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Total Pages : 5

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May-2026

B.Sc. Physics IV SEMESTER

Elements of Modern Physics (BPH-402A)

Time: 3 Hours]

[Max. Marks : 75

Instructions :

1. *It is compulsory to answer all the questions (1.5 marks each) of Part-A in short.*
2. *Answer any four questions from Part-B in detail.*
3. *Different sub-parts of a question are to be attempted adjacent to each other.*
4. Take h = 6.626×10^{-34} Js, m = 9.11×10^{-31} kg.

PART—A

1. (a) An electron is accelerated through a potential difference of 150 V. Calculate its de Broglie wavelength. (1.5)

   (b) State Heisenberg's uncertainty principle and explain its physical significance. (1.5)

   (c) What is the Compton effect, and what does it reveal about the nature of light? (1.5)

(d) Define work function. How does it affect the emission of electrons in the photoelectric effect? (1.5)

(e) What is a wave function in quantum mechanics, and what is its physical interpretation? (1.5)

(f) What are eigenvalues and eigenfunctions in the context of the Schrödinger equation? (1.5)

(g) What is the difference between spontaneous emission and stimulated emission? (1.5)

(h) Explain the concept of binding energy of a nucleus. Why is it important for nuclear stability? (1.5)

(i) A radioactive sample has a half-life of 5 days. If the initial number of nuclei is $N_o=10^{-6}$, calculate the decay constant and the number of nuclei remaining after 15 days. (1.5)

(j) What is the significance of the Bohr radius in atomic physics? (1.5)

PART—B

2. (a) State and explain the time-energy uncertainty principle. Using it, estimate the lifetime of an excited atomic state with an energy uncertainty of 2 eV. (6)

(b) Derive the time-independent Schrödinger equation and explain the physical significance of the wave function. (6)

(c) An electron is confined in a one-dimensional box of length 0.5 nm. Calculate the energy difference between the first excited state and the ground state. (3)

3. (a) What is LASER? Discuss spontaneous emission and stimulated emission, and explain why population inversion is necessary for laser operation. (6)

(b) Explain the gamma-ray microscope thought experiment in reference to the development of the uncertainty principle. (6)

(c) Calculate the binding energy in MeV per nucleon for $_5B^{10}$ with mass number 0.0161 a.m.u. Given that mass of a proton is 1.0081 a.m.u. and mass of a neutron is 1.008 a.m.u. (3)

4. (a) Explain quantum tunneling and derive the expression for the transmission coefficient for a rectangular potential barrier. (5)

(b) Explain the photoelectric effect on the basis of quantum theory of light. Discuss the dependence of kinetic energy of emitted electrons on frequency and intensity. (5)

(c) A particle is confined in a one-dimensional box of length 2×10^{-10} m. Calculate : (i) Ground state

energy. (ii) Energy difference between first and second states. (iii) Wavelength of radiation emitted during transition from n = 2 to n = 1. (5)

5. (a) Discuss the Liquid Drop Model of the nucleus. Derive the semi-empirical mass formula and explain the physical significance of its terms. (5)

(b) An electron is localized within a nucleus of radius 10^{-15} m. Using uncertainty principle, estimate its minimum kinetic energy and comment whether the electron can exist inside the nucleus. (5)

(c) The binding energy per nucleon of a nucleus is 8.5 MeV and its mass number is 120. Calculate total binding energy. Also estimate energy released if the nucleus splits into two equal fragments each having binding energy per nucleon of 8.7 MeV. (5)

6. (a) Describe the semi-empirical mass formula. Using this, explain how nuclear binding energy varies with mass number. (5)

(b) Derive the relation between group velocity and phase velocity of a wave packet. Show that the group velocity corresponds to the particle velocity. (5)

(c) In a two-slit interference experiment; compare the behaviour of photons, electrons, and atoms. (5)

7. Write short notes on :

(a) Davisson Germer Experiment.

(b) Nuclear Fission reactor.

(c) Beta decay. (3×5=15)