UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
(ONLINE)
SEMESTER II
SESSION 2020/2021

COURSE NAME	:	ADVANCED MEDICAL IMAGING
COURSE CODE	:	MEU 10103
PROGRAMME CODE	:	MEE
EXAMINATION DATE	:	JULY 2021
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS **OPEN BOOK EXAMINATION**

THIS QUESTION PAPER CONSISTS OF **FIVE (5)** PAGES

Q1 (a) Ultrasound image is produced when the reflected ultrasound waves return back to the transducer.

(i) Predict the quality of ultrasound images when a higher frequency is applied to scan the deeper organ with the standard sound velocity.

(4 marks)

(ii) Wave reflection occurs at tissue boundaries with differences in acoustic impedance. Evaluate the intensity reflection coefficients, R, at tissue-liver boundary and tissue-skull bone boundary. Here, the impedance, Z, of tissue, liver, and skull bone are 1.63, 1.65, and 7.80, respectively.

(4 marks)

(iii) Based on the results calculated in **Q1(a)(ii),** give an opinion on the image quality of the produced ultrasound images.

(2 marks)

(b) Tissue Harmonic Imaging (THI) technique is commonly being used to enhance the image quality by reducing the sidelobes.

(i) By using illustration, summarize the concept of THI.

(8 marks)

(ii) Pulse Inversion (PI) technique is one of the applications in harmonic imaging. Discuss the technique.

(4 marks)

(iii) List down **THREE (3)** advantages of the Pulse Inversion (PI) technique over conventional ultrasound imaging.

(3 marks)

Q2 (a) Describe **THREE (3)** disadvantages of Magnetic Resonance Imaging (MRI) in comparison to Computed Tomography (CT).

(3 marks)

(b) The magnetic moment, μ is the magnetic strength and orientation of a magnet or other object that produces a magnetic field. Derive the equation for the magnitude of magnetic moment, $|\mu|$, if the spin quantum number, I is ¼.

(4 marks)

(c) In the MRI receiver system, two major components are signal demodulator and quadrature mixer.

(i) State the function of both components, respectively.

(2 marks)

(ii) By assuming the input signal to the demodulator as $q(t)$, design the circuit diagram combining both the signal demodulator and quadrature mixture. Label all the related signals and components.

(7 marks)

(d) Calculate both Larmor precession frequency, ω and Larmor frequency, f for magnetic fields, B_0 of 0.5 Tesla. Use $\gamma = 267.54 \times 10^6$ HzT^{-1}.

(3 marks)

(e) Given a typical B_1 magnetic field is 40 μT. Estimate the duration this B_1 field must be applied to produce a 45° pulse. Use $\gamma = 267.54 \times 10^6$ HzT^{-1}.

(3 marks)

(f) Magnetic field gradient coils are used in MRI so that the proton resonant frequencies within the patient are spatially dependent. List **THREE (3)** important design requirements for these gradient coils.

(3 marks)

Q3 (a) There are two major mechanisms by which X-rays interact with tissue, namely, photoelectric interaction and Compton scattering.

(i) By using appropriate electron shell diagrams, describe the photoelectric interaction.

(5 marks)

(ii) The energy of the scattered X-ray, $E_{X,scat}$ can be calculated by applying the laws of conservation of momentum and energy as described below.

The Compton equation is given as:

$$\lambda_{scat} - \lambda_{inc} = \frac{h}{m_0 c}\left(1 - \cos\theta\right) \qquad \text{Equation (1)}$$

And the relevant loss in energy is:

$$E_{X,inc} - E_{X,scat} = \frac{hc}{\lambda_{inc}} - \frac{hc}{\lambda_{scat}} \qquad \text{Equation (2)}$$

By using Equation (1) and (2), prove that the energy of the scattered X-ray, $E_{X,scat}$ is:

$$E_{X,scat} = \frac{E_{X,inc}}{1 + \left(\frac{E_{X,inc}}{m_0 c^2}\right)\left(1 - \cos\theta\right)}.$$

(7 marks)

(b) A patient with the chest of 16-cm-thick will undergo a chest X-ray scan. By assuming half-value layer (HVL) of muscle and bone are 3.5 and 1.8 cm, respectively, and the thickness ratio of muscle to the bone as 13 cm:3 cm, estimate the percentage of X-rays that will be transmitted through the patients' chest at an incident X-ray energy of 70 keV.

(5 marks)

(c) Computed tomography (CT) has been used in a wide range of clinical conditions such as pulmonary imaging, liver imaging, cardiac imaging, and cerebral scans. There is a process known as filtered backprojection that is used to produce the CT images.

(i) Discuss the effect of the number of projections, *N* on the backprojected image of the object as shown in **Figure Q2(c)(i).**

(4 marks)

(ii) Justify the reason(s) why the backprojection process needs to be filtered to give better output images.

(2 marks)

(d) Fill in the blanks with appropriate answers.

(i) Helical CT is the _____-generation scanners. It has multiple _____ which are used for power and signal transmission.

(1 mark)

(ii) Fourth-generation CT scanners operate with a _____ X-Ray tube and a _____ ring of detectors.

(1 mark)

Q4 (a) The radionuclide ^{67}Ga, has a half-life of 3 days. Determine the minimum mass of ^{67}Ga for the radioactivity of 1 mCi. Given that 1 Ci is equal to 3.7 x 10^{10} dps and that Avogadro's number is 6.023x10^{23}.

(5 marks)

(b) As a junior biomedical engineer, you have been assigned a special task to design the technical specifications of a gamma camera instrumentation. Using the design requirement information as described in **Figure Q4(b)**, suggest suitable technical specifications that can achieve the design requirements. The suggested technical specification design must be supported with suitable diagrams.

(11 marks)

(c) Single Photon Emission Computed Tomography (SPECT) is grouped under the advanced nuclear medicine imaging modalities.

(i) With the aid of diagrams, briefly explain the difference between scatter and attenuation correction in SPECT.

(7 marks)

(ii) Evaluate the effects of the tissue attenuation on the images in SPECT and CT Scan.

(2 marks)

-END OF QUESTIONS –

FINAL EXAMINATION

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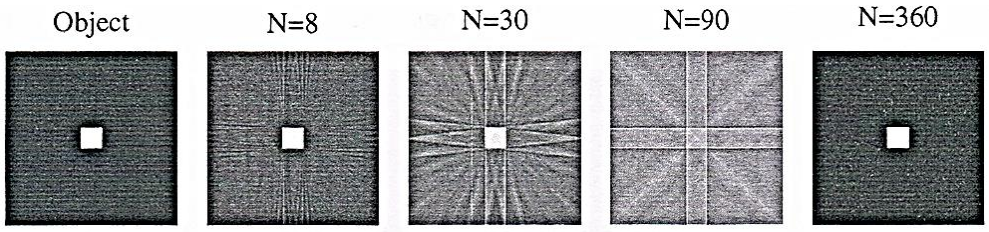

Figure Q2(c)(i): Number of projections, *N* on the backprojected image of the object

DESIGN REQUIREMENT
TASK: To design a gamma camera.
AIM: To image a very small organ.

ADDITIONAL REQUIREMENT:

1. The technical design must consider the SNR, spatial resolution, and CNR of the resulted images.
2. Able to define the location of scintillation event in the crystal and reject the Compton scattered.

Figure Q4(b): Design requirements