

Homework 1
Projection Radiography
Resources: Chapter 2, 3, 5, 6 & 11
Due Date: Friday, March 14, 2008 in class

- 1) The following multiple choice/short answer problems relate to basic concepts in the physics of radiation. To answer the questions refer to the lecture notes and Chapters 2 & 3 of the book.
- 1.1) In the production of X-rays, the term “Bremsstrahlung” refers to which of the following?
- The cut-off wavelength, λ_{\min} , of the X-ray tube
 - The discrete X-ray lines emitted when an electron in an outer orbit fills a vacancy in an inner orbit of the atoms in the target metal of the X-ray tube
 - The discrete X-ray lines absorbed when an electron in an inner orbit fills a vacancy in an outer orbit of the atoms in the target metal of the X-ray tube
 - The smooth, continuous X-ray spectra produced by high-energy blackbody radiation from the X-ray tube
 - The smooth, continuous X-ray spectra produced by rapidly decelerating electrons in the target metal of the X-ray tube
- 1.2) Select the X-ray interaction mechanism for which the following statements are true. Your answer can be any combination of: Rayleigh Scattering, Compton Scattering, and Photoelectric Absorption.
- Involves the interaction of an x-ray photon and an outer-shell electron
 - Results in the ejection of an electron
 - The probability of interaction increases with the electron density of the absorber material
 - The probability of interaction increases with the density of the absorber material
 - Causes characteristic peaks in the output spectrum of an X-ray tube
- 1.3) What is the difference between X-rays and gamma rays?
- X-rays are produced extranuclearly whereas gamma rays are produced in nuclear decays
 - X-rays have higher energies than gamma rays
 - gamma rays are produced by Bremsstrahlung
 - X-rays and gamma rays interact with matter differently
- 1.4) Which photon processes are dominant in the context of diagnostic radiology?
- Compton scattering and photoelectric effect.
 - Photoelectric effect and pair production.
 - Compton scattering and pair production.
 - Compton and Rayleigh scattering.
- 1.5) Choose a pair of words to complete the following sentence correctly. High energy X-rays suffer _____ photoelectric absorption and _____ Compton scattering compared to low energy X-rays
- more, more
 - less, more
 - more, less
 - less, less
 - equal, equal
- 1.6) X-rays used for diagnostic imaging are typically 1keV to 200keV. What are the corresponding wavelengths and frequencies for both of these energies? Planck’s constant is $4.13 \cdot 10^{-18}$ keV-sec.
- | Energy (keV) | Wavelength (nm) | Frequency (Hz) |
|--------------|-----------------|----------------|
| 1 | | |
| 200 | | |
- 1.7) In a Tungsten atom (see the energy level diagram on page 22 of your book) the characteristic x-ray produce by a transition of an M to K shell is ~67 keV. What is the energy of a characteristic X-ray produced by a transition from the L to K shell?

2. In figure 1, calculate the X-ray intensity (I_d), as a function of the incident intensity I_o , that reaches the film for each of the three X-ray beams. The dark-shaded area represents bone and the light-shaded area represents tissue. Assume that the X-ray beams are monochromatic (at one energy). The linear attenuation coefficients at the effective X-ray energy of 68 keV are 10 and 1 cm^{-1} for bone and tissue, respectively.

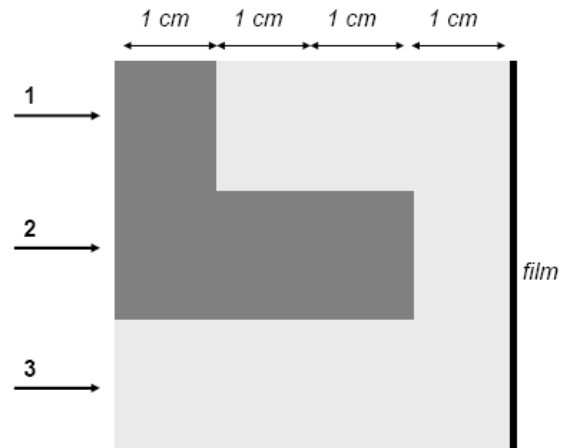


Figure 1

3. A region of the body has a 10-cm thickness of muscle tissue (see figure 2). Part of this region has a superimposed 2-cm thickness of bone. The densities of the muscle and bone are 1.0 and 1.75 g/cm^3 , respectively. For this problem you need the X-ray mass attenuation coefficients for muscle and bone. You can download these data from the NIST website at:

