Instituto Tecnológico y de Estudios Superiores de Monterrey

Análisis de Sistemas de Imagenología (Grupo 201 y 202)

Actividad 1.
Rayos X

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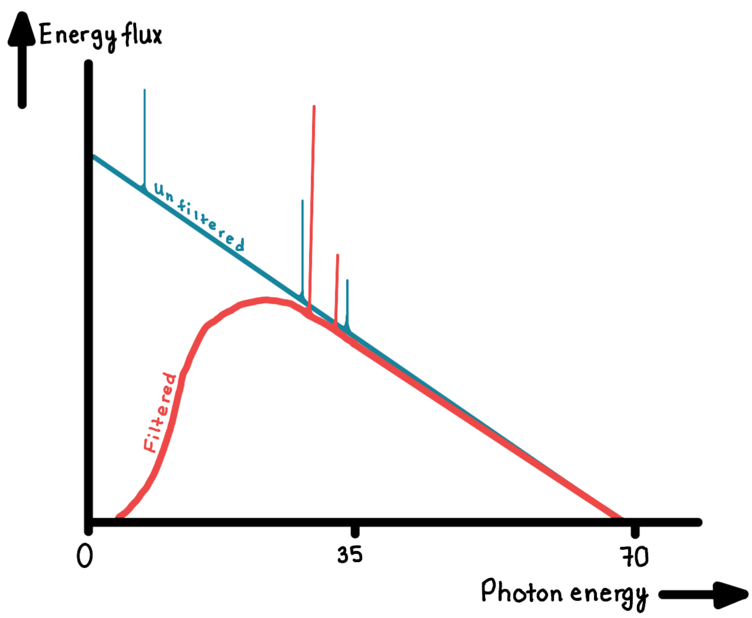
Actividad 1. Rayos X

1. **X-rays.**
    a. **What is the physical difference between X-rays, γ-rays, light and radio waves? How do they interact with tissue (in the absence of a magnetic field)?**

The difference between those waves is the change in the wavelength, as described in Table 1.

Table 1. Waves (wavelength and interaction with tissue)		
Wave	***Wavelength***	***Interaction with Tissue***
X-rays	10x10e-09 m	Penetrate the human tissue but get attenuated with tissue like bones. Can cause ionization.
γ-rays	10x10e-12 m	Completely penetrate the human tissue, when they go through can cause ionization.
Light (Visible Spectrum)	780x10e-09 m	Almost completely absorbed by the tissue; the reflexed portion is the one which creates the color of what a tissue is perceived. Do not cause ionization.
Radio	10x10e03 m	Do not cause ionization. Can go through some tissues, and get blocked by others.

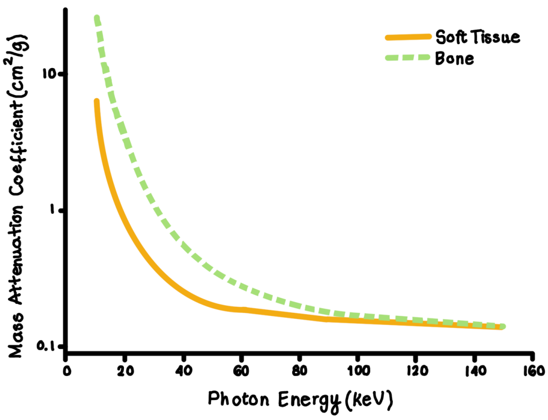
    b. **Draw the X-ray tube spectrum, i.e., the intensity distribution of X-rays as a function of the frequency of emitted X-ray photons (1) at the exit of the X-ray tube before any filtering takes place, and (2) after the filter but before the X-rays have reached the patient.**



c. **How does the tube voltage influence the wavelength of the X-rays?**

The wavelength decreases as the voltage increases, thus an inversely proportional behavior is described between these.

d. **Draw the linear attenuation coefficient (for an arbitrary tissue type) as a function of the energy.**



2. **What is the effect of the kV and mAs of an X-ray tube on**
   a. **the patient dose, and**

The dose increases as the energy (kV) or the intensity (mAs) applied increases. Is important to establish that the increase of the intensity has a stronger effect on that increase than the energy has.

b. **the image quality?**

The quality of the image is directly proportional to the intensity and inversely proportional to the energy applied. The improvement on the quality by the increasing of intensity is related to the quantity of photons sent to the tissue.

