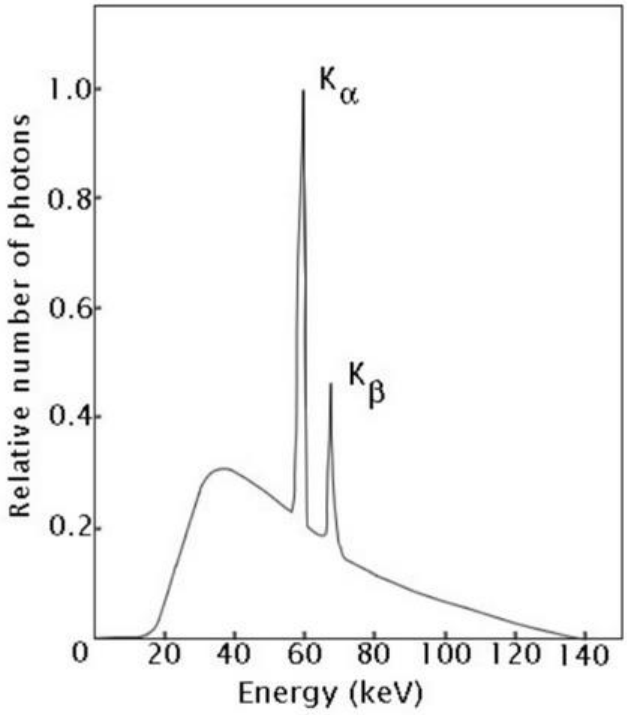
Physics in Modern Medicine Winter 2025

Chapter 5 Problems

5.1 X-ray generation

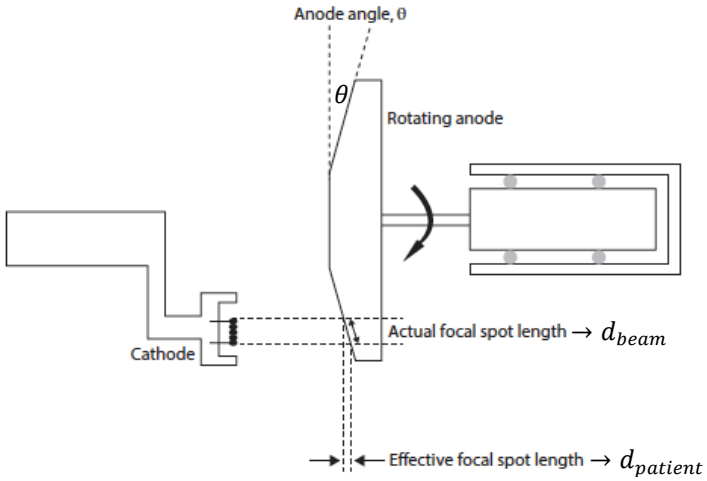
Consider the x-ray intensity (number of photons) versus energy spectrum shown below.

a. What is the operating voltage of the tube?
b. What is the anode material?
c. Explain the features of the curve. What are the parts of the curve generated by?
d. Qualitatively, what would happen to the spectrum produced if the operating voltage of the tube say were halved? What about if the tube current were doubled?



5.2 X-ray beam spot size

a. Consider the diagram below of a rotating anode x-ray generating system. The beam is incident on the anode and makes a spot of size d_{beam}. The beam that is directed to the patient has some effective size $d_{patient}$ and can vary from as small as $0.1mm$ (mammography) to $1.5mm$ (radiography/CT). Using the diagram below, derive an expression relating d_{beam} to $d_{patient}$ and the anode angle θ.

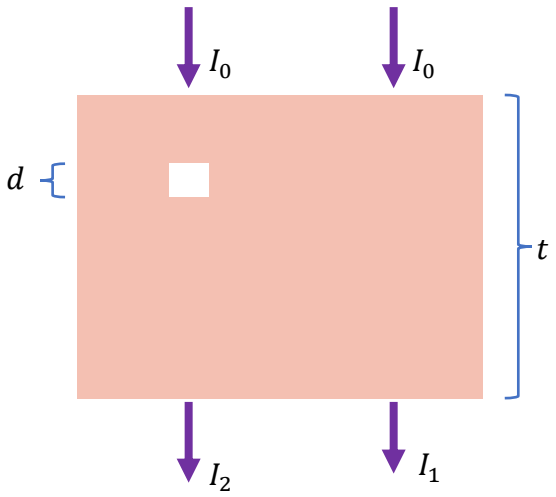


b. For an anode angle of $\theta = 12^0$, what beam size d_{beam} would be needed so that the effective focal spot size is $d_{patient} = 1.2mm$. Note: you can vary d_{beam} by collimating the beam of electrons from the cathode heading to the anode and by controlling d_{beam}, you can control $d_{patient}$.

5.3 Breast micro-calcification and contrast

a. Suppose that a beam of x-rays was incident on a piece of material (tissue) of thickness $t = 1mm$. Imbedded in the tissue is a spherical bead of calcium of diameter (thickness) $d = 200\mu m$ as shown below. This scenario could represent breast tissue in which there is a micro-calcification, and this could be indicative of breast cancer. If the x-ray beam does not scatter, what is the contrast C between the calcium bead and the tissue for x-ray energies $20keV$, $50keV$, and $100keV$? Use the table below for the attenuation coefficients.

Energy (keV)	$\mu_{Tissue}\ (cm^{-1})$	$\mu_{calcium}\ (cm^{-1})$
20	0.793	20.150
50	0.227	1.547
100	0.170	0.397



b. What conclusion can you draw about the contrast and the photon energy? Which energy range gives the highest contrast? Which energy ranges gives the lowest? Which energy would you use to visualize something as small as this micro-calcification?