UNIVERSITY OF COLOMBO, SRI LANKA

FACULTY OF SCIENCE

FIRST YEAR EXAMINATION IN SCIENCE - SEMESTER 1 - 2003

PH 1001– MODERN PHYSICS

(Two Hours)

Answer ALL (FOUR) questions

Electronic calculators are allowed*.

(This question paper consists of 04 questions in 07 pages.)

Important Instructions to the Candidates

- If a page or a part of this question paper is not printed, please inform the supervisor immediately.
- Enter Your Index Number in all pages.
- Use the papers provided to answer questions 1, 2 and 3. Question 4 consists of 15 Multiple Choice Questions. In each of these multiple choice questions pick one of the alternatives (a), (b), (c), (d) and (e) which is correct or most appropriate and underline your response on the question paper itself.
- At the end of the time allowed for this paper, attach question 4 with the marked responses to your written answers to questions 1, 2 and 3 (answer book) and hand them over to the supervisor or invigilator as one answer script.
- You are permitted to remove only questions 1, 2 and 3 of the question paper from the Examination Hall.

* No calculators and electronic devices capable of storing and retrieving text, including electronic dictionaries and mobile phones may be used.

Some useful constants and conversions are;

Planck constant $= 6.63\times10^{-34}$ Js

Velocity of light $= 3.00\times10^{8}$ $\mathrm{m\,s^{-1}}$; $hc = 12.4\times10^{3}$ eV $\mathring{A}$

Rest mass of the electron $=$ 0.511 MeV $= 9.11\times10^{-31}$ kg

Electronic charge $= 1.60\times10^{-19}$ C

1 eV $= 1.60\times10^{-19}$ J

Boltzmann constant $k = 1.38\times10^{-23}$ $\mathrm{J\,K^{-1}}$

All the symbols have their usual meaning.

(1) (i) Photoelectric effect occurs only for bound electrons. Explain this statement.

(ii) The wavelength of the incident light in a photoelectric experiment is increased from 3000 $\mathring{A}$ to 3010 $\mathring{A}$. Find the corresponding change in the stopping potential.

(iii) Consider a potassium surface that is 75 cm away from a 100 W bulb. The energy radiated by the bulb is 5% of the input power. Treating each potassium atom as a circular disc of diameter 1 $\mathring{A}$, determine the time required for each atom to absorb an amount of energy equal to its work function of 2.0 eV, according to the wave theory of light.

(iv) In a Compton scattering experiment, the scattered photon and electron are detected. It is found that the electron has a kinetic energy of 75 keV and the scattered photon has an energy of 200 keV. What was the initial wavelength of the photon?

(2) (i) Explain the origin of continuous X-rays and characteristic X-rays.

(ii) An experiment measuring the K_{α} lines for various elements yields the following data :

Fe : 1.94 $\mathring{A}$ Co : 1.79 $\mathring{A}$ Ni : 1.66 $\mathring{A}$ Cu : 1.54 $\mathring{A}$

Determine the atomic number of each of the elements from these data.

(The Moseley's relation is given by $f^{1/2} = (4.97\times10^{7})(Z-1)\ \mathrm{Hz}^{1/2}$)

(iii) Determine the ratio of the energy emitted from a 2000 K blackbody in wavelength bands of width 100 $\overset{\circ}{A}$ centered on 5000 $\overset{\circ}{A}$ (visible) and 50,000 $\overset{\circ}{A}$ (infrared).

Planck's radiation formula for a black body is given by $I(\lambda) = \dfrac{2\pi hc^2}{\lambda^5\left(e^{hc/\lambda kT} - 1\right)}$

(Hint : Since the bandwidth $\Delta\lambda = 100$ $\overset{\circ}{A}$ is sufficiently small, one can treat $I(\lambda)$ as constant over the wavelength interval centered at 5000 $\overset{\circ}{A}$ and 50,000 $\overset{\circ}{A}$)

(3) (i) Does a photon have a de Broglie wavelength? If so, how is it related to the wavelength of the corresponding electromagnetic wave? Explain your answer.

(ii) In an electron microscope, what accelerating voltage is needed to produce electrons with wavelength 4.0×10^{-2} nm?

