UNIVERSITY OF COLOMBO, SRI LANKA

FACULTY OF SCIENCE

FIRST YEAR EXAMINATION IN SCIENCE - SEMESTER 1 – 2007/2008

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 encircle your response on the question paper itself.
- At the end of the time allowed for this paper, attach question 4, both English and Sinhala versions 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, conversions and formulae are;

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

Speed of light in free space $c = 3.00\times10^{8}$ ms^{-1} ; $hc = 12.4\times10^{3}$ eV Å $= 1240$ eV nm

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

Rest mass of the proton $m_p = 1.67\times10^{-27}$ kg

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

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

Compton shift formula : $\lambda' - \lambda = \frac{h}{m_e c}(1-\cos\theta)$;

Energy of a Bohr atom in a n^{th} state : $E_n = -\frac{Z^2 13.6}{n^2}$ eV

Rydberg's formula for a Bohr atom : $\frac{1}{\lambda} = Z^2 R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

Rydberg's constant $R = 1.09\times10^{7}$ m^{-1}

Wien displacement constant 2.9×10^{-3} m K

All the symbols have their usual meaning.

1. (i) Sunlight, whose visible wavelengths range from 380 nm to 750 nm, is incident on a sodium surface. The photo electric work function for sodium is 2.28 eV. Find the maximum kinetic energy of the photoelectrons emitted from the surface and the range of wavelengths that will cause photoelectrons to be emitted.

   (ii) A photon with wavelength 9.0×10^{-12} m moves along the $+x$ axis and strikes a free electron initially at rest. For scattering angles
   (a) $\theta = 90.0°$ and
   (b) $\theta = 180.0°$, calculate the x and y components of the electron's momentum after the collision.

   (iii) Show that when a positron and an electron both essentially at rest annihilate, creating two photons, the wavelength of both photons is equal to the Compton wavelength.

2. (i) A hydrogen atom is in the third excited state. It makes a transition to a different state, and a photon is either absorbed or emitted. Determine the quantum number (n) of the final state of the electron and the energy of the photon when the photon is (a) emitted with the shortest possible wavelength, (b) emitted with the longest possible wavelength, and (c) absorbed with the longest possible wavelength.

(ii) A certain species of ionized atoms produces an emission line spectrum according to the Bohr model, but the number of protons Z in the nuclei is unknown. A group of lines in the spectrum forms a series in which the shortest wavelength is 22.79 nm and the longest wavelength is 41.02 nm. Find the value of Z of the atoms and the next-to-the-longest wavelength in the series of lines.

3. (i) An electron and a proton have the same kinetic energy and are moving at speeds much less than the speed of light. Determine the ratio of the de Broglie wavelength of the electron to that of the proton.

(ii) The K-shell and L-shell ionization energies of a metal are 8979 eV and 951 eV, respectively. (a) Assuming that there is a vacancy in the L shell, what must be the minimum voltage across an X-ray tube with a target made from this metal to produce K_α X-ray photons? (b) Determine the wavelength of a K_α X-ray photon.

- 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.

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(i) If the rest mass of a proton is m_0, its linear momentum when it moves with half the speed of light (c) in free space is

(a) $3m_0c/4$ (b) $m_0c/2$ (c) m_0c (d) $2m_0c/\sqrt{3}$ (e) $m_0c/\sqrt{3}$

(ii) A constant force F acts on an object of rest mass m_0 for an indefinitely long period of time.

(a) The object's inertia or "relativistic mass" increases indefinitely, but its velocity approaches c.

(b) The object's inertia or "relativistic mass" increases indefinitely, and its velocity increases linearly.

(c) The object's inertia or "relativistic mass" decreases indefinitely, and its velocity increases linearly.

(d) The object's inertia or "relativistic mass" decreases indefinitely, and its velocity approaches c.

(e) The object's inertia or "relativistic mass" remains the same, and its velocity increases linearly.

(iii) If the temperature of the sun were twice the present value, the radiation of the sun would be mostly in

(a) microwave region (b) infra red region (c) visible region

(d) X-ray region (e) ultraviolet region.

