NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

MODERN PHYSICS - SPH 1104

Supplementary examination

BSc HONOURS PART I: July 2005 *DURATION 3 HOURS*

Instructions To Candidates:

1. Answer ALL parts of question 1 in Section A.
2. Answer any **THREE** questions from Section B
3. Section A carries 40 marks and Section B carries 60 Marks.
4. Show all your steps clearly in any calculation.

Planck's Constant --	h = 6.63×10^{-34}J.S
Electron rest Mass --	M = 9.11×10^{-31} Kg
Speed of light --	C = 3.00×10^{8} ms^{-1}
1 electron volt --	eV= 1.60×10^{-19}J
Mass of electron --	Me = 5.48×10^{-4}u
Mass of proton --	Mp = 1.007825u
Mass of neutron ---	Mn = 1.008 665u
1 atomic mass unit --	1u = 931.49 MeV/c^2
Electronic charge --	e = 1.60×10^{19}C
Stefan-Boltzmann Constant -------------------------------	σ = 5.67×10^{-8}W/m^2.K^4
Wien's Constant ---	b = 2.898×10^{-3}m.K
Mass of ${}^{2}_{1}H_{1}$ ---	2.014102u
Mass of ${}^{56}_{26}Fe_{30}$ ---	55.934939u
Mass of ${}^{238}_{92}U_{146}$ --	238.049553u
1 Ci --	3.70×10^{10} Bq
Nuclear radii Constant ------------------------------------	R_0 = 1.2 Fermi

SECTION A

1\. a) (i) What do you understand by the binding energy of an atomic nucleus? [3]

(ii) Find the binding energy per nucleon $\left(\frac{B}{A}\right)$ for ${}^{2}_{1}H_{1}$, ${}^{56}_{26}Fe_{30}$ and ${}^{238}_{92}U_{146}$ [3]

(iii) Explain why binding energy per nucleon is lowest for the lightest nucleus and why it is lower in the heaviest of the above three compared to the medium sized. [3]

(iv) Referring to binding energy per nucleon, explain briefly "nuclear fission" and "nuclear fusion". [3]

b) (i) Explain the origins of "Ultraviolet catastrophe". [3]

(ii) A blackbody is at a temperature of 750k, find the wavelength of the most intense part of its spectrum. [2]

(iii) Why would a blackbody be described as having no surface properties? In what way is a grey body different from a blackbody? [3]

(iv) Wien's law is said to be a "displacement law", explain why? [2]

c) (i) Why is the sky blue on a clear summer afternoon? Name the process responsible for this phenomenon. [4]

(ii) Compute the approximate nuclear radius of carbon (A=12) [2]

(iii) Compute the density of a typical nucleus and find the resultant mass if we could manufacture a nucleus with a radius of 5cm. [3]

d) (i) A source emits light of wavelength 4,8 x 10^{-7} m at a rate of 1.25W. How many photons leave the source every second? [4]

(ii) What is the minimum wavelength in a Bremsstrahlung process caused by electrons accelerated through 2.50×10^{4}V [2]

e) For the photoelectric effect, define the following terms:

(i) work function

(ii) the photoelectric equation [3]

SECTION B

2. a) (i) Show that the radius for the nth orbit of Bohr's model of the hydrogen atom is given by:

$$r_n = \left[\frac{4\pi\varepsilon_o\hbar^2}{me^2}\right]n^2$$ [5]

(iii) Show also, that the energy of the electron in the nth orbit is given by:

$$E_n = \frac{-me^4}{32\pi^2\varepsilon_o^2\hbar^2n^2}$$ [5]

b) Find an expression for the energy quantum emitted when a hydrogen atom falls from its "second excited state" to the ground state. [5]

c) (i) List four deficiencies of Bohr's model. [5]

3. a) Which observations of the photoelectric effect does classical physics fail to explain? [6]

b) When a metal is illuminated with radiation of wavelength 4.199×10^2nm, the stopping potential is found to be 0.652V; when the wavelength is changed to 3.099×10^2nm, the stopping potential becomes 1.69V.

(i) Find Planck's constant from the experimental data. [5]

(ii) Find the work function of the material [5]

c) Calculate the kinetic energy of the most energetic electrons emitted from the surface of the material when illuminated with radiation of wavelength 4.10×10^2nm. [4]

4. a) An electron is accelerated through a potential difference of 60kV. After striking a target nucleus of a certain material, a photon of wavelength 0.55×10^{-10}m is liberated.

(i) What is the energy of the electron after the interaction? [5]

(ii) What is the maximum photon frequency that this accelerated electron is capable of generating in the material? [5]

b) A particular pair is produced such that the positron is at rest and the electron has a kinetic energy of 1.2MeV moving in the direction of flight of the pair producing photon.

(i) Neglecting the energy transferred to the nucleus of the nearby atom, find energy of the incident photon. [5]

(ii) What percentage of the photon's momentum is transferred to the nucleus? [5]

5. a) (i) Observations show that a radioactive – decay process follows the exponential law:

$$N = N_0 e^{-\lambda t}$$

Define all the quantities in the above expression. [3]

(ii) What do you understand by mean life time (τ) and half life $\left(T_{\frac{1}{2}}\right)$ for radioactive decay. [4]

b) (i) The following table shows the results of measuring the dependence of activity A of a certain radioactive element on time t.

T(hrs)	0	3	6	9	12	15
A (mCi)	21,5	12,5	7,5	4,1	2,3	1,7

Find the half-life of this element. [6]

(ii) A radioactive substance with decay constant λ has an activity A_1 at $t = t_1$ and activity A_2 at $t = t_2$. What is the total number of atoms that have decayed between t_1 and t_2? [7]

6. a) (i) Using appropriate diagrams for your illustrations, show that the Compton Shift can be evaluated by using the expression:

$\lambda' - \lambda = \frac{h}{m_o c}[1 - \cos\vartheta]$ where all symbols have their usual meanings. [12]

(ii) What would be the effect of replacing "free electrons" with protons in the Compton Scattering experiment? [2]

b) Describe how Davisson and Germer observed the wave nature of particles and explained why they concluded that what they were observing was the wave nature of particles. [6]

- END OF EXAMINATION -