<http://physics.nist.gov/PhysRefData/XrayMassCoef/tab4.html>

Use [Muscle, Skeletal](#) (ICRU-44) for the attenuation of muscle and use [Bone, Cortical](#) (ICRU-44) for the attenuation of bone.

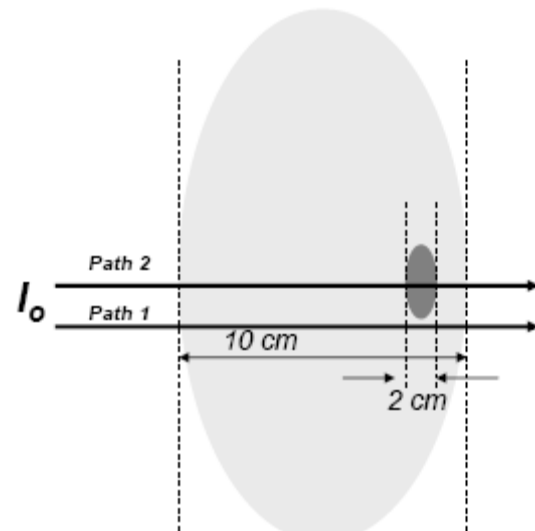


Figure 2

a. Calculate the x-ray transmission in the muscle tissue alone and in the combined muscle and bone region at energies of 30 and again at 100keV, using the attenuation data from NIST.

b. Use matlab to make a semi-log plot of the mass attenuation coefficients (bone & muscle) as a function of energy, similar to the plot shown in Figure 3-10 on page 43 of your book.

c. Which energy (30 keV or 100 keV) is preferable for bone-muscle contrast? Which is preferable for visualizing variations in muscle thickness in the presence of bone? Justify your answers by with reference to the plot you made in part b.

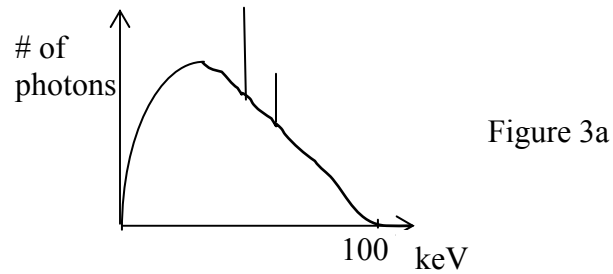
4. This is a **Matlab** question. Include your code in the answer. In this question we investigate the effects of filtration on a polyenergetic X-ray tube spectrum. Download the file **XrayData.mat** from the HW 2 folder on Angel. The file contains 5 vectors: energy, N80, N120, muWater, muAL.

a) Make a plot of the unfiltered tube spectrum at 80kVp and 120kVp on the same scale. Calculate the mean energy of both spectra and mark these points on your plot.

