NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

APPLIED PHYSICS DEPARTMENT

MODERN PHYSICS - SPH 1104/1106

EXAMINATION

BSc HONOURS PART I: DECEMBER 2004 *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 --	$h = 6.63 \times 10^{-34}$J.s
Electron rest Mass --	$m_e = 9.11 \times 10^{-31}$ Kg
Speed of light --	$c = 3.00 \times 10^{8}\,ms^{-1}$
1 electron volt --	$eV = 1.60 \times 10^{-19}$J
Mass of electron --	$Me = 5.48 \times 10^{-4}$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 --	$e = 1.60 \times 10^{19}$C
Stefan-Boltzmann Constant --	$\sigma = 5.67 \times 10^{-8} W/m^2.K^4$
Wien's Constant --	$b = 2.898 \times 10^{-3}$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--	Ro = 1,2 fermi
Mass of Proton --	$1,673 \times 10^{-27}$kg
$m(^{4}_{2}H_e)$ --	4,002603u
Mass of sun --	$1,99 \times 10^{30}$ kg
Mass of $(^{1}_{1}H_o)$ --	1,007825u

SECTION A

Question 1

a) (i) Calculate the values of the photon energy (E) and the momentum (p) for a monochromatic beam of wavelength 500nm [2]

(ii) What is the photoelectric effect? [2]

(iii) Write down the equation for the photoelectric effect and explain all the terms [4]

(iv) Explain why the photoelectric effect does not work for free electrons [2]

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 4.8×10^{-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 2.50×10^4V [2]

(ii) The most abundant isotope of helium is ${}^4_2He$. Using the atomic mass units and electron volts, determine the mass deficit and the binding energy per nucleon of ${}^4_2He$. [3]

e) The following symbols represent five nuclides:

$^{58}_{29}A$; $^{54}_{27}B$; $^{59}_{29}C$; $^{58}_{30}D$; $^{59}_{30}E$

Which daughter nuclide could be produced from which parent nuclide by the emission of an alpha particle? [2]

SECTION B

Question 2

(a) (i) Explain the observations that led to the failure of classical physics in explaining photoelectric effect. [3]

(ii) How does Einstein explain these observations? [3]

b) When a metal is illuminated with radiation of wavelength 4.199x10^2nm, the stopping potential is found to be 0.652V; when the wavelength is changed to 3.099x10^2nm, the stopping potential becomes 1.69V.

(i) What is meant by "Stopping Potential"? [2]

(ii) find Planck's constant from the experimental data. [4]

(iii) Find the work function of the material [4]

c) Calculate the kinetic energy of the most energetic electrons emitted from the surface of the material when illuminated with radiation of wavelength 4.10x10^2nm. [4]

3. (a) Compute the de Brogie wavelengths for the following cases:

(i) A 1005kg automobile traveling at 110m/s. [2]

(ii) An election with a kinetic energy of 1eV [2]

(ii) Using the answers obtained in parts (i) and (ii), explain why waves associated with man-sized objects cannot be observed in a normal Laboratory. [3]

(b) (i) Briefly describe the Davisson and Germer experiment. [4]

(ii) Use the set of data below to prove that the wavelength predicted by a double slit experiment for electrons is the same as calculated from the Davisson and Germer experiment. [9]

atomic row separation (d) = 0.215nm

first order peak (n = 1) at $\phi = 50^0$

accelerating voltage (V) = 54V

4. (a) (i) Write down the Law of Radioative decay. [2]

(ii) Define for a radioactive sample, the decay constant. [2]

(b) The half-life of ^{198}Au is 2,70 days.

(i) What is the decay constant of ^{198}Au ? [3]

(ii) What is the probability that any ^{198}Au nucleus will decay in one second ?. [1]

(iii) Suppose we had a $100\,\mu g$ sample of ^{198}Au. What is its activity? [5]

(iv) How many decays per second occur when the sample is one week old? [4]

(c) (i) What is meant by the "binding energy" of a nucleus? [1]

(ii) What is the binding energy of $^{89}Y_{39}$ Nucleus

Mass of $^{89}Y_{39}$ = 88,93421u [2]

5. (a) (i) Explain how Compton's experiment can be used to support the notion that electromagnetic radiation has a particle nature. [4]

(ii) Show, using diagrammatic illustrations, that the expression for the Compton shift, $\Delta\lambda$ is given by:

$$\Delta x = \lambda^1 - \lambda = \frac{h}{m_e}(1 \quad \text{Cos}\,\theta)$$ where θ is the scattering angle of the photon [10]

(b) (i) Explain a "head-on" collision in the Compton Scattering experiment and write an expression for the resulting compton shift, $\Delta\lambda$. [2]

(ii) Explain why in the Compton scattering experiment, the recoil electrons are regarded as "free". [2]

(iii) What could be the effect of replacing electrons by protons.? [2]

6. (a) (i) Listing all your assumptions, calculate the wavelength for the most intense part of the spectrum produced by the human body. [4]

(ii) Show that for the most intense part of radiation by a blackbody. Planck's radiation relation reduces to Wien's displacement law. [6]

Plank's formular: $R(\lambda) = \frac{2\pi c^2 h}{\lambda^5} \cdot \frac{1}{e^{hc/\lambda KT} - 1}$

(b) The spectral composition of solar radiation is much the same as that of a blackbody whose maximum emission corresponds to the wavelength 4,4nm.

(i) Find the average temperature of the sun. [2]

(ii) If the sun's radiative power is 1400 w/m^2, compute the energy radiated by the sun per second [3]

(iii) Evaluate the time interval during which the mass of the sun diminishes by 1 percent. [5]

END