B.Sc. 4th Semester (Honours) Examination, 2022 (CBCS)
Subject: Physics
Paper: CC-IX
(Elements of Modern Physics)

Time: 2 Hours **Full Marks: 40**

The figures in the margin indicate full marks.
Candidates are required to give their answers in their own word as far as practicable.

Group-A

1. Answer any *five* questions from the following: **2×5=10**

(a) Calculate in MeV the kinetic energy of a proton having de -Broglie wavelength of 1 fm. (Given: rest energy of a proton = 938 MeV. h=6.626x10^{-34}J-s)

(b) Show that the probability current density for a free particle is equal to the product of its probability density and its speed.

(c) Show that pair- production cannot occur in empty space.

(d) Find the Spin and parity of the ground state of (i) $^{11}_{5}B$ and (ii) $^{33}_{16}S$ nucleus according to the nuclear shell model (including spin-orbit coupling).

(e) In a He-Ne laser transition from 3S to 2P level gives a laser emission of wavelength 632.8 nm. If the 2P level has energy equal to 15.2 x 10^{-19} J. Calculate the pumping energy(ev) required . Assume no loss. (h=6.626x10^{-34}J-s)

(f) Draw graphs showing the experimental observation on photoelectric current against accelerating potential/ retarding potential for light having the same frequency ν but three different intensities I_1 , I_2 , I_3 ($I_1 > I_2 > I_3$). Explain that the observations depicted in your graphs cannot be explained by the classical wave theory of light but can be explained by the quantum theory of light.

(g) The wave function for a particle moving along the positive X-direction is given by $\Psi(x,t) = Ae^{\frac{i}{\hbar}(p_x x - Et)}$.(Symbols have their usual meanings).Using this derive an expression for momentum and kinetic energy operator in one dimension.

(h) Explain the function of moderator in Uranium fed nuclear reactors.

Group-B

2. Answer any two of the following questions: **5x2=10**

(a). *The wave function for the ground state of a particle confined to a one-dimensional box with boundaries at*

X = 0 and x = L is given by $\psi(x) = \sqrt{\frac{2}{L}}\, Sin\frac{\pi x}{L}$ $\quad 0 \le x \le L$

$= 0 \quad$ *for* $x < 0$ *and* $x > L$

(i) Calculate the uncertainties in position (Δx) and momentum (Δp) in this state. (ii) Show the validity of the uncertainty relation in the state.

2+2+1

(b) Draw the $u(\lambda)$ vs λ curves schematically for two temperatures T_1 , T_2 ($T_1 > T_2$) where $u(\lambda)\, d\lambda$ is the energy density of blackbody radiation in the range of wavelength between λ , $\lambda + d\lambda$. Under what condition does Plank's law reduce to the Rayleigh-Jeans law? Draw the Rayleigh- Jeans distribution curve on the same diagram at T_2 . What is Ultraviolet catastrophe?

1+2+1+1

(c) (i)Define Phase velocity (v_p) and group velocity (v_g) of a wave packet. (ii) Show that the de-Broglie wave group associated with a moving relativistic particle travels with the same velocity as that of the particle.
(iii)Hence by using relativistic expression derive the de-Broglie's relation .

$(1+1) + 1\frac{1}{2} + 1\frac{1}{2}$

(d) Give the statement of Heisenberg's Uncertainty principle for position and momentum measurement. Show how the gamma ray microscope thought experiment validates the principle.

1+4

Group-C

3. Answer any two of the following questions: **10x2=20**

(a) (i) An incident X-ray photon of frequency ν is scattered by a free electron at rest through an angle θ. Using relativistic expression of electron energy Show that the change in wavelength of the photon is given by

$\Delta\lambda = \frac{h}{m_0 c}(1 - \cos\theta)$ where m_0 is the rest mass of the electron.

(ii) Find the ratio of incident frequency to scattered frequency in terms of α where α = ratio of incident photon energy to electron's rest energy.

7+3

(b) Consider a particle of energy $E < V_0$ moving from left to right towards a region having a rectangular potential barrier of height V_0 represented by the equations

$$V = 0 \quad \text{for} \quad -\infty < x < 0$$
$$V = V_0 \quad \text{for} \quad 0 < x < L$$

$V=0 \quad \text{for} \qquad L < x < \infty$

(i) Write the Schrodinger wave equations and its physically acceptable solution in the three regions and also mention the boundary conditions of the problem.

(ii) Use the equations to work out the transmission coefficient for $E< V_0$.

(iii) What is quantum mechanical tunneling ? 3+5+2

(c) (i) Using the liquid drop model find the most stable isobar for a given odd A (mass number) and for A= 25 ,43, 77 find also the most stable nuclei. (Co- efficients are b_1 = 14 MeV, b_2 = 13 MeV, b_3 =0.58MeV,b_4 = 19.3MeV.)

(ii)Assuming that protons and neutrons possess equal masses, Calculate how many times nuclear matter is denser than water if nuclear radius is given by $1.2 \times 10^{-15} A^{1/3}$m. Where A is the mass number. (Mass of neutron = 1.008u., 1 u = 1.66×10^{-27}kg.)

(iii) What are the magic number nuclei? . (3+3)+3+1

(d) (i) Discuss the energy spectrum curve of β - decay from a radioactive nuclide. Discuss how the neutrino hypothesis explains the energy, momentum and angular momentum conservation in β - decay.

(ii) *A radio active source contains two radio isotopes each with initial activity $10^3 \ln 2$ Bq.(1 Bq =1 decay per sec.)The half life of one of the radio isotopes is 1 hour and that of the other is 2 hours.Calculate the total number of radio active nuclei present initially in the radio active source.*

2+5 + 3