**ECE8803 Bioelectromagnetics: Fundamentals and Applications**

**Spring 2024**

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## 1. Course Objectives

Bioelectromagnetics is a discipline that examines the interaction of electromagnetic field with biological tissues. This course will educate students about the concept of bioelectromagnetics and its various applications. Specifically, students will learn (i) about bioelectric, biomagnetics and bioelectromagnetics phenomena in biological tissues (ii) how to apply numerical methods for bioelectromagnetic simulation (iii) how to characterize electromagnetic wave propagation in multilayered heterogeneous tissues layers (iv) about the design of state-of-the-art measurement and stimulation systems towards various clinical applications. Fundamentals of electromagnetic fields will be also reviewed. The course will emphasize the use of electromagnetic field for diagnostic and therapeutic purposes such as stimulation, sensing, and imaging purposes.

## 2. Learning Outcomes

In this course, students will be able to:

1. Define and provide examples of the fundamentals of bioelectromagnetics
2. Explain the generation, characterization, and relationship between the bioelectric, biomagnetic and bioelectromagnetic phenomena in biological tissues
3. Apply the appropriate numerical methods for bioelectromagnetic simulation
4. Design stimulation and recording probes (electrodes) used in medical applications of bioelectromagnetics
5. Identify and explain the circumstances for various medical applications of bioelectromagnetic.

## 3. Course Information

Lectures will be given by the instructor. Some class lectures will be dedicated to literature review and analysis of state-of-the-art bioelectromagnetics-based measurement and stimulation systems.

## 4. Textbook and Optional References

Course notes will be provided by the instructor. Recommended (*not required*) textbooks are listed below.

1. Plonsey & Malmivuo, *Bioelectromagnetism*, Oxford University Press, 1995.
2. C. Furse, D.A Christensen, C.H. Durney, and J. Nagel, “Basic Introduction to Bioelectromagnetics,” CRC Press 3rd Ed, 2018.

## 5. Course Requirements and Grading

**Requirements:**

- Homework assignments every week.
- Two in-class exams covering material from lectures and homework.
- Final project. Students will be grouped into small teams, and will propose (written) a research project related to bioelectromagnetics in consultation with the professor. The project will focus on bioelectromagnetics related topics (scientific, engineering, commercial, etc.) with emphasis on characterization and modeling of electromagnetic field interaction with biological tissues (using computational tools); and design of stimulation and recording probes towards select clinical applications, for example, neuromodulation. At the end of the term, students will then present the proposed work to the class in a 10-12 minute presentation, and provide a project write-up (10 pages maximum length). Grading will be based on depth of coverage, correctness, originality and quality of the design or analysis, and the overall clarity of the paper and presentation.

**Grading:**

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| Homework | 20% |
| 2 Exams | 40% |

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| Final Project Proposal | 15% |
| Final Project Write-Up | 25% |

**6. Prerequisites**

ECE 2040 [min C], ECE 3025 [min C], ECE 4784 [min C] or BMED 4784 [min C]. No prior knowledge of physiology or biology is needed.

**7. Tentative Outline**

A. Introduction to Bioelectromagnetics
   a. History of bioelectromagnetics
   b. Definition of bioelectric, biomagnetics and bioelectromagnetism
B. Review of Electromagnetics
   a. Electric and Magnetic Fields
   b. Maxwell's equations: differential, large-scale forms, and time-periodic case
   c. Plane wave propagation: Transmission, Reflection and Refraction
   d. Electrical Properties of Biological Tissues
C. Numerical Methods for Bioelectromagnetic Simulation
   a. Finite-Difference Time-Domain (FDTD) Method
   b. Impedance Method
   c. Finite Difference Method (FDM) and Finite Element Method (FEM)
D. Anatomical and Physiological concepts in Bioelectromagnetics
   a. Electrolytic Solutions and Electric Double layers
   b. Polarized Cells and Action Potentials
   c. Cellular Current Sources and Fields
E. Bioelectromagnetics at Different Frequencies
   a. Bioelectromagnetics at low frequencies (DC to 1 MHz)
   b. Bioelectromagnetics at radio frequencies (300 MHz to 300 GHz)
   c. Bioelectromagnetics at Terahertz frequencies ( > 300 GHz)
F. Bioelectromagnetic for Clinical Applications
   a. Electrical Therapies (ablation, stimulation, etc.)
   b. Magnetic Fields and Uses (imaging etc.)
   c. Wireless Biotelemetry: Radiofrequency Communication in Bioimplants
   d. Powering of Bioimplants (Near-field coupling, RF-to-DC conversion)
G. Neuromodulation System Design (for Deep Brain Stimulation)
   a. Electrical Measurement of Brain Activity (EEG, ECOG, MEG)
   b. Stimulation Methods: Electrical Stimulation and Optical Stimulation (Optogenetics)
   c. Probe (Electrode) Design for Local Field Potential Measurements
   d. Novel Closed-Loop Neuromodulation System Design
   e. Neural Potential Recording and Low Power Wireless Telemetry.

**Other Course Expectations & Guidelines**

**Academic Integrity**

Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. For information on Georgia Tech's Academic Honor Code, please visit http://www.catalog.gatech.edu/policies/honor-code/ or http://www.catalog.gatech.edu/rules/18/.

Any student suspected of cheating or plagiarizing on an exam, or assignment will be reported to the Office of Student Integrity, who will investigate the incident and identify the appropriate penalty for violations.

**Accommodations for Students with Disabilities**

If you are a student with learning needs that require special accommodation, contact the Office of Disability Services at (404)894-2563 or http://disabilityservices.gatech.edu/, as soon as possible, to make an appointment to discuss your special needs and to obtain an accommodations letter. Please also e-mail me (at seun.sangodoyin@gatech.edu) as soon as possible in order to set up a time to discuss your learning needs.

**Student-Faculty Expectations Agreement**

At Georgia Tech we believe that it is important to strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty members and the student body. See http://www.catalog.gatech.edu/rules/22/ for an articulation of some basic expectation that you can have of me and that I have of you. In the end, simple respect for knowledge, hard work, and cordial interactions will help build the environment we seek. Therefore, I encourage you to remain committed to the ideals of Georgia Tech while in this class.