UNIVERSITY OF COLOMBO, SRI LANKA

FACULTY OF SCIENCE

LEVEL I EXAMINATION IN SCIENCE – SEMESTER I – 2012

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 $h = 6.63\times10^{-34}$ J s

Stefan Constant $= 6.0\times10^{-8}$ W m^{-2} K^{-4}

Wien's Constant = 3000 μm K

Speed of light in free space $c = 3.00\times10^{8}$ m s^{-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

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

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

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

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

All the symbols have their usual meaning.

(1) In a phototube a beam of light of total intensity 1 μW cm^{-2} falls on a clean iron sample 1 cm^2 in area. Assume that the iron sample reflects 96% of the incident light and that only 3% of the absorbed energy lies in the violet region of the spectrum above the photo-electric threshold frequency of iron.

(a) What intensity is actually available for the photo-electric effect?

(b) Assuming that all the photons in the violet region have an effective wavelength of 250 nm and the efficiency of ejection of photo-electrons is 100%, how many electrons will be emitted per second?

(c) Calculate the current in the phototube.

(d) If the cutoff frequency for iron is 1.1×10^{15} Hz, find the photo-electric work function for iron.

(e) Find the stopping potential for iron if photoelectrons are produced by light with wavelength of 250 nm.

(2) (i) Calculate the Compton shift ($\Delta\lambda$) for the scattering at 90^0 from free electrons in a graphite target for the following cases.

(a) High energy gamma rays from cobalt, $\lambda = 0.0106 \overset{0}{A}$.

(b) X - rays from molybdenum, $\lambda = 0.712 \overset{0}{A}$.

(c) Green light from a mercury lamp, $\lambda = 5461 \overset{0}{A}$.

(ii) X – ray photons are being used in the Compton experiments rather than visible light photons. Justify this statement from the results you have obtained from (i) above.

(iii) The so-called free electrons in carbon are actually conduction electrons with a binding energy of about 4 eV. Why may this binding energy be neglected for X – rays with $\lambda = 0.712 \overset{0}{A}$?

(3) The mysterious lines observed by Pickering in 1896 in the spectrum of the star ζ - Puppis fit the following empirical formula

$$\frac{1}{\lambda} = R\left(\frac{1}{\left(n_f/2\right)^2} - \frac{1}{\left(n_i/2\right)^2}\right)$$

Starting from first principles show that these lines can be explained by the Bohr theory as originating from He^+.

- **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) A particle leaving a cyclotron has a total relativistic energy of 10 GeV and a relativistic momentum of 8 GeV/c. The rest mass of this particle is

(a) 0.25 GeV/c^2 (b) 1.20 GeV/c^2 (c) 2.00 GeV/c^2 (d) 6.00 GeV/c^2 (e) 16.0 GeV/c^2

(ii) A potential difference of 20 kV is applied across an X - ray tube. The minimum wavelength of the emitted X – rays is

(a) 0.46×10^{-10} m (b) 0.62×10^{-10} m (c) 0.68×10^{-10} m

(d) 0.74×10^{-10} m (e) 0.85×10^{-10} m

(iii) A cavity radiator has its maximum spectral radiancy at a wavelength of 30.0 μm. The absolute temperature of the body is increased so that the radiant intensity of the radiator is doubled. The new temperature of the radiator is

(a) $\sqrt[4]{100}$ K (b) $\sqrt[4]{200}$ K (c) $\sqrt[4]{2} \times 100$ K (d) $\sqrt[4]{4} \times 100$ K

(e) $\sqrt{1000}$ K

(iv) Ultraviolet light of wavelength λ_1 and λ_2 ($\lambda_2 > \lambda_1$) when allowed to fall on a photosensitive surface is found to liberate electrons with maximum kinetic energies of E_1 and E_2 respectively. The value of the Planck constant could be determined from the relation

(a) $h = \frac{1}{c}(\lambda_1 - \lambda_1)(E_1 - E_2)$ (b) $h = \frac{1}{c}(\lambda_1 + \lambda_1)(E_1 + E_2)$

(c) $h = \frac{(E_1 - E_2)}{c(\lambda_2 - \lambda_1)}\lambda_1\lambda_2$ (d) $h = \frac{(E_1 + E_2)}{c(\lambda_2 + \lambda_1)}\lambda_1\lambda_2$

(e) $h = \frac{1}{c}(\lambda_1\lambda_2)(E_1 E_2)$

(v) A particle of mass M at rest decays into two particles of masses m_1 and m_2 having non zero velocities. The ratio of the corresponding de-Broglie wavelengths of the particles $\frac{\lambda_1}{\lambda_2}$ is given by

