Northeastern University

BIOE5235 Biomedical Imaging

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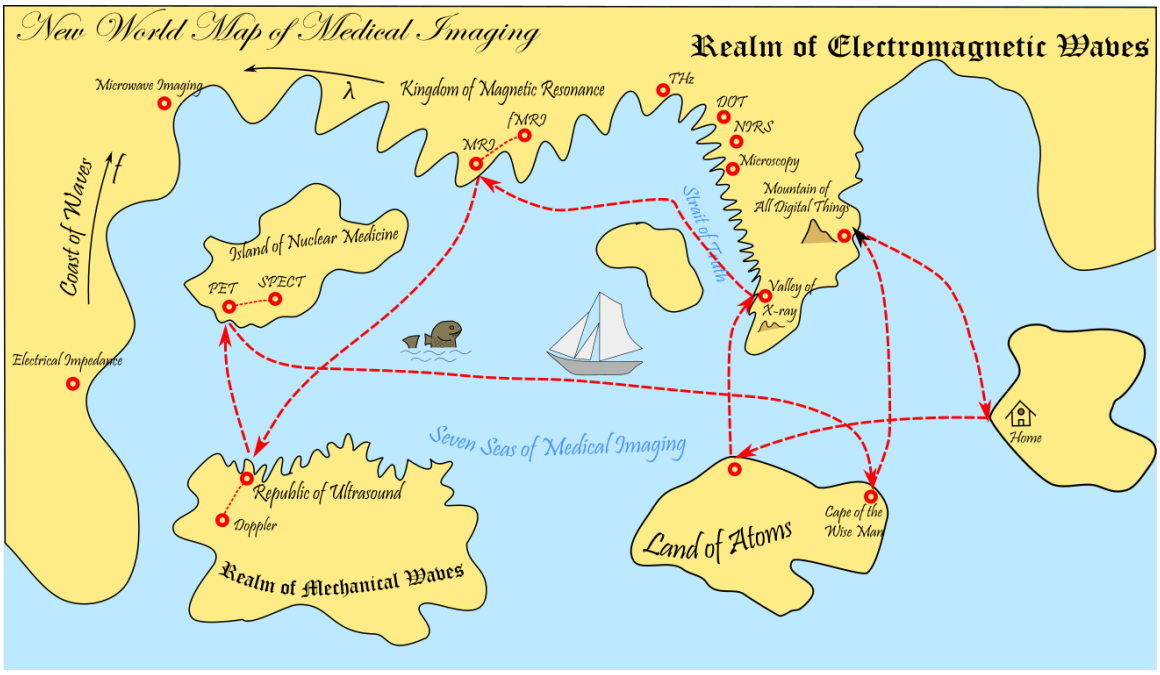
Course Time: Tuesday/Friday 1:35-3:15 PM | Richards 275 | Sep. 08 – Dec. 16 2017
Office Hours: Monday 3:00-5:00PM, (additional office hours by appointment)

(**Note**: this syllabus was last updated on **Oct. 3, 2017**)

Textbook

- *The Essential Physics of Medical Imaging, 3rd Edition* - by J. T. Bushberg, etc, Lippincott Williams & Wilkins, 2011

Visual Syllabus



Sailors, welcome on board! This is your Captain. We will embark on a journal to the "World of Medical Imaging" far far away. Be prepared! There will be storms of various rays and waves, we will also have to sail through the "Vortexes of image artifacts" and noises. But, we are fearless sailors! We are determined to end this journey with a ship-load of knowledge and treasures gathered from all lands. We start from the "Land of Atoms" and understand the source of all waves, rays and radiations. We will learn to tame the waves and help us to ride to our first stop, the "Valley of X-rays" and meet Mr. X and his noble family – radiography, fluoroscopy, mammography, tomosynthesis and CT. We will pass the "Strait of Truth", open our eyes to see all the good and evil hidden in the images, and become a wiser sailor. That prepares us to continue this journey to the "Kingdom of Magnetic Resonance" and dance with millions and millions of protons. At the "Town of fMRI", we will meet witches why have mastery of mind-reading voodoos, the "EEG", "MEG" and