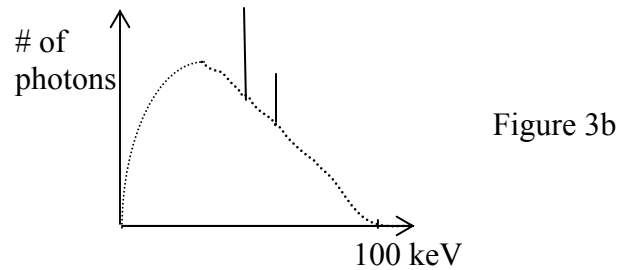
b) Calculate the energy spectra (at 80 and 120 kVp) after it's been attenuated with 5 mm of Aluminum. You can assume that the density of Aluminum is 2.7 g/cm^3 . Make a new plot of the filtered tube spectrum at 80kVp and 120kVp on the same scale. Calculate the mean energy of both spectra and mark these points on your plot.

c) Calculate the energy spectra (at 80 and 120 kVp) after it's been further attenuated with 20 cm of water. Make a new plot of the filtered tube spectrum at 80kVp and 120kVp on the same scale. Calculate the mean energy of both spectra and mark these points on your plot.

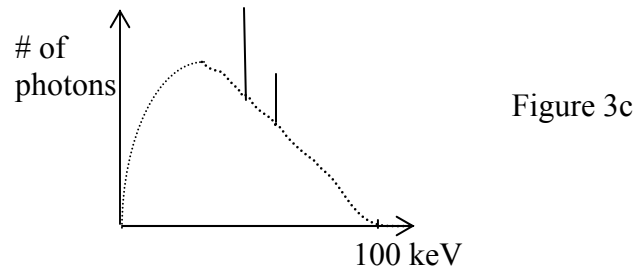
5. The figure below illustrates the output spectrum of an x-ray tube for a particular x-ray acquisition.



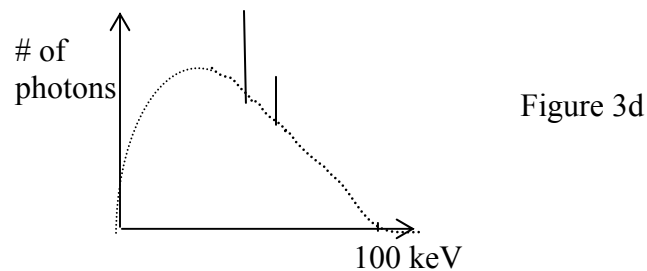
a) Using Figure 3a as a reference, sketch the spectrum that would result from a lower kVp setting



b) Using Figure 3a as a reference, sketch the spectrum that would result from a decrease in tube current.

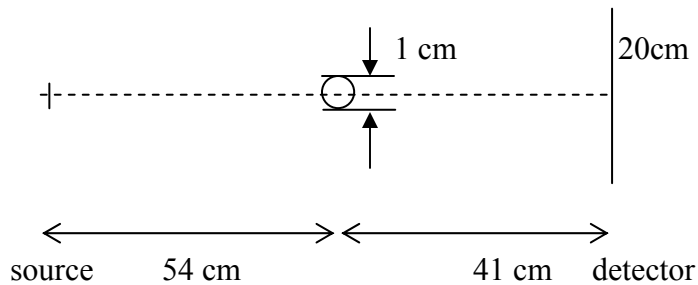


c) Using Figure 1 as a reference, sketch the spectrum that would result from using an aluminum filter at the output of the tube.



d) Assume that the spectrums sketched in parts a, b, and c contain the same total number of photons. Which spectrum would result in the lowest dose to the patient for identical x-ray exams? Justify your answer.

6. Referring to the figure below:



- a) A 1-cm wide object is located 54 cm from the source and 41 cm from the detector on the central ray of the x-ray beam as shown below. The width of the detector is 20cm. Calculate the following parameters:
 - i) The field of view of the X-ray system
 - ii) The magnification factor
 - iii) Assuming a point source, what is the width of the object at the detector?
- b) If the Source-to-object distance is increased and everything else stays the same, qualitatively what is the effect on the parameters calculated in part a)?
- c) Assuming the focal spot of 5mm, what is the width of the object at the detector?
- d) An effective focal spot of 1 mm is projected from an x-ray tube. The true focal spot is 5 mm. What is the target angle?
- e) What are the tradeoffs involved in changing the actual focal spot from 5 mm to 2 mm? (assume the target angle is unchanged)