RAJARATA UNIVERSITY OF SRI LANKA
FACULTY OF APPLIED SCIENCES

Bachelor of Science in Applied Sciences

Third Year - Semester II Examination – Jan/Feb 2023

PHY 3211 – MEDICAL PHYSICS

Time: Two (02) hours

Instructions:

1. Answer **all** the questions
2. A non-programmable calculator is permitted.

Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^{8}\ ms^{-1}$
electron charge	$e = 1.60 \times 10^{-19}\ C$
the Plank constant	$h = 6.63 \times 10^{-34}$ Js
mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
acceleration of free fall on the Earth's surface	$g = 9.81\ ms^{-1}$
electron volt	$1\ eV = 1.60 \times 10^{-19}$ J
Rydberg constant	$R_H = 1.097 \times 10^{7} m^{-1}$
Atomic mass unit	$1\ u = 931.6$ MeV
Angstrom	$1\ Å = 1 \times 10^{-10}$ m
Roentgen	$1R = 2.58 \times 10^{-4}$ C/kg (X-ray or rays in dry air at STP)
Rad	1 rad $= 0.01$ J/ kg
Curie	1 Ci $= 3.7 \times 10^{10}$ decays/s
	1 Bq = 1 decay/s

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1. Ultrasound imaging is quick, cheap, non-invasive and a non-ionising imaging technique. It is therefore a regularly used diagnostics tool in medicine. In this question you will explore two types of ultrasound imaging: Doppler scans and regular ultrasound.

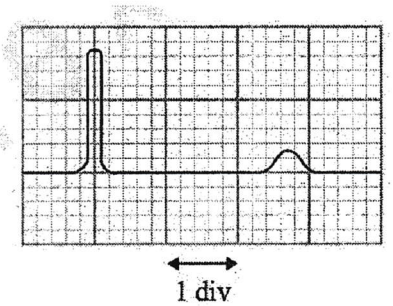
   a) Define ultrasound waves. (2 marks)
   b) State the major difference between type -A and type -B ultrasound images. (2 marks)

   c) Why is a special gel used in ultrasound imaging? Perform calculations to back up your explanation using the table given below.

Medium	Density/kgm^{-3}	Ultrasound velocity/ms^{-1}
Air	1.3	340
Gel	1040.0	1590
Skin	1070.0	1590

(4 marks)

d) The following diagram shows an A-scan trace on an oscilloscope. The pulse represents reflections from opposite sides of the head of a fetus.



The time base of the oscilloscope is set at $50\mu s$ div^{-1}. The speed of sound in the fetal head is 1.5×10^3 ms^{-1}.
Calculate the size of the head of the fetus. (6 marks)

e) Why, for Doppler ultrasound scans, the transducer must be held at an angle to skin?
(2 marks)

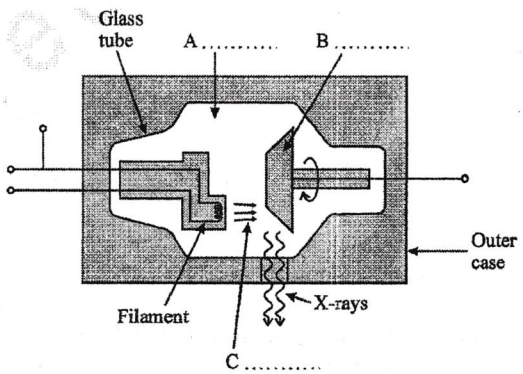
f) In a pregnant woman, the bladder is between the outside of the body and the baby. A pregnant woman needs to have a bladder full of urine if she wishes to have a successful ultrasound scan of her baby. The principal contents of an 'empty' bladder are gaseous.