"fNIRS" rituals will be performed and learned by all of you. We will arrive at the "Republic of Ultrasound" and master the skills of listening to the "sound of silence". Our next stop is the hot and humid "Island of Nuclear Medicine", where radioactive materials make everything glow in the dark night. We will tour the cities of PET and SPECT, and hear the stories of radiating sugar. On our way back, we will stop by the "Cape of the Wise Man", and pass on the wisdom from gurus that know the light (optical imaging), the healing (radiation therapy) and the future by heart. We will make our last stop at the "Mountain of Digital Things" and learn how to harness the power of computers and digital image processing. We are then heading home! Every one of you has showered by the wind and tide of the "Seven Seas of Medical Imaging". Congratulations! You earn yourself a Captain title!

Course summary

Medical imaging does not have a long history as physics, chemistry and mathematics, but it has already become a crucial element of our modern society. Medical imaging is truly an interdisciplinary field, positioned at the intersection of medical physics, instrumentation design, computer algorithms, clinical sciences and regulatory policies. The goal of this class is to give students an update-to-date view of many established medical imaging modalities, including radiography, fluoroscopy, mammography, tomosynthesis, CT, MRI, fMRI, ultrasound, PET and SPECT. In addition to explaining "how this modality works", the fundamental principles of the underlying physics and the mathematical models of the image forming process will also be discussed in an easy-to-understand fashion. Furthermore, the class explores the state-of-the-art in each imaging technique, discussing expanding applications and reviewing current challenges. We want to inspire our students to identify new challenges and applications in the medical imaging arena, and become motivated to further advance medical imaging to better meet our needs.

Calendar and Course Outline (Tentative)

WEEK	TOPICS	NOTES
1		
	Lecture 1: To see the invisible – in which you meet everyone else, and find out the master plan of the course 09/08	**Objectives**: Understand the overall structure of the course; understand the key modalities and techniques in modern medical imaging.
2	**Lecture 2**: Atoms and waves – in which you split an atom and fly alongside with two perpendicular vectors 09/12	**Objectives**: Understand wavelength, wavenumber, EM waves, polarization (linear, circular), reflection and transmission, also sub-atomic structures.
	Lecture 3: Horton hears a Who! – in which you hear about the cries from an atom - alpha, beta, gamma and delta rays 09/15 (Homework 1)	**Objectives**: Can explain the common radiations – alpha, beta, gamma and delta rays, where they come from, and what are their main characteristics.
3	**Lecture 4**: A billiard ball game – in which you follow a beam of light to dive into your skin 09/19	**Objectives**: Understand the key pathways of radiation-matter interactions, including heating, vibration and ionization; you will also understand Rayleigh scattering, Compton scattering and pair production etc.
	Lecture 5: Mr. X (-ray) – in which you find out how X-ray was discovered, and how you can recreate it 09/22	**Objectives**: Understand the origin of modern medical imaging, and the devices and mechanisms to create X-ray radiation, including bremsstrahlung.

