CHUKA UNIVERSITY

UNIVERSITY EXAMINATIONS

EXAMINATION FOR THE AWARD OF DEGREE OF BACHELOR OF SCIENCE OF SCIENCE IN BIOMEDICAL SCIENCE AND TECHNOLOGY

BMET 452: MEDICAL IMAGING TECHNIQUES

STREAM BSC (BMED) **TIME 2 HOURS**

DAY/DATE: MONDAY 16/12/2024 **2.30 P.M. –4.30 P.M**

INSTRUCTIONS:

- Answer Question One in Section A and any other Two Questions in Section B
- Do not write anything on the question paper
- This is a closed book exam, No reference materials are allowed in the examination room
- There will be No use of mobile phones or any other unauthorized materials
- Write your answers legibly and use your time wisely

QUESTION ONE (30 MARKS)

a)

i. Explain the concept of beam hardening in X-ray imaging. **(2 marks)**

ii. How does the use of filtration help reduce the patient's radiation dose without significantly affecting image quality? **(2 marks)**

iii. Draw a graph of X-ray intensity vs. X-ray energy before and after beam hardening. **(1 mark)**

b) Explain how a CT scan produces images of the body. In comparison, discuss one advantage and one limitation of CT scans over MRI**.** **(4 marks)**

c) A patient has been experiencing severe chest pain and is referred for a vascular assessment. After conducting an imaging study, the physician determines that intervention is necessary to restore blood flow.

i. What is the purpose of an angiogram, and how is it performed? **(2 marks)**

ii. Based on the results of the angiogram, what cardiovascular conditions could lead to the need for intervention? Provide at least two possible diagnoses. **(2 marks)**

iii. Define coronary angioplasty **(1 mark)**

d) Explain why the three statements you have left out in (d) above are incorrect. **(3 marks)**

i. Define **acoustic impedance.** Include the SI unit for acoustic impedance in your definition. **(2 marks)**

ii. Explain its significance in ultrasound imaging **(2 marks)**

iii. Given the following acoustic impedances in SI units:

Fat: $Z_{fat} = 1.38\,MRayl = 1.38 \times 10^6\,units$

Muscle: $Z_{muscle} = 1.70\,MRayl = 1.70 \times 10^6\,units$

Bone: $Z_{bone} = 7.80\,MRayl = 7.80 \times 10^6\,units$

Calculate the **reflection coefficient** (R) at the interface between muscle and fat. **(2 marks)**

A computed radiography (CR) image was acquired with a matrix size of 2048 × 2500 pixels, covering a field of view of 35.56 × 43.18 cm².

i. Calculate the size of each pixel in the image. **(2 marks)**

ii. Determine the bit depth of the CR image, given that it is stored with 10 bits per pixel. (**1 mark**

e) Discuss the principles of Magnetic Resonance Imaging (MRI) and explain how they contribute to the generation of high-resolution images. Address each of the following aspects: **(4 marks)**

i. Explain how MRI utilizes strong magnetic fields to align hydrogen nuclei (protons) in the body.

ii. Describe the function of the magnetic field in maintaining the alignment of protons and its effect on the behavior of hydrogen nuclei in tissues.

iii. Explain how radiofrequency (RF) pulses are used to excite the aligned protons and cause them to absorb energy

iv. Describe how the relaxation of excited protons generates signals that are detected and processed to create high-resolution images, emphasizing their importance in diagnosing medical conditions.

QUESTION TWO (20 MARKS)

A 50-year-old male patient comes to your dental practice for a routine check-up. He reports not having visited a dentist in over five years. The patient mentions he has previously had multiple fillings and a bridge, but he is unsure about his current dental status. He expresses concern about occasional discomfort in a lower posterior tooth when chewing.

i. What would you communicate to the patient regarding the importance of obtaining dental X-rays or radiographs to assess his dental health? **(4 marks)**

ii. Identify and briefly describe three different types of dental X-ray radiographs that may be useful in this situation. **(6 marks)**

iii. Out of the three types of radiographs identified in part (2), which one would you recommend for this patient and why? **(3 marks)**

iv. What is one potential risk or concern you might have regarding this patient's dental evaluation? **(1 mark)**

v. Explain the safety measures that are implemented to minimize the patient's exposure to unnecessary radiation during x-ray procedures **(3 marks):**

Define ALARA and discuss its significance in the context of dental radiography. **(3 marks)**

QUESTION THREE (20 MARKS)

a) Describe the step-by-step process of digital subtraction angiography (DSA), using illustrative figures to enhance your explanation. **(7 marks)**

b) List and explain at least two clinical scenarios where DSA is preferred over conventional angiography. **(2 marks)**

c) Analyze the effects of digital image subtraction on noise characteristics, including how it affects both quantum noise and structure noise in DSA images. **(3 marks)**

d) Suggest a strategy to minimize motion artifacts during DSA procedures to improve image clarity. **(2 marks)**

e) Discuss the potential complications associated with DSA procedures. **(3 marks)**

f) Identify the essential properties that contrast media must possess for optimal use in digital subtraction angiography. **(3 marks)**

QUESTION FOUR (20 MARKS)

Today's medical imaging is incredibly advanced and sophisticated. They have been invented all by physicists, utilizing the latest physics principles and technologies. Let's explore five important three-dimensional scanning:

a) X-ray CT scan,
b) MRI,
c) PET (Positron Emission Tomography),
d) OCT(Optical Coherent Tomography), and
e) Ultrasound.

Explain briefly the **physical principle** concisely. Try to address the following five key points for each:

(1) What kind of particles/waves is used? **(4 marks)**
(2) What wavelength and energy? **(4 marks)**
(3) How deep can it penetrate in human body? **(4 marks)**
(4) What is the most useful application(s)? **(4 marks)**
(5) What is the most useful application(s) **(4 marks)**

QUESTION FIVE (20 MARKS)

a) In the context of Ultrasonic waves, what are reflection, refraction, scatter and absorption? What is their effect on an ultrasound image? Tabulate your response . **(8 marks)**

b) Calculate the angle of transmission for ultrasound striking the interface between fat and muscle at an incident angle of 25°. Given the speed of sound for fat and muscle is 1450 ms^{-1} and 1590 ms^{-1}, respectively.
(4 marks)

c) The intensity of a 3 MHz ultrasound beam entering tissue is 10 $mWcm^{-2}$. Calculate the intensity at a depth of 4 cm. (The attenuation coefficient is 1 dB cm^{-1} MHz^{-1}. **(6 marks)**

d) What is the physical reason to avoid an air gap between the transducer and the patient? How can it be avoided? **(2 marks)**
