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# RAJARATA UNIVERSITY OF SRI LANKA
# FACULTY OF APPLIED SCIENCES

B.Sc. (General) Degree in Applied Sciences
Third Year - Semester II Examination – September/ October 2014

## PHY 3212 – MEDICAL PHYSICS II

Answer any four (4) questions | Time: 2 hour

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**Values of constants**

| | |
|---|---|
| speed of light in a vacuum | $c = 3.00 \times 10^8 \mathrm{ms}^{-1}$ |
| elementary charge | $e = 1.60 \times 10^{-19} \mathrm{C}$ |
| the Plank constant | $h = 6.63 \times 10^{-34} \mathrm{J\,s}$ |
| mass of electron | $\mathrm{m}_e = 9.11 \times 10^{-31} \mathrm{kg}$ |
| mass of proton | $\mathrm{m}_p = 1.67 \times 10^{-27} \mathrm{kg}$ |
| acceleration of free fall on the Earth's surface | $g = 9.81 \mathrm{~m\,s}^{-1}$ |
| electron volt | $1 \mathrm{~eV} = 1.60 \times 10^{-19} \mathrm{J}$ |
| Reydberg constant | $R_H = 1.097 \times 10^7 \mathrm{m}^{-1}$ |

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1. (a) Electromagnetic waves (photons) and sound waves can travel through solids, liquids and gases. Electromagnetic waves can also travel through a vacuum but sound waves cannot. Explain this difference and describe the difference between sound waves in a solid and in a liquid. [4]

   (b) (i) What is acoustic impedance? [2]

   (ii) Describe how the principle of acoustic impedance, reflection and refraction can be applied to ultrasound. [4]

   (iii) 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, explain why 'empty' bladder would an ultrasound scan unsuccessful. [4]

(iv) Give one reason why ultrasound might be preferred to a method involving a radioisotope for investigating the size of a body organ. [1]

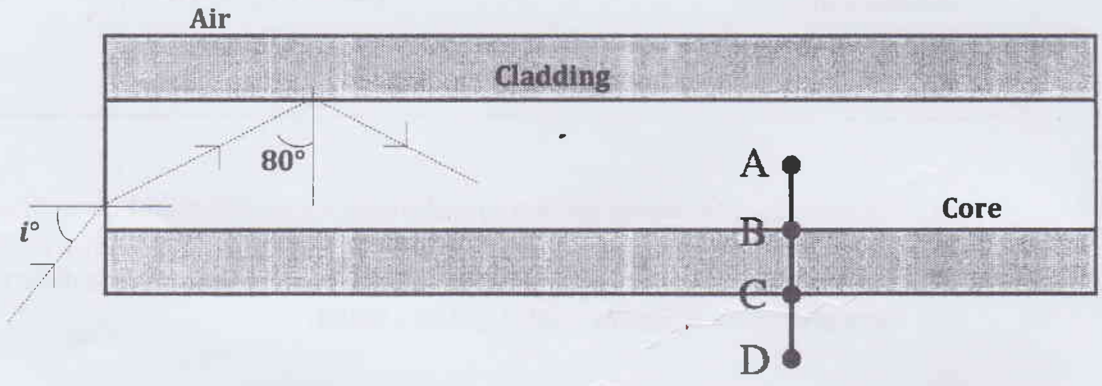
(c) Describe the Doppler effect in sound waves and how it is used to obtain flow characteristics of blood moving through the heart. [5]

2. Bundles of optical fibres are described as either coherent or non-coherent.

(a) (i) Describe how the fibres are arranged in each type of bundle and explain how the different designs determine their optical characteristics [3]

