# Model Question Paper

USN | | | | | | | | | | |

**Course Code: 1BPHYS102**

**First Semester B.E. Degree Examination, January 2025**
**Quantum Physics and Applications (CSE Stream)**

**TIME:3 hrs.** **Max.Marks:100**

***Note: 1. Answer any FIVE full questions, choosing ONE question from each MODULE***
***2. VTU Formula Hand Books Permitted***
***3. M: Marks, L: Bloom's level,C: Course outcomes.***

| | | **Module-1** | **M** | **L** | **C** |
|---|---|---|---|---|---|
| **Q.1** | **a** | Use the time-independent Schrödinger wave equation for the particle in an infinite well to arrive at an expression for the eigenvalues and eigen functions. | 8 | L2 | CO1 |
| | **b** | Discuss Heisenberg's uncertainty principle and state the three relationships. Use the energy-time uncertainty to explain the broadening of spectral lines. | 8 | L2 | CO1 |
| | **c** | Calculate the change in the de Broglie wavelength of an electron decelerated through a potential difference of 1 kV from 5 kV to 4 kV. | 4 | L3 | CO1 |
| | | **OR** | | | |
| **Q.2** | **a** | Use the classical wave equation to arrive at an expression for the time independent Schrodinger equation. | 7 | L2 | CO1 |
| | **b** | Discuss the principle of complementarity and physical significance of a wave function. | 8 | L2 | CO1 |
| | **c** | Calculate first three energy eigen values in an one-dimensional infinite well of width 1 nm. | 5 | L3 | CO1 |
| | | **Module–2** | | | |
| **Q.3** | **a** | Explain the Failure of Classical free electron theory of metals and the Assumptions of Quantum free electron theory. | 8 | L2 | CO2 |
| | **b** | Derive an expression for the electron carrier concentration in an intrinsic semiconductor at temperature T in the low temperature limit. | 8 | L2 | CO2 |
| | **c** | Calculate the probability of an electron occupying an energy level 0.02eV below the Fermi level at 400K. | 4 | L3 | CO2 |
| | | **OR** | | | |
| **Q.4** | **a** | Prove that the Fermi energy in an intrinsic semiconductor at finite temperature differs from its value at T =0 K by a value proportional to the temperature. | 7 | L2 | CO2 |
| | **b** | With a neat labeled diagram, derive an expression for the Hall voltage and its applications. | 8 | L2 | CO2 |
| | **c** | A semiconductor sample 0.5 mm thick carries a current of 5 mA in a magnetic field of 0.2 T. If the Hall voltage is 1 mV, determine the Hall coefficient. | 5 | L3 | CO2 |
| | | **Module–3** | | | |
| **Q.5** | **a** | With the help of a diagram, explain the concept of Cooper pair tunneling process and retro-reflection at N-S interface. | 8 | L2 | CO3 |
| | **b** | Explain Josephson Junction with a diagram. What is flux quantization ? Explain DC & AC Josephson effect. | 8 | L2 | CO3 |

| | | | | | |
|---|---|---|---|---|---|
| | **c** | A superconducting wire of radius 0.25 mm carries a persistent current in a magnetic field of 0.05 T. Calculate the critical current. | 4 | L3 | CO3 |
| **OR** | | | | | |
| **Q.6** | **a** | What are phonons? Explain the role of phonons in Cooper pair formation. | 7 | L2 | CO3 |
| | **b** | Distinguish between Type I and Type II superconductors using M–H characteristics. | 8 | L2 | CO3 |
| | **c** | For a superconducting sample with critical temperature 7.2 K and critical field at 0K is $6.5\times10^{4}$ $Am^{-1}$, find the critical field at 4 K | 5 | L3 | CO3 |
| **Module-4** | | | | | |
| **Q.7** | **a** | Derive an expression for the numerical aperture and acceptance angle of an optical fibre, with the help of a neat labeled diagram. | 8 | L2 | CO4 |
| | **b** | Explain the working of a SNSPD with a neat diagram. | 7 | L2 | CO4 |
| | **c** | A fiber has a core refractive index of 1.48 and a cladding index of 1.46. Calculate its numerical aperture (NA) and acceptance angle in air. | 5 | L3 | CO4 |
| **OR** | | | | | |
| **Q.8** | **a** | Explain the principle and working of a Single Photon Avalanche Diode. | 8 | L2 | CO4 |
| | **b** | Derive an expression for the energy density using Einstein's A and B coefficients. | 7 | L2 | CO4 |
| | **c** | Calculate the V-number and number of modes supported by an optical fiber of core radius 25 μm, operating at wavelength 1.3 μm with NA = 0.2. | 5 | L3 | CO4 |
| **Module–5** | | | | | |
| **Q.9** | **a** | Define a qubit. Explain the concept of superposition and represent it on the Bloch sphere. | 7 | L2 | CO5 |
| | **b** | Explain quantum entanglement and discuss its importance in quantum communication. | 7 | L2 | CO5 |
| | **c** | A quantum state is given by $\|\psi\rangle = (1/\sqrt{3})\|0\rangle + (\sqrt{2}/\sqrt{3})\|1\rangle$.<br>Calculate the probability of obtaining $\|1\rangle$ and the expectation value of $\sigma_z$. | 6 | L3 | CO5 |
| **OR** | | | | | |
| **Q.10** | **a** | Explain the Hadamard gate with its matrix representation and show its action on $\|0\rangle$ and $\|1\rangle$ states. | 7 | L2 | CO5 |
| | **b** | Discuss the operation of the CNOT gate and explain how it can create Bell states. | 7 | L2 | CO5 |
| | **c** | A two-qubit system is initially in the state $\|00\rangle$. It passes through a Hadamard gate on the first qubit followed by a CNOT gate. Determine the final state vector. | 6 | L3 | CO5 |

********