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The Open University of Sri Lanka
Faculty of Natural Sciences
B.Sc/ B. Ed Degree Programme

Department	**: Physics**
Level	**: 4**
Name of the Examination	: Final Examination
Course Title and - Code	**: Modern Physics –PHU4300**
Academic Year	**: 2020/2021**
Date	**: 30/03/2022**
Time	**: 9.30am-11.30am**
Duration	**: 2 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **(6)** questions in **(3)** pages.
3. Answer any **... (4)** questions only. All questions carry equal marks.
4. Answer for each question should commence from a new page.
5. Draw fully labelled diagrams where necessary
6. Involvement in any activity that is considered as an exam offense will lead to punishment
7. Use blue or black ink to answer the questions.
8. Clearly state your index number in your answer script

You may assume that, $c=3\times10^{8}\,ms^{-1}$, $h=6.63\times10^{-34}$ Js, $1eV=1.6\times10^{-19}$ J, $\pi=3.14$, mass of the electron$=9.1\times10^{-31}$ kg, mass of the proton$=1.67\times10^{-27}$ kg, $e=1.6\times10^{-19}$ C,

1. Electrons can be emitted due to the interaction between matter and photons in photo electric effect

   (a) Define the terms (i) photoelectric work function (ii) stopping potential and (iii) Threshold frequency . **(3 marks)**

   (b) A uniform monochromatic beam of light of wavelength 4000 Å falls on a cesium plate having a work function of 2.00 eV. The beam has an intensity of $3\times10^{-9}\,Wm^{-2}$.

   (i) Calculate the corresponding energy of the 4000 Å photon in eV. **(4marks)**

   (ii) Considering the wave-particle duality, calculate the momentum of the photon with the above energy. **(4 marks)**

   (iii) Calculate the number of emitted photoelectrons in a unit time per unit area. **(4 marks)**

   (iv) Find the maximum and minimum values of kinetic energy of the emitted photoelectrons. **(4 marks)**

   (v) Plot the variation of maximum kinetic energy (K_{max}) of emitted electrons when the frequency (f) of incident photons are changed, and mark the threshold frequency (f_o) **(3 marks)**

   (vi) Above light beam falls on a silver plate with a work function of 4.00 eV. Plot the variation of maximum kinetic energy (K_{max}) with frequency (f) on the same Graph and name them. **(3 marks)**

2. (a) Name two non-classical concepts introduced in the Bohr Theory. **(4 marks)**

   (b) In the Bohr model of the hydrogen atom, an electron is orbiting around a proton such that its angular momentum $mvr_n = n\hbar$ (where n is an integer 1,2,3.....)

   (i) Derive the expressions for, the kinetic energy and potential energy of the electron in the r_n th orbit of the hydrogen atom. **(8 marks)**

   (ii) Hence, show that the energy of the electron is given by $E_n = \frac{-me^4}{8\varepsilon_0^2 h^2 n^2}$ **(5 marks)**

   (iii)Derive the expression for the change in energy ,(ΔE),for an electron transitioning between two energy states. **(4 marks)**

   (iv)If the spectral line resulting from the transition E_2 to E_1 is at 122nm, calculate the wavelength of light emitted from the E_3 to E_2 transition. **(4 marks)**

3.

(a) What do you mean by a wave function? State the conditions, which a well-behaved wave function is expected to satisfy. **(3marks)**

(b) A particle limited to the X-axis has the wave function $\psi = ax,\ 0 < x < 1$.and $\psi = 0$ otherwise.

(i) Find the constant "a" **(3marks)**

(ii) Find the probability that the particle can be found between x=0.45 and 0.55. Also find the expectation value of the position of the particle.

(6marks)

(c) The allowed energy levels ,E_n, and the corresponding wave functions ,Ψ_n, of a free particle of mass, m, in a 1-dimensional (x-direction) box of length, l, are given by the following expressions, where h is the Plank constant.

$$E_n = \frac{n^2h^2}{8ml^2} \quad \text{and} \quad \psi_n(x) = \sqrt{\frac{2}{L}}\sin(\frac{n\pi x}{L}) \ \ for\ 0 \le x \le l$$

Draw a graph of E_n (on y-axis) against length (from 0 to l, on x-axis) and mark the appropriate energy levels from E_1 to E_4. At the each energy level, E_n (n=1, 2, 3 and 4), sketch the shape of the correspondingΨ_n, from x=0 to x=l. **(8 marks)**

(d) This particle is excited to higher energy states by interacting it with electromagnetic radiation. Starting from the energy of the particle in the box, derive an expression for the wavelength of radiation emitted when this particle returns to ground state from the second exited state. **(5 marks)**

4. (a) State the Einstein's postulates of special relativity. **(4marks)**

(b) Explain clearly the meaning of length contraction and time dilation in special relativity. **(4 marks)**

(c) Write down the Lorentz transformations with usual notation. **(5 marks)**

(d) The average lifetime of a π meson in its own frame of reference is 26.0 ns. If the π meson moves with speed 0.95c with respect to the Earth,

(i) What is its lifetime as measured by an observer at rest on Earth? **(3marks)**

(ii) What is the average distance it travels before decaying as measured by an observer at rest on Earth? **(3 marks)**

(e) A rod of length 100 m moves with speed 0.6c along the horizontal direction. The rod makes an angle 45^0 with respect to the x$'$ -axis.

(i) Determine the length of the rod as measured by a stationary observer. **(3marks)**

(ii) Determine the angle θ the rod makes with the x axis **(3marks)**

5.

(a) Explain the meaning of the terms "red shift" and "blue shift" as they relate to the relativistic Doppler Effect. **(4marks)**

(b) If an observer directly moving away from a light source of wavelength λ_0 with a relative velocity, v .Write an expression for the wavelength λ measured by the observer. **(4marks)**

(c) Calculating a Doppler shift suppose a galaxy is moving away from Earth at a speed 0.825c. It emits radio waves with a wavelength of 0.525 m. What wavelength would we detect on Earth? **(6marks)**

(d) Consider S and S$'$ are two observers. Observer S$'$ is moving at uniform velocity v in the positive X- direction relative to S. An object is moving with velocity component U_x' in the frame of reference S$'$, and U_x is the corresponding velocity component according to S, and c is the velocity of light.
Obtain an expression for U_x, Using the Lorentz transformations equations. **(6marks)**

(e) A stationary observer on Earth observes spaceships A and B moving in the same direction toward the Earth. Spaceship A has speed 0.5c and spaceship B has speed 0.80c.
Determine the velocity of spaceship A as measured by an observer at rest in spaceship B. **(5marks)**

6.

(a) If a particle of mass m moves with a speed v, write down the relativistic expression for the mass m in terms of its rest mass m_o, its speed v and the velocity of light c. **(3 marks)**

(b) Using the relativistic expression for mass, show that the kinetic energy of a particle , E_k , is given by $E_k = m_0c^2(\gamma - 1)$
Here the symbols have their usual meaning. **(8 marks)**

(c) A cosmic-ray proton is moving 3.8×10^5 km distance at certain speed in 1.5 s.
(i) At what fraction of the speed of light is the proton moving? **(5 marks)**
(ii) What is its kinetic energy? **(5 marks)**

(d) Calculate the uncertainty of the position of a particle of mass 1.00 mg travelling with an uncertainty of 0.01% of the speed of light. **(4 marks)**