(a) $\frac{m_1}{m_2}$ (b) $\frac{m_2}{m_1}$ (c) $\sqrt{\frac{m_2}{m_1}}$ (d) $\sqrt{\frac{m_1}{m_2}}$ (e) 1

(vi) The K_α X-ray emission line of tungsten occurs at $\lambda = 0.021$ nm. The energy difference between K and L levels in tungsten atoms is about

(a) 0.51 MeV (b) 1.2 MeV (c) 11 keV (d) 59 keV (e) 95 keV

(vii) A laser emits photons of energy 2.5 eV with a power of 10^{-3} W. How many photons are emitted in one second?

(a) 4.0×10^{14} (b) 2.5×10^{15} (c) 4.0×10^{18} (d) 1.0×10^{21} (e) 2.5×10^{21}

(viii) How does the maximum Compton shift, $\Delta\lambda_{max}$, depend on the incident wavelength λ?

(a) $\Delta\lambda_{max} \propto \lambda^2$ (b) $\Delta\lambda_{max} \propto \lambda$ (c) $\Delta\lambda_{max} \propto \lambda^{-2}$ (d) $\Delta\lambda_{max} \propto \lambda^{-1}$

(e) $\Delta\lambda_{max}$ is independent of λ

(ix) Which of the following X-ray lines will have the largest wavelength in a given element?

(a) K_α (b) K_β (c) L_α (d) L_β (e) It depends on the element.

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(x) Which of the following reasons explains why a photon cannot decay to an electron and a positron in free space?

(a) Both linear momentum and energy are not conserved.

(b) Both linear momentum and angular momentum are not conserved.

(c) Both linear momentum and parity are not conserved.

(d) Both angular momentum and energy are not conserved.

(e) Both linear momentum and charge are not conserved.

(xi) The shortest wavelength of X – rays emitted from an X – ray tube depends upon

(a) the current in the tube

(b) the voltage applied to the tube

(c) the nature of the gas in the tube

(d) the atomic number of the target material

(e) the mass number of the target material

(xii) Electrons with de-Broglie wavelength λ fall on the target in a X – ray tube. The cut-off wavelength (λ_0) of the emitted X - ray is given by

(a) $\lambda_0 = \dfrac{2mc\lambda^2}{h}$ (b) $\lambda_0 = \dfrac{2h}{mc}$ (c) $\lambda_0 = \dfrac{2m^2c^2\lambda^2}{h^2}$

(d) $\lambda_0 = \dfrac{2mc\lambda}{h}$ (e) $\lambda_0 = \lambda$

(xiii) An electron and a positron are moving toward each other with the same kinetic energy of 5.0 MeV. They collide head-on and annihilate each other. The wavelength of the resulting photons is equal to

(a) 0.2250 pm (b) 0.2050 pm (c) 0.1250 pm (d) 0.1050 pm

(e) 0.0255 pm

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(xiv) The power (P) per unit area radiated from the surface of the sun in the wavelength range from 600.0 nm to 605.0 nm is given by (the surface temperature of the sun is equal to T K)

(a) $P = \dfrac{2\pi hc^2}{(6.025\times10^{-7})^5\left(e^{\frac{hc}{6.025\times10^{-7}kT}}-1\right)}(5.0\times10^{-9})$

(b) $P = \dfrac{2\pi hc^2}{(6.000\times10^{-7})^5\left(e^{\frac{hc}{6.005\times10^{-7}kT}}-1\right)}(5.0\times10^{-9})$

(c) $P = \dfrac{2\pi hc^2}{(6.05\times10^{-7})^5\left(e^{\frac{hc}{6.025\times10^{-7}kT}}-1\right)}(5.0\times10^{-9})$

(d) $P = \dfrac{2\pi hc^2}{(6.025\times10^{-7})^5\left(e^{\frac{hc}{6.025\times10^{-7}kT}}-1\right)}$

(e) $P = \dfrac{2\pi hc^2}{(6.025\times10^{-7})^5\left(e^{\frac{hc}{6.025\times10^{-7}kT}}-1\right)}\dfrac{1}{(5.0\times10^{-9})}$

(xv) A photon of frequency f falls from a height H under gravity. The fractional change in the frequency is given by

(a) 0 (b) 1 (c) $\sqrt{\dfrac{gH}{c^2}}$ (d) $\left(\dfrac{gH}{c^2}\right)^2$ (e) $\dfrac{gH}{c^2}$

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