



DEPARTMENT OF PHYSICS AND RESEARCH CENTR **(VTU-RC)**

QUANTUM PHYSICS AND APPLICAIONS 1BPHYS102/202, QUIZ COMPUTATION

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MODULE-1: QUANTUM MECHANICS

Two-Mark Questions

1. State de Broglie hypothesis.
2. Write Heisenberg's uncertainty principle.
3. What is the principle of complementarity?
4. Define wave function.
5. State Born interpretation of wave function.

Three-Mark Questions

1. Explain the physical significance of wave function.
2. Write Schrödinger time-independent wave equation and explain the terms.
3. What are expectation values? Explain their significance.
4. Explain eigen functions and eigen values.
5. Distinguish between classical and quantum particle behavior.

Four-Mark Questions

1. Explain the wave particle dualism
2. Explain Bohr's Complementarity principle
- 3.

Five-Mark Questions

1. Derive the energy eigen values of a particle in a one-dimensional infinite potential well.
2. Explain Heisenberg's uncertainty principle and apply it to spectral line broadening.
3. Explain quantum tunneling with suitable examples.
4. Discuss normalization of wave function and its necessity.
5. Explain particle in a finite potential well (qualitative).

Six -Mark Questions

1. State and explain the de Broglie hypothesis
2. Explain the physical significance of a wave function (Probability Density) and Born interpretation
3. Explain expectation value and its physical significance
4. Describe the Eigen functions and Eigen Values.
5. Explain the operators and the normalization condition
6. Describe the expectation value of position, momentum, energy and its physical significance
7. Explain the concept of quantum tunneling and list its applications in devices

SEVEN MARKS

1. Explain de Broglie hypothesis and derive the expression for de Broglie wavelength.
2. Explain the principle of complementarity and discuss its importance in quantum mechanics.

Eight-Mark Questions

1. Derive an expression for de Broglie wavelength(λ) by an analogy and discuss different forms of expression for (λ)
2. What are matter waves and mention their properties
3. Explain broadening of spectral lines and atomic stability?
4. Describe wave function and their properties.
5. Setup of a time independent Schrodinger wave equation from the classical wave equation in 1D and extend it to 3D.
6. Explain the physical significance of wave function, normalization condition, and expectation values.
7. Solve the Schrödinger equation for a particle in a one-dimensional infinite potential well and discuss the nature of wave functions

NINE MARKS

1. Explain Heisenberg's uncertainty principle and apply it to estimate the minimum uncertainty in position and momentum of an electron.
2. Discuss eigen functions and eigen values with reference to quantum mechanical operators.
3. Using the Schrodinger wave equation for a particle in a 1 D infinite potential well, obtain the eigen function and energy eigen values. Explain the role of higher dimensions.
4. Explain the variation of wave functions and probability density distributions for $n=1,2,3$ states
5. Discuss the equations and solutions for a particle in 1D finite potential well and explain the concept of the barrier penetration.

6.

TEN MARKS

1. Derive the energy eigenvalues and eigenfunctions of a particle in a one-dimensional infinite potential well and discuss their physical significance.
2. Explain quantum tunneling in detail and discuss its applications in modern devices.

MODULE-2: ELECTRICAL PROPERTIES OF METALS AND SEMICONDUCTORS

Two-Mark Questions

1. Define Fermi energy.
2. State Matthiessen's rule.
3. What is density of states?
4. Define intrinsic semiconductor.
5. What is Hall effect?

Three-Mark Questions

6. Explain failures of classical free electron theory.
7. Describe Fermi-Dirac distribution function.
8. Explain variation of Fermi factor with temperature.
9. Distinguish intrinsic and extrinsic semiconductors.
10. Explain the significance of Fermi level.

Five-Mark Questions

1. Explain quantum free electron theory and its assumptions.
2. Derive expression for electron concentration in an intrinsic semiconductor.
3. Explain Hall effect and its applications.
4. Discuss electrical conductivity of metals based on quantum theory.
5. Explain Fermi level position in intrinsic and extrinsic semiconductors.

Six-Mark Questions

1. Describe drift velocity, mobility and electron scattering mechanism in metals
2. List the assumptions of classical and quantum free electron theory of metals
3. Explain Matthiessen's rule of resistivity
4. Derive an expression of electron concentration
5. Mention the expression for electrical conductivity as per both CFET and QFET along with explanation of relevant terms.
6. Distinguish between intrinsic and extrinsic semiconductor.
7. Mention the expression of electron and hole concentration in case of extrinsic semiconductor with explanation of relevant terms.
8. Show that the Fermi level lies at the center of the band gap in case of an intrinsic semiconductor with the relevant equations.

7 MARKS

1. Explain the failures of classical free electron theory in detail.
2. Explain density of states and its significance in electrical conduction.

