NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 4160 MEDICAL PHYSICS I

SUPPLEMENTARY EXAMINATION JULY 2002

BSc HONOURS PART I :JULY 2002 DURATION : 3 HOURS

ANSWER ALL PARTS OF QUESTION 1 IN SECTION A AND ANY THREE QUESTIONS FROM SECTION B. SECTION A CARRIES 40 MARKS AND SECTION B CARRIES 60 MARKS

Rydberg Constant	$R = 1.10 \times 10^{7}\ m^{-1}$
Planck's constant,	$h = 6.63 \times 10^{-34}$ J.s
Boltzmann constant,	$k = 1.38 \times 10^{-23}$ J/K
Avogadro's Number,	$N = 6.02 \times 10^{23}\ mol^{-1}$
Electron rest mass,	$m_e = 9.11 \times 10^{-31}$ kg
Speed of light,	$c = 3.00 \times 10^{8}\ m\ s^{-1}$
1 electron volt	$e = 1.60 \times 10^{-19}$ J
Mass of electron,	$m_e = 5.48 \times 10^{-4}$ u
Mass of proton,	$m_p = 1.007\ 825$ u
Mass of neutron,	$m_n = 1.008\ 665$ u
1 atomic mass unit,	$1u = 931.49\ MeV/c^2$
Electronic Charge,	$e = 1.60 \times 10^{-19}$C
Stefan – Boltzmann constant	$\sigma = 5.67 \times 10^{-8}\ W/m^2.K^4$
Wein's constant,	$k = 2.90 \times 10^{-3}$ m .K
Wien's displacement law constant	$= 2.898 \times 10^{-3}$ *m. K*
Mean radius of the sun,	$R_0 = 6.96 \times 10^{8}$ m
Mass of the sun,	$m_{sun} = 1.99 \times 10^{30}$ kg
1 Ci	$= 3.70 \times 10^{10}$Bq
1 Tesla	$= 10^{4}$ G (Gauss)
Gyromagnetic ratio,	γ = 42.58 MHz/T

SECTION A

1. (a) A sample contains water at two locations, x = 0 cm and x = 2.0 cm. A one-dimensional magnetic field gradient of 1 G/cm is applied along the x-axis during the acquisition of an FID. The frequency encoding gradient is 1 G/cm. What frequencies (relative to the isocenter frequency) are contained in the Fourier transformed spectrum? [5]

   (b) Computed tomography is based on the interpretation of Hounsfield Numbers. What are they? [4]

(c) What is the term used given for :

(i) the difference in dB between the thresholds of hearing and the uncomfortable loudness level [1]

(ii) the test to determine the relationship between stimuli and the sensations they produce? [1]

(d) Discuss one method by which directional flow can be detected in Doppler ultrasound [5]

(e) Using illustrative diagrams, describe the general mechanisms of production of the refraction artefact in ultrasound imaging. [5]

(f) Name four desirable properties for radioisotopes used for nuclear medicine imaging. [2]

(g) Define the following terms

(i) tenth value layer, [2]

(ii) dose equivalent, and [2]

(iii) mass attenuation coefficient. [2]

(h) A sample has a T_1 of 1.0 seconds. If the net magnetization is set equal to zero, how long will it take for the net magnetization to recover to 98% of its equilibrium value? [5]

(i) What do you understand by the term 'fast film'? [2]

(j) With the help of a diagram, show the effect of x-ray focal spot on the quality of the x-ray image. [4]

SECTION B

2. (a) Explain the difference between T1 and T2 processes in Magnetic Resonance Imaging (MRI). [12]

(b) Write short notes on the safety of MRI [8]

3. Digital sound recording has seen the traditional *wav* format replaced for most applications by *mp3* and *WMA* audio formats. Give a technical overview of the *mp3* and *WMA* audio format highlighting the compression algorithm used and advantages over traditional *wav* and *cd* formats. [20]

4. (a) The radionuclide ^{99}Mo has a half life of 66.7 hrs and decays to ^{99m}Tc. Show that for a sample which initially contains N_0 atoms of ^{99}Mo and no atoms of ^{99m}Tc, the number of ^{99m}Tc atoms (N_T) present at a later time t is given by $N_T = \frac{N_0\lambda_T}{\lambda_m - \lambda_T}\left(e^{-\lambda_m t} - e^{-\lambda_T t}\right)$ where λ_m and λ_T are the decay constants of ^{99}Mo and ^{99m}Tc respectively. [7]

(b) A ^{99}Mo-^{99m}Tc system has an initial ^{99}Mo activity of 7.4 GBq at 8.00 am on a Wednesday. ^{99m}Tc is extracted from the system at 8.00 am the following day. Determine the activity of the extracted ^{99m}Tc if the extraction efficiency were 80%. [7]

(c) At what time should the next extraction take place in order to obtain the maximum activity of the ^{99m}Tc? [6]

5. (a) Outline the physics of X-ray photon production in the X-ray tube anode/target and explain how and why the energy characteristics of such X-ray output must be modified for use in the imaging of patients. [5]

(b) Outline the two interactions of X-ray photons in the tissues of a patient being imaged. Explain how these interactions influence the quality of image production and patient dose as overall X-ray energy is progressively increased. [10]

(c) Draw and label a double coated film suitable for x-ray imaging. [5]

6. (a) Describe how the attenuation coefficient varies with frequency for different tissues, and discuss the consequences of these variations (or lack of them) for ultrasonic imaging. [5]

(b) How do the parameters describing image quality in list A depend on the scanner characteristics in list B?

List A	**List B**
Lateral resolution	Transmission pulse bandwidth
Maximum useful penetration	Transducer aperture
	Depth of selected field of view
	Transmission focal length
	Width of selected field of view
	Transmission pulse centre frequency

[5]

(c) Draw a functional block diagram for a continuous wave Doppler machine. [4]

(d) A 4 MHz pulsed Doppler system is used to examine blood flow in part of an artery at a range of 10 cm. In the examined part of the artery, the direction of blood flow is towards the probe, at an angle of 45° to the direction of the ultrasound, and the peak speed achieved by the blood in each cardiac cycle is 1.80 m/s. (Assume that the speed of sound is 1540 m/s, and that cos 45 = 0.707.)
Calculate the
(i) peak Doppler frequency shift. [2]
ii) highest pulse repetition frequency that could be used, if range ambiguity is to be avoided. [2]
iii) highest blood speed that could be measured without aliasing. [2]

END OF PAPER