EE 416 - Biomedical Signals, Instrumentation and Measurement

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Course Description: Fundamentals of biomedical signals, measurement and instrumentation; biomedical transducers; membrane biophysics, electrophysiology of excitable cells, membrane models; theory of bioelectrical signals, electrocardiography, electroencephalography, electromyography; biopotential electrodes; biopotential amplifiers and instrumentation techniques, electrical and patient safety; examples of monitoring, therapeutic and prosthetic devices. Pre-requisite: EE 311.

Course Objectives: To introduce basic physiology of the human body from an electrical engineering and mathematical modeling point of view, to provide background and understanding of biomedical signals, measurement issues, related instrumentation and devices.

Text Books:

1. Introduction to Biomedical Engineering (3rd. Ed.), J.D. Enderle, and J.D. Bronzino, 2012 (ISBN: 978-0123749796)
2. Medical Instrumentation – Application and design (4th. Ed.), John G. Webster, 2010 (ISBN: 978-0471676003)

Reference Materials:

1. Lecture Notes
2. Human Physiology, Vander, Sherman, Luciano, 2001 (ISBN: 978-0072516807)
3. Bioelectricity - a quantitative approach, Robert Plonsey and Roger Barr, 2007 (ISBN: 978-0387488646)
4. Sensors and Signal Conditioning, Ramon Pallas-Areny and John G. Webster, 2000 (ISBN: 978-0471332329)
5. Analysis and Application of Analog Electronic Circuits to Biomedical Instrumentation , Robert B. Nortrop, 2003 (ISBN: 978-0849321436)

Course Outline:

CHAPTER	SUBJECT	DETAILS
1	Introduction	Introduction to Biomedical Engineering with Electrical Engineering perspective. Elements of a generalized Medical Instrumentation System.
2	Biomedical signals and measurement	Properties of biomedical signals and measurement constraints. Static and dynamic performance characteristics of measurements (absolute/relative error, accuracy, precision, sensitivity, resolution, reliability, repeatability systematic/random error). Design constraints and process for medical instruments.
3	Biomedical transducer principles	Resistive, capacitive, inductive, optical and ultrasonic sensors (transducers) to measure biophysical parameters such as force, displacement, temperature and velocity.
4	Laws of Membrane Biophysics	Resting electrical properties of cells and electrical equivalent model for the excitable cell membrane.
5	Action potential generation and Hodgkin-Huxley Model	Action potential generation, voltage clamp experiment and Hodgkin-Huxley model of the action potential generation. Action potential propagation and cable model.
6	Electroneurogram (ENG) and Electromyogram (EMG).	Synaptic transmission and neuromuscular junction. Electroneurogram (ENG) and Electromyogram (EMG).
7	Electrical activation of the heart	Anatomy and function of the heart, electrical behavior of cardiac cells, electrical activation of the heart.
8	Dipole theory of Electrocardiogram (ECG) and Vector cardiogram	Dipole theory of Electrocardiogram (ECG) and Vector cardiogram. Unipolar and Bipolar measurement techniques. Wilson's central and augmented lead terminal common.

9	Electroencephalography (EEG)	Basic anatomy and function of the brain, cerebrum, cerebellum, brain stem, cerebral cortex, electrical potentials from the brain, resting rhythms of the brain, clinical Electroencephalography (EEG).
10	Biopotential electrodes Biopotential amplifiers	Polarisation, polarising and non-polarising electrodes. Electrode-electrolyte interface and electrode circuit models, Electrode-skin interface and motion artifact. Modifying and interfering signals.
11	Biopotential (Instrumentation) amplifiers	Specific requirements to measure low level signals in noise, Biopotential (Instrumentation) amplifiers, Interference reduction techniques, Common mode reduction (Driven-Right-Leg) circuits.
12	Biopotential (Instrumentation) amplifiers	Noise and noise reduction techniques. Isolation, grounding and shielding in biomedical instrumentation. Electrical and Patient safety.
13	Therapeutic and prosthetic devices	Neural stimulator, pacemaker, defibrillator, respirator, etc.
14	Circulatory and respiratory measurements and instruments	Measurement of blood pressure and related equipment. Doppler effect and measurement of blood flow and velocity. Measurement of respiratory volumes and flow, related devices.

Grading:

2 Midterm Exams	15% each
Term project, homework, class performance, attendance, etc	20%
Final Exam	30%
Laboratory (9 experiments)	20%

Laboratory Schedule:

WEEK	EXPERIMENT NAME	DESCRIPTION
1	Action potential generation	Simulation of Hodgkin - Huxley Membrane Model
2	Position and velocity Measurement	Sensors for Light and Position Measurement, Ultrasonic Transducers and Applications
3	Temperature and Ultrasound Measurement	Sensors for Temperature and Ultrasound Measurement Applications
4	Electromyography and Electroneurography	Measurement of evoked EMG, nerve conduction velocity
5	Electrooculogram	Measurement of biopotentials originating from the eye
6	Electroencephalography	Measurement of biopotentials originating from the brain, brain rhythms
7	Electrocardiography & Plethysmography	Measurement of ECG Components, vector cardiography and pulse measurements
8	Blood Pressure & Heart Sounds	Measurement and Analysis of Blood Pressure & Heart Sounds
9	Pulmonary Function Test	Measurement of respiratory volumes, capacities and respiration cycle
10	Instrumentation Amplifiers	Instrumentation amplifier design, properties, CMRR