Syllabus for Phys 531 : Intro. To Medical Imaging

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 and proton CT, image quality analysis, and the physics of MRI. Supplemental material from other books will be provided. The grades for the course will be determined from weekly homework assignments (60%), a mid semester imaging project using X-ray CT projection data (20%), and a final exam (20%).

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 – Calculate attenuation of 20 and 100 KeV photons through 20 cm water plus bone.

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 – 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.
   HW – extend deadline for Week 3 HW. No new HW.

Week 5. Continue Proton radiography

1. Work HW 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 – 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 3 weeks).

Week 6. Complete discussion of proton radiography and proton CT.

Week 7. Image quality analysis of proton vs. X-ray radiography. Discuss Ch. 3 of Depauw's PhD thesis.

Week 8 – 12. Physics of MRI imaging. (4 weeks)

Week 13-14. PET an SPECT imaging

Week 15. Review

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