Approved in 44th BoA Meeting (24-11-2021)

Course number : BE302
Course Name : Bioelectric Systems Modeling
Credit Distribution : 3-0-2-4
Intended for : Core for IDD BE, Elective for other B.Tech students
Prerequisite : Understanding Biotechnology and its applications (IC136), Cell Biology (BE201), Electrical Systems around us (IC160)
Mutual Exclusion : NA

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1. **Preamble:** The course aims at modeling biomedical systems in the electrical perspective and uses those models for further analysis of signal extraction from biomedical systems. The course deals with the electrical and magnetic modeling and analyses of human body systems. Also, the notion of control theory is extended for the understanding of homeostasis as applied to human body systems. Some discussion on signal extraction from biomedical systems and its initial conditioning will also be covered in this course.

2. **Course Modules with quantitative lecture hours:**

A. Electrical modeling of cells: Charge transport mechanism in cells, application of circuit theory to cell analysis – electrotonus model, Hodgkin Huxley model for membrane current, voltage changes in cell over space and time. Biological cables –the axons, potential outside a long cylindrical cell, exterior potential for an arbitrary pulse, RC modeling of axon as a transmission line, electrical properties of organs and organ-systems. 14 hours

B. Magnetic modeling of cells: Magnetic field of a cell in an infinite homogeneous conducting medium, electromagnetic induction, modeling of exterior magnetic field of a cylindrical cell. 2 hours

C. Applications of electrical modeling for biosignal extraction from different organs:
A. Biosignal extraction from heart: Origin of cardiac action potential, electric dipole modeling of heart, atrial depolarization causing P wave, sequential ventricular depolarization causing QRS complex, sub-epicardial repolarization causing T wave, recording of electrocardiogram using leads, stimulating the heart – the pacemakers.
B. Biosignal extraction from brain: Origin of neuronal action potential, origin of electroencephalogram signals, understanding neural oscillations (Alpha- Beta-, Gamma, Delta- and Theta Waves).
C. Biosignal extraction at neuromuscular junction: Origin of action potentials at axon hillock, propagation of bipolar signals in muscle fibers, recording of electromyogram signals.

D. Detection of weak magnetic fields: Magnetocardiograms and magnetoencephalograms 8 hours

3. **Feedback and control:** Basics of control engineering – notion of open loop and closed loop systems, homeostasis from the electrical model perspective, single loop and multiple loop homeostasis, stability of systems, criteria of stability, example study in neurorehabilitation, closed loop control of blood insulin and glucose regulation, closed loop control of brain stimulation. 18 hours

Lab experiments: 28 hours

1. Cable model of neurons
2. Hodgkin Huxley's model of neurons
3. Modeling of exterior electric field of a cylindrical cell
4. Modeling of electromagnetic induction in living cells
5. Modeling of electrical conduction in heart
6. Modeling of electrical conduction in brain
7. Modeling of electrical conduction in muscles
8. Modeling a feedback loop with one and two time constant(s)
9. Modeling of homeostasis process
10. Stability analysis of physiological systems

4. Text books:

1. Irving P. Herman, "Physics of the human body", 2nd edition, Springer Verlag, 2016.

2. John D. Enderle, Susan M. Blanchard, Joseph Bronzino, "Introduction to Biomedical Engineering", Elsevier Press, 2015.

5. References:

1. Eugenio Culurciello, Wei Tang, Evan Joon Park, "Biomedical Circuits and Systems", CRC Press, 2017.

2. Harold S. Burr, "The Fields of Life. Our Links with the Universe", Ballantine Publishers, 1973.

3. Robert Berker, Gary Selden, "The Body Electric: Electromagnetism And The Foundation Of Life", Harper Collins Publishers, 1998.

5. Similarity Content declaration with existing courses:

S. No.	Course Code	Similarity Content	Approx. % of Content
01.	EE516	Hodgkin Huxley Model, ECG, EEG (5 lectures)	12%

6. Justification of new course proposal if cumulative similarity content is >30%:

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