BME 650: Biomedical Measurements and Instrumentation

Units: 4

Spring 2021— Mondays and Wednesdays, 9–10:50 am.

Location: OHE100B & ONLINE

Instructor: Maral Mousavi

Office: DRB 170
Office Hours: TBD based on student availability, two one-hour timeframes within 8 am-6 pm
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Teaching Assistant: TBD
Office Hours: TBD

Course Description

This class will introduce basic concepts in medical measurements and diagnostic devices. The class is designed for students with multidisciplinary and diverse educational backgrounds and is typically populated by PhD and MS students (with backgrounds in biomedical engineering, electrical engineering, chemical engineering, sciences such as biology and chemistry, etc.). Only a basic science and engineering knowledge is required prior to this class, and the course is designed to cover the engineering concepts required for biomedical engineering students in higher education. This course will go over: (i) design of biomedical measurement systems and diagnostic devices, (ii) design of different transducers to measure physiological parameters, (iii) design of biomedical instrumentation, (iv) architecture of electronic instruments used to measure physiological parameters and analysis of major process functions integrated in these instruments, (v) design of diagnostic devices and methods for detection of biomarkers in biological fluids (blood, sweat, saliva), (vi) regulatory aspects of diagnostic devices, and (vii) safety in biomedical measurements.

Learning Objectives, Specific Outcomes of Instruction, and Relationship to Program Outcomes

1. *Learning objectives*
   - Understand the principles and concepts of biomedical measurements and origins of biopotentials
   - Understand the principles and concepts of design of medical electronics and signal processing for biomedical measurements
   - Understand the principles and concepts of transducers and their application in biomedical devices and biomedical measurements
   - Understand different aspects involved in development of medical devices (design of transducer, signal measurement, conditioning and processing, and regulatory aspects of device development)
   - Understand fundamentals of diagnostic devices and biomarker testing in biological fluids
   - Understanding the technical and societal factors involved in point-of-care diagnostics and wearable sensors
   - Develop communication and team-working skills to be able to work in interdisciplinary biomedical teams

2. *Course outcomes*
   - Outcome 1: Apply principles and concepts of electronics to analyze input and output signals in medical electronics

- Outcome 2: Apply principles and concepts of electronics to design filters for de-noising of medical measurements
- Outcome 3: Recognize different types of transducers, ongoing progress in improving their design, and their application in medical measurements
- Outcome 4: Apply principles and concepts of engineering to quantify and model measurements of biopotentials
- Outcome 5: Apply principles and concepts of sensing and engineering to (i) design diagnostic devices for detection of markers in biofluids, and (ii) be able to evaluate quality of diagnostic devices
- Outcome 6: Apply engineering tools to evaluate parameters needed for point-of-care health screening and mobile-health, and design of appropriate point-of-care diagnostic devices

Prerequisite(s): None
Co-Requisite(s): None
Concurrent Enrollment: None
Recommended Preparation: BME 513 recommended. Basic knowledge of electronics (EE 202 or equivalent courses), physics (PHYS 152L or equivalent courses), and chemistry (CHEM 105 A or equivalent courses). Fundamental knowledge of basic electronic circuits is required for doing well in this class.

Textbook: None, lecture notes and assigned reading only.

Recommended References: (Available for 2 hr check-out in Science and Engineering Library)
King, P., R. C. Fries. Design of Biomedical Devices and Systems, Marcel Dekker, 2003.
Normann, R.A. Principles of Bioinstrumentation, John Wiley & Sons, 1988.
Pallás-Areny, R., J. G. Webster. Sensors and Signal Conditioning, Wiley, 2000.
Togawa, T., T. Tamura, P.A. Oberg. Biomedical Transducers and Instruments, CRC Press, 1997.
Webster, J.G. Bioinstrumentation, Wiley, 2004.
Webster, J.G. Medical Instrumentation: Application and Design, 3rd ed., John Wiley & Sons, 1998.

Course Notes: This course is designed to introduce you to different aspects of biomedical instrumentation and diagnostics. Through homework assignments, exams, critical reading of primary literature, class presentations, and a collaborative project, students will learn design of biomedical instruments and diagnostic systems. The timeline on which the material will be covered is provided below and is subject to change, at the instructor's discretion.

Web page: A class website will be setup on Backboard containing information about the course: syllabus, reading handouts, homework assignments, grades, information about class activities, solutions to the homework sets, and an email directory of all students in the class. Use it as much as you find it useful. The web page can be accessed at: https://Blackboard.usc.edu.

