Syllabus for Phys 531/790 : Intro. To Medical Imaging Instructor: George Coutrakon

The course will be taught using Smith and Webb's book, "Introduction to Medical Imaging." Cambridge University Press, 2011 edition. We will cover the physics of X-ray proton imaging in 2D and 3D, image quality analysis, and the physics of MRI. Supplemental material from other books will be provided. A $24 subscription to Top Hat is required for periodic in-class quizzes.

Grading policy for this course

The grades for the course will be determined from

1. weekly homework assignments (40%)
2. In class quizzes from software Top Hat (10%)
3. a midterm exam 10%
4. a mid semester imaging project using X-ray CT projection data (20%)
5. A final exam (20%).

Students can follow their running total in Black Board as a percent of total points. The curve for the course will determined at the end of the semester.

Week 1: Introduction to X-rays and their interaction with matter – Read Sections 2.1-2.5

1. The linear attenuation coefficient; relationship to electron density, cross section, and interaction probability/unit length
2. Photo-electric and Compton Effect, pair production, Z and E dependences in water
3. Production of X-rays using Tungsten target, Characteristic X-rays and Bremstrahlung, angular and energy dependence.
4. Application to Mammography

HW – Derive the energy and angle relations for Compton scattering

Week 2: Introduction to 2D Radiography and Dose calculations for X-rays in water – Read Sections 2.6-2.8 and Sections 1.4-1.5 in Webb and Smith

1. Radiography as a map of $\int \mu(x, y, z)\ dz$
2. Definition of Contrast, Mottle (noise), X-ray dose, CNR (contrast to noise ratio)
3. Definition of spatial resolution of images
4. Definitions of Dose for X-rays in water, mass energy absorption coefficient

HW #1 – Calculate the attenuation of 20 and 100 KeV photons through 20 cm water plus bone. Using photon attenuation date from J & C for 100 KeV x-rays, calculate photon intensity (photons/mm^2)behind the phantom for 0 and 1 and 4 cm bone. Compute a) dose at surface, b) contrast, CNR and c) signal to noise for 1 cm and 4 cm compared to water.

Week 3: 2D image reconstruction [of μ(x,y)] technique for X-ray CT ; the filtered back projection (FBP) calculation: Read Steve Webb, Ch 4 and handout notes. Derive equations for FBP.

HW #2 – Perform 2D image reconstruction of a 2 x 2 map of μ(x,y) using FBP.

Week 4. Work week 2 HW and Start proton radiography

1. Work HW for week 2 in class. Calculate attenuation of photons through (16-20 cm) water and (4 to 0 cm) bone for 20 KeV and 100 KeV photons, calculate dose at entrance, calculate contrast,CNR.
2. The dE/dx equation for protons in water and heterogeneous tissue. Relative stopping power (RSP) for protons, range of protons in tissue.
3. The proton radiograph as 2D energy loss map across the field. Parallels with X-ray radiographs.
4. No new HW.

Week 5. Continue Proton radiography

1. Work HW #2 from Week 3 with 2 x 2 planar mu values (1 hour)
2. Continue Bethe Bloch Equation and calculation of Range
3. RSP and relative electron density
4. Proton energy dependence of RSP
5. Definition of Dose for proton radiation and the Bragg Peak
6. Definition of WEPL and its relation to RSP
7. Sinograms as tools for quality control, how to recognize 2D shapes from sinograms.
   HW #3 Create WEPL data for 2 x 2 image with water and Titanium.
   HW #4 Read Ch. 1.10-1.13 (pg. 25-30) in Smith and Webb. Work problems 1.16 and 1.17

(sinograms), show equivalence of Eq. 1.20 with mu(x,y) in A. Webb with the equation for mu derived in class from S. Webb's book.

Assign image reconstruction of George W. Bush photo from simulated projection data. Due in 4 weeks.

Week 6. Continue discussion of proton radiography from week 5, Bethe Bloch eqn, range energy, and WEPL. Comparison of integral density resolution of 100 KeV photons vs. 200 MeV protons in radiography at the same dose using example from HW #1.

Week 7. Work proton CT HW problem in class. Discuss image quality analysis of proton vs. X-ray radiography using Ch. 3 of Depauw's PhD thesis. Definition of contrast from AAPM report 39, definition of spatial resolution, density resolution and CNR from DePauw thesis.

Week 8. Work Ch. 1 HW on sinograms in class. Finish DePauw thesis Ch. 3 on image quality of radiography.

Week 9. Spring break

Week 10. Review, three aspects of image quality in Webb and Smith, then start Ch 5 on MRI. 35 x 35 image of George W. Bush is due.

Week 11 – Week 13. (April 1 – 15) Continue Spatially Localized MRI. T1 , T2 and spin density imaging.

Week 14 – Week 15. Physics of Ultrasound

Week 15. Review

Week 16. Final Exam as scheduled for week of May 4th.