RAJARATA UNIVERSITY OF SRI LANKA
FACULTY OF APPLIED SCIENCES

B.Sc. (General) Degree
Third Year - Semester II Examination – September/ October 2013

PHY 3212 – MEDICAL PHYSICS II

Answer any four (4) questions Time: 2 hours

Values of constants

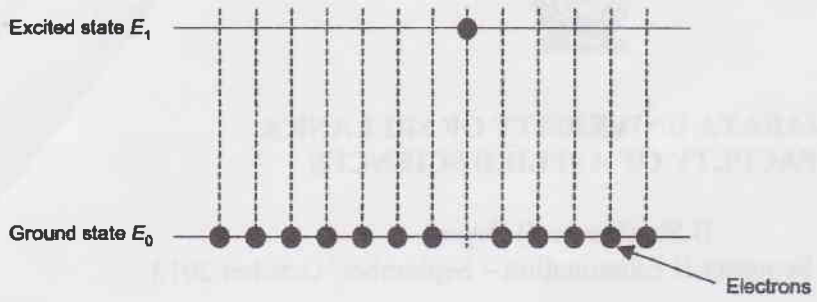
speed of light in a vacuum	$c = 3.00 \times 10^{8}$ m s^{-1}
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
mass of proton	$m_p = 1.67 \times 10^{-27}$ kg
acceleration of free fall on the Earth's surface	$g = 9.81$ m s^{-2}
electron volt	1 eV = 1.60×10^{-19} J

1. Surgeons often use lasers when operating on patients

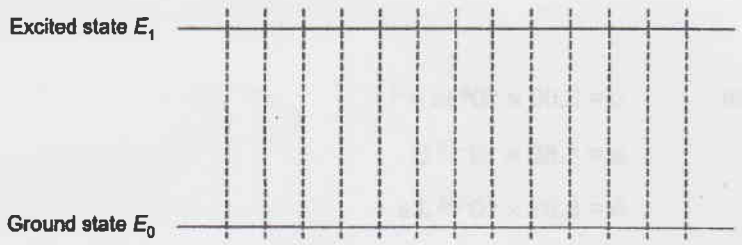
(a) (i) What does the term 'laser' stands for? [2]

(ii) Explain 4 characteristics of laser light [8]

(b) The following figure illustrates the electron arrangement within the atoms of a laser before it has been switched on. Most of the electrons are in their ground state with an occasional electron in an excited state.



(i) In the figure below, draw a possible electron arrangement when the laser is **switched on**. [2]



(ii) What name is given to this situation? Explain the mechanism in your own words. [4]

(iii) Spontaneous emission occurs when an electron randomly falls to the ground state. What causes the electron to fall due to **stimulated** emission? Explain. [4]

(c) Name at least four types of lasers [2]

(d) Laser eye surgery uses a computer-controlled excimer laser. One such laser has fluoride as the lasing material. It produces electromagnetic radiation of wavelength 193 nm. Calculate the energy of an electron's excited state if it relaxes to a state with energy of - 9.18 eV and emits radiation of wavelength 193 nm as a result. [3]

2. (a) A medical flexible endoscope contains two bundles of optical fibers and several other channels.

(i) State the **function** of the two optical fiber bundles. Explain clearly how the arrangement of fibers in the two bundles differs. [4]

(ii) State a possible function of one of the other channels. [2]

(iii) Briefly describe how an endoscope works. [3]

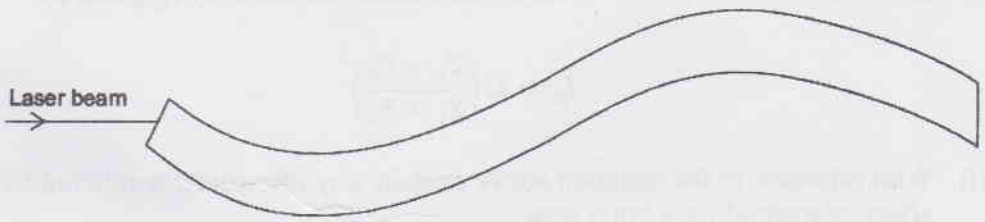
(iii) A thin optical fiber in an endoscope is 1.45 m long. If the refractive index of the fiber is 1.53, calculate the minimum time taken for a pulse of monochromatic light to pass from one end of the fiber to another end. [3]

(iv) Each fiber has a core surrounded by cladding. Calculate the critical angle at the core-cladding interface of the fiber.

Refractive index of core = 1.60
Refractive index of cladding = 1.55 [3]

(b) Optical fibers are sometimes used to guide a laser beam.

(i) Complete the diagram to show the path the laser beam would take through the optical fiber shown.



(ii) Explain why a surgeon may prefer to use a laser rather than a scalpel when operating on a patient. [2]

(iii) Explain two medical applications of laser. [4]

(iv) A particular laser uses light waves with a wavelength of 6×10^{-6} m. The speed of light is 3×10^{8} ms^{-1}. Calculate the frequency of these light waves. Don't forget to state the correct unit in your answer. [2]

3. (a) Describe

(i) What is meant by ultrasound? [2]

(ii) How ultrasound may be produced and detected? [4]

(b) The table gives information on the speed of sound, the density and the acoustic impedance for various materials.

Material	Speed of sound / ms^{-1}	Density / kgm^{-3}	Acoustic impedance / $kg\ m^{-2}\ s^{-1}$
Air	330	1.3	430
Bone	2800	1.5×10^{3}	
Tissue	1600	1.0×10^{3}	1.6×10^{6}

Calculate the acoustic impedance of bone and enter your answer in the table above.