8 MARKS

1. Explain Fermi-Dirac statistics and discuss variation of Fermi function with temperature.
2. Explain intrinsic and extrinsic semiconductors with energy band diagrams.
1. Explain density of states and mention its expression along with explanation of relevant terms

2. Explain Fermi energy (E_F) and Fermi factor $f(E)$
3. Describe the variation of Fermi factor $f(E)$ with energy and temperature
4. Give the qualitative analysis of Fermi Dirac distribution theory
5. Derive an expression of electron concentration in an intrinsic semiconductor
6. Derive an expression of hole concentration in an intrinsic semiconductor
7. Discuss the Fermi level in case of n-type and p-type semiconductor with the relevant diagram.

9 MARKS

1. Explain Hall effect with derivation of Hall coefficient and discuss its applications.
2. Discuss electrical conductivity of metals based on quantum free electron theory.
3. Discuss the success of quantum free electron theory
4. Discuss the failure of classical free electron theory

10 MARKS

1. Derive the expression for electron concentration in an intrinsic semiconductor and explain the position of Fermi level.
2. Explain quantum free electron theory, its assumptions, successes, and limitations.
3. What is Hall effect? Derive an expression for hall coefficient and list its applications.
- 4.

MODULE-3: SUPERCONDUCTIVITY

Two-Mark Questions

1. Define superconductivity.
2. What is critical temperature?
3. Define Meissner effect.
4. What is persistent current?
5. Define critical magnetic field.

Three-Mark Questions

6. Explain Cooper pair formation.
7. Describe two-fluid model of superconductivity.
8. Distinguish Type-I and Type-II superconductors.
9. Explain flux quantization.
10. What is Josephson junction?

Five-Mark Questions

1. Explain Meissner effect and its importance.
2. Explain critical parameters of superconductors.
3. Discuss BCS theory of superconductivity.
4. Explain Josephson effects and applications.
5. Explain formation of vortices in Type-II superconductors.

Six-Mark Questions

1. Explain the concept of critical temperature (superconductivity) and the persistent currents.
2. Describe the Meissner effect with a suitable equation and diagram.
3. Explain the critical field with necessary equations and graphs.
4. Describe the critical current with Silsbee's effect.
5. Derive an expression for a cylindrical wire using Ampere's law

- Using the concept of the Cooper pair tunneling process and retro- reflection at the N-S interface, explain the Andreev reflection with necessary diagrams.
- Explain the formation of the Josephson junction and hence the flux quantization with a neat diagram.

Eight -Mark Questions

- Explain the zero resistance of a superconductor using the BCS theory with the concepts of phonon, electron-phonon interactions, the formation of Cooper pairs and their energy gap.
- Describe the two-fluid model with the normal and super electrons and hence explain the thermal conductivity. Give examples for low and high electron-phonon coupling.
- Explain Type 1 and 2 superconductors using the M-H characteristics, and discuss the flux expulsion, formation of vortex and the upper critical field.
- Describe the DC & AC Josephson Effect with a suitable diagram
- Give a qualitative account of DC and RF SQUIDS with necessary diagrams. List their applications

MODULE-4: PHOTONICS

Two-Mark Questions

- Define spontaneous emission.
- What is stimulated emission?
- Define population inversion.
- What is numerical aperture?
- Define optical fiber.

Three-Mark Questions

- Explain Einstein A and B coefficients.
- List prerequisites for laser action.
- Explain Pockels effect.
- Explain Kerr effect.
- What is Mach-Zehnder interferometer?

Five-Mark Questions

- Derive expression for numerical aperture of an optical fiber.
- Explain semiconductor diode laser with advantages.
- Explain optical fiber losses.
- Discuss working of photodetectors (SPAD or SNSPD).
- Explain principle and applications of optical modulators.
- Describe V and N number with relevant equations

Six -Mark Questions

- Explain the interaction of radiation with matter with neat diagram
- Describe the prerequisites for lasing action
- List and explain the types of laser

Eight -Mark Questions

- Derive an expression for energy density in terms of Einstein A and B coefficients
- Describe the principle, construction and working of semiconductor diode laser with a schematic and relevant energy level diagram
- Explain the role of single photon attenuators in quantum communication with the relevant

- diagram
4. Describe how electro optic modulators use Pockel's and kerr effect for phase modulation with the relevant diagram
 5. Describe the construction and working of Single-Photon Avalanche Diodes (SPAD) with a neat diagram
 6. Describe the construction and working of Superconducting Nano-wire Single-Photon detector (SNSPD) with a neat diagram.
 - a. Explain the construction and principle of optical fibers with a relevant diagram
 - b. Derive an expression for acceptance angle and numerical aperture with a neat diagram
 - c. (4 marks)
 - d. What is meant by attenuation, mention its equation and also explain the factors affecting the losses with the relevant diagram (8 marks)
 - e. Describe the principle and working of Mach-Zehnder interferometer with a neat diagram (8 marks)

MODULE-5: QUANTUM COMPUTING

Two-Mark Questions

1. Define qubit.
2. What is superposition?
3. What is Dirac notation?
4. Define entanglement.
5. What is Moore's law?

Three-Mark Questions

1. Compare classical bit and qubit.
2. Explain Bloch sphere representation.
3. Explain Pauli quantum gates.
4. Explain Hadamard gate operation.
5. Explain CNOT gate.

