UNIVERSITY OF COLOMBO, SRI LANKA

FACULTY OF SCIENCE

LEVEL I EXAMINATION IN SCIENCE – SEMESTER I – 2011

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

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

All the symbols have their usual meaning

(1) (i) The radius of our sun is 7.0×10^{5} km and its surface temperature is 5800 K. Assume that the sun behaves like a black body. Calculate the total power radiated from the sun.

(ii) A "blue super-giant" star has a surface temperature of 30,000 K. Assume that the star behaves like a black body.

(a) What is the principal wavelength it radiates? Use your answer to explain why this star appears to be blue.

(b) If the total power radiated by the star is 10^{5} times that of our sun, determine the radius of this star.

(2) (i) Consider Compton scattering with **visible light.** A photon with wavelength 500 nm scatters backward from a free electron initially at rest. What is the fractional shift in wavelength, $\frac{\Delta\lambda}{\lambda}$, for the photon?

(ii) The wavelength of light incident on a surface is reduced from λ_1 to λ_2. (Both λ_1 and λ_2 are less than the threshold wavelength for the surface) When the wavelength is reduced in this way, derive an expression in the change in the stopping potential for photoelectrons emitted from the surface in terms of usual parameters.

(3) Hydrogen atom in its ground state is excited by means of monochromatic radiation of wavelength 972.5 $\overset{0}{A}$.

(a) Determine the state (n value) to which it is excited.

(b) How many different lines are possible in the resulting spectrum?

(c) Calculate the longest wavelength amongst them.

- **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)

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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) According to the photon theory, increasing the brightness of a beam of light without changing its color will increase

(a) the number of photons per second (b) the energy of each photon (c) the photon speed (d) the frequency of each photon (e) the wavelength of each photon

(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) When radiations of wave length λ are incident on a photosensitive surface, the maximum kinetic energy of the photoelectrons emitted from the surface is 2 eV. When the wave length of the incident radiation is changed to 2λ, the maximum kinetic energy of the photoelectrons emitted from the surface is 0.5 eV. The photoelectric work function of the surface and the threshold wavelength for photoelectric emission from the surface are respectively

(a) 0.15 eV, $\lambda/2$ (b) 0.25 eV, λ (c) 0.5 eV, $3\lambda/2$

(d) 0.75 eV, 2λ (e) 1.0 eV, 3λ

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(v) The photon or "particle" theory of electromagnetic radiation is necessary to explain the

(a) refraction of light by a prism.
(b) diffraction of light by a grating.
(c) reflection of light from a mirrored surface.
(d) results of Compton scattering experiments.
(e) interference of light in Young's double-slit experiment.

(vi) A beta particle, gamma ray, and alpha particle all have the same momentum. Which has the longest de Broglie wavelength?

(a) beta particle.
(b) gamma ray.
(c) alpha particle.
(d) all the same.
(e) depends on gamma ray energy.

(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) In the hydrogen spectrum, the ratio of the wavelengths for Lyman - α radiation (n = 2 to n = 1) to Balmer - α radiation (n = 3 to n = 2) is

(a) 5/48 (b) 5/27 (c) 1/3 (d) 3 (e) 27/5

(xii) The ground state energy of positronium atom is most nearly equal to

(a) – 27.8 eV (b) – 13.6 eV (c) – 6.8 eV (d) – 3.4 eV

(e) 13.6 eV

(xiii) The energy required to remove both electrons from the helium atom in its ground state is 79.0 eV. How much energy is required to ionize helium (i.e., to remove one electron)?

(a) 24.6 eV (b) 39.5 eV (c) 51.8 eV (d) 54.4 eV (e) 65.4 eV

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(xiv) Electromagnetic radiation provides a means to probe aspects of the physical universe. Which of the following statements regarding radiation spectra is **NOT** correct?

(a) The wavelengths identified in an absorption spectrum of an element are among those in its emission spectrum.

(b) Lines in the infrared, visible, and ultraviolet regions of the spectrum reveal primarily the nuclear structure of the sample.

(c) Absorption spectra can be used to determine which elements are present in distant stars.

(d) Spectral analysis can be used to identify the composition of galactic dust.

(e) Band spectra are due to molecules.

(xv) A photon of wavelength λ enters a region with free electrons. The **minimum** number of collisions that could result in the photon being completely absorbed is equal to

(a) 1 (b) $\dfrac{\lambda mc}{2h}$ (c) $\dfrac{\lambda mc}{h}$ (d) $\dfrac{2\lambda mc}{h}$ (e) $\dfrac{h}{\lambda mc}$

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