(iii) An electron and positron are moving in opposite directions with same speed. They collide head-on, annihilating each other and producing two photons. Find the energies, and wavelengths of the two photons if the initial kinetic energies of e^- and e^+ are
(a) both negligibly small
(b) both 5.0 MeV

(iv) Determine the mass ratio $\left(\dfrac{M_D}{M_H}\right)$ of deuterium (D) and hydrogen (H) if, their H_α lines have wavelengths of 6561.01 $\overset{\circ}{A}$ and 6562.80 $\overset{\circ}{A}$ respectively.

[In terms of the reduced mass of the atom, the Rydberg formula can be written as

$\dfrac{1}{\lambda} = \dfrac{R}{1+\dfrac{m}{M}}\left(\dfrac{1}{n_f^2} - \dfrac{1}{n_i^2}\right)$, where m and M are the electronic and nuclear masses respectively ; Take $\dfrac{m}{M_H} = \dfrac{1}{1836}$] .

Enter Your Index Number in all pages.

- Question 4 consists of 15 Multiple Choice Questions. In each of these multiple choice questions pick one of the alternatives (a), (b), (c), (d) and (e) which is correct or most appropriate and underline your response on the question paper itself.

(4) **Index No.** :......................

(i) The correct expression relating the energy E of a particle to its rest mass m_0, its momentum p, and the speed of light c, is

(a) $E^2 = p^2c^2 + m_0c^2$ (b) $E^2 = p^2c^2 + (m_0c)^2$ (c) $E^2 = p^2c + (m_0c^2)^2$

(d) $E^2 = pc^2 + (m_0c^2)^2$ (e) $E^2 = p^2c^2 + (m_0c^2)^2$

(ii) A particle moves in such a way that its kinetic energy just equals its rest energy. The velocity of this particle is

(a) 0.866c (b) 0.707c (c) 0.500c (d) 0.250c (e) 0.100c

(iii) The cosmic microwave background radiation is

(a) radiation emitted from the quasars.

(b) produced from processes going on all over the present universe.

(c) radiation emitted from the Sun.

(d) radiation from the Big Bang that was around when electrons and protons combined to form neutral hydrogen atoms.

(e) radiation produced from electron-positron annihilation in the intergalactic regions.

(iv) The maximum kinetic energy of electrons ejected from barium (whose work function is 2.50 eV) when it is illuminated by light of wavelength 350 nm is

(a) 0.20 eV (b) 0.41 eV (c) 0.63 eV (d) 0.95 eV (e) 1.04 eV

Index No. : ....

(v) The kinetic energies of emitted photoelectrons range from zero to 4.0×10^{-19} J when light of wavelength 3000 $\mathring{A}$ falls on a surface. The corresponding stopping potential is

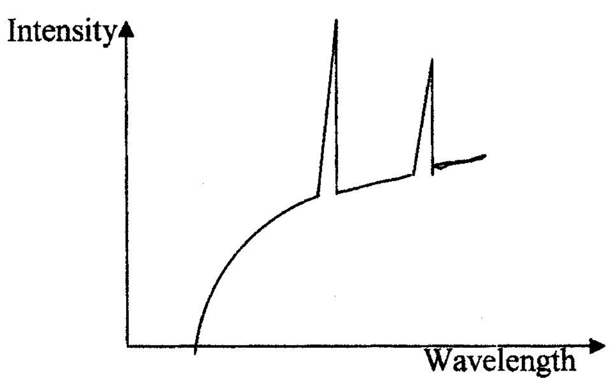
(a) 1.0 V (b) 1.5 V (c) 2.0 V (d) 2.5 V (e) 3.0 V

(vi) In a Compton experiment an electron attains a kinetic energy of 0.1 MeV when an X – ray of energy 0.5 MeV strikes an electron. If the electron is initially at rest, the wavelength of the scattered photon is

(a) $3.1\times10^{-2}\,\mathring{A}$ (b) $2.1\times10^{-2}\,\mathring{A}$ (c) $1.1\times10^{-2}\,\mathring{A}$ (d) $3.1\times10^{-3}\,\mathring{A}$

(e) $1.1\times10^{-3}\,\mathring{A}$

(vii) The following diagram shows the spectrum of X – rays emitted from an X – ray tube. Consider the following statements made about it.



