NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 4260: MEDICAL PHYSICS II

BSc HONOURS PART II: APRIL/MAY 2002 DURATION: 3 HOURS

ANSWER ALL PARTS OF QUESTION I 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	$= 5.49 \times 10^{-4}$ u
Mass of proton,	m_p	= 1.007276 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	σ	$= 5.67 \times 10^{-8}\ W/m^2.K^4$
Wein's constant,	k	$= 2.90 \times 10^{-3}$ m .K
Wien's displacement law proportionally 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
Mass of ^{6}Li		= 6.015 122 u
Mass of ^{2}H		= 2.014 102 u
Mass of ^{4}He		= 4.002 603 u
Mass of ^{7}Li		= 7.016 004 u
Mass of ^{8}Be		= 8.005 305 u
I Ci		$= 3.70 \times 10^{10}$ Bq
Density of Carbon		$= 2250\ kgm^{-3}$

SECTION A

1. (a) Draw the equivalent circuit of the electrode-electrolyte interface. Label all components. Indicate the physical meaning of each component. [4]

(b) Two electrodes were implanted into the body and their combined electrical characteristics were measured. When no current passed through the circuit, 180 mV was measured between the electrodes. When a DC current of 10μA was applied, the voltage seen between the two electrodes increased until it reached 290 mV and remained constant. What are the lumped sum value of the resistances for the two electrodes and the tissue? [4]

(c) Using clear diagrams, show the difference between unipolar and multipolar neurons [4]

(d) External beams of high energy electromagnetic radiation are used to treat malignant tumours. Give typical photon energies that are suitable for treating skin tumours. [3]

(f) Using the Nernst equation, show that the membrane potential of K^+ ions is -88 mV if the K^+ concentration outside the cell is 140 $mol\ m^{-3}$ and 5 $mol\ m^{-3}$ inside the ell. [5]

(g) For a wedge filter define the following:

(i) wedge angle, and [3]

(ii) wedge attenuation factor [3]

(h) well-collimated beam containing 10^4 photons of energy 10 MeV impinges on a large block of carbon 20 cm thick. Calculate:

(i) the number photons reaching 10 cm depth, [3]

(ii) the energy transferred and energy absorbed, and also [3]

(iii) determine the energy absorbed in a layer of carbon 1 mm thick at a depth of 10 cm in the block. [3]

(i) Draw a sketch diagram for the standard treatment plan for an oesophageal tumour. [5]

SECTION B

2. Sketch a graph showing an ECG of a normal heartbeat. Label the axes, giving approximate values, and mark on the trace the *P-wave*, the *QRS-wave* and the *T-wave*. Explain what is happening in the heart during each of these features. If the patient had suffered a heart attack, how would the ECG be changed? [20]

3. (a) Draw the functional diagram of a medical linear accelerator. [5]

(b) Choose any **one major** component in each of the systems below and write brief notes on the options for implementation in a typical medical linear accelerator.

(i) RF subsytem, [5]

(ii) beam bending system, and [5]

(iii) dose monitoring system. [5]

(a) Define the following terms as they are used in the AAPM dose measurement protocols

(i) Cobalt-60 chamber exposure Calibration factor, N_X [3]

(ii) Correction for charge collection P_{ion}, and [3]

(iii) Press/temp correction factor, P_{TP}. [3]

(b) Your hospital received your secondary standard dosimeter from the Standards Laboratory with a calibration certificate stating ND = 9.1377 x 10^{-3} Gy/nC. Calibration measurements of 6 MV photon beam was carried out in your hospital in a water phantom under standard calibration set-up. Using the following data provided:

Electrometer: 2560/199
Ion Chamber: 2561/242
Measurement depth: 50 mm
F.S. 10 x 10 cm
FSD = 100.0 cm
MU set = 1.00 per measurement
Average meter reading = 83.04 nC
P = 1013 hPa
T = 22.3°C
Ionic Recombination = 1.005
D_{20}/D_{10} = 0.58
PDD = 86.6%

(i) calculate the temperature/pressure correction factor, [3]

(ii) what is the dose delivered at the point of measurement? [4]

(iii) List **eight** QA test equipment required for megavoltage machines. [4]

5. (a) Discuss the engineering problems in the design of a pacemaker and heart valves. [10]

(b) Describe, outlining technical design aspect, an instrument that can be used to monitor the process of labour in a maternity ward. [10]

6. (a) Outline the relative importance of different processes by which energy is deposited in a medium. [10]

(b) Discuss briefly the different external radiotherapy modalities for both photons and electrons. [10]

- END OF EXAM -