

Five Year Integrated M.Sc. Examination, 2019

Semester - IV

Course: PH-2-4-1(New)

(Quantum Mechanics and Relativity)

Time: Three Hours

Full Marks: 60

Questions are of value as indicated in the margin.

Answer **Question No.1** and **any five** from the rest.

1. Answer **any five** from the following: 5x2=10
 - a) A beam of electrons bombards a sample of hydrogen. Through what potential difference must the electrons be accelerated if the first line of the Balmer series is to be emitted? Given: Rydberg constant $= 1.097 \times 10^7 \text{ m}^{-1}$.
 - b) A photon of energy 110 keV suffers 10% change in wavelength on being scattered by a stationary free electron. Find the kinetic energy of the recoil electron. Given: $h = 6.62 \times 10^{-34} \text{ J s}$.
 - c) Wavelengths can be determined with accuracies of one part in 10^6 . What is the uncertainty in the position of a $1 \text{ \AA}$ X-ray photon when its wavelength is simultaneously measured?
 - d) Thermal neutrons in equilibrium with matter at 300 K have average energies of about $1/25 \text{ eV}$. Find their de Broglie wavelength.
 - e) Show that one-dimensional position and momentum operators do not commute with each other.
 - f) What is the physical significance of the wave function $\Psi(x)$?
 - g) Write down Einstein's postulates of special theory of relativity.
 2.
 - a) What do you mean by blackbody radiation?
 - b) Derive Planck's radiation formula and show it graphically for two different temperatures. 3+7=10
 3.
 - a) Give an account of Bohr's theory of the spectra of hydrogen-like atoms, stating the postulates clearly (with energy diagram).
 - b) The total energy of the electron in the ground state of hydrogen atom is negative. Why?
 - c) Write and explain Bohr's correspondence principle.
 - d) Briefly discuss the failure of Bohr's theory. 4+1+4+1 = 10
 4.
 - a) Explain Compton effect and find an expression for the Compton shift.
 - b) A beam of X-rays is scattered by free electrons. At an angle of 45° from the beam direction, the scattered X-rays have a wavelength of $0.022 \text{ \AA}$. What is the wavelength of X-rays in the direct beam? Given: $m_e = 9.1 \times 10^{-31} \text{ kg}$. 7+3 = 10
 5.
 - a) Write de Broglie hypothesis.
 - b) Explain the statement "a moving body must be regarded as a de Broglie wave packet rather than as a localized entity".
 - c) Discuss an experiment to verify de Broglie hypothesis. 1+3+6 = 10
 6.
 - a) Calculate the commutator $\left[x^2, -i\hbar \frac{\partial}{\partial x} \right]$.
 - b) Starting from free particle wave function, derive one-dimensional Schrödinger equation (both time-dependent and time-independent) in presence of a potential. 3+7 = 10
 7.
 - a) Discuss and explain Michelson-Morley experiment.
 - b) On the basis of Lorentz transformation equations, explain what is meant by length contraction. 7+3 = 10
 8.
 - a) Derive the relativistic law of the variation of mass of an object with its velocity.
 - b) A μ meson decays into an electron in an average time $2 \text{ } \mu\text{s}$. They are created about 10 km up in the atmosphere by fast cosmic ray particles from space and reach sea level with a velocity $0.998c$. Explain how they reach sea level. 6+4 = 10
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