Concordia University
Department of Electrical and Computer Engineering
Fall 2019-20: Course outline

ELEC 691 S: Radiation detectors for medical imaging

Instructor: Dr. M. Z. Kabir
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Office hours: Tuesdays, 11:00 am -12:00 pm

Course Web site: https://users.encs.concordia.ca/~kabir/ELEC691R.htm

Lectures: **Wednesdays 2:45-5:15 pm,** MB S2.401

Course Contents:
Ionizing radiation and its sources. Interactions of ionizing radiation with matter. Review of counting statistics. Principles and types of radiation detectors. Semiconductor radiation detectors. X-ray imaging modalities and Flat panel image sensors. Photoconductor requirements. Image quality, cascaded system model, and signal and noise propagation. Noise in imaging sensors and detective quantum efficiency. Imaging detectors for nuclear medicine.

Prerequisite: Basic understanding on atomic structures and semiconductor materials.

Required Materials:

(1) Lecture notes

(2) Text book: G. F. Knoll, *Radiation detection and measurement*, 4th edition (Publisher: Wiley, 2010, ISBN 978-0470131480)

References:

(1) J. T. Bushberg, J. A. Seibert, E. M. Leidholdt Jr., J. M. Boone, *The Essential Physics of Medical Imaging*, 3rd edition (Publisher: Lippincott Williams & Wilkins, 2012, ISBN 978-0781780575)

(2) J. Beutel et al., *Handbook of medical imaging*, vol. 1 (Publisher: SPIE press, 2000, ISBN 978-0-8194-3621-6)

Learning outcomes:
Upon successful completion of this course:

1. Students will learn the fundamental sciences on sources and interactions of ionizing radiations (X-rays, gamma rays, alpha and beta particles etc.) with matter.
2. They will learn the principles and types of various radiation detection schemes, and required photoconductor properties for various imaging detectors.
3. They will learn principles of imaging science, diagnostic imaging modalities and metrics of image quality.

4. They will get the state-of-the-art on diagnostic medical imaging (e.g., using X-rays) sensors and imaging detectors for nuclear medicine.
5. Students will be able to design an imaging detector based on specifications and application, and be able to analyze various imaging performances of their design.

Detailed course Syllabus:

1. *Radiation*: ionizing and nonionizing radiations, sources of electromagnetic (X-rays and γ-rays) and particulate radiation (electron, neutron, alpha and beta particles) and their interactions with matter, photoelectric effect, attenuations of X-rays and γ-rays and radiation doses (Text Ch 1 & 3, and Ref. 1)
2. *Counting statistics*: Characterization of data, review of statistical models (binomial, Poisson and normal distributions) and their applications (Text Ch 3)
3. *Principles and types of radiation detectors*: modes of detector operation, pulse height spectra, energy resolution, Gas-filled and Scintillator detectors (Text Ch 4 & 8, Ref. 1)
4. *Semiconductor detectors*: pn, pin and Schottky junction photodiodes, avalanche photodiode, photoconductive detectors, Ramo's theorem and signal formation mechanism, vertical, coplanar and Frisch grid detectors (Text Ch 11 & 13)
5. *X-ray imaging technologies and Flat panel image sensors*: X-ray tubes, Active matrix arrays, direct and indirect conversion detectors, pixelated detectors, energy integration versus photon counting detectors, Photoconductor requirements, and design of detectors for general radiography, mammography and fluoroscopy. (Refs. 2)
6. *Image quality*: X-ray sensitivity, modulation transfer function (MTF), cascaded system model, noises in digital imaging sensors, signal and noise propagations, and detective quantum efficiency (DQE) (Refs. 1 & 2)
7. *Nuclear medicine Imaging detectors*: gamma camera, silicon photomultiplier, and CdZnTe pixelated detectors (Text Ch 9, Refs. 1 and 2) for SPECT and PET.

Tentative timetable:

Weeks	Course materials	Reading
Week 1 & 2	1. Various radiation sources and their interaction with matter	Text Ch 1 & 3, and Ref. 1
Week 3	2. Counting statistics and their applications in radiation detectors	Text Ch 3

Week 4	3. Principles and types of radiation detectors	Text Ch 4 & 8, Ref. 1
Week 5 & 6	4. Semiconductor radiation detectors, their types and applications	Text Ch 11 & 13
Week 7, 8 & 9	5. X-ray imaging technologies and Flat panel image sensors	Refs.1 & 2
Week 10 & 11	6. Image quality assessments: Sensitivity, MTF, DQE, noise	Refs. 1 & 2
Week 12	7. Nuclear medicine Imaging detectors	(Text Ch 9, Refs. 1 and 2)

Grading Scheme (tentative)

Project	30 %
Assignments	20 %
Midterm exam(closed book)	20 %
Final exam (closed book)	30 %

Project (Individual or a group of three students): Students will have to do a design project. They have to select appropriate photoconductor material and design for an imaging detector based on required specifications and application. They will have to analyse the imaging performances of their detector design. They need to perform analytical and/or numerical simulation using MATLAB or other suitable software. They will have to present the project and submit a report. The report should include the justifications of the particular design and results of performance analysis.

Assignment: Assignments are compulsory. They have to submit approximately 6/7 assignments. Approximately half of the assignments are conventional design and problem solving types, and the other half are research-type. For the research type assignments, they will be given research papers, and a few specific problems and questions will be asked based on the paper. Assignments and their submission deadlines will be announced in the class.

Midterm exam: This closed book exam will be held on March 04, 2020, during class time. Students are permitted to bring one 8.5″ × 11″ sheet of notes. They can use one side. Notes must be hand written (original).

Final exam: ***The final exam will be closed book***. Students are permitted to bring one 8.5″ × 11″ sheet of notes. They can use both sides. Notes must be hand written (original).

Office hours:

Office hours are provided for any extra help. If anyone finds the time schedule inconvenient, he/she should contact the instructor for getting an appointment.

Expectations of originality and Professionalism:

One important component of professionalism is academic integrity. Please pay attention to academic integrity. The copying of materials from anywhere (internet, books, labs and assignments of other students) is not permitted, and is deemed a serious academic offence. *Plagiarism* is a common form of academic misconduct. There are many other forms of academic misconducts. Please consult Concordia Website for detailed descriptions of academic misconducts.
http://www.concordia.ca/students/academic-integrity.html

Cheating is a serious offence. You must abide by the Academic Code of Conduct as described in the University Calendar. *Any suspected violation of the Code will be reported* to the Associate Dean for investigation. Penalties can be as severe as dismissal from the University.

1. Submit the expectations of originality form with your signature, full name, ID #, and date and attach with your first assignment.
2. Write "I certify that this submission is my original work and meets the faculty's Expectations of originality" with your signature, full name, ID #, and date in all other assignments.