4	**Lecture 6**: The noble family of Mr. X – in which you hear about fluoroscopy, mammography, tomosynthesis and CT 09/26	**Objectives:** Understand the basic working principles behind a list of X-ray based medical imaging modalities, understand image reconstructions in CT.
	Lecture 7: A picture is worth 1,000 words – in which you hear about the good and evil hidden in the images 09/29 (Homework 2)	**Objectives:** Understand the metrics to assess the quality of medical images, including contrast, PSF, SNR, CNR, MTF, noise and image artifacts.
5	**Lecture 8**: The invisible killer – in which you learn about X-ray dosimetry and radiation safety 10/03	**Objectives:** Understand the risks of EM/particulate radiations, how to measure the dosage and how to protect one from radiation
	Guest Lecture 1: CT Imaging & **Lab 1**: Lab tour of a clinical CT at MGH - by Dr. Rajiv Gupta, MGH/MIT 10/06	**Objectives:** To visit a CT research lab at MGH and meet experts in CT imaging; if possible, get some sample data.
6	**Lecture 9**: Brain & the dance of protons – in which you dive into your brain and see proton dancing together, then understand how MRI works 10/10 (Project 1)	**Objectives:** We will review the brain anatomical structures, and explain the working principles of MRI imaging and how to read an MRI sequence; we also explain MRI artifacts and safety.
	Lecture 10: Teslas, lots of Teslas – in which you hear about a levitated frog and other use of MRI 10/13 (Homework 3)	**Objectives**: Explain a list of MRI based imaging techniques, including MRI spectroscopy, dynamic contrast agent, flow and DTI, also explain MRI artifacts.
7	**Lab 2:** Tour of an MRI scanner – in which you visit a MRI scanner in the basement of ISEC 10/17	**Objectives**: We will visit the MRI scanner and ask questions with the expert and researchers, if possible, sample data can be acquired.
	Lecture 11: Telepathy and mind-reading voodoos – in which you hear about the stories of EEG, MEG and fNIRS 10/20	**Objectives**: Understand other neuroimaging techniques, including EEG, MEG and functional near-infrared spectroscopy (fNIRS)
8	**Middle-term exam**: A half-sail check-up 10/24	**Objectives**: In-class exam to verify that the learning goals set in the 1st half of the class are met.
	Guest Lecture 2: See through you, I can – in which you hear about functional MRI and state-of-the-art in neuroimaging - by Dr. Kenneth Kwong, MGH 10/27	**Objectives**: We will invite word-expert in MRI research and discuss how fMRI works, and explain the state-of-the-art in MRI/fMRI research in understanding our brains.
9	**Lecture 12:** The sound of silence – in which you hear about the story of Ultrasound 10/31 (Homework 4)	**Objectives**: Can explain the physics of Ultrasound (US) imaging, understand the components of an ultrasound scanner – how it transmits, receives and processes US to create A-/B-/M-scans of your body.
	Lecture 13: A beacon in your body – in which you learn about sending a	**Objectives**: Understand the basics of nuclear medicine, how to create

	beacon signal from inside your body and taking radioactive medicines! 11/03	radiotracers, how to store them and use them in imaging diseases.
10	**Lecture 14:** The life of a radiating sugar – in which you learn about PET, SPECT and how to join multiple imaging modalities 11/07	**Objectives**: Can explain how PET and SPECT imaging works, understand the image forming process in PET/CT and SPECT/CT, the associated image artifacts and solutions
	Lab 3: PET and SPECT image forming and analysis 11/10 (Homework 5)	**Objectives**: We will run an in-class lab for validating PET/SPECT images, design different inclusions and test the recovered image quality.
11	**Lecture 15**: The invisible killer – sequel – in which you learn more about biological effect of radiation and methods for radiation protection 11/14	**Objectives**: Understand how radiation affects biology, from whole-body to cellular and molecular level; learn about methods to prevent radiation harms.
	Guest Lecture 3: Optical imaging and fluorescence molecular imaging – by Dr. Abbas Yaseen, MGH 11/17	**Objectives**: Understand optical microscopy techniques and the use fluorescence in optical imaging.
12	**Guest Lecture 4**: Radiation therapy and image-guided therapy planning – by Dr. Greg Sharp, MGH 11/21	**Objectives**: Understand how radiation/ proton-beam therapy works, how to estimate dosage, and make optimal treatment planning using images.
	11/24	Thanksgiving break
13	**Lecture 16**: Bits, bytes, words and images [in which you learn about how digital medical images are stored and transformed] 11/28 (Lab 2 Report)	**Objectives**: Understand digital medical image informatics infrastructure, including image processing workflow, storage, and review procedures, learn about PACS and DICOM.
	Lecture 17: Photoshop for medical images – in which you learn about image filtering, segmentation, registration and other transformations 12/01	**Objectives**: Understand Fourier representations of images and common image filtering techniques; Explore medical image segmentation, registration, and 3D object modeling;
14	**Guest Lecture 5**: The crystal-ball imaging – in which we predict the future of medical imaging through a crystal-ball - TBD 12/05	**Objectives**: Discuss emerging medical imaging techniques, including functional imaging methods, multi-modal imaging, point-of-care diagnosis, high-speed and super-resolution imaging.
	Student Proposal Competition: Presentations 12/08	**Objectives:** Prepare the students for future research career through a mock research proposal competition.
15	**Student Proposal Competition:** Presentations 12/12	**Objectives:** Continuation of student proposal presentations.
	Final review of the course 12/15	**Objectives:** Evaluate the learning goals set for the entire course.

