Tutorial

Series 3

Advanced Biomedical Signal and Image Processing

Master: Plasturgy & Biomedical Engineering

Pr. Omar ELOUTASSI

Exercise 1

1. What is medical imaging, and why is it important in healthcare?
2. List and briefly describe four key benefits of medical imaging technologies.
3. What are the primary imaging modalities used in medical imaging, and what are their applications?
4. How has the field of medical imaging evolved over time?
5. What role does medical imaging play in preventative care?
6. Discuss the significance of ongoing innovations in medical imaging.
7. What is X-ray imaging, and why is it commonly used in medical diagnostics?
8. Describe the basic physics of X-rays, including their properties and how they are produced.
9. Explain the photoelectric effect and its significance in X-ray imaging.
10. What is the Beer-Lambert Law, and how does it relate to X-ray attenuation?
11. What are some applications of X-ray imaging?
12. Discuss the importance of radiation protection measures in X-ray imaging.

Exercise 2

1. Write a concise definition of radiation and explain its types.
2. Describe the electromagnetic spectrum and identify at least three types of radiation in it.
3. List and explain three key properties of ionizing radiation.
4. Explain how radiation interacts with matter and the significance of these interactions in medical applications.
5. Identify and explain three safety measures that should be taken when working with ionizing radiation.

Exercise 3:

1. A radioactive isotope has a half-life of 10 years. If you start with 100 grams of this isotope, how much will remain after 30 years?
2. A radioactive isotope has a half-life of 10 years. If you start with 100 grams of this isotope, how much will remain after 30 years?

Exercise 4

1. Explain how the photoelectric effect contributes to image contrast in X-ray imaging.
2. Given that the initial intensity I_0 of an X-ray beam is 1000 units, the linear attenuation coefficient μ of a material is 0.1 cm^{-1}, and the thickness x of the material is 5 cm, calculate the intensity I of the X-ray beam after passing through the material using the Beer-Lambert Law.

Exercise 5

O. ELOUTASSI: o.eloutassi@umi.ac.ma

1. Identify the two types of radiation produced in an X-ray tube when high-speed electrons collide with the anode material (usually tungsten).
2. Discuss how the density of different tissues affects their appearance on X-ray images.
3. List three specialized techniques that utilize X-ray imaging and briefly describe their applications.

Exercise 6

An X-ray beam with an initial intensity $I_0=1500$ units passes through three different materials in sequence before reaching the detector. The details of each material are as follows:

Material A: Thickness $x_A=3$ cm and linear attenuation coefficient $\mu_A=0.2$ cm^{-1}

Material B: Thickness $x_B=2$ cm and linear attenuation coefficient $\mu_B=0.15$ cm^{-1}

Material C: Thickness $x_C=4$ cm AND Linear attenuation coefficient $\mu_C=0.25$ cm^{-1}

Calculate the final intensity I of the X-ray beam after passing through all three materials.

Exercise 7

A vacuum tube operates with a cathode made of tungsten, which has a work function ϕ of 4.5 eV. The Richardson constant A for tungsten is approximately 6.0×10^6 A/m^2·K^2.

1. Calculate the current I emitted from the cathode when it is heated to a temperature of 1200 K.
2. If the tube operates with an accelerating voltage of 100 kV, calculate the energy of the X-ray photons generated when the emitted electrons collide with the tungsten anode.

Boltzmann constant K=1.38×10^{-23} J/K, Charge of an electron $e=1.6\times10^{-19}$ C

Exercise 8

An X-ray imaging system uses a tungsten target (atomic number $Z=74$) and is designed to operate at an energy of 100 keV for medical imaging.

1. Calculate the photoelectric absorption coefficient μ_{PE} for tungsten, assuming it follows the relationship $\mu_{PE} \propto \frac{Z^3}{E^3}$, constant of proportionality $k=1\times10^{-4}$ cm^3/g for the calculation.
2. If the work function ϕ for tungsten is 4.5 eV, determine whether the photoelectric effect will occur for the given energy of 100 keV.
3. If an X-ray beam passes through two different tissues, where the transmitted intensities are $I_1=300$mGy (muscle) and $I_2=150$mGy (fat), calculate the contrast C in the X-ray image.

O. ELOUTASSI: o.eloutassi@umi.ac.ma