UNIVERSITY OF COLOMBO, SRI LANKA

FACULTY OF SCIENCE

FIRST YEAR EXAMINATION IN SCIENCE - SEMESTER 1 – 2005/2006

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 and conversions are;

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

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

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

All the symbols have their usual meaning.

1. (i) Planck's radiation formula for a black body is given by

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

Use the Planck's radiation formula to derive the Wien displacement law $\lambda_{\max}T = \text{constant}$.

[The solution to the equation $e^{-x} + \frac{x}{5} = 1$ is 4.965]

(ii) A neutron has a kinetic energy of 10 MeV. What is the size of the object which is necessary to observe neutron diffraction effects? (Use non relativistic formulae) Is there anything in nature of this size that could serve as a target to demonstrate the wave nature of neutrons? If so, what is it ?(mass of a neutron $= 1.67\times10^{-27}$ kg)

2. (i) (a) Calculate the frequency of the photon produced when an electron of 20 *keV* is brought to rest in one collision with a heavy nucleus.

(b) Using the relativistic expression for the kinetic energy and momentum of an electron calculate the momentum of the incident electron.

(c) Determine the momentum of the photon produced and hence show that linear momentum is not conserved in this process if one considers only the electron and the photon.

(d) What happens to the excess momentum?

(ii) The threshold wavelength for the emission of photoelectrons from a surface of 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. The Pickering series of the spectrum of He^+ (singly – ionized helium) consists of spectral lines due to transitions to the $n = 4$ state of He^+. Experimentally, every other spectral line of the Pickering series is very close to a spectral line in the Balmer series for hydrogen transitions to the $n = 2$.

(a) Show that the above fact is true.
(b) Calculate the wavelength of a transition from the $n = 6$ level to the $n = 4$ level of He^+, and show that it corresponds to one of the Balmer lines.

$$\left[\frac{1}{\lambda} = Z^2 \times 1.097 \times 10^{-3}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) \text{Å}^{-1}\right]$$

- 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) 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) c

(iii) An electron traveling at 0.980c has a total energy of

(a) 0.245 MeV (b) 0.511 MeV (c) 0.756 MeV (d) 1.736 MeV

(e) 2.55 MeV

(iv) As a particle of rest mass m_0 approaches the speed of light, its total energy

(a) becomes entirely kinetic (b) increases without bound. (c) approaches zero.

(d) approaches m_0c^2. (e) is trapped in a black hole.

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(v) In the quantum theory of the atom, which of the following classical ideas is assumed to be true?

(a) The electrons circulate about the nucleus in definite orbits.

(b) Atoms radiate because of the acceleration of the electrons.

(c) The force of attraction between the electrons and the nucleus is the usual Coulomb force.

(d) The frequency of radiation is the same as the frequency of revolution of the electrons in their orbital motion.

(e) The energy of the electrons can take any value.

(vi) The maximum kinetic energy of electrons ejected from barium (work function 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) 1.05 eV

(vii) The speed of an electron whose de Broglie wavelength is 0.0010 m is approximately

(a) 7.3×10^{-7} m s^{-1} (b) 7.3×10^{-4} m s^{-1} (c) 0.73 m s^{-1} (d) 5.1 m s^{-1}

(e) 5.1×10^{4} m s^{-1}

(viii) Diffraction of sound waves is more easily observable than that of light waves because

(a) sound waves are longitudinal and not transverse.

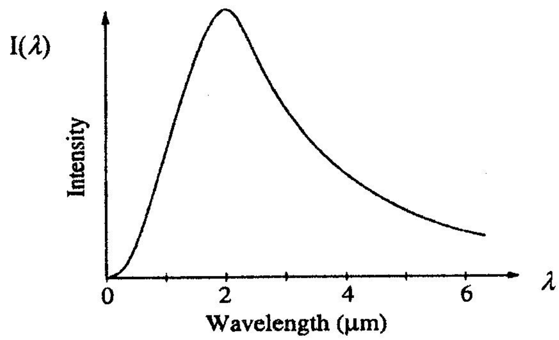
(b) sound waves have a higher frequency than light waves.

(c) sound waves have a lower velocity than light waves.

(d) sound waves have longer wavelengths than light waves.

(e) interference occurs more readily for longitudinal waves.

(ix)



The distribution of relative intensity [I(λ)] of blackbody radiation emitted from a solid object versus the wavelength (λ) is shown in the figure above. If the Wien displacement constant is 2.9×10^{-3} m K, what is the approximate temperature of the object?

(a) 10 K (b) 50 K (c) 250 K (d) 1500 K (e) 6250 K

(x) A possible value of the orbital angular momentum of an electron in the $n = 2$ state is

(a) $\frac{1}{2}\left(\frac{h}{2\pi}\right)$ (b) $\frac{h}{2\pi}$ (c) $2\left(\frac{h}{2\pi}\right)$ (d) $\frac{h}{\pi}$

(e) $2\left(\frac{h}{\pi}\right)$

(xi) Suppose that the photoelectric threshold frequency in a certain metal lies in the red region of the visible spectrum. Yellow, green, and violet light are all directed at the surface of this metal. Which of these colours will cause electrons to be ejected from the surface?

(a) violet only (b) violet and green only (c) green and yellow only

(d) all yellow, green and violet (e) none of the colours

(xii) A particular quantum system has allowed quantum states with energy $E = n^2$ eV. ($n = 1, 2, 3, ...$) Which of the following energy photons will never be absorbed by the system?

(a) 1 eV (b) 3 eV (c) 5 eV (d) 8 eV (e) 15 eV

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(xiii) K_α - X-ray line of wavelength 0.1641 nm is emitted by a certain metal. What is the value of Z and which element is it? $f^{1/2} = 4.97 \times 10^7 (Z-1)\ \text{Hz}^{1/2}$

(a) 24, Cr (b) 25, Mn (c) 26, Fe (d) 27, Co (e) 28, Ni

(xiv) In a Compton experiment an electron attains kinetic energy of 0.100 MeV when an X – ray of energy 0.500 MeV strikes it. The wavelength of the scattered photon is

(a) 21×10^{-3} Å (b) 31×10^{-3} Å (c) 41×10^{-3} Å (d) 51×10^{-3} Å

(e) 61×10^{-3} Å

(xv) Consider the following statements made about the hydrogen atom and the doubly ionized lithium (Li^{++}) atom. $\left(E_n = -\dfrac{Z^2E_1}{n^2}\right)$

(A) Both could be considered as Bohr atoms.

(B) The energy level diagram of Li^{++} contains all the energy levels of hydrogen plus two extra levels for each hydrogen level.

(C) There are more lines in the optical spectrum of hydrogen than in the optical spectrum of Li^{++}.

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 true