

MEDICAL IMAGING SCIENCES AND APPLICATIONS

HST.565; Tue, Thu 4:30pm-6:00pm; Lecture Zoom Link: [Course Zoom Link](#)

Course Directors: Georges El Fakhri, PhD ; Moses Q. Wilks, PhD (MWilks@mgh.harvard.edu)

Week	Date	Suggested Literature	Description
1	Thur 9/9/2021	SC12 Chp. 1, 15	Introduction to molecular imaging (Georges El Fakhri) <i>Covers types of imaging modalities used in medicine (MRI, US, PET, SPECT, CT) providing an overview of the applications in medical imaging and how they complement each other (i.e. what does MRI do that CT does not and v.v., what does PET do and SPECT cannot and v.v.; these are covered at an application level, where advantages/disadvantages are mentioned from a pathology detection perspective).</i>
2	Tues 9/14/2021	SC12 Chp. 3, 4, 6	Radioactive Decay, Particle Interactions, Dose and Exposure (Lisa Blackberg) <i>Covers the basics of nuclear physics, and implications from exposure to radiation.</i>
2	Thur 9/16/2021	SC12 Chp. 13, 14	Radiation detectors, Counting Statistics I (Lisa Blackberg) <i>Covers the physics of radiation detection and different types of detectors (gas, semiconductors and scintillators), as well as the basics of counting statistics.</i>
3	Tues 9/21/2021	SC12 Chp. 13, 14	Radiation detectors, Counting Statistics II (Lisa Blackberg) <i>Covers types of radiation detector systems (PMT, monolithic crystals, solid state, pixelated crystals) and their applications to imaging systems, event positioning algorithms (advantages and disadvantages, and possibility for improvement), how the physical properties and (mechanical) design of crystals provides potential for the improvement of image quality.</i>
3	Thur 9/23/2021	SC12 Chp. 13, 14	Gamma Camera Imaging (Hamid Sabet) <i>Covers topics in transmission tomography imaging, such as the mathematics of computed tomography (parallel, fan-beam, and cone-beam integral transforms), analytic reconstruction algorithms (FPB, FBP, etc.).</i>
4	Tues 9/28/2021	SC12 Chp. 16	Introduction to Tomographic Imaging/HW1 Review (Moses Wilks) <i>Covers topics in transmission tomography imaging, including the mathematics revolving around cone-beam integral transforms, types of acquisition (circular, spiral), and an introduction to the interior problem in CT.</i>

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- 4 Thur 9/30/2021 SC12 Chp. 17, Single Photon Emission Computed Tomography
MW04 Chps. 7 & (Hamid Sabet)
22,

Covers topics in SPECT acquisition such as artifacts during acquisition (e.g. center-of-rotation artifacts), and principles of collimation (compatibility with radiotracer, collimator-detector response compensation including intrinsic response, geometric response, and septal penetration/scatter response), flood-field uniformity correction, attenuation correction, scatter correction, and partial voluming.

- 5 Tues 10/5/2021 SC12 Chp. 18 Positron Emission Tomography I
(Yoann Petibon)

Topics on the fundamentals of Positron Emission Tomography.

- 5 Thur 10/7/2021 SC12 Chp. 18 Positron Emission Tomography II
(Georges El Fakhri)

Expanded topics on PET Imaging Acquisition and Corrections

- 6 Tues 10/12/2021 SC12 Chp. 21 CT: Analog, Digital, Dual Energy, and Proton
(Bill Worstell)

Covers physical principles of X-ray computed tomography (Hounsfield units, types of acquisitions, detectors, etc.), artifacts arising from the physics of CT (beam hardening, low-dose), and artifact correction methods

- 6 Thur 10/14/2021 Problem Set II
(Staff)

Review of problem set 2

- 7 Tues 10/19/2021 Handouts Kinetic Modeling of Physiologic Data I
(Nicolas Guehl)

