00328

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	**: 2024/2025**
Date	**: 17/05/2025**
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 **(4)** 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

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c=3x10^8 ms^{-1}, h= 6.63x10^{-34} Js, 1eV=1.6x10^{-19} J, π=3.14, mass of the electron=9.1x10^{-31} kg, mass of the proton=1.67x10^{-27} kg.

1. A.

(i) An X-ray photon of wavelength λ recoils (Compton scatters) with increased wavelength λ' from a stationary electron of mass m and at an angle φ with respect to its initial direction. Show that the change in wavelength is $\lambda' - \lambda = \frac{h}{mc}(1 - \cos\phi)$

(6 marks)

(ii) A beam of x-rays of wavelength 0.2 nm is incident on a free electron and gets scattered in a direction with respect to the direction of the incident radiation resulting in a maximum wavelength shift. Find the percentage energy loss of the incident radiation.

(8 marks)

B.

Consider the experiment of photoelectric effect. Define the term of "work function."

(3 marks)

Electrons are ejected from a metallic surface with speeds ranging up to 4.6x10^5 ms^{-1} when light with a wavelength of 625 nm is used.

(i) What is the work function of the metallic surface? **(4 marks)**

(ii) What is the cut-off frequency for this metallic surface? **(4 marks)**

2. A.

Write down the Bohr postulates for the atomic model. **(4 marks)**

In the Bohr model of the hydrogen atom, an electron is orbiting around a proton such that its non-relativistic velocity v_n, and its radius of orbit is r_n

(i) Show that radius of any orbit is $r_n = \frac{n^2\hbar^2}{mk_e e^2}$ (where $k_e = \frac{1}{4\pi\epsilon_0}$ =8.9x10^9 Nm^{2}C^{-2})

(4 marks)

(ii) What is meant by Bohr radius of the hydrogen atom? , and show that Bohr radius is given as $a_0 = \frac{\hbar^2}{mk_e e^2}$ **(5 marks)**

(iii) If the total energy of the atom E is given by $E = -k_e\frac{e^2}{2r}$, show that the energy of the electron in the hydrogen atom is given by $E_n = \frac{-1}{n^2}\frac{k_e e^2}{2a_0}$ **(5 marks)**

(iv) Calculate the binding energy of the hydrogen atom using the above results. **(5 marks)**

(B) Explain what is meant by the Balmer series of Hydrogen by illustrating the corresponding lines in a EM spectrum. **(2 marks)**

3. An electron with energy E is incident on a potential step with height $U_0 > E$.
The situation may be described by the 1-D time independent Schrödinger equation

$$-\frac{\hbar^2}{2m}\frac{d^2\psi(x)}{dx^2}+U(x)\psi(x)=E\psi(x)$$

with potential

$$U(x)=\begin{cases} 0 & for\ x<0 \\ U_0 & for\ x\geq 0 \end{cases}$$

(i) If the wave function in the region $x < 0$ is $\Psi_1(x) = Ae^{ikx} + Be^{ikx}$,
, determine the value of k using the Schrödinger equation. **(5 marks)**

(ii) If the wave function in the region $x \geq 0$ is $\Psi_2(x) = Ce^{-\alpha x}$,
, determine the value of α using the Schrödinger equation. **(5 marks)**

(iii) Write down the boundary conditions at x=0 **(2 marks)**

(iv) Using the boundary conditions mentioned in part (iii) ,show that

$$\frac{A}{B}=\frac{(ik-\alpha)}{(ik+\alpha)}$$ **(5 marks)**

(v) Write down the wave function for the incident wave (Assume that A is known)
(4 marks)

(vi) Find the position probability of the incident wave. **(4 marks)**

4. (i) Write down the Lorentz transformation equations. Using these equations derive expression for (a) length contraction and (b) time dilation.
(12 marks)

(ii) What is meant by the "simultaneous events"? **(2 marks)**

(iii) The space -time coordinates of two events as measured by an observer O are given as $(x_1,0,0,t_1)$ and $(x_2,0,0,t_2)$. Show that the velocity ,v, of the observer O′ with respect to observer O, if O′ measures the two events to occur simultaneously as,

$$v=\frac{c^2(t_2-t_1)}{x_2-x_1}$$

(6 marks)

(iv) According to observer O, a blue flash occurs at x_b=10.4 m when t_b=0.124 μs, and a red flash occurs at x_r=23.6 m when t_r=0.138 μs. According to observer O', who is in motion relative to O at velocity v, the two flashes appear to be simultaneous.
Find the velocity ,v **(5 marks)**

5. (i) Explain the meaning of the terms "red shift "and "blue shift" related to the Doppler effects in light. **(5 marks)**

(ii) 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.

(4 marks)

(iii) Consider S and S$^{/}$ as two observers. Observer S$^{/}$ is moving at uniform velocity v in the positive X- direction relative to S. An object is moving with a 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. Use Lorentz transformation to show that,

$$U_x^{/} = \frac{U_x - v}{1 - \frac{U_x v}{c^2}}$$

(6 marks)

(iv) A man in a spaceship moving with a speed $0.6c$ away from a space platform shines a light of wavelength 5000Å towards the platform.

(a) What is the wavelength of the light as seen by an observer on the platform? **(5 marks)**

(b) What is the wavelength of the light as seen by a passenger in a second spaceship of 0.8c relative to the space platform? **(5 marks)**

6. (i) Write down the relativistic expression for the mass m of a particle with rest mass m_0, moving at a speed v in terms of m_0, v and velocity of light c. **(2 marks)**

(ii) 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. **(6 marks)**

(iii) If P and E are the momentum and energy of the particle, show that.
$E^2 = p^2c^2 + m_0^2c^4$ **(6 marks)**

(iv) A particle of rest mass $2m$ moving along x-axis with velocity v collides with a particle of rest mass m moving along x-axis with velocity $-v$.

If the two particles join together, show that the rest mass $m^{/}$ of the resulting particle will have the value.

$$m^{/} = m\sqrt{\frac{9c^2 - v^2}{c^2 - v^2}}$$ **(6 marks)**

(v) Find the classical limit for the mass of the resulting particle. **(5 marks)**