00172

THE OPEN UNIVERSTY OF SRI LANKA

BACHELOR OF SCIENCE DEGREE PROGRAMME – LEVEL 05

FINAL EXAMINATION 2010/2011

MEDICAL PHYSICS -PHU 3158

Duration: TWO AND HALF HOURS (2 ½ hrs)

Date 20th June 2011 **Time 1.30 pm – 4.00 pm**

Answer Four (4) questions only

1. (a) Explain briefly the following atomic-scale processes involved in X-ray production:

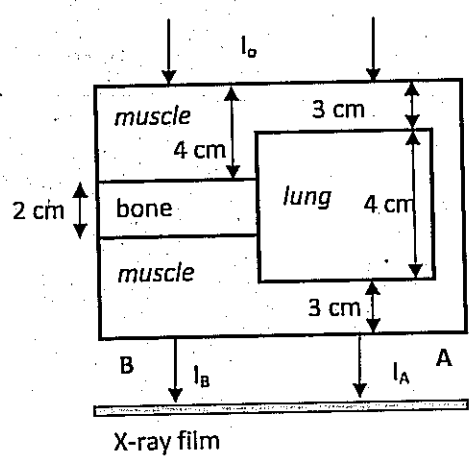
(i) Inner shell ionization.

(ii) Bremstrahlung.

Indicate which is used for medical imaging, and why? *[30 marks]*

(b) Before taking an X-ray image, the X-ray beam emerging from the tube is passed through a filter. Explain briefly, the reasons for filtering the X-rays and name a material which can be used as a filter. *[20 marks]*

(c) In a simple chest X-ray a cross-sectional scan of the human body may be approximated by the figure below:



In this scan a linear X-ray beam of intensity 1.00 W m^{-2} with 100 keV photons, is incident upon on soft tissue and passes in turn through a bone, lung and mussels as shown in the above figure.

The linear attenuation coefficients (μ) for bone, muscle and lung are 0.60 cm^{-1}, 0.21 cm^{-1} and 0.07 cm^{-1} respectively.

Calculate the contrast between the two regions A and B of the exposed X-ray film, where contrast C is defined as the difference in optical density D (absorbance) of the two regions and is given by

$$C = D_A - D_B = \gamma log10\,[\frac{I_A}{I_B}]$$

(You may assume that the beam intensity I_0 and the exposure time are chosen such that the exposures at A and B fall on the linear region of the film's response curve, slope $\gamma = 2.5$).

[50 marks]

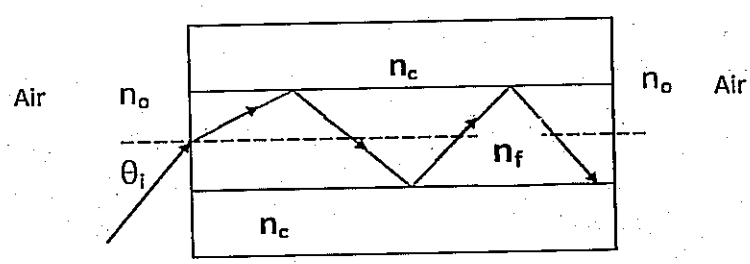
2. (a) What is the difference between *spontaneous* and *stimulated emission*? *[25 marks]*

(b) Explain what is meant by *population inversion* and explain why this is a necessary condition for lasing to take place. *[25 marks]*

(c) State which property of the lasers suit medical applications and why?. Name three examples of the uses of lasers in medicine. *[25 marks]*

(d) In a process which is referred to as "spot welding" a pulse of about 50 mJ of energy is delivered to an area of about 0.75 mm^2, in less than 0.50 ms . Calculate the intensity of the light used in "spot welding" in $W\ m^{-2}$. *[25 marks]*

3. (a) An optical fibre is made from an inner material with refractive index n_f and a cladding material of refractive index n_c as shown in the figure below. When the incident array reaches the critical angle *C*, any further reduction of θ results in transition through the side wall.



What is the relationship among n_i, n_f , n_o and the critical angle *C* ?

Derive the expression $\theta_{max} = \sin^{-1}\left[\frac{1}{n_o}\right] (n_f^2 - n_c^2)^{1/2}$

for the maximum external acceptance half angle of the fibre.

Calculate the numerical aperture of this fibre

[40 marks]

(b) Light falls at an angle of 15° on the plane end of a straight fibre having cladding. The core and cladding have refractive indices of 1.55 and 1.35 respectively. Show by calculation whether light will or will not be transmitted along this fibre. *[20marks]*

(c) With the help of diagrams distinguish the formation of coherent and incoherent bundles of optical fibres and their roles in endoscopy.

[25 marks]

(d) Write down three ways in which a doctor might use an endoscope.

[15 marks]

4. (a) . The acoustic impedance (Z) of air is 400 kg m^{-2} s^{-1}

	Density (kg m^{-3})	Velocity of sound (m s^{-1})
Muscle	1076	1580
Bone	1912	4080
Brain	1025	1540

Calculate the intensity of the reflected ultrasound at the interface between chest muscle and air as a proportion of the incident intensity. *[30 marks]*

(b) State two reasons why ultrasound imaging is preferred than X-ray for monitoring foetal development and why it is not appropriate to detect a 3 mm brain tumour ?

[15 marks]

(c) Describe how the Doppler Effect is used in ultrasound imaging and outline information that a Doppler ultrasound scan can provide about blood flow in the heart. *[25 marks]*

(d) Compute the frequency shift due to a blood flow velocity of 20 cm s^{-1} for 3.0 MHz beam incident upon the blood vessel at 10° to the flow. Make a drawing of the geometry for measurement that you have assumed. What percentage shift in frequency is this?

[30 marks]

5. (a) What does the acronym "NMR" means ? What are two types of molecules responsible for the signal in MRI ?. *[10 marks]*

(b) Describe the sequence of event and associated processes of physics by which an image is produced using magnetic resonance imaging. *[40 marks]*

(c) Name and describe briefly three applications of NMR in diagnostic medicine.

[20 marks]

(d) Describe the relaxation time T1 and T2 associated with MRI. *[30 marks]*

6. (a) List three Cancer warning signals *[20 marks]*

(b) How does radiation cause cancer? *[20 marks]*

(c) Why are X- ray or gamma (γ) ray photons and electrons the most commonly used radiation for cancer therapy. Give at least two reasons. *[20 marks]*

(d) Why is it important that radioisotope implants used to treat cancer have a long half –life?

[20 marks]

(e) Technetium-99 has a physical half –life of 6 hours. Calculate how long it would take for 200g sample of active technetium-99 to decay to 25g. *[20 marks]*