বিদ্যাসাগর বিশ্ববিদ্যালয়

VIDYASAGAR UNIVERSITY

Question Paper

B.Sc. Honours Examinations 2022

(Under CBCS Pattern)

Semester - IV

Subject : PHYSICS

Paper : C 9 - T

Elements of Modern Physics

Full Marks : 40

Time : 2 Hours

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

Group - A

Answer any ***four*** questions : 5×4=20

1. What is Hermitian operator? Prove that the eigenvalues of Hermitian operators are real. If $\hat{\alpha}$ and $\hat{\beta}$ are two Hermitian operators prove that $\left(\hat{\alpha}\hat{\beta}\right)^{\dagger} = \hat{\beta}^{\dagger}\hat{\alpha}^{\dagger}$. 1+2+2=5

2. A wave packet is formed by superposition of two harmonic waves of frequencies ω and $\omega + d\omega$ and propagation vectors k and $k + dk$. Find the extension Δx of the wave packet and hence obtain the uncertainty principle of position-momentum conjugate pair. What happens to the extension Δx, if there is superposition of infinite number of waves having continuous distribution of wavelengths. 2+2+1

3. (a) Find the ground state energy of a linear harmonic oscillator applying Heisenberg Uncertainty Principle.

   (b) Why is the Compton shift not visible in ordinary light?

   (c) Define quantum yield of a photoelectric phenomenon. 2+2+1

4. Non-normalized wavefunction of a particle in one dimensional infinitely deep potential well of length L is $\psi(x) = A\sin\left(\frac{n\pi x}{L}\right)$.

   (a) Normalize it and check the orthogonality of the wave function. 2+1

   (b) Find the most probable positions of the particle for $n = 1$ and $n = 2$ states. 1+1

5. (a) If U-236 nucleus is fissioned by a neutron, two fission fragments of mass numbers 96 and 138, and two neutrons are obtained. If the masses of the nuclei and neutron are 235.1175, 95.9385, 137.9487 and 1.00898 amu, calculate the amount of energy released.

   (b) An X-ray photon of wavelength 0.1Aº is reflected at an angle 90º with its original direction after collision with an electron at rest. Find the energy it loses on collision. 3+2=5

6. (a) What do you mean by Einstein's A, B coefficients? Show that $\frac{A_{nm}}{B_{nm}} = 8\pi h\nu^3 / c^3$, where the symbols have their usual meanings. 3

   (b) The spot size of a gas laser beam is 0.5 mm and the wavelength is 6330Å. If the laser cavity is of confocal type, calculate its length. 2

Group - B

Answer any ***two*** questions : 10×2=20

7. (a) What do you mean by ''photoelectric effect''? Ultraviolet light of wavelength 350nm and intensity 1.00 W/m^2 is directed at a potassium surface. Find the maximum KE of the photoelectrons.

   (b) What is radioactivity? Define the decay constant λ of a radioactive material. Hence obtain an expression for the number of radioactive atoms at time t, given that their initial number was N_0. Define half-life of a radioactive element. (2+2)+(1+1+3+1)=10

8. (a) Explain the need for a wave equation to describe the behavior of a quantum system. Discuss the required characteristics of such a wave equation.

(b) Starting from the de Broglie's hypothesis, set up the one dimensional Schrodinger wave equation for a free particle. How it is modified if the particle is under the influence of a potential field?

(c) Determine the probability density and the probability current density for a wave function given by (at $t = 0$) $\psi(x) = A\exp\left(-\sigma^2 x^2/2\right)\exp(ikx)$.

(1+2)+(3+1)+3=10

9. (a) Verify Heisenberg Uncertainty Principle through gamma-ray thought experiment. Can this experiment be done with visible light? Expain. 4+2

(b) Write de Broglie's relation. Distinguish between macroscopic regime where classical Newton's law of motion is applied and microscopic regime where quantum mechanics to be applied in terms of de Broglie wavelength and dimension of the moving particle. 2

(c) Establish Bohr's angular momentum quantization condition using de Broglie's relation. 2

10. (a) Explain the non-existence of electron in a nucleus from Heisenberg's Uncertainty Principle. (H.U.P.) 2

(b) If the expectation value of the momentum is <p> for the wavefunction $\psi(x)$, then what will be the expectation value of momentum for the wavefunction $e^{jkx/\hbar}\psi(x)$. 2

(c) Evaluate the commutation relations $\left[\hat{x}, \hat{p}_x\right]$ and $\left[\hat{x}, \hat{p}_y\right]$. Hence write the pair of components of position-momentum commutation relations in terms of Kronecker delta. Have you got any connection of these results with H.U.P.? 3

(d) Deduce expression for probability current density. Give its physical interpretation. 3