Office Hours: Time and location for office hours will be identified at the beginning of first session of the class. Students are encouraged to take advantage of office hours

Class Format and Grading Policy: There will be two 110-minute lectures per week.
The final grade will be based on the following:

(1) Homework Assignments (30%)
    a. In general, weekly homework is assigned on the first lecture of the week, and due on the first lecture of the following week (at the beginning of the class). Six to ten homework assignments each containing 5–10 questions will be distributed through the semester. Homework assignments are designed to test your understanding of material presented in class and your ability to apply that knowledge to engineering problems. From time to time, you may also be asked do your own research and discover new material as part of

your homework assignment. Appropriate reading (journal articles, reports, etc.) will be assigned to assist in homework and learning of the class content.

b. All questions on homework should be posted to the appropriate discussion board on Blackboard.

c. Show all work. All derivations must be included with symbols before numbers are "plugged in." Units must accompany numerical results when applicable.

d. Collaboration is permitted on HW, however copying is not. Collaboration is highly encouraged and includes discussions of concepts, exchange of information, and working together. Each student is responsible for individually preparing and fully understanding the work they submit. Review the university and course Integrity Policies (links below). They will be strictly enforced. This class has a **no-tolerance** policy on academic integrity violations – copying is a form of cheating.

e. Late homework is not accepted (only exception is a medical emergency with valid physician's note).

(2) Exam 1 (30%)

Exam 1 questions topics covered from week 1 to 5.

(3) Exam 2 (25%)

Exam 2 questions topics covered from week 6 to 11.

(4) Class participation (5%)

Class participation includes attendance in lecture sessions and engagement in class discussions and answering of questions.

(5) Final project (10%) [5% written report, 5% oral presentation]

a. The goal of this final project is to cultivate team-working skills of the students, and provide an opportunity to exercise the theoretical knowledge gained in the classroom towards real-life medical problems. The project entails identifying a medical need and designing a biomedical device to address this need (using the knowledge gained in the classroom). Examples of such projects include: (i) Smart wound dressings for monitoring wound healing, (ii) Enhancing mobility of physically disabled patients using wearable technology, and (iii) Application of smartphones for management of wound healing in diabetic patients.

b. Students will be asked to work in teams of 3–5 to complete the final project. Registration in BME 650 varies between 20–30 students. Number of students per team will be adjusted to have no more than 7 teams total, allowing 15-minute in-class presentations in one class session.

c. The team should submit a written document (less than 5 pages excluding references, single space, font size between 10-12 Times New Roman or Calibri) with appropriate citations, motivation of the work, proposed design, control experiments, and discussion about regulatory process for testing of the device. Each team will present the work in the classroom (10-15 minutes duration of presentation, no limitation on number of slides). One grade will be assigned to all the team members for their written report and oral presentation. All students are expected to contribute equally towards the final project. A one-page document stating individual contributions from each team-member should be submitted after the in-class presentations. A rubric for grading of final written report and oral presentation is provided (please see the Addendum).

d. Students on DEN will work on the project individually and will only submit the written report (10% of their total grade).

Grading Breakdown

Grades will be based on the individual homework assignments and exams.

The weighting scheme for the final grade is below:

Exam 1	**30%**
Exam 2	**25%**
Class Participation	**5%**
Homework Assignments	**30%**
Final Project	**10%**
	Total: 100%

Homework/Academic Integrity Policy

Students are expected to spend approximately eight hours per week on readings and assignments. Students are expected to do their own homework assignments and should completely understand everything that they submit as their own. It is anticipated and expected that students consult one another for clarification of concepts, advice, to compare the final numerical homework solution, etc. It is not acceptable to show someone else your written homework, even if it is easier than explaining a concept verbally. You may also use whatever materials you find on the web, in other texts, or other sources to assist in preparing your homework. Also, copying homework prepared by another student and plagiarizing are strictly prohibited. Violations of this policy will result in an **automatic F** in the class and filing of an academic misconduct report to the Office of Student Conduct. All students are expected to adhere to the USC standards of Academic Integrity (http://www.usc.edu/student-affairs/SJACS/docs/AcademicIntegrityOverview.pdf and http://www.usc.edu/student-affairs/SJACS/docs/GradIntegrity.pdf).

Course Schedule: A Weekly Breakdown

	Topics Covered
Week 1 **01/18–01/24**	• Course Introduction, Characteristics of Measurement Systems, Types of Medical Measurements, Considerations in Design of Medical Devices, Precision, Accuracy, and Noise in Data, Introduction to Human Physiology • MLK Day Holiday (no class, university holiday, reading will be assigned)
Week 2 **01/25–01/31**	• Structure of Matter, Chemical equilibrium, 2nd law of thermodynamics, Activity vs. concentration, Introduction to biochemistry and disease diagnosis • Interaction of matter with light, Light and spectrophotometry
Week 3 **02/01–02/07**	• Spectroscopy Instrumentation, Types of Spectroscopy • Light Sources, Pulse oximetry
Week 4 **02/08–02/15**	• Spectroscopy in Diagnostic Devices, Introduction to Biosensors • Biosensors continued, Biomolecules used in biosensors
Week 5 **02/15–02/21**	• President's Day (No class, University Holiday) Biomarkers used in Diagnostics • Introduction to point-of-care sensing, Lab on a Chip
Week 6 **02/22–02/28**	• Journal Review, Origin of Biopotentials, Human Biopotentials • Nernst Equation, Introduction to electrochemical measurements and biopotential electrodes
Week 7 **03/01–03/07**	• Biopotential Measurements, Journal Review • Electrochemical measurements continued
Week 8 **03/08–03/14**	• Electrochemical diagnostic devices, active and passive techniques • Clark Electrode, Patch Clamp Technique, Biopotential recording

