GENERAL INFORMATION

Physics of Diagnostic Radiology, MDPH 614 (3 credits)
Mon: 9:15-10:45; Wed: 9:15-10:45, Montreal General Hospital, D5-227

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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

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. Linear system theory-Blur and resolution-Point-spread function-Line spread
function-Modulation transfer function-Definition and measurement setups.
4. 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

INSTRUCTIONAL METHOD
The class consists of lectures and a mini research project.

COURSE MATERIAL
- Instructor’s notes, electronically available at: MyCourses. These acts as bullet points and do not substitute for taking your own notes from the material covered in the lectures.
- Supplementary Texts:
  - Image-Guided IMRT, Bortfeld et al., (Springer, 2005).
  - Image-Guided and Adaptive Radiation Therapy, Timmerman and Xing, (Williams & Wilkins, 2009).
ASSIGNMENTS AND EVALUATION

<table>
<thead>
<tr>
<th>Assignment</th>
<th>Description</th>
<th>Weight</th>
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</thead>
<tbody>
<tr>
<td>Homework/Quizzes</td>
<td>Short problems</td>
<td>10%</td>
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<tr>
<td>Mid-Term Examination</td>
<td>Lectures 1 through 14</td>
<td>30%</td>
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<tr>
<td>Final Examination</td>
<td>Lectures 15 through 24</td>
<td>40%</td>
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<tr>
<td>Research Project</td>
<td>Outline 10/15, project 12/01</td>
<td>20%</td>
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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.
<table>
<thead>
<tr>
<th>#</th>
<th>Date</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>03 Sep</td>
<td>Introduction to Physics of Radiology</td>
</tr>
<tr>
<td>2</td>
<td>08 Sep</td>
<td>Radiation Physics Review</td>
</tr>
<tr>
<td>3</td>
<td>10 Sep</td>
<td>Diagnostic X-ray Spectra: Specifications</td>
</tr>
<tr>
<td>4</td>
<td>15 Sep</td>
<td>Diagnostic X-ray Spectra: Generation</td>
</tr>
<tr>
<td>5</td>
<td>17 Sep</td>
<td>Interactions of diagnostic x-ray with tissue I</td>
</tr>
<tr>
<td>6</td>
<td>22 Sep</td>
<td>Interactions of diagnostic x-ray with tissue II</td>
</tr>
<tr>
<td>7</td>
<td>24 Sep</td>
<td>Imaging concepts and formalism I</td>
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<tr>
<td>8</td>
<td>29 Sep</td>
<td>Imaging concepts and formalism II</td>
</tr>
<tr>
<td>9</td>
<td>01 Oct</td>
<td>Imaging concepts and formalism III</td>
</tr>
<tr>
<td>10</td>
<td>06 Oct</td>
<td>X-ray detectors and systems</td>
</tr>
<tr>
<td>11</td>
<td>08 Oct</td>
<td>Fluoroscopy</td>
</tr>
<tr>
<td>12</td>
<td>15 Oct</td>
<td>Thanksgiving Holiday</td>
</tr>
<tr>
<td>13</td>
<td>20 Oct</td>
<td>Computed Radiography</td>
</tr>
<tr>
<td>14</td>
<td>22 Oct</td>
<td>Mammography I</td>
</tr>
<tr>
<td>15</td>
<td>27 Oct</td>
<td>Mid-term Exam (TBA)</td>
</tr>
<tr>
<td>16</td>
<td>29 Oct</td>
<td>Computed Tomography I</td>
</tr>
<tr>
<td>17</td>
<td>03 Nov</td>
<td>Computed Tomography II</td>
</tr>
<tr>
<td>18</td>
<td>05 Nov</td>
<td>X-ray imaging dosimetry</td>
</tr>
<tr>
<td>19</td>
<td>10 Nov</td>
<td>Ultrasound I</td>
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<tr>
<td>20</td>
<td>12 Nov</td>
<td>Ultrasound II</td>
</tr>
<tr>
<td>21</td>
<td>17 Nov</td>
<td>Imaging in Radiotherapy I</td>
</tr>
<tr>
<td>22</td>
<td>19 Nov</td>
<td>Imaging in Radiotherapy II</td>
</tr>
<tr>
<td>23</td>
<td>24 Nov</td>
<td>Hybrid Diagnostic Imaging</td>
</tr>
<tr>
<td>24</td>
<td>26 Nov</td>
<td>Advanced Medical Imaging</td>
</tr>
<tr>
<td>25</td>
<td>01 Dec</td>
<td>Project discussion/presentations</td>
</tr>
<tr>
<td>26</td>
<td>03 Dec</td>
<td>Final review session</td>
</tr>
<tr>
<td>27</td>
<td>08 Dec</td>
<td>Final Exam (TBA)</td>
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