NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

SPH 1104 MODERN PHYSICS

BSc HONOURS PART I :Nov/Dec 2001 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,	$m_p = 1.007\ 325$ 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
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

SECTION A

1. (a) A source emits light of wavelength 4.5×10^{-7} m at a rate of 1.1 W. How many photons leave the source every second? [4]

(b) A cricket ball, mass 0.15 kg , is bowled at 110 km/hr. Determine its de Broglie wavelength. [4]

(c) For a blackbody of temperature T, the Wien displacement law applies, i.e. maximum intensity occurs at wavelength λ_{max}. If T = 750 K would the maximum intensity occur in the part of the spectrum described as:

(i) Infrared
(ii) Blue
(iii) x-ray
(iv) microwave

[2]

(d) The most abundant isotope of helium is ${}^{4}_{2}He$. Using atomic mass units and electron volts, determine the mass deficit and the binding energy per nucleon of ${}^{4}_{2}He$. [4]

(e) If an electron makes a transition from the $n = 4$ to the $n = 1$ Bohr orbital in a hydrogen atom, determine the wavelength of the light emitted and the recoil speed of the atom. [5]

(f) What is the difference between bremsstrahlung x-rays and characteristic x-rays? [4]

(g) A mono-energetic beam of marbles which have a mass of 5.0 *g* is hurled into a board with two slits. The velocity of the marbles is 15.0 *m/sec*, and the slits are separated by 6.0 *cm*. How far from the slits must one place a screen to get an interference pattern where the first interference maximum is 20 *cm* from the central peak? [5]

(h) A 10 μCi radioactive source has a half-life of 8 hours.
(i) How many moles of radioactive material are present?
(ii) What is the activity after 24 hours have elapsed?

[5]

(i) Define the following terms:
(i) activity,
(ii) neutrino, and
(iii) positron.

[3]

(j) Write down Einstein's equation for the photoelectric emission and explain the meaning of each term.

[4]

SECTION B

2. (a) Give an experimental account of the Compton effect, and show and explain the results obtained. [10]

(b) State three (3) characteristics of the photoelectric effect arising from experimental results and contrast them with the classical theory. [10]

3. (a) (i) Write down the Law of Radioactive decay. [2]

(ii) Show how such a deterministic statement can arise from an essentially random phenomenon. [5]

(iii) Explain the significance of the decay constant λ for an individual nucleus. [4]

(b) (i) Explain the origin of the three main types of radioactive decay and how their properties were first investigated. [5]

(ii) The ^{14}C content decreases after the death of a living system with a half-life of 5739 years. If the ^{14}C content of an old piece of wood is found to be 12.5% of that of an equivalent present-day sample, how old is the piece of wood? [4]

4. (a) Suppose that the sun consists entirely of hydrogen and that the dominant energy-releasing reaction is $4\left({}^{1}_{1}H\right)\rightarrow{}^{4}_{2}He+2\left({}^{0}_{1}e\right)+2\nu+\gamma$. If the total power output of the sun is assumed to remain constant at 3.9×10^{26} W, how long will it take for all of the hydrogen to be burned up? [10]

(b) Write brief notes on the following:
(i) Fusion reactions, and [5]
(ii) Fission reactions. [5]

5. (a) Using a well labelled diagram, describe a gas filled radiation detector in terms of its output – bias voltage characteristic. [10]

(b) Write brief notes on scintillation detectors. [5]

(c) Define the following terms:

(i) resolution [2]

(ii) dead time. [3]

6. (a) State postulates of Bohr's theory of the hydrogen atom [4]

(b) Show that the radius of the n^{th} 'orbit' of a hydrogen-like ion of charge Z is $r = 4\pi\varepsilon_0 \dfrac{n^2\hbar^2}{mZe^2}$ [5]

(c) The Balmer spectrum of a hydrogen-like atom consists of all emission lines caused by electronic transitions where the electron falls down to the $n = 2$ level. In this problem we consider the spectrum of an atom with one electron (like hydrogen) but with a nucleus with a charge different from one. For this special atom we find that the smallest wavelength of the Balmer series is 620 nm. What is the energy needed to ionize this atom when it is in the $n = 1$ state? [5]

(d) Using the Bohr model of the atom, a Rydberg's constant is given by the formula $\dfrac{E_0}{hc} \cong R_\infty = \dfrac{m_e e^4}{4\pi c\hbar^3 (4\pi\varepsilon_0)^2}$. Compare the calculated value to that obtained experimentally.

[6]

END OF PAPER