to the informational needs and technical background of audience;	M	i)
xxviii) communicate facts supported by evidence and/or sufficiently detailed explanation;	M	i)
xxix) effectively assimilate feedback from a reviewer/ audience;	M	i)
xxx) submit written work without errors in spelling, punctuation, and usage;	M	i)
xxxi) understand the social, cultural, political, and environmental impacts of biological engineering practice;	I	j)
xxxii) independently research scientific literature and engineering references;	D	k)
xxxiii) independently assimilate knowledge based on strong grasp of fundamentals	D	k)
xx) understand the role Biological Engineers face in addressing societal challenges.	D	l)

† I = Introductory; D = Developmental; M = Mastery.

‡ UH Biological Engineering Program Outcomes:

a) The graduate has the ability to solve problems involving differential equations.
b) The graduate has the ability to solve physics problems involving mechanics, electromagnetics, and optics; chemistry problems involving inorganic and organic chemistry; problems involving general and micro-biology.
c) The graduate has the ability to solve engineering problems related to statics, dynamics, fluid mechanics, and thermodynamics.
d) The graduate has the ability to design a system, component, or process in which biology plays a significant role.
e) The graduate has the ability to design and conduct experiments to gather information for engineering designs.

f) The graduate has the ability to use modern engineering techniques, skills, and tools to define, formulate, and solve engineering problems.

g) The graduate has the ability to function effectively on multi-disciplinary teams.

h) *The graduate has the ability to identify professional and ethical responsibilities when practicing engineering*.

i) The graduate has the ability to communicate effectively in large and small groups.

j) The graduate has the background to understand the impact of engineering solutions on the surrounding context.

k) The graduate recognizes the need to engage in life-long learning through participation in professional conferences, workshops, and courses, and by reading and writing in the relevant literature.

l) The graduate has the ability to intelligently discuss contemporary issues.