UNIVERSITY OF COLOMBO, SRI LANKA

FACULTY OF SCIENCE

LEVEL I EXAMINATION IN SCIENCE – SEMESTER I – 2015

PH 1001– MODERN PHYSICS

(Two Hours)

Answer ALL (FOUR) questions

Electronic calculators are allowed*****.

(This question paper consists of 04 questions in 06 pages.)

<u>Important Instructions to the Candidates</u>

- 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 $h = 6.63 \times 10^{-34}$ J s

Stefan-Boltzmann constant = $= 6.0 \times 10^{-8}$ W m^{-2} K^{-4} ; Wien's constant = 3000 μm K

Speed of light in free space $c = 3.00 \times 10^{8}$ m s^{-1} ; $hc = 12.4 \times 10^{3}$ eV Å = 1240 eV nm

Rest mass of the electron $m_e = 9.11 \times 10^{-31}$ kg ; Rest mass of a proton $m_p = 938$ MeV

Electronic charge $= 1.60 \times 10^{-19}$ C ; 1 eV = 1.60×10^{-19} J

Energy of the n^{th} orbit of an Bohr atom $E_n = -\frac{13.6\, Z^2}{n^2}$ eV

Permittivity of free space $\epsilon_0 = 8.85 \times 10^{-12}$ C^2 N^{-1} m^{-2}

All the symbols have their usual meaning.

(1) Astronomers sometimes determine the size of a star by a method that relies on the Stefan-Boltzmann law. Determine the radius of the star Capella from the following data. Assume the star radiates like a black-body.
The flux of starlight reaching the Earth = 1.2×10^{-8} W m^{-2} ; the surface temperature of the star = 5200 K ; the distance from the Earth to the star = 4.3×10^{17} m

(2) (a) Show that Moseley's law for K_α radiation can be expressed as

$\sqrt{f} = \sqrt{\frac{3}{4}\left(\frac{13.6}{h}\right)}(Z-1)$, where f is the X-ray frequency and Z is the atomic number.

(b) Deduce an expression similar to the above for L_α X-rays. Assume, as in the case of K_α X -rays, that electrons in the shell of origin (in this case M) produce no screening, and that all screening is caused by electrons in the inner shells (in this case L and K). In a neutral atom L shell has eight electrons.

(3) The atom positronium consists of an electron and a positron orbiting about their common center of mass. Apply the Bohr theory to find out

(a) the smallest possible circular orbit of this system.

(b) the wavelength of the photon released in the transition $n = 2$ to $n = 1$.

- **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) Rest mass energy of an electron is

(a) 0.511 keV (b) 1.022 keV (c) 0.511 MeV (d) 1.022 MeV (e) 2.022 MeV

(ii) Linear momentum of a photon of frequency f is

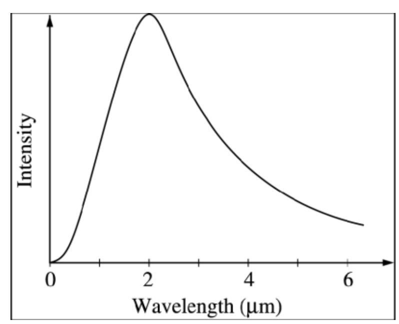
(a) 0 (b) $\frac{hf}{c}$ (c) $\frac{hf}{2c}$ (d) $\frac{2hf}{c}$ (e) $\left(\frac{hf}{c}\right)^2$

(iii) The production of X-rays can be regarded as an inverse

(a) Compton effect (b) pair production (c) pair annihilation

(d) photoelectric effect (e) piezoelectric effect

(iv) The distribution of relative intensity $I(\lambda)$ of blackbody radiation from a solid object *versus* the wavelength (λ) is shown in the figure. The approximate temperature of the object is



(a) 10 K (b) 50 K (c) 250 K

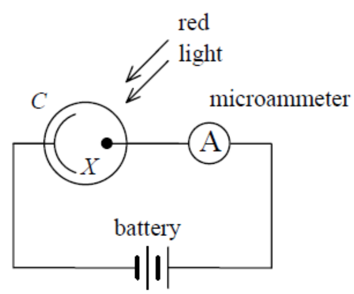
(d) 1500 K (e) 6250 K

(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 two 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) Red light shines on the photoelectric cell C as shown. If the reading of the micrometer is zero, this may be explained by the fact that

(A) the e.m.f of the battery is too small
(B) the intensity of light is too low
(C) electrode X is made of a material with too high work function

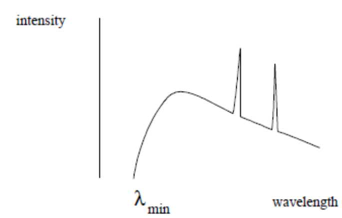


(a) All (A), (B) and (C) (b) (A) and (B) only

(c) (B) and (C) only (d) (A) only

(e) (C) only

(vii) The graph shows the spectrum of X-rays from an X-ray tube. When the accelerating potential is increased, what will happen to λ_{min} and the wavelengths of the characteristic lines?



