Department : **COMPUTER SCIENCE AND ENGINEERING**

Year & Semester : **III & V**

Sub Code & Sub Name : **INTRODUCTION TO QUANTUM TECHNOLOGIES AND APPLICATIONS**

Unit-I

S.No	Part-A Questions
1.	Define superposition with an example.
2.	What is quantum entanglement?
3.	State Heisenberg's uncertainty principle.
4.	Define wave-particle duality.
5.	Mention two differences between classical and quantum mechanics.
6.	What is a quantum state?
7.	Define the concept of quantization.
8.	Name two applications of quantum technologies.
9.	Mention two strategic significances of quantum technology.
10.	Write any two global quantum missions.
11.	Define a qubit and mathematically express its general state. What is the fundamental property that distinguishes it from a classical bit?
12.	Using the Born rule, calculate the expectation value of the Pauli-Z operator (□z) for the state in part (b). Show your steps.
13.	Interpret the physical meaning of your result from part (c) in the context of a spin−½ system.
14.	What is mean by Quantum Non-locality
15.	Mention one key feature of Entanglement.

S.No	Part-B Questions
1.	Explain the transition from classical to quantum physics.
2.	Describe superposition and entanglement with suitable examples.
3.	Compare classical mechanics and quantum mechanics
4.	Explain the concept of wave-particle duality.
5.	Write short notes on quantum states and measurement.
6.	What are quantum photons and atoms? Explain.
7.	Explain the concept of quantization of energy levels.
8.	Discuss India's National Quantum Mission.
9.	Explain the uncertainty principle with derivation.
10.	Write a detailed note on global initiatives in quantum technologies (EU, USA, China).
11.	Difference between Classical Mechanics and Quantum Mechanics.
12.	Explain Quantum Communication
13.	Explain Quantum Sensing and National and Global Quantum missions.

14.	How does Decoherence limit the practical use of Qubits in quantum technologies.
15.	Discuss the difference between a classical state and a quantum state, focusing on how Superposition and Entanglement define the unique nature of the quantum state.

Unit-II

S.No	Part-A Questions
1.	Write down the matrix representations of the Pauli-X and Hadamard (H) gates.
2.	Show the action of the Hadamard gate on the $\|0\rangle$ and $\|1\rangle$ states, both algebraically and by stating the resulting output states.
3.	A qubit starts in state $\|1\rangle$. A Hadamard gate is applied, followed by a Pauli X gate. What is the final state of the qubit? Show the full matrix calculation.
4.	If you were to measure this final state in the computational basis, what would the measurement outcomes be? Explain why this sequence of gates is not equivalent to just applying a Pauli-X gate.
5.	What is a qubit?
6.	Define polarization.
7.	Differentiate between classical bits and quantum bits.
8.	Define decoherence.
9.	What are trapped ions?
10.	What is Hilbert space?
11.	State the role of entanglement in quantum systems.
12.	Define quantum operators.
13.	Mention any one philosophical implication of quantum theory.
14.	Write the difference between randomness and determinism.
15.	What is Quantum Physics?

S.No	Part-B Questions
1.	Explain the conceptual understanding of a qubit using spin and polarization.
2.	Compare classical bits and quantum bits
3.	Explain quantum coherence and decoherence with examples.
4.	Discuss Hilbert space and state vectors.
5.	Explain entanglement and non-locality.
6.	Write short notes on quantum operators.
7.	Discuss philosophical implications of determinism and observer role.
8.	Explain the theoretical concepts behind quantum information