BE/EC 555: Introduction to Biomedical Optics

Syllabus: Fall 2024

Professor Irving J Bigio (BME and ECE)

Course Description:

This course surveys the applications of optical science, engineering and technology to a variety of biomedical problems, teaching the interactions of light with biological systems, from the nanoscale to tissue levels. Emphasis is on optical science and photonics technologies that enable real, minimally invasive clinical and laboratory biomedical applications. The course teaches only those aspects of the physiology and biology that are necessary to understand the purpose and methods of the applications. The first weeks introduce the optical properties of tissue, and following classes cover a range of topics in three general areas: 1) Optical spectroscopy applied to diagnosis of cancer and other tissue pathologies; 2) Photon migration and diffuse optical imaging of subsurface structures in tissue; and 3) new tissue imaging methods, laser manipulation of of particles and cells and other applications of light for biomedical purposes.

The format of this course is “semi-flipped.” There are assigned readings from the required textbook, prior to each class. Half of class time will invoke informal lecture and discussion, to amplify and clarify the readings; and half of the class time will be in the style of a "flipped" class, devoted to working, in small groups, on problems and discussing and understanding the connection to the readings. The textbook must be acquired before the start of classes.

Prerequisites for undergraduate students: math through differential equations; Physics I and II; a junior-level course in signals.

Required textbook: "Quantitative Biomedical Optics," Irving J. Bigio and Sergio Fantini, Cambridge University Press (2016); ISBN 978-0-521-87656-8. This text is available in print (purchase or rental) and as an e-book. Some students in past classes have found the print version preferable to e-book.

Expectations regarding safety:

All students are expected to follow all University guidelines with respect to COVID and Flu vaccination status. Mask wearing is up to the individual but not required, and respect for the choices of others is expected.

Classroom Courtesy: Our classroom will be a phone-free zone. Please turn off or silence your phones for the duration of the class and leave them in your pockets or bags.

Similarly, open laptops or iPads are for taking notes or referencing the textbook, not for browsing.

Grading:

- Four exams over the course of the semester, each worth 22% of the final grade. The exams are closed book, but notes on paper will be allowed. Exam specifics to be explained in class.
- 5 random quizzes, given at the beginning of classes, total value of 12% of the final grade. The quizzes will simply test that you have read the text assignment for that class, and the lowest of your quiz scores will not be counted: i.e., the 12% will be based on your top 4 quiz scores.

Topics by Number of Weeks:

Topic:	**Number of weeks**
Introduction:	1
What is biomedical optics? What is biophotonics? Structure of the course, grading elements Motivation of the topic Nomenclature of optical parameters Overview of tissue optical properties	
Diagnostic Optical Spectroscopy	5
Instrumentation for biomedical spectroscopy (light waves and spectrometers) Tissue autofluorescence and reporter fluorescence Vibrational spectroscopy: Raman and IR spectroscopies Elastic-scattering theory and methods of spectroscopy	

Scattering and absorption properties of tissue in the sub-diffuse regime

Photon Migration and Optical imaging 5
- The diffusion approximation to the Boltzmann transport equation
- Time-domain methods for diffuse imaging
- Frequency-domain methods for diffuse imaging
- Introduction to image reconstruction approaches
- Optical mammography and brain imaging

Laser tools and recent optical methods 2
- Optical coherence tomography
- Optical tweezers