λ_{min}	wavelengths of characteristics lines
(a) decrease	unchanged
(b) decrease	decrease
(c) decrease	increase
(d) increase	unchanged
(e) increase	decrease

The questions from (viii) to (xi) are based on the atom described in the question (viii)

(viii) A single electron orbits around a stationary nucleus of charge + Ze. It requires 47.2 eV to excite the electron from the second Bohr orbit to third Bohr orbit. The value of Z is

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

(ix) The ionization energy of the above atom is

(a) 340 eV (b) 218 eV (c) 122 eV (d) 84 eV (e) 13.6 eV

(x) The potential energy of an electron in the first Bohr orbit in the above atom is

(a) 340 eV (b) -340 eV (c) -680 eV (d) -1020 eV (e) -1360 eV

(xi) The angular momentum of an electron in the first Bohr orbit in the above atom is

(a) $\frac{5h}{2\pi}$ (b) $\frac{3h}{2\pi}$ (c) $\frac{h}{\pi}$ (d) $\frac{h}{2\pi}$ (e) 0

(xii) The maximum wavelength of each photon produced when a proton and an antiproton annihilate is

(a) 2.64×10^{-15} m (b) 1.32×10^{-15} m (c) 0.66×10^{-15} m

(d) 2.64×10^{-16} m (e) 1.32×10^{-16} m

(xiii) A photon produces a proton-antiproton pair at rest. If a nearby nucleus of mass 1.66×10^{-25} kg (initially at rest) carries off the photon's momentum, the wavelength of the photon is

(a) 2.62×10^{-15} m (b) 1.30×10^{-15} m (c) 0.64×10^{-15} m

(d) 2.62×10^{-16} m (e) 1.30×10^{-16} m

(xiv) In Compton effect, the wavelength of scattered photon is

(a) more than or equivalent to that of incident photon.

(b) less than or equivalent to incident photon.

(c) always more than incident photon

(d) always less than incident photon.

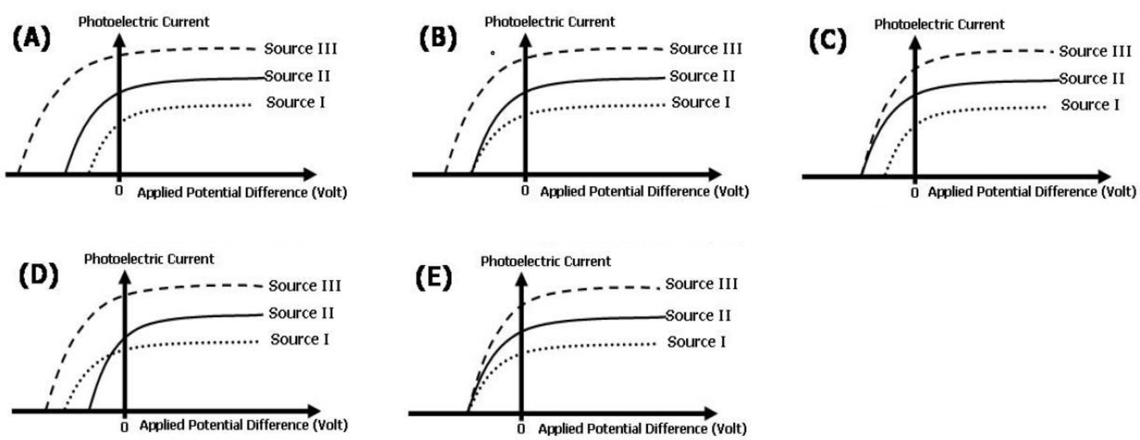
(e) always equivalent to that of incident photon

Index No. :…………………..

(xv) A student performed three separate experiments on photoelectric effect using three different monochromatic light sources. The properties of the three light sources are summarized in the table below.

Light Source	**Light Intensity**	**Wavelength of incident light**
I	***I***	λ
II	**2*I***	λ
III	**3*I***	$2\lambda/3$

Which of the following figures would be the results of photocurrent versus applied potential obtained from these three separate experiments? The same metal surface was used throughout the experiments.



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