(iv) Two copper spheres A and B having the same emissivity have radii 12 cm and 3 cm respectively. If they are maintained at temperatures 727 °C and 1727 °C respectively, $\frac{\text{the total energy radiated by A}}{\text{the total energy radiated by B}}$ is

(a) 0.032 (b) 0.12 (c) 0.48 (d) 1 (e) 2

(v) Two identical photo cathodes receive light of frequencies f_1 and f_2. If the maximum speeds of the photoelectrons (mass m) coming out are respectively v_1 and v_2, then

(a) $v_1 - v_2 = [2h(f_1 - f_2)/m]^{1/2}$ (b) $v_1^2 - v_2^2 = 2h(f_1 - f_2)/m$

(c) $v_1 + v_2 = [2h(f_1 + f_2)/m]^{1/2}$ (d) $v_1^2 + v_2^2 = 2h(f_1 + f_2)/m$ (e) $v_1 = v_2$

(vi) The cutoff wavelength (in $\mathring{A}$) of X – rays produced by 50 keV electrons in a X – ray tube is

(a) 0.148 (b) 0.200 (c) 0.218 (d) 0.248 (e) 0.345

(vii) A photo cell is illuminated by a point source of light 50 cm away. When the source is shifted to 2 m away from the cell, then

(a) each emitted electron carries a quarter of the initial kinetic energy

(b) the number of electrons emitted is a quarter of the initial number

(c) each emitted electron carries one sixteenth of the initial kinetic energy

(d) the number of electrons emitted is one sixteenth of the initial number

(e) the number of electrons emitted and the kinetic energy of each electron are one sixteenth of the initial values.

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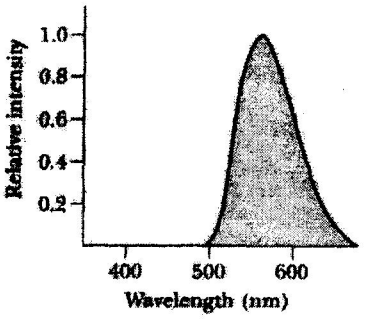

Figure shows the spectrum of light emitted by a firefly. The approximate temperature of a black body that would emit radiation peaked at the same wavelength is

(a) 10 K (b) 50 K (c) 250 K (d) 5200 K (e) 9250 K

(ix) If the kinetic energy of a particle is increased to 16 times, the percentage change in the de Broglie wave length of the particle is

(a) 25% (b) 75% (c) 60% (d) 50% (e) 30%

(x) The threshold wavelength for the production of a positron-electron pair is

(a) 1000 fm (b) 1215 fm (c) 1524 fm (d) 2514 nm (e) 3543 nm

(xi) Which state of the triply ionized Be^{+++} has the same orbital radius (for the electron) as that of the hydrogen atom in the ground state?

(a) first excited state (b) second excited state (c) third excited state

(d) fourth excited state (e) ground state

(xii) The Compton Effect

(a) verifies the wave nature of EM Radiation.

(b) predicts a lower frequency for back – scattered radiation.

(c) predicts a higher frequency for back – scattered radiation.

(d) shows that there is no ether.

(e) depends on the Fourier series for a moving electron.

(xiii) The smallest wavelength in the infra red region of the hydrogen spectrum (to the nearest integer) is

(a) 802 nm (b) 826 nm (c) 1648 nm (d) 1882 nm (e) 1994 nm

(xiv) The ionization energy of the hydrogen atom is 13.6 eV. If hydrogen atoms in the ground state absorb quanta of energy 12.75 eV, how many discrete spectral lines will be emitted according to the Bohr's model?

(a) 1 (b) 2 (c) 4 (d) 6 (e) 0

(xv) Suppose that the molybdenum (Z = 42) target in an X-ray tube is replaced by a silver (Z = 47) target. The voltage across the tube is constant and is sufficient to produce characteristic X-rays from both targets.

Consider the following statements.

(A) the cutoff wavelength (λ_0) will be the same for both X-ray spectra.

(B) the wavelength of the K_α X-ray photon will decrease.

(C) the wavelength of the K_β X-ray photon will decrease.

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