THE OPEN UNIVERSITY OF SRI LANKA

BACHELOR OF SCIENCE DEGREE PROGRAMME – LEVEL 05

FINAL EXAMINATION 2024/2025

MEDICAL PHYSICS –PHU5307/PHE5307

Duration: TWO HOURS (2 hrs)

Date: 03rd May 2025 **Time 9.30 am – 11.30 am**

Answer Any Four (4) questions only

Plank Constant, $h = 6.62 \times 10^{-34}$ J s , Speed of light, $C = 3 \times 10^{8}$ m s^{-1}

1. (a). An endoscope contains two bundles of optical fibres. Name the two bundles and describe their arrangements of fibres. Explain their purposes in the operation of the endoscope.

(20 marks)

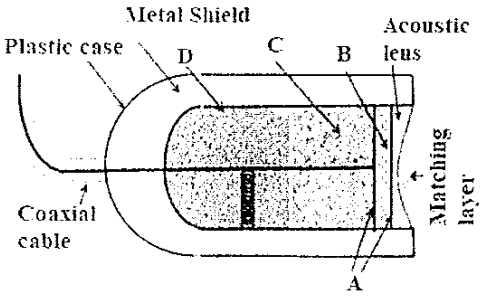
(b). What is meant by numerical aperture (NA) in fibre optics? An optical fibre has a NA of 0.20 and a refractive index of cladding is 1.59. Determine the numerical aperture for the fibre in water which has a refractive index of 1.33. *(20 marks)*

(c). Identify and describe three crucial components of a laser system, and explain the specific role of each component plays in the production of laser light. *(20 marks)*

(d). A He-Ne laser emits a continuous beam with an average power output of 50 mW at a wavelength of 632.8 nm. Calculate the number of photons emitted per second by the laser.

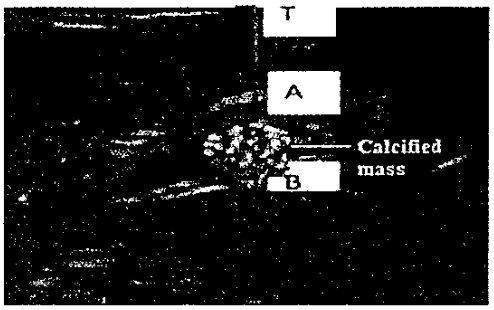
(20 marks)

2. (a). Schematic diagram of an ultrasound transducer is shown in the following figure. Name the components labeled with A, B, C and D in the diagram Explain the role of each of them in the production of ultrasound waves. *(20 marks)*



(b). Various ultrasound scanning modes are available for clinical applications. Which ultrasound mode is commonly used to measure the thickness of a patient's eye lens? Provide a comprehensive explanation of it, with a help of a diagram, if necessary. *(20 marks)*

(c). A child was found to have a noticeable mass in the abdominal area. Ultrasound scans revealed a calcified mass in the liver hilum, which was later diagnosed as neuroblastoma. Assuming the mass is uniform and spherical in shape, estimate its diameter using the data provided below. *(20 marks)*

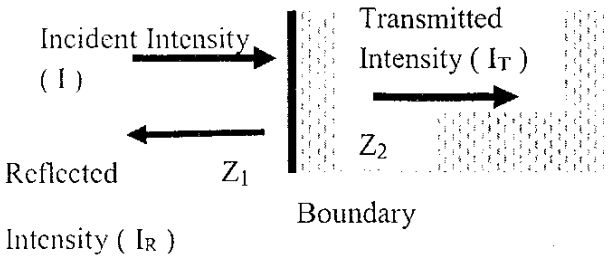


Location	Arrival time (μs)
T → A → T	13.0
T → B → T	15.4

(d). Two materials with acoustic impedances Z_1 and Z_2 are in contact, and an ultrasound beam is incident at their boundary as shown in the following diagram. The beam splits into a transmitted component with intensity I_T and a reflected component with intensity I_R.

Using the data provided in the table below, calculate the reflection coefficient α for the following boundaries:
(i) between gel and soft tissue, and (ii) between air and soft tissue.

Hence. explain the importance of applying gel to the skin during medical ultrasound examinations.