(A) The peaks appear only when the voltage across the tube exceeds a certain value for a given target.

(B) For a given voltage across the tube, the cut-off wavelength depends on the material of the target.

(C) The cut-off wavelength decreases as the tube current increases.

Of the above statements,

Index No. : ....

(a) only (A) is true (b) only (B) is true (c) only (A) and (B) are true

(d) only (B) and (C) are true (e) all (A), (B) and (C) are true

(viii) Consider the following statements made about pair production and pair annihilation.

(A) In contrast to pair production, pair annihilation can take place in empty space.

(B) In pair annihilation, at least two photons must be produced.

(C) In pair production, two oppositely charged particles must be produced.

Of the above statements,

(a) only (A) is true (b) only (A) and (C) are true (c) only (A) and (B) are true

(d) only (B) and (C) are true (e) all (A), (B) and (C) are true

(ix) The ratio $\dfrac{\text{Compton wavelength of a relativistic particle}}{\text{de Broglie wavelength of the particle}}$ is given by

(E = total energy of the particle ; E_0 = rest energy of the particle)

(a) $\sqrt{\left(\dfrac{E}{E_0}\right)^2} - 1$ (b) $\sqrt{\left(\dfrac{E}{E_0}\right)^2 - 1}$ (c) $\sqrt{\left(\dfrac{E_0}{E}\right)^2 - 1}$ (d) $\left(\dfrac{E}{E_0} - 1\right)^2$ (e) $\left(\dfrac{E}{E_0}\right)^2 - 1$

(x) To observe an object which is about 2.5 $\mathring{A}$ in size, the minimum energy of photon that can be used is

(a) 1.22×10^2 eV (b) 2.22×10^2 eV (c) 4.96×10^2 eV (d) 4.96×10^3 eV

(e) 5.22×10^3 eV

Index No. : ....

(xi) The shortest and longest wavelengths of the Lyman series of hydrogen atom are

$$\frac{1}{\lambda}=1.097\times10^{-3}\left(\frac{1}{n_f^2}-\frac{1}{n_i^2}\right)\overset{\circ}{A}^{-1}$$

(a) 912 $\overset{\circ}{A}$,1215 $\overset{\circ}{A}$ (b) 3646 $\overset{\circ}{A}$,6563 $\overset{\circ}{A}$ (c) 2312 $\overset{\circ}{A}$,3215 $\overset{\circ}{A}$

(d) 3646 $\overset{\circ}{A}$,6563 $\overset{\circ}{A}$ (e) 6563 $\overset{\circ}{A}$,8564 $\overset{\circ}{A}$

(xii) The highest energy state that unexcited hydrogen atoms can reach when they are bombarded with 12.6 eV electrons is $\left(E=-\frac{13.6}{n^2}\text{eV}\right)$

(a) $n=1$ (b) $n=2$ (c) $n=3$ (d) $n=4$ (e) $n=5$

(xiii) A photon of wavelength 0.003 $\overset{\circ}{A}$ in the vicinity of a nucleus produces an electron positron pair. If the kinetic energy of the positron is twice that of the electron, the kinetic energy of the electron is

(a) 2.45 MeV (b) 1.04 MeV (c) 1.00 MeV (d) 0.04 MeV (e) 0.02 MeV

(xiv) A metal plate is illuminated with a beam of light of a certain frequency. Which of the following determines whether the electrons are emitted or not from the metal surface?

(a) The intensity of light (b) The surface area of the metal

(c) The length of the time of exposure to the light (d) The type of the metal

(e) The speed of the incident photons.

(xv) The intensity of solar radiation at the Earth surface is 1.4 kW m^{-2}. Given that the mean distance from the Sun to the Earth is 1.5×10^{11} m, the luminosity (power) of the Sun is,

(a) 4.0×10^{26} W (b) 6.0×10^{26} W (c) 4.0×10^{30} W (d) 6.0×10^{31} W

(e) 6.0×10^{32} W

______%%%%%%______