With reference to the formula for reflection coefficient, $[(Z_2 - Z_1)(Z_2 + Z_1)]^2$, explain why an 'empty' bladder would make an ultrasound scan unsuccessful. (4 marks)

2. X-ray scans take many forms. However, the basic mechanisms are uniform to all.

a) The diagram shows the main features of an X-ray tube.

i. Label features A, B and C. (3 marks)



ii. Suggest an appropriate operating voltage for this tube. (1 mark)

iii. Why is the anode rotated? (2 marks)

iv. Why is the X-ray tube evacuated? (2 marks)

v. Suggest an appropriate material for the outer case (1 mark)

b) Briefly describe how an x-ray is produced. What would be the minimum wavelength produced if the accelerating potential difference is 60 kV? (4 marks)

c) State two mechanisms of scattering. (6 marks)

d) Give two advantages and two disadvantages of CAT scans compared to standard x-ray imaging techniques. (4 marks)

e) Explain why iodine might be given to a patient who is about to undergo an x-ray scan? (2 marks)

f) A slice of bone and muscle with 1 cm thickness each are subjected to x-rays of the same intensity. In the case of the bone sample, the transmitted intensity is 10 W and the attenuation coefficient is 0.60 cm^{-1}. Calculate the attenuation coefficient of muscle, given that the transmitted intensity of the x-rays is 15 W. (5 marks)

3. a) As well as ultrasound and x-ray imaging, many other types of diagnostic scans are used. In some, medical tracers are needed to highlight the particular body part.

i. Briefly describe how an image is produced using a gamma camera. (4 marks)

ii. For what imaging techniques might technetium-99m and fluorine-18 be used in medical diagnostics? Why must they be produced in proximity to the site on which they are used? (3 marks)

b) Radioactive decay is something that has only come to be understood in the twentieth century, after having been discovered by accident in 1896. It is now widely exploited for its medical, military and industrial uses.

i. What are the two defining characteristics of radioactive decay? (3 marks)

ii. What is meant by ionising radiation? (2 marks)

iii. Compare and contrast the nature and range of α, β and γ radiation. (6 marks)

c) Zircons are minerals typically found in old igneous rocks. Uranium and lead are usually found in small quantities within zircons. ^{238}U decays radioactively, eventually forming ^{206}Pb.

i. Rewrite the following equation for α decay, replacing each instance of x with the correct substitution.

$$\frac{A}{x}P \rightarrow {}_{z-2}^{x}Q + {}_{x}^{4}X$$

(2 marks)

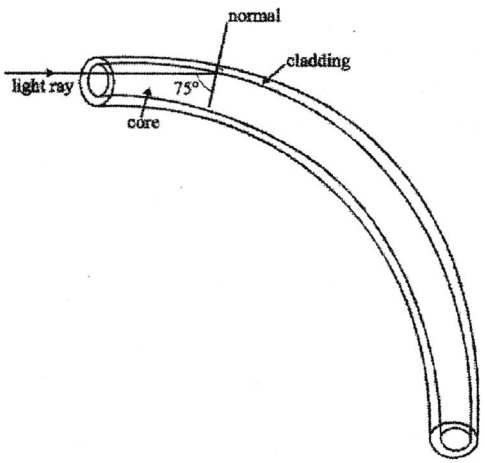
ii. Given that the half-life of ^{238}U is 1.41×10^{17} s, calculate its decay constant. (4 marks)

4. a) Bundles of optical fibres are described as either coherent or non-coherent.

i. Describe how the fibres are arranged in each type of bundle and explain how the different designs determine their optical characteristics. (2 marks)

ii. State an application for each type of bundle. (4 marks)

b) The diagram shows a glass optical fibre with a central core of refractive index 1.55 and a surrounding cladding of refractive index 1.40.



i. Complete the path of the light ray shown in the diagram. (2 marks)

ii. Calculate the critical angle, C, for the boundary between these two types of glass. (3 marks)

c) State and explain whether the following changes in the optical fibre would increase or decrease the probability of light escaping from the fibre.

i. Increasing the refractive index of cladding

ii. Bending the fiber into a tighter curve

(4 marks)

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