Notes: All students must submit their homeworks and reports via the Blackboard website. You are strongly encouraged to submit your reports in **PDF and Word** (doc, docx, …) formats, because we can write detailed comments from the grader. Please DO NOT submit compressed reports (.zip, .rar). For each week, homework will be assigned on Friday, and the due date is the following Friday at the end of the day. Each "student presentation" session requires a presentation and a written report. The lab tour happens at the location near Boston. Students need to arrange their own transportation. For students who can complete the **TRACE survey** before its deadline will be receiving a 5-point credit for the final project, which has a total point of 20.

Condensed Course Calendar Map (15 weeks, 30 slots)

Sep 05								*Week 1-4*
Oct 03	Lab 1		Guest 1		Lab 2	Middle		*Week 5-8*
Oct 31			Lab 3		Guest2	Guest 3		*Week 9-12*
Nov 28		Guest 4	Prop. 1	Prop. 1	Final			*Week 13-16*

Legend: each cell in the above chart represents a class time slot; two slots per week. Color code: - Regular Lecture; - Discussions and presentations; - Lab tours and exercise; - Exams; Guest - Invited speakers; Empty – No class.

Course Policies

Grading

Assignments in this course are divided into these general categories, which carry the following weight in your final grade calculations:

Midterm Exam	15%
Final Exam	15%
Homework	20%
Lab Reports	20%
Discussion Presentations	10%
Discussion Written Report	20%

Some of the homeworks will include Bonus questions. The total point (used to compute the percentage score) for each homework **will include** the points from the Bonus questions. All students are encouraged to complete the bonus questions. Successfully completing those questions will help advance the overall ranking of the student in the class. A **late submission** of homework will result in a 1-3 points deduction, depending on the severity.

Report, Presentation and Student Proposal Grading Guidelines

If an assignment is a report, it will be graded according to the following criteria: 1). comprehensiveness, 2). technical accuracy, 3). use of reference, 4). writing and language, and 5). relevance to the assignment topic.

If an assignment involves presentation and slides, the grading considerations will include 1) organization of the materials (introduction, transition, logical orders etc), 2) clarity of the points, 3) oral delivery and audience engagement, 4) oral and visual styling, and 5) question handling.

If an assignment involves a short proposal, the grading considerations will cover 1) innovation (is this idea new?), 2. feasibility (are the promises real?), 3) approach (can you actually do it?) 4) grantsmanship (story telling).

Receiving Grades & Instructor Feedback

Assignment grades and feedback are provided generally ***1 week*** after the assignment is due and always before an assignment of the same type is due. Unless otherwise stated, grades and feedback will be available via the ***Grades*** area of the online course site.

Accepting Late Work

Late work may be accepted for extenuating circumstances. These include family emergencies, sickness, and various other unforeseen circumstances. All work must be submitted by the last day of the course; no extensions or late work will be accepted beyond that date. Please plan ahead.

Communication

Feel free to ask questions by phone, email, or scheduling meetings in my office (during office hours or another scheduled time), or by video conferences (skype). I will try to respond to your question within a day or two.

Minimum Technical Skills

Students are expected to be comfortable accessing the online course site and downloading files such as Microsoft Office documents, YouTube videos, and PDFs. In addition, students should be able to use Microsoft Office to compose written documents, spreadsheets, and PowerPoint presentations. A basic knowledge of MATLAB is required.

Academic Integrity

The University views academic dishonesty as one of the most serious offenses that a student can commit while in college and imposes appropriate punitive sanctions on violators. The Student Handbook contains more information on what is considered academic dishonesty and is available here. A first offense will result in a grade of zero on the assignment. A second offense will result in a failing grade for this course and disciplinary action through Northeastern University's student judicial committee.

University Policies

Students with Disabilities

Students needing disability accommodations should visit the Northeastern University Disability Resource Center (DRC).

Student Privacy (FERPA)

The Family Educational Rights and Privacy Act (FERPA) affords students certain rights with respect to their education records. For information about these rights, visit the Northeastern University Office of the Registrar.

Diversity

Northeastern University is committed to providing equal opportunity to its students and employees, and to eliminating discrimination when it occurs. For more information, including grievance procedures, please visit the Northeastern University Office of Institutional Diversity and Inclusion.