ATTENUATION OF X-RAY AND PHOTON ENERGY

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Fundamental of Radio Physics

Fall semester

Week 6

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Outline

Attenuation of x-ray and photon energy in

- Soft tissue
- Radiography
- Calciun
- Iodine and Barium contrast
- Scatter radiation and contrast

Objectives

The student should be able to do the followings;

- Describe the attenuation of x-ray and photon energy in (Soft tissue, Radiography, Calciun, Iodine and Barium contrast, Scatter radiation and contrast)
- Solve mathematical problems to calculate the attenuation through materials and soft tissue.
- Explain the reason of using contrast agents.

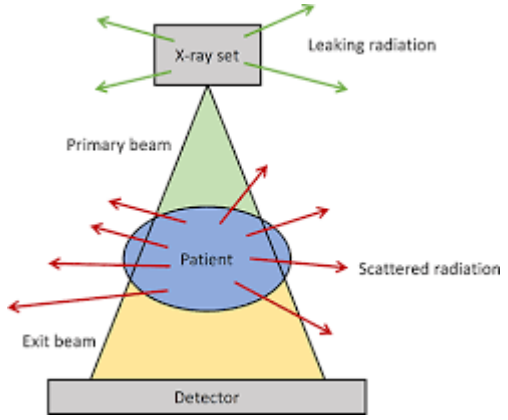
Attenuation of X-Ray

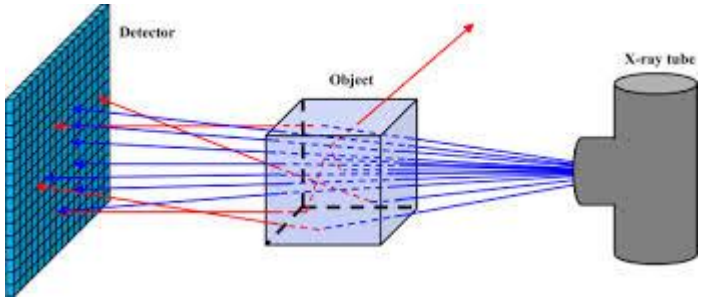
When an x-ray impinges upon a material, there are three possible outcomes.

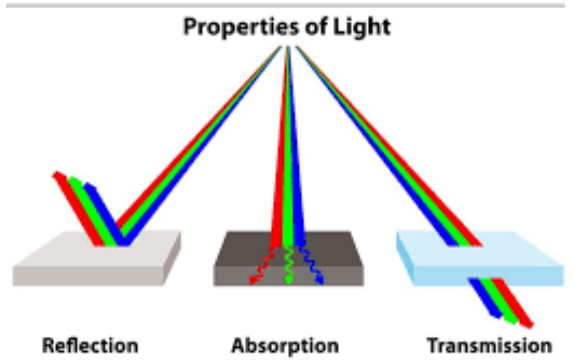
(1) Absorption (transfer its energy to atoms of the target material during one or more interactions)

(2) Scattering

(3) Traversing the material without interaction







Attenuation of X-Ray and Photons

The number of photons penetrating a medium I :

$$I = I_{\circ} \times e^{-\mu.x}$$

where μ is the attenuation coefficient of the medium for the photons

$I_{\circ}$ the initial number of photons in the beam before interacting the matter.

The number of photons attenuated I_{at}

$$I_{at} = I_{\circ} - I$$

Attenuation of X-Ray and Photons

Question:

A narrow beam containing 2000 monoenergetic photons passing by a slab of copper (0.01 m) thick. What is the number of photons passing the slab if the total linear attenuation coefficient (69.3 m^{-1}) ?

Question: A narrow beam containing 2000 monoenergetic photons is reduced to 1000 photons by a slab of copper 10^{-2} m thick. What is the total linear attenuation coefficient of the copper slab for these photons?

Attenuation of X-Ray and Photons in Soft Tissue

The attenuation coefficient for x-rays in human tissue varies significantly with

1- The X-ray's energy: Lower-energy photons are more likely to be absorbed, resulting in higher attenuation, but less penetration. Higher-energy photons penetrate further with less attenuation

2- Tissue density

3- Atomic composition: Materials with a higher atomic number absorb x-rays more effectively. This is **why** bones (high Z) appear bright white, while soft tissues (low Z) are darker.

4- Material thickness: A thicker material will cause more attenuation than a thinner one.

with values ranging from approximately 0.20 cm^{-1} to over 5 cm^{-1} for lower energies and **decreasing** as **energy increases**.

Question: A narrow beam of x-ray (8 keV) containing 50000 monoenergetic photons passing soft tissue with 10 cm thickness. If the total linear attenuation coefficient of soft tissue is 5.7 cm^{-1} what is the number of passing photons?

Attenuation of X-Ray and Photons in Radiography

Measuring attenuation

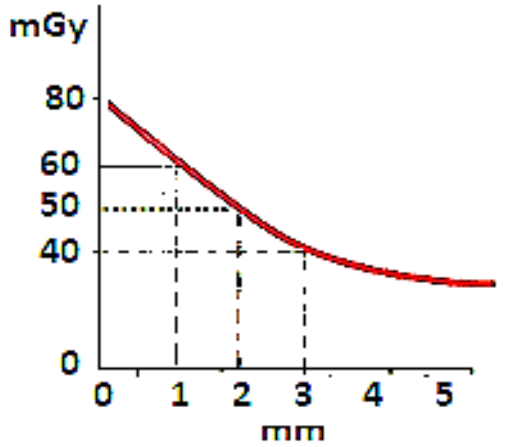
- **Attenuation coefficient:** A measure of how effectively a material attenuates X-rays. It can be a linear or mass coefficient.

$$I = I_{\circ} \times e^{-\mu.x}$$

- **Half-value layer (HVL):** The thickness of a material required to reduce the X-ray beam's intensity by half. It is a way to describe the penetrating power of a beam.

$$HVL = \frac{\ln 2}{\mu} = \frac{0.693}{\mu}$$

Question: Calculate the total linear attenuation coefficient of the material.



Attenuation of X-Ray and Photons in Calcium

X-rays and photons are strongly attenuated in Calcium due to **its high atomic number and density**, so it appear white on medical images.

The attenuation process is

1- The **photoelectric effect** at lower energies: the photon is completely absorbed by an inner-shell electron, which is then ejected from the atom.

2- **Compton scattering** at higher energies: the x-ray photon interacts with a free or loosely bound outer-shell electron, causing the photon to scatter in a different direction with reduced energy.

* High Z materials (calcium) have a greater probability of participating in interactions that absorb and remove photons from the beam.

Attenuation of X-Ray and Photons in Iodine and Barium contrast

The **photoelectric effect** is the way iodine and barium attenuate x-rays and photons primarily due to their high atomic numbers and the presence of K-edges in the diagnostic energy range.

Iodine and barium are used as contrast agents in diagnostic radiology (medical imaging) due to their highly effective x-ray and photon attenuators, due to their high atomic numbers, which is the basis for their to enhance the visibility of specific anatomical structures.

Question: Why we don't use contrast agent with high energy x-ray photons?

Ans: High energy photons interact with human tissue by Compton scattering and the Compton mass attenuation coefficient is **nearly independent** of the atomic number of the attenuating medium.

For this reason, radiographs exhibit very poor contrast when exposed to high-energy photons.

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References

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