Four-Mark Questions

1. Mention the elements of Quantum theory
2. Mention the matrix representation of $|0\rangle$ and $|1\rangle$ states and apply the identity operator to show there is no change in state
3. Explain a) identity b) Conjugate c) Transpose d) Unitary matrix e) Hermitian f) Row and column matrix and their inner product with suitable example (each 4 marks)
4. Discuss a) probability b) quantum superposition c) Normalization rule d) Orthogonality e) Orthonormality
5. State the Pauli matrices and apply them on the $|0\rangle$ and $|1\rangle$ states
6. Explain the operation of Pauli Gates (X, Y, Z), Phase gate (S, T), Hadamard Gate (H) on the basis states $|0\rangle$ and $|1\rangle$ with the relevant circuit symbol, matrix representation and the truth table (each 5 marks)
7. Predicting the output of various combinations of single and two-qubit gates (a) Show that $T^2=S$ (4 marks)

(b) 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 (4 marks)

8. Numerical Problems (4 marks)

(a) A quantum state is given by $|\psi\rangle = (1/\sqrt{3})|0\rangle + (\sqrt{2}/\sqrt{3})|1\rangle$. Calculate the probability of obtaining $|1\rangle$ and the expectation value of σ_z . (4 marks)

(b) Limitations of quantum computing (4 marks)

Five-Mark Questions

1. Explain limitations of Moore's law and need for quantum computing.
2. Explain Bloch sphere and visualization of qubit states.
3. Explain quantum gates and their role in quantum circuits.
4. Discuss Bell states and their significance.
5. Explain superconducting qubits and need for anharmonicity.

Six-Mark Questions

9. Explain Moore's law and list limitation of VLSI
10. Distinguish between Classical and Quantum Computation
11. Explain bit, Qubit and its significance and properties
12. Explain Harmonic oscillator and its need for anharmonicity along with a relevant diagram
13. Explain quantum entanglement and discuss its importance in quantum communication
14. What are Quantum Gates and list single and two qubit gates
15. Explain the action of CNOT, SWAP, TOFFOLI gate on the basis states $|0\rangle$ and $|1\rangle$ with the relevant circuit symbol, matrix representation and the truth table

Eight -Mark Questions

1. Briefly explain Dirac notation, their properties and the types of qubit
2. With a neat diagram explain the representation of Qubit using Bloch Sphere. Discuss different cases
3. Describe the superconducting qubits: phase, charge and flux with a relevant diagrams

MODULE-2: ELECTRICAL PROPERTIES OF METALS AND SEMICONDUCTORS

MODULE-3: SUPERCONDUCTIVITY

7 MARKS

1. Explain zero resistance state and persistent current in superconductors.
2. Explain critical temperature, critical magnetic field, and critical current.

8 MARKS

1. Explain Meissner effect and show how superconductors exhibit perfect diamagnetism.
2. Explain Type-I and Type-II superconductors with suitable diagrams.

9 MARKS

1. Explain Cooper pair formation and two-fluid model of superconductivity.
2. Discuss flux quantization and Josephson junction.

10 MARKS

1. Explain BCS theory of superconductivity and discuss its successes and limitations.
2. Explain DC and AC Josephson effects and describe working of DC and AC SQUIDS.

MODULE-4: PHOTONICS

7 MARKS

1. Explain interaction of radiation with matter using Einstein's coefficients.
2. Explain prerequisites for laser action and population inversion.

8 MARKS

1. Explain construction and working of semiconductor diode laser with advantages and applications.
2. Explain Pockels and Kerr effects with suitable examples.

9 MARKS

1. Derive expression for numerical aperture of an optical fiber and explain acceptance angle.
2. Explain optical fiber losses and methods to minimize them.

10 MARKS

1. Explain optical fiber communication system with block diagram.
2. Explain Mach-Zehnder interferometer and discuss its applications.

MODULE-5: QUANTUM COMPUTING

7 MARKS

1. Explain the concept of qubit and superposition with mathematical representation.
2. Compare classical computation and quantum computation.

8 MARKS

1. Explain Bloch sphere representation of a qubit and visualize quantum states.
2. Explain single-qubit quantum gates with matrix representation.

9 MARKS

1. Explain two-qubit gates with emphasis on CNOT gate and entanglement.
2. Discuss Bell states and their importance in quantum information.

10 MARKS

1. Explain limitations of Moore's law and justify the need for quantum computing.
2. Explain superconducting qubits, Josephson junctions, and the need for anharmonicity.