GENERAL INFORMATION

Physics of Diagnostic Radiology, MDPH 614 (3 credits)
Mon & Wed, 11:00-12:30 / Glen Site, DS1-7001

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LEARNING OUTCOMES

By the end of this course students should be able to:

- Physical basis of medical imaging and diagnostic radiology
- Radiological imaging instrumentation principles
- Optimization of imaging system quality
- Application of imaging in radiotherapy
- Exposure to new directions in medical imaging

COURSE CONTENT

(I) Diagnostic radiation spectra: Description and specification.

Atom structure· Electromagnetic radiation·Bremsstrahlung·Characteristic X-ray· Radioactivity· Angular distribution of diagnostic x-rays·Heel effect·Filtration· X-ray spectrum features·Beam quality·Half-value layer

(II) Diagnostic x-ray spectra: Generation and control.

Apparatus·X-ray generators and x-ray tubes: physical principles and design· Rectification. Exposure timers·X-ray spectrum relation to kVp, mAs, target material and rectification·Space charge·Anode heating/cooling charts

(III) Interactions of diagnostic x-ray with tissue.

Photoelectric and Compton effects on image contrast · Radiation quantities: exposure, dose, attenuation coefficient, and absorption coefficient · Entrance skin exposure · Tissue dose.

(IV) Imaging concepts and formalism.

1. Radiographic film as a receptor ·Emulsion·Film granularity·Characteristic curve·Film speed·Film gamma·Optical density Radiographic film-screen detectors·Design and physical principles·Film-screen combinations· Screen speed versus screen resolution · Photographic image subtraction principles · Dual-energy subtraction
2. Radiographic contrast· Effect of scatter on image contrast· Imaging parameters that affect radiographic contrast· Contrast Improvement Factor· Scatter reduction techniques·Advantages and disadvantages·Grids·Bucky factor·Projection radiography·Focal spot size·Geometric unsharpness·Motion unsharpness.
3. Noise spectrum·Quantum mottle·Signal-to-noise ratio·Detective quantum efficiency·Cascaded systems: signal and noise propagation·Rose's model·ROC·Aliasing.

(V) X-ray detectors and systems.

Fluoroscopy·System design·XRII design and principles of operation·System resolution·Television bandwidth·Aperture role. System noise· Digital fluoroscopy system design·**Computed radiography system**·Physical principles and design·Detector properties·**Digital radiography**· Physical principles and design of systems based on amorphous selenium and amorphous silicon detectors·**Electronic Portal Imaging**· **Devices (EPID)** Matrix-Ion and Chamber Active Matrix Flat Panel Imagers.

(VI) X-ray imaging modalities.

Mammography·System design ·Imaging quality·Breast thickness considerations·Automatic exposure control and compression·Digital Mammography·Radiation doses·Digital subtraction angiography.

(VII) Computed tomography.

Physical principles·Image reconstruction·Central slice theorem. Derivation of the filtered back projection algorithm·Projection sampling: detector quarter offset·Influence of detector width, reconstruction algorithm and display resolution on CT resolution·Different generation CT scanners·SNR as a function of dose and resolution·Image artifacts·Multi-slice scanners: operation principle·Helical scanning: definition, pitch and image reconstruction: fan-beam, cone-beam, and spiral (helical)·Daily imaging: kV versus MV-CT.

(VIII) X-ray dosimetry in diagnostic radiology.

Dose-metrics · Equivalent dose · Effective dose · Absorbed dose is Radiography and fluoroscopy·CT dosimetry·Diagnostic reference levels·Dose estimation in patients.

(IX) Ultrasound.

Ultrasound physics: physical quantities, wave propagation, wave equation·Speed of sound in biological tissues·Acoustic impedance·Ultrasound attenuation·Frequency dependence·Transmission and reflection·Display modes·Ultrasound in a moving medium·Transducer design and operation· Piezoelectric Elements·Ultrasound beam properties: Fresnel and Fraunhofer zones·Multi transducers arrays·Biological aspects.

(X) Introduction to Imaging in Radiotherapy

Target Definition and Localization·Image-guidance radiotherapy (IGRT) · Assessment of Patient Setup and Verification· Adaptive radiotherapy (ART)·Onboard imaging·Errors and Margins·Management of Motion

INSRUCTIONAL METHOD

The class consists of lectures and a mini research project.

COURSE MATERIAL

- Text: *The Essential Physics of Medical Imaging,* Bushburg et al., 3rd Ed., William & Wilkins, 2011.

ASSIGNMENTS AND EVALUATION

Homework/Quizzes	Short problems	10%
Mid-Term Examination	Lectures 1 through 14	30%
Final Examination	Lectures 15 through 24	40%
Research Project	Outline 10/15, project 12/01	20%

Exams Policy:
The exams are closed books and closed notes. However, you are allowed one 2-sided A4 sheet of paper of notes. Calculators are allowed, but only if needed. The passing grade is 65%.

RESEARCH PROJECT GUIDELINES

The goal of the project is to provide you with the opportunity to research latest advances in medical imaging that build upon the principles covered in the class but go beyond that into the future of diagnostic radiology. For this task, you could work alone or partner with a colleague on a topic suggested by the instructor. The project could involve computer simulation or literature review. Write a short report not to exceed 10 pages (single spaced typed with standard margins). The report should include:

- How does the topic relate to medical imaging or diagnostic radiology?
- Summarize the latest advances in the suggested topic using a personalized review paper style
    - Overview
    - Introduction/Background
    - Literature survey
    - Summary of findings and discussions
    - Issues/problems for application in diagnostic radiology
    - Recommendations for future directions
    - Conclusions
    - Bibliography
    - Prepare a 15 minutes presentation of your project to the class

- The project descriptive outline and presentation could be provided as a team but the report needs to be written individually. Important in the report to include your own perspectives and point-of-view on how these technologies may or may not lead to the advancement of diagnostic medical imaging.

#	Date	Topic
1		Introduction to Physics of Radiology
2		Radiation Physics Review
3		Diagnostic X-ray Spectra: Specifications
4		Diagnostic X-ray Spectra: Generation
5		Interactions of diagnostic x-ray with tissue I
6		Interactions of diagnostic x-ray with tissue II
7		X-ray imaging dosimetry
8		Imaging concepts and formalism I
9		Imaging concepts and formalism II
10		Fluoroscopy
11		X-ray detectors and systems
12		Computed Radiography
13		Mammography I
14		Mammography II
15		**Mid-term Exam (TBA) / Spring Break (TBA)**
16		Computed Tomography I
17		Computed Tomography II
19		Computed Tomography III
20		Ultrasound I
21		Ultrasound II
22		Imaging in Radiotherapy I
23		Imaging in Radiotherapy II
25		Hybrid Diagnostic Imaging
26		Project discussion/presentations
27		Review and discussions/questions for the Final Exam
28		**Final Exam (TBA)**