UNIVERSITY OF COLOMBO, SRI LANKA

FACULTY OF SCIENCE

FIRST YEAR EXAMINATION IN SCIENCE - SEMESTER 1 – 2006/2007

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 $c = 3.00\times10^{8}\ \mathrm{ms^{-1}}$; $hc = 12.4\times10^{3}\ \mathrm{eV\,\mathring{A}} = 1240$ eV nm

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

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

Boltzmann's constant $= 1.38\times10^{-23}\ \mathrm{J\,K^{-1}}$

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 the n^{th} state : $E_n = -\dfrac{13.6}{n^2}$ eV

Uncertainty principle : $\Delta x \Delta p \geq \dfrac{h}{4\pi}$; $\Delta E \Delta t \geq \dfrac{h}{4\pi}$

All the symbols have their usual meaning.

1. (i) Light of wavelength $\lambda_1 = 550\,\mathrm{nm}$ incident on a surface causing the ejection of photoelectrons for which the stopping potential $V_{s1} = 0.19\,\mathrm{V}$. Suppose that light of wavelength $\lambda_2 = 190\,\mathrm{nm}$ were incident on the surface, calculate (a) the stopping potential V_{s2}, (b) the work function of the surface, and (c) the threshold frequency of the surface.

   (ii) A photon with $\lambda = 0.5$ nm is moving along the $+x$ axis when it strikes a free electron initially at rest and is scattered so as to move along the $+y$ axis. What are 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) Starting from first principles derive expressions for the following for a hydrogen atom.

   (a) Speed (v_n) of the electron when it is in n^{th} orbit.
   (b) Frequency of the orbital motion of the electron while it is moving in the n^{th} orbit.
   (c) Frequency of the radiation emitted when the electron transits from n^{th} orbit to $(n\text{-}1)^{th}$ orbit.
   (d) Frequency obtained in (c) as $n \to \infty$. Compare and comment on the results obtained in (d) and (b). Is Bohr's correspondence principle justified?

(ii) The average kinetic energy of a particle in a gas at a temperature T is $\frac{3}{2}kT$, where k is the Boltzmann's constant. At what temperature would this be equal to the energy needed to make a transition from the ground state to $n = 2$ state of hydrogen. Hence show that it would be quite difficult to excite the hydrogen atom purely by thermal collision.

3. (i) A particle of mass m is confined to a one dimensional line of length L. From arguments based on the wave interpretation of matter, show that the energy of the particle can have only discrete values and determine these values.

(ii) If Planck constant were $h' = 660$ J s, what would be the de Broglie wavelength of a 100 kg football player running at 5 m s^{-1}. Determine the least uncertainty of his location according to an opposing player, if the uncertainty in his momentum is equal to his momentum.

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(i) The correct expression relating the kinetic energy T of a particle to its rest mass m_0, its momentum p, and the speed of light c, is

(a) $T^2 = p^2c^2 + m_0c^2$ (b) $T^2 + 2Tm_0c^2 = p^2c^2$ (c) $T^2 + Tm_0c^2 = p^2c^2$

(d) $T^2 + m_0c^2 = p^2c^2$ (e) $T^2 = p^2c^2 + (m_0c^2)^2$

(ii) A particle with rest mass of 10^{-31} kg is moving at 0.98c. Its relativistic mass is

(a) 1.01×10^{-31} kg (b) 2.02×10^{-31} kg (c) 5.03×10^{-31} kg

(d) 6.31×10^{-31} kg (e) 7.56×10^{-31} kg

(iii) In order to break a chemical bond in the molecules of human skin, causing sunburn, a photon energy of 3.5 eV is required. To what wavelength does this correspond?

(a) 354 nm (b) 456 nm (c) 546 nm (d) 623 nm (e) 654 nm

(iv) As the speed of a particle approaches the speed of light, its relativistic mass

(a) approaches a constant. (b) increases without bound. (c) approaches zero.

(d) decreases slightly. (e) increases slightly.

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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 work function of sodium metal is 2.3 eV. The longest wavelength of light that can cause photoemission from sodium is

(a) 400 nm (b) 445 nm (c) 500nm (d) 525 nm (e) 539 nm

(vii) 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

(viii) A phenomena that demonstrates that electrons have wave like properties is

(a) black body radiation.

(b) photo electric effect.

(c) Compton scattering.

(d) pair annihilation.

(e) electron diffraction.

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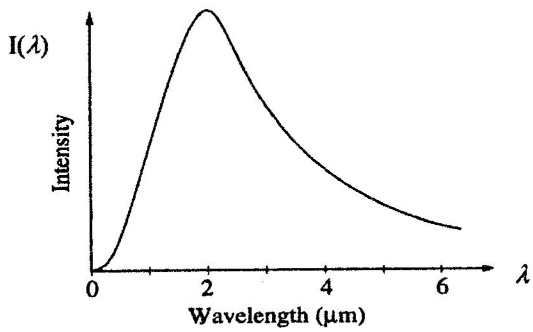

The distribution of relative intensity [I(λ)] of blackbody radiation emitted from a solid object versus the wavelength (λ) is shown in the figure above. If the Wien displacement constant is 2.9×10^{-3} m K, what is the approximate temperature of the object?

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

(x) If the uncertainty in the time during which an electron remains in an excited state is 10^{-7} s, the least uncertainty in the energy of the excited state is

(a) 0.527×10^{-27} J (b) 0.328×10^{-27} J (c) 0.228×10^{-27} J (d) 0.128×10^{-27} J

(e) 0.028×10^{-27} J

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

(a) 1000 fm (b) 1213 fm (c) 1524 fm (d) 2514 nm (e) 3543 nm

(xii) A collimated beam of light of intensity 30 kW m^{-2} is incident normally on an area of 100 mm^2 completely absorbing screen. Pressure exerted on the screen by the beam is

(a) 10^{-4} Pa (b) 10^{-3} Pa (c) 10^{-2} Pa (d) 0.1 Pa (e) 1.0 Pa

(xiii) The momentum transferred by the beam in question (xii) during a 10^3 s time interval is

(a) 10^{-1} kg m s^{-1} (b) 10^{-2} kg m s^{-1} (c) 10^{-3} kg m s^{-1} (d) 10^{-4} kg m s^{-1}

(e) 10^{-5} kg m s^{-1}

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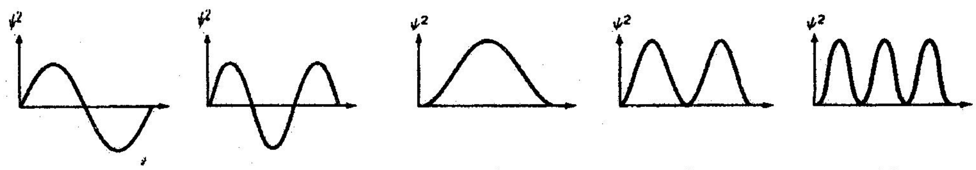
(xiv) A microscopic particle is confined to a box with impenetrable walls. The probability density $\left(\psi^2\right)$ of finding the particle in its ground state is best represented by



(a) (b) (c) (d) (e)

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

(A) Both could be considered as Bohr atoms.

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

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