UNIVERSITY OF COLOMBO, SRI LANKA

FACULTY OF SCIENCE

FIRST YEAR EXAMINATION IN SCIENCE – SEMESTER I – 2004/2005

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 on all pages of the answer script.
- MCQ TYPE: In each of these multiple choice questions, encircle the number of the correct response.
- ESSAY TYPE: Write the answers to these questions on writing papers provided.
- Electronic devices capable of storing and retrieving text, including electronic dictionaries and mobile phones are not allowed.
- In this question paper, questions 1, 2 & 3 are essay type questions. Question 4 consists of 15 Multiple Choice Questions.
- 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. Please make sure that you handover both English and Sinhala versions of the question 4 to the supervisor or invigilator.
- You are permitted to remove only questions 1, 2 and 3 of the question paper from the Examination Hall.

Some useful constants and conversions are;

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

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

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

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

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

All the symbols have their usual meaning.

1. (i) Certain regions of the sky appear to contain so-called "radio stars". What can you conclude about the temperature of such a star?

   (ii) What familiar example can you give of the fact that the wavelength of the radiation emitted by a hot object decreases as the temperature of the object increases?

   (iii) Planck's radiation formula for a black body is given by

$$I(\lambda)=\frac{2\pi hc^{2}}{\lambda^{5}\left(e^{hc/\lambda kT}-1\right)}$$

   Where all symbols have their usual meaning.

   Use the Planck's radiation formula to derive the Stefan-Boltzmann law.

$$\left\{\int_{0}^{\infty}\frac{x^{3}}{e^{x}-1}dx=\frac{\pi^{4}}{15}\right\}$$

   (iv) Show that the Rayleigh-Jeans radiation law $I(\lambda)d\lambda=\frac{2\pi ckT}{\lambda^{4}}d\lambda$ is not consistent with the Wien displacement law $\lambda_{max}T=\text{constant}$.

2. (i) How does the photon concept of light explain the following features of the photoelectric effect?

    (a) Existence of a threshold wavelength;
    (b) Photo-current is directly proportional to light intensity;
    (c) Photo-current flows the instant light is turned on;
    (d) Stopping potential is inversely proportional to wavelength;

   (ii) A beam of light is shone onto a flat surface. In which case will the pressure exerted by the beam be greatest, when the surface is highly reflecting or when it is highly absorbing? Explain your answer.

   (iii) The threshold wavelength for potassium is 570 *nm*. If light having a wavelength of 400 *nm* falls on potassium, find
    (a) the work function for potassium.
    (b) the stopping potential for the photoelectrons.
    (c) the kinetic energy of the most energetic electrons.

3. (i) How do you account for the presence of unmodified component of X-rays in Compton effect?

   (ii) Why visible light cannot be used to demonstrate Compton effect?

   (iii) A photon of frequency f is scattered by a free electron initially at rest. Show that the maximum kinetic energy (K_{max}) of the recoiling electron is given by

$$K_{\max} = \frac{hf}{1 + \dfrac{m_e c^2}{2hf}}$$

   (You may use the formula for the Compton shift without any derivation)

   Hence, show that a photon cannot transfer its entire energy to an electron in Compton scattering.

- 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 encircle your response on the question paper itself.

(4)

Index No. :......................

(i) The momentum p of a photon with energy E is given by

(a) $p=\frac{E}{c}$ (b) $p=Ec$ (c) $p=\frac{E^2}{c}$ (d) $p=\frac{E}{c^2}$ (e) $p=\frac{\sqrt{E}}{c}$

(ii) What is the velocity of an electron whose kinetic energy is 2 MeV?

(a) 0.98c (b) 0.71c (c) 0.50c (d) 0.25c (e) 0.10c

(iii) The existence of cosmic microwave background radiation supports

(a) the Einstein's theory of relativity.

(b) the Planck's theory of quantisation.

(c) the wave – particle duality.

(d) the Big Bang theory of the evolution of universe.

(e) the Maxwell's theory of electromagnetism.

(iv) What is the work function for potassium if the largest wavelength for electron emission is 5620 $\mathring{A}$

(a) 0.20 eV (b) 0.41 eV (c) 1.63 eV (d) 1.95 eV (e) 2.21 eV

Index No. : ....

(v) The kinetic energies of emitted photoelectrons range from zero to 4.0×10^{-19} J when light of wavelength 3000 $\overset{o}{A}$ 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) The fractional change in the wavelength of an X – ray of wavelength 0.400 $\overset{o}{A}$ that undergoes a 90^0 Compton scattering from a free electron is

(a) 0.0511 (b) 0.0608 (c) 0.1245 (d) 0.2785 (e) 1.100

(vii) Potassium is illuminated with ultraviolet light of wavelength 2500 $\overset{o}{A}$. If the intensity of the beam is 2 W m^{-2}, the rate of electron emission per unit area is (Assume a quantum efficiency of 10%)

(a) 1.52×10^{16} s^{-1} (b) 1.52×10^{17} s^{-1} (c) 2.52×10^{17} s^{-1} (d) 2.52×10^{18} s^{-1}

(e) 3.00×10^{18} s^{-1}

(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

Index No. : ....

(ix) The effective mass of a 5000 $\overset{o}{A}$ photon is

(a) 4.42×10^{-34} kg. (b) 4.42×10^{-35} kg (c) 4.42×10^{-36} kg (d) 4.42×10^{-37} kg

(e) 4.42×10^{-38} kg

(x) Annihilation occurs between an electron and positron at rest, producing three photons. If the energies of two of the photons are 0.20 MeV and 0.30 MeV, the energy of the third photon is

(a) 0.241 MeV (b) 0.522 MeV (c) 0.876 MeV (d) 1.123 MeV

(e) 2.234 MeV

(xi) How many positrons can a 200 MeV photon produce?

(a) 54 (b) 95 (c) 100 (d) 195 (e) 215

(xii) A TV tube operates with a 20 kV accelerating potential. The shortest wavelength of X – rays produced from the TV set is

(a) 0.62 $\overset{o}{A}$ (b) 0.72 $\overset{o}{A}$ (c) 0.82 $\overset{o}{A}$ (d) 0.92 $\overset{o}{A}$ (e) 1.92 $\overset{o}{A}$

(xiii) Consider the following statements made about photo electric effect and Compton effect

(A) Photo emission occurs only with free electrons

(B) Compton effect occurs only with bound electrons.

(C) Photo emission occurs only with high energy photons.

Of the above statements,

(a) only (C) 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 **not** true

Index No. : ....

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

(a) The intensity of light
(b) The surface nature of the metal
(c) The wavelength the incident light
(d) The type of the metal
(e) The frequency the incident light.

(xv) The luminosity (power) of the sun is 4.0×10^{26} W. Given that the mean distance from the Sun to the Earth is 1.5×10^{11} m, the intensity of solar radiation at the Earth surface is

(a) 0.4 kW m^{-2}
(b) 0.8 kW m^{-2}
(c) 1.0 kW m^{-2}
(d) 1.4 kW m^{-2}
(e) 5.6 kW m^{-2}