**Name:**

**Enrolment No:**

**UPES**

**End Semester Examination, December 2024**

**Programme Name : B.Sc. Physics (Hons. and Research)** **Semester : III**

**Course Name : Elements of Modern Physics** **Time : 3 hrs**

**Course Code : PHYS 2026** **Max. Marks: 100**

**Nos. of page(s) : 2**

**Instructions:**

1) Scientific calculators are allowed during exams.
2) Values of constants are given at the end of the question paper.

**SECTION A**

**All questions are compulsory**

| S. No. | | Marks | CO |
|---|---|---|---|
| Q1 | Elaborate the relevance of phase and group velocity in the context of quantum mechanics. | **4** | **CO1** |
| Q2 | Which among a proton and deuteron will have longer wavelength if they are having equal kinetic energy? | **4** | **CO2** |
| Q3 | Explain the nuclear fission and fusion processes. | **4** | **CO1** |
| Q4 | Calculate the ratio of densities between a Chlorine ($^{35}_{17}Cl$) and a Helium ($^{4}_{2}He$) nucleus. Given: 1 a.m.u=1.66×$10^{-27}$ Kg/u. | **4** | **CO3** |
| Q5 | Can we determine the exact diameter of a very thin wire (around ≈ 100μm thick) using white light? Elaborate your opinion. | **4** | **CO3** |

**SECTION B**

**Q6, Q7 and Q8 are compulsory. There is an internal choice in Q9.**

| | | | |
|---|---|---|---|
| Q6 | Discuss the context of Heisenberg uncertainty principle in quantum mechanics. Discuss how the verification of Heisenberg uncertainty principle can be carried out using a Gamma ray microscopy. | **10** | **CO2** |
| Q7 | Assume a particle is define by the wavefunction $\varphi\,(x,t) = \sqrt{\frac{8}{L}}\,e^{ikx}$ in the region $0 \leq x \leq 2L$. Find the expectation value of position and momentum. | **10** | **CO3** |
| Q8 | Define the range of the α-particle. Explain Gamow's theory of alpha decay with the necessary diagram. | **10** | **CO2** |
| Q9 | Describe the construction of a pulsed laser with a neat diagram and explain its working with the help of an energy level diagram.<br>**OR**<br>(a) Discuss absorption and emission process in case of LASER system.<br>(b) Considering a two-level system in thermal equilibrium having transition wavelength 6200 Å, estimate the ratio of population in these levels at 600K.<br>**(4+6)** | **10** | **CO1** |

| SECTION-C<br>Q10 is compulsory. There is an internal choice in Q11. | | | |
|---|---|---|---|
| Q10 | (a) Establish a relation between the half-life time and mean lifetime after properly defining them.<br>(b) The half-life period of Radium is 168 years. After how many years will one gram of the pure element<br>i. be reduced to 10 milligram<br>ii. loose one centigram<br><br>(b) What is nuclear binding energy? The binding energy of the neon isotope $^{20}_{10}Ne$ is 160.647 MeV. Find its atomic mass. The mass for proton and neutron is given by 1.007825 and 1.008665 a.m.u respectively and 1 a.m.u =931.49 MeV. **(4+6)** | **20** | **CO3** |
| Q11 | (a) Elaborate wave-particle duality. Illustrate how the existence of matter waves was verified experimentally. **(3+7)**<br>(b) A photon of energy $E$ is scattered by an electron initially at rest (rest mass energy,$E_0$) (Compton scattering problem). Show that the maximum kinetic energy ($KE_{max}$) of the recoil electron can be calculated as<br>$KE_{max} = \frac{2E^2/E_0}{\left(1+ 2E/E_0\right)}$ **(10)**<br>**OR**<br>(a) Evaluate the normalized wavefunction of 1st excited state for a free electron in a one-dimensional infinite potential well of dimension L. **(10)**<br>(b) A free electron is inside potential in two-dimensional box is given as<br>$V = \begin{cases} 0 \; for \; 0 \le x \le 2L, 0 \le y \le L \\ \infty \; for \; x < 0, y < 0 \; , x > 2L \; and \; y > L \end{cases}$<br>Find the energy and wave function of the first three states. **(10)** | **20** | **CO4** |

| Constant | Standard Values |
|---|---|
| Planck's Constant ($h$) | $6.63 \times 10^{-34}$ J. s |
| Permittivity of free space ($\varepsilon_0$) | $8.85 \times 10^{-12} \; Fm^{-1}$ |
| Velocity of light ($c$) | $3 \times 10^{8} \; ms^{-1}$ |
| Boltzmann constant ($k_B$) | $1.38 \times 10^{-23}$ JK$^{-1}$ |
| Rest mass of an Electron ($m_o$) | $9.11 \times 10^{-31}$ kg |
| Mass of the proton ($m_p$) | $1.67 \times 10^{-27}$kg |
| Charge of an electron ($e$) | $1.6 \times 10^{-19}$ C |