Medium	Acoustic Impedance (Kg m^{-2} s^{-1})
Air	4.3×10^2
Gel	1.5×10^6
Soft Tissue	1.6×10^6

(20 marks)

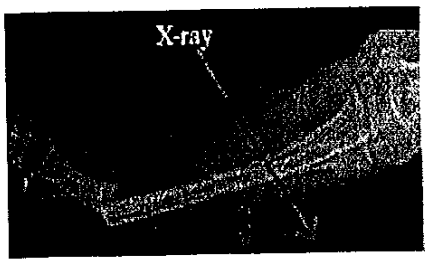
3. (a). An X-ray tube operates at 80 kVp and 200 mA for 0.1 seconds. If the x-ray production efficiency is 0.8% how much energy (in joules) is converted to X-rays? *(20 marks)*

(b). What are the two primary mechanisms of X-ray production in a medical X-ray tube? Explain their mechanisms briefly. *(20 marks)*

(c). Name the two principal interactions of X-rays with matter that are most relevant in diagnostic radiology. Briefly explain the mechanism of one of these interactions. *(20 marks)*

(d). What is the primary role of intensifying screens in an X-ray photographic cassette? How do they contribute to image formation? *(20 marks)*

4. (a). An X-ray radiograph of the right human humerus is shown below. X-rays are incident from the top, as indicated, with an initial intensity I_0. Using the thickness values of the muscles and bone and their respective linear attenuation coefficients (μ) provided in the table below, calculate the intensity of the X-rays that would emerge in the direction of the arrow shown in teh figure below. *(20 marks)*



Distance along the direction of arrow (cm)	μ (cm^{-1})
Skin to bone = 5.00	Muscles (with skin) = 0.20
Bone = 2.00	Bone =12.00
Bone to skin = 2.50	

(b). What are the two primary types of filtrations utilized in medical X-ray imaging, and how does filtration modify the energy spectrum of the X-ray beam? *(20 marks)*

(c). What is the Heel effect, and how is it utilized to optimize X-ray imaging in patient diagnosis? *(20 marks)*

(d). How does computed tomography (CT) differ from conventional X-ray imaging, and what are two advantages of CT in medical diagnostics? *(20 marks)*

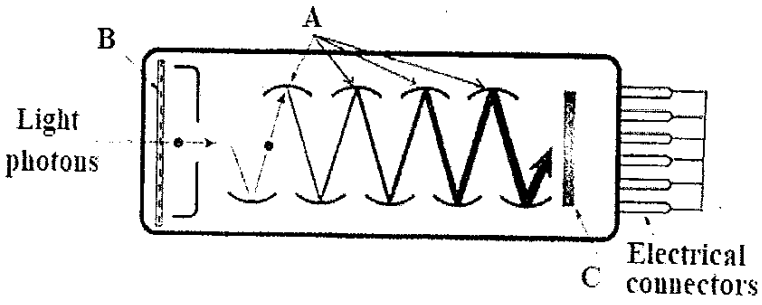
5. (a). A radioactive substance has a half-life of 10 hours. If it's activity decreases from 800 Bq to 100 Bq, determine the time elapsed during this decay process. *(20 marks)*

(b). Iodine-131 is a medical tracer with a physical half-life of 8 days. A patient is administered Iodine-131 with an initial activity of 3.2 GBq. In this patient, the biological half-life of Iodine-131 is 66 days. Hospital discharge is permitted only when the activity in the patient's body falls to 1.1 GBq or lower. Determine whether the patient can be safely discharged after 10 days. *(20 marks)*

(c). In a diagnostic procedure, a patient's lungs receive an absorbed dose of 0.02 Gy from X-ray radiation, and the liver receives an absorbed dose of 0.015 Gy from neutron radiation. Given that the radiation weighting factors are 1 for X-rays and 10 for neutrons, and the tissue weighting factors are 0.12 for the lungs and 0.05 for the liver, calculate the equivalent dose for each organ and determine the total effective dose received by the patient. *(20 marks)*

(d). During an emergency maintenance operation, a radiation safety officer is exposed to a cobalt-60 (Co-60) source with an activity of 1.85 GBq at a distance of 1.5 meters. The duration of exposure is 45 minutes. Given that the specific gamma constant for Co-60 is 0.35 mSv. m^2 . h^{-1} . GBq^{-1}, calculate the total equivalent dose received by the officer. *(20 marks)*

6. (a). The diagram below shows a schematic of the photomultiplier tube (PMT) of a gamma camera. Identify the components labeled A, B, and C in the diagram and explain the role of each component in the functioning of the PMT. *(20 marks)*



(b). Name three primary methods used in the production of radiopharmaceuticals for medical applications. Outline four important factors to consider when choosing an ideal radiopharmaceutical for clinical use. *(20 marks)*

(c). Compare and contrast the two main types of radiation effects on biological systems. *(20 marks)*

(d). What are the primary forms of DNA damage induced by exposure to ionizing radiation? *(20 marks)*

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