University of Ghana

Second semester examinations: 2014/2015

Level **400**: Bachelor of Science in Biomedical Engineering
BMEN 412: **Medical Physics** (2 credits)

INSTRUCTION: Answer **ALL questions in Section A and Section B.**

TIME ALLOWED: 2 HOURS

Section A (30 marks)

1. Why is the foetus considered to have a higher risk from ionizing radiation than an adult? (3 marks)
2. Which is more likely to cause the most harm in any one year: a radiation dose of 20 mSv or smoking 500 cigarettes? Explain. (3 marks)
3. What is Rayleigh scattering? (3 marks)
4. Is the absorption of ultrasound greater in muscle than in blood? Explain. (3 marks)
5. Is lung tissue more or less conductive than brain tissue? Explain. (3 marks)
6. Explain the main biological effect of low-frequency (100 Hz to 1 kHz) electric fields? (3 marks)
7. Explain what happens if an incident gamma photon with energy more than 1.02 MeV interacts with matter. (3 marks)
8. Explain **annihilation radiation.** (3 marks)
9. Is tissue permittivity dominant at very high or very low frequencies? Explain. (3 marks)
10. What is brachytherapy? (3 marks)

Section B (70 marks)

Answer **all questions** from this Section

1. What is a photon? Describe the process of photo electric absorption and explain a characteristic x-ray photon. (7 marks)

   a. The gamma photon produced by ^{133}Xe has energy 0.081 MeV and that produced by ^{40}K has energy 1.53 MeV. Which of these photons is most suitable for lung scanning if all the energy is to be absorbed by photoelectric process? Explain your answer. (5 marks)

   b. How is photo electric absorption different from the Compton effect? (8 marks)

   c. The equation below could be used to describe the Compton effect:

$$E_o = E + m_o c^2 \left[\frac{1}{\left(1-\beta^2\right)^{\frac{1}{2}}} - 1 \right]$$

   Define the symbols and explain the bracket/parenthesis (6 marks)

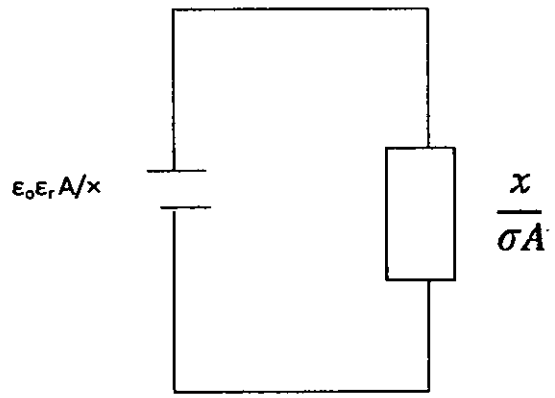
   d. A gamma photon incident at an absorber at a glancing angle, φ can be described by the equation:

$$\frac{1}{E} = \frac{1}{E_o} + \frac{1}{m_o c^2}(1-\cos\varphi)$$

   (i) What does it mean if $\varphi = 0^\circ$ and 180° (4 marks)

   (ii) If the incident photon has energy 200 keV, what is the maximum energy lost by the photon in eV after the interaction with the absorber. State any assumptions you made. Assume $m_o = 0.91 \times 10^{-31}$ kg, $c = 3 \times 10^8$ m/s. (10 marks)

2. The electrical conduction in tissues can be modeled as having both the capacitive and resistive properties as shown in the figure below; where x is the thickness of the tissue and the other symbols have their usual meaning.



If the complex permittivity and conductivity of tissue are given as

$$\varepsilon^* = \varepsilon_r - \frac{j\sigma}{\omega\varepsilon_o} \quad \text{..... (1)}$$

$$\sigma^* = \sigma + j\omega\varepsilon_o\varepsilon_r \quad \text{..... (2)}$$

a. Use the above equations to discuss the frequency dependency of conduction in tissues, and explain the relaxation time. (8 marks)

b. (i) Give two reasons why ultrasound of different frequencies are used in medical diagnosis. (4 marks)
(ii) Explain how bats make use of ultrasound when flying at night. (5 marks)

c. Distinguish between an **A-scan** and **B-scan** as used in ultrasound transmission humans. Give one medical application of each type. (8 marks)

d. Explain why if you inhale helium the pitch of your voice would rise. (5 marks)