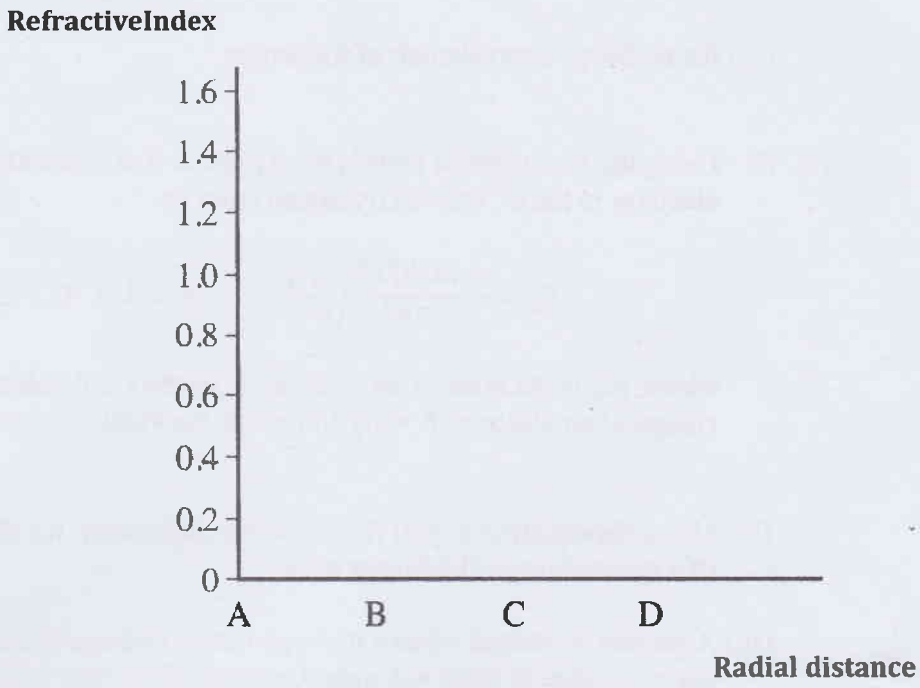
(ii) State an application for each type of bundle [2]

(b) The following figure shows the cross-section through a glass optical fibrewhich has a core of refractive index 1.50 and a surrounding cladding of refractive index 1.40.




(i) Complete the path of the ray through the fibre and out at the other end.[2]

(ii) Complete the graph below to show how the refractive index changes with the radial distance along the line ABCD in the figure. [3]




(iii) Calculate the value of the angle of incidence, $i°$ shown in the figure. [3]

(iv) Calculate the critical angle, $c$ for the boundary between the two types of glasses. [3]

(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 the cladding [2]

(ii) Bending the fibre into a tighter curve [2]

3. (a) Electrons behave in two distinct ways. This is referred to as the duality of electrons.

(i) State what is meant by the duality of electrons [1]

(ii) Give one example of each type of behavior of electrons [2]

(b) A proton and an electron have the same velocity. The de Broglie wavelength of the electron is $3.2 \times 10^{-8}$ m. Calculate

(ii) the velocity of the electron [2]

(iii) the de Broglie wavelength of the proton [2]

(c) (i) Using the postulates of Bohr's theory, show that the**total energy of the electron** in the $n^{th}$ orbit of hydrogen atom is,

$$E_n = -\frac{m_e k_e^2 e^4}{2\hbar^2}\left(\frac{1}{n^2}\right) \qquad n = 1, 2, 3, \dots\dots\dots$$

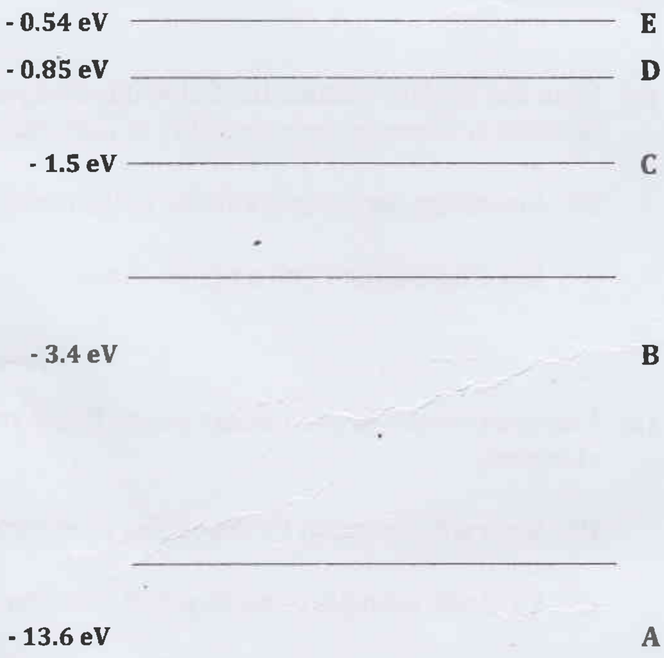
where, $m_e$ is the mass of an electron, $k_e$ is the Coulomb constant, $e$ is the charge of an electron, $\hbar = h/2\pi$and $h$is the Plank's constant.