Covers compartmental modeling kinetics, applications to PET and SPECT imaging

- 7 Thur 10/21/2021 Handouts Kinetic Modeling of Physiologic Data II
(Marc Normandin)

Covers compartmental modeling kinetics, applications to PET and SPECT imaging

- 8 Tues 10/26/2021 Midterm Exam
(Staff)

Covers topics from lectures up to 10/120/2021

- 8 Thur 10/28/2021 Handouts Magnetic Resonance Imaging I
(Jonghye Woo)

Covers topics in MR physics (magnetization, relaxation, Bloch equations), signal detection concepts, basics of multi-dimensional MR Imaging (slice selection, phase and frequency encoding).

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- 9 Tues 11/2/2021 ZPL99 JP10 DWM07 Magnetic Resonance Imaging II
(Chao Ma)

Covers topics on interpretation of k -space, signal in k -space, sampling and aliasing, signal/contrast/noise, and basics of acquisition (spin echo, gradient echo).

- 9 Thur 11/4/2021 Handouts Iterative Tomographic Reconstruction
(Quanzheng Li)

Covers the Bayesian framework under which iterative tomographic reconstruction is interpreted (this includes a detailed explanation of Expectation Maximization), followed by a presentation of the MLEM algorithm, and continued by an introduction to maximum a posteriori (MAP) methods of image reconstruction (modeling of the prior distribution, anatomical priors, bias on the solution, penalty/regularization term in optimization).

- 10 Tues 11/9/2021 Problem Set III
(Staff)

Review of problem set 3

- 10 Thur 11/11/2021 Veterans Day (Holiday)

- 11 Tues 11/16/2021 Clinical PET
(Thomas Ng)

Covers common uses of PET in clinical practice, including common tracers, diseases, and complications of clinical interest.

- 11 Thur 11/18/2021 Handouts Radiochemistry for Molecular Imaging
(Pedro Brugarolas)

Covers fundamentals of radiochemistry, and a survey of radiochemistry techniques with regards to specific radiotracers and their clinical/experimental applications

- 12 Tues 11/23/2021 Handouts Ultrasound Imaging
(Viksit Kumar)

Topics in ultrasound elastography will be discussed, the physical basis and clinical context in which this technology is applied, through the framework of precision medicine for diffuse liver disease.

- 12 Thur 11/25/2021 Thanksgiving (Holiday)

- 13 Tues 11/30/2021 Handouts Optical Imaging and Immunotherapy
(Satoshi Kashiwagi)

Covers topics in optical fluorescence imaging and immunotherapy using near-infrared fluorescence imaging devices and targeted contrast agents.

- 13 Thur 12/2/2021 Handouts Nanomedicine: Small Molecules to Nanoparticles
(Kai Bao & Homan Kang)

Covers topics in design and applications of targeted contrast agents ranging from small molecules to nanoparticles for nanomedicine and image-guided surgery.

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14 Tues 12/7/2021 Multi-modality/Hybrid Imaging
(Moses Wilks)

Covers topics in multi-modality imaging such as challenges in simultaneous acquisition (providing an overview of state of the art image registration methods that may be used to fuse the modalities), and hybrid imaging for PET/MR and PET/CT comparing advances in each modality.

14 Thur 12/9/2021 Problem Set IV
(Staff)

Review of Problem Set IV

15 Tues 12/15/2020 Final Exam
(Staff)

Covers material from all lectures – Held in lecture hall from 4:30-6

Bibliography

SC12: Simon Cherry, Physics in Nuclear Medicine, 2012

MW04: Miles Wernick, Emission Tomography: The Fundamentals of PET and SPECT, 2004

ZPL99: Zhi-Pei Liang, Paul C. Lauterbur, Principles of Magnetic Resonance Imaging: A Signal Processing Perspective, 1999

JP10: Jerry Prince, Jonathan Links, Medical Imaging Signals and Systems, 2010

DWM07: DW McRobbie, EA Moore, MJ Graves, MR Prince, MRI from Picture to Proton, 2007