Week 9 **03/15–03/21**	• **Exam 1** • Impedance Spectroscopy and its application in biomedical measurements
Week 10 **03/22–03/28**	• Review of Electronics and Introduction to Filters (Signals and Noise) • Operational Amplifiers, Filters, Analog Linearization, and Interfacing to Computers
Week 11 **03/29–04/04**	• Instrumentation Amplifiers, Discussions on Project Choice • Temperature Transducers
Week 12 **04/05–04/11**	• Mechanical Transducers, • Wellness Day (No Class), Homework and reading will be assigned
Week 13 **04/12–04/18**	• Pressure, Motion, and Force Measurement • Measurement of Flow (fluids and gases)
Week 14 **04/19–04/25**	• Introduction to Machine Learning • Safety in Bioinstrumentation, Regulation in Medical Devices
Week 15 **04/26–04/30**	• **Exam 2** • Final Review, Homework Review, Course Evaluation, Presentations of Final Project by Students
Final Weeks	**Final report due (at its assigned date)**

Statement on Academic Conduct and Support Systems

Academic Conduct:

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Part B, Section 11, "Behavior Violating University Standards" policy.usc.edu/scampus-part-b. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, policy.usc.edu/scientific-misconduct.

Support Systems:

Counseling and Mental Health - (213) 740-9355 – 24/7 on call
studenthealth.usc.edu/counseling
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

National Suicide Prevention Lifeline - 1 (800) 273-8255 – 24/7 on call
suicidepreventionlifeline.org
Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

Relationship and Sexual Violence Prevention and Services (RSVP) - (213) 740-9355(WELL), press "0" after hours – 24/7 on call
studenthealth.usc.edu/sexual-assault
Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

Office of Equity and Diversity (OED)- (213) 740-5086 | Title IX – (213) 821-8298
equity.usc.edu, titleix.usc.edu
Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and

applicants. The university prohibits discrimination or harassment based on the following *protected characteristics*: race, color, national origin, ancestry, religion, sex, gender, gender identity, gender expression, sexual orientation, age, physical disability, medical condition, mental disability, marital status, pregnancy, veteran status, genetic information, and any other characteristic which may be specified in applicable laws and governmental regulations. The university also prohibits sexual assault, non-consensual sexual contact, sexual misconduct, intimate partner violence, stalking, malicious dissuasion, retaliation, and violation of interim measures.

Reporting Incidents of Bias or Harassment - (213) 740-5086 or (213) 821-8298
usc-advocate.symplicity.com/care_report
Avenue to report incidents of bias, hate crimes, and microaggressions to the Office of Equity and Diversity |Title IX for appropriate investigation, supportive measures, and response.

The Office of Disability Services and Programs - (213) 740-0776
dsp.usc.edu
Support and accommodations for students with disabilities. Services include assistance in providing readers/notetakers/interpreters, special accommodations for test taking needs, assistance with architectural barriers, assistive technology, and support for individual needs.

USC Support and Advocacy - (213) 821-4710
uscsa.usc.edu
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

Diversity at USC - (213) 740-2101
diversity.usc.edu
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call
dps.usc.edu, emergency.usc.edu
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-120 – 24/7 on call
dps.usc.edu
Non-emergency assistance or information.

Addendum

Scoring Rubric for Oral Presentations

Category	Scoring Criteria	Total Points	Score
Organization (15 points)	Information is presented in a logical sequence.	10	
	Presentation appropriately cites requisite number of references.	5	
Content (65 points)	The motivation of the work is clearly explained.	15	
	Technical terms are well-defined.	5	
	Presentation contains accurate information.	10	
	Material included is relevant to the overall goal of the project.	5	
	Methodology is clearly explained.	15	
	Conclusion summarizes the key point of the work.	5	
	Length of presentation is within the assigned time limits.	10	
Presentation (20 points)	Speaker maintains good eye contact with the audience and is appropriately animated (e.g., gestures, moving around, etc.).	5	
	Speaker uses a clear, audible voice.	5	
	Visual aids are well prepared, informative, effective, and not distracting.	10	
Score	**Total Points**	**100**	

Scoring Rubric for Written Report

Category	Scoring Criteria	Total Points	Score
Introduction (45 points)	Motivation of the work is presented clearly.	10	
	Prior work is clearly explained and cited.	15	
	Gaps in the literature are explained.	10	
	Proposed method and element of novelty is explained clearly.	10	
Discussions (30 points)	Details of proposed method is explained.	10	
	Control experiments are discussed.	5	
	Design and fabrication are depicted using illustrations and figures.	10	
	Appropriateness of the proposed approach and to the medical need is discussed.	5	
Conclusion (10 points)	The key findings in the proposed approach are summarized.	5	
	Advantages and disadvantages of the proposed approach are discussed.	5	
Grammar and Writing (15 points)	Writing is grammatically correct.	5	
	Words have correct spelling.	5	
	Writing is simple and understandable and avoids use of unnecessary jargon and complicated wording.	5	
Score	**Total Points**	**100**	