3. **A digital radiograph is acquired but the CNR in the region of interest is insufficient. Calculate the relative CNR and relative dose of the following options**
   a. **double the mAs;**
   b. **take two radiographs and calculate the average image;**

The situations determined in letter a and b are quite similar; to explain this similarity and the resulting impact in CNR and dose, is necessary to establish the number of increase or number of radiographs as N, so for the letter a (double) and b (two) a $N = 2$ is obtained. By doing the next equation (1), a proportional behavior is observed in the CNR, and also in the dose applied.

$$(1)\ SNR = \sqrt{N} \rightarrow SNR_2 = \sqrt{2N} \rightarrow SNR_2 = \sqrt{2}\, SNR_1 \Rightarrow CNR\, \alpha \sqrt{N}$$

c. apply a window/level image operation;

In most of the cases, if a window/level image operation is executed, the CNR and the dose do not change in a significant way. However, if the image background has less intensity than the object to examine, it has a better effect on the CNR, but does not impact on the dose applied.

d. change the kV.

The CNR is inversely proportional to the energy applied, thus if the amount of kV increases, the contrast gets worse, and vice versa. Also, the patient's dose increases.

4. **A radiograph of a structure consisting of bone and soft tissue (see Figure B.1) is acquired by a screen film detector. The exposure time is 1 ms. The radiographic film has a sensitometric curve $D = 2\,log\,E$. The film screen system has an absorption efficiency of 25%. Assume that the X-rays are monochromatic and the linear attenuation coefficient of bone, soft tissue, and air are respectively** $0.50\ cm^{-1}$, $0.20\ cm^{-1}$, $0.00\ cm^{-1}$.

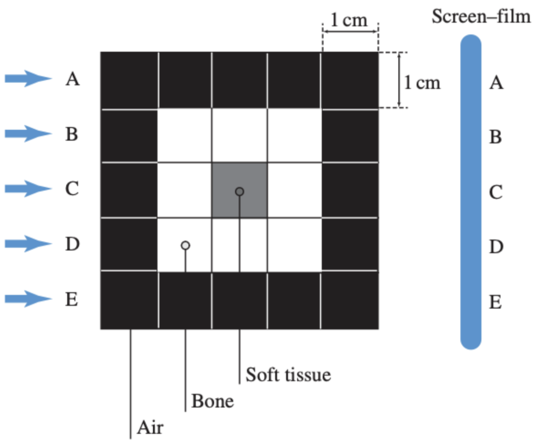


Figure B.1

a. Calculate the optical density D in positions A through E of the image.

$$A = 0.00\ cm^{-1} + 0.00\ cm^{-1} + 0.00\ cm^{-1} + 0.00\ cm^{-1} + 0.00\ cm^{-1} = 0.00\ cm^{-1}$$
$$B = 0.00\ cm^{-1} + 0.50\ cm^{-1} + 0.50\ cm^{-1} + 0.50\ cm^{-1} + 0.00\ cm^{-1} = 1.50\ cm^{-1}$$
$$C = 0.00\ cm^{-1} + 0.50\ cm^{-1} + 0.20\ cm^{-1} + 0.50\ cm^{-1} + 0.00\ cm^{-1} = 1.20\ cm^{-1}$$
$$D = 0.00\ cm^{-1} + 0.50\ cm^{-1} + 0.50\ cm^{-1} + 0.50\ cm^{-1} + 0.00\ cm^{-1} = 1.50\ cm^{-1}$$
$$E = 0.00\ cm^{-1} + 0.00\ cm^{-1} + 0.00\ cm^{-1} + 0.00\ cm^{-1} + 0.00\ cm^{-1} = 0.00\ cm^{-1}$$

b. Calculate the contrast, i.e., the difference in density, between positions B and C. How can this contrast be improved?

$$C_{BC} = D_B - D_C = 1.50\ cm^{-1} - 1.20\ cm^{-1} = 0.30\ cm^{-1}$$

The contrast can be improved by reducing the amount of energy (kV) or increasing the photons/intensity (mA) of the X-Ray.

5. **In mammography the breasts are compressed with a paddle. Explain why.**

The three main reasons why the breasts are compressed during the mammography are: less patient's exposure to the X-Ray (same tissue, less thickness, less energy needed), less distortion and better quality of the resulting image (there is a shorter distance between the microcalcifications and the plates of the device).