[3]

(c) Ultrasound of intensity I_0 is traveling in a medium of impedance Z_1 and is incident on a medium of impedance Z_2. The **reflected** ultrasound has intensity I_R given by

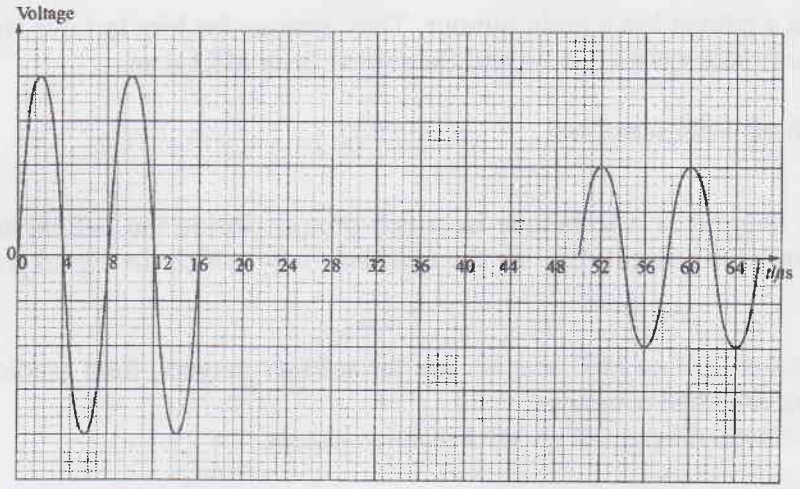
$$I_R = I_0\left(\frac{Z_1 - Z_2}{Z_1 + Z_2}\right)^2$$

(i) With reference to the equation above explain why ultrasound would not be an effective method for a brain scan. [3]

(ii) Using data from the table in (b) determine the ratio $\frac{I_R}{I_0}$ of ultrasound entering tissue from air. [3]

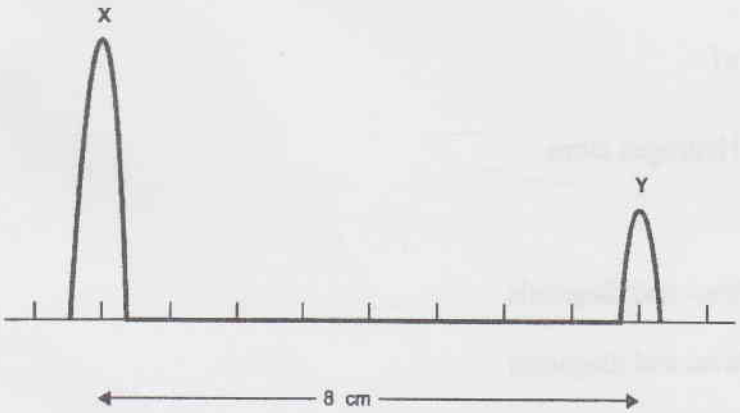
(iii) Using your answer to (c)(ii), explain the purpose of the **gel** that is applied to the skin before an ultrasound scan. [2]

(d) A pulse of ultrasound is emitted from a transducer placed on a patient's skin. The pulse is reflected by the stomach and is received back at the transducer. The graph (an A scan) shows how the voltage due to the transmitted and the reflected pulse varies with time. The speed of sound in tissue is 1600 ms^{-1}.



(i) Using data from the graph determine the **distance** between the stomach and the transducer. [3]

(e) Ultrasound can be used in non-invasive examinations of internal structures of the human body. One such investigation used ultrasonic A scans to measure the thickness of a bone. A pulse of ultrasound is partially reflected at the front surface of the bone and then again at the back surface of the bone. The pulse echoes from the bone are converted into electrical signals which are displayed on a CRO screen. The resulting output on the CRO screen is shown in the figure below where the pulse labeled **X** is for the first reflection and **Y** is for the second reflection.



The time base on the CRO is set to 1 μs per cm.

(i) Explain why the pulse X is of greater amplitude than pulse Y. [2]

(ii) If the speed of ultrasound in bone is 4000 ms^{-1}, calculate the thickness of the bone. [3]

4. Doctors suspect that a patient has a brain tumour. They arrange for him to have two different diagnostic tests. The first test is a CT scan and the second is an MRI scan.

(a) What do the initials MRI stand for? [1]

(b) NMR (or MR) imaging is a technique in which protons inside the patient are made to emit an electromagnetic signal. Outline the mechanism by which the signal is emitted by the protons. [3]

(c) The main components of an MRI scanner are the scanner magnet, field gradient coils, rf transmitter, rf receiver and computer.

(i) Draw a schematic diagram of an MRI scanner system. [2]

(ii) Describe briefly the function of each component stated above. [10]

(iii) Explain two advantages of using MRI compared to X-ray radiography or CT scanning to investigate a possible brain tumour. [4]

(d) (i) Explain the meaning of de Broglie wavelength. [2]

(iii) Electrons are accelerated through a potential difference.
Calculate the momentum of electrons of wavelength 1.51×10^{-10} m. [3]

5. Write short descriptions of

(a) Bohr's model of the Hydrogen atom [5]

(b) Piezoelectric effect [5]

(c) A-scan method in ultrasound diagnosis [5]

(d) B-scan method in ultrasound diagnosis [5]

(e) He-Ne laser [5]