[3]

(ii) Using the equation in part (i), obtain the expression for **the wavelength** of a spectral line of hydrogen atom. [3]

(iii) A photon is emitted when a hydrogen atom undergoes a transition from the $n = 5$ state to the $n = 3$ state. Calculate the energy and the wavelength of the emitted photon. [3]

(iii) Figure bellow shows **some** of the electron energy levels in the hydrogen atom




(I) Explain why energy levels are given negative energy values. [2]

(II) A hydrogen atom is excited so that its electron is raised to level C. It falls back to the ground state in two stages with the emission of twophotons of different wavelengths.Calculate the wavelength of the photon with the shortest wavelength. [2]

4. Magnetic Resonance Imaging (MRI) is a powerful diagnostic tool requiring complex analysis of data based on atoms in the human body which have experienced nuclear magnetic resonance (NMR)

   (a) Describe the nuclear magnetic resonance phenomenon. [4]

   (b) One component in the magnetic resonance system requires a current of around 700 A to flow. Name this component and state the main design feature it incorporates to reduce power losses. [2]

   (c) Explain why each of the following must be removed before undergoing an MRI scan:

   (i) A credit card [1]

   (ii) Gold chain [1]

   (d) (i) Derive the Larmor equation,

$$f_L = \left(\frac{\gamma}{2\pi}\right) B_0$$

   where, $f_L$ is the Lamor frequency, $\gamma$ is the gyromagnetic ratio and $B_0$ is the magnetic field. [2]

   (ii) The static magnetic field on a MRI machine is 1.7 T. What is the Larmor frequency of the protons? [Take the gyromagnetic ratio of the hydrogen nucleus to be 42.5 MHz $T^{-1}$] [2]

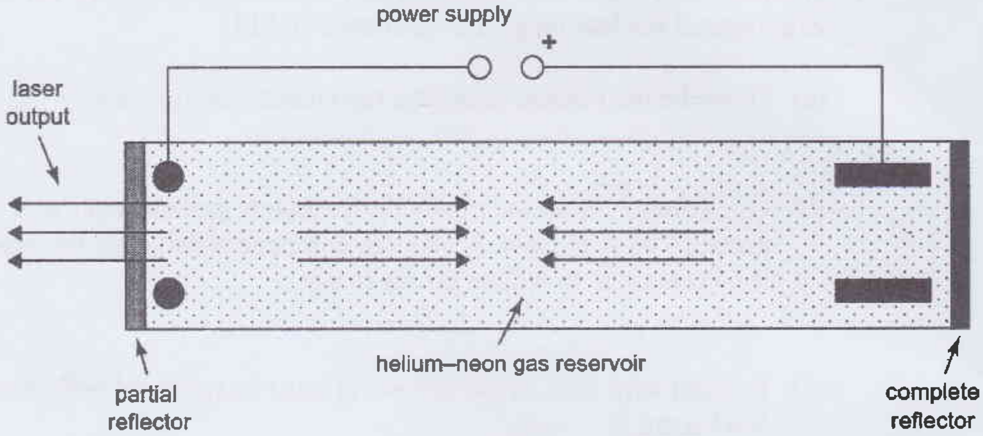
   (e) (i) Explain the relaxation process [3]

   (ii) Define $T_1$relaxation [1]

   (iii) Define $T_2$relaxation [1]

(f) Explain two advantages of using MRI scan rather than X-ray to investigate a possible brain tumor. [3]

5. (a) The diagram of the main components in a gas laser.




(i) With reference to laser action, define the term "population inversion" [2]

(ii) Explain function of the reflectors at either end of the laser and why it is vital for laser action. [3]

(iii) What are the two necessary conditions for obtaining coherent light from stimulated emission [3]

(iii) Explain the action of laser in terms of population inversion and stimulated emission [4]

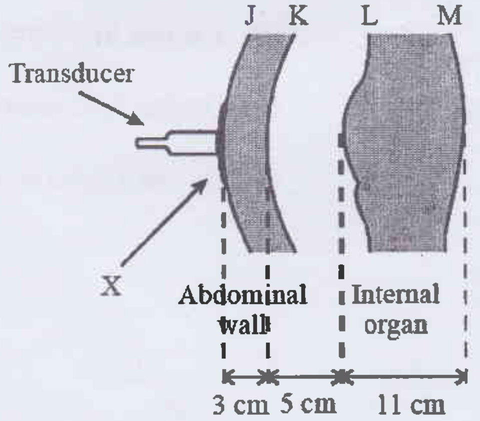
(b) Ultrasound is typically produced and detected by a piezoelectric transducer.

(i) What is piezoelectric effect [3]

(ii) In an ultrasound A-scan, a single transducer can be used both to send and receive pulses of ultrasound.

The diagram shows a lateral cross-section through part of the abdomen (not to scale)

(I) What is **X** and what is its function? [2]



(II) Calculate the time delay between sending out a signal pulse and receiving its echo from interface **K**. (Speed of ultrasound in soft tissue = 1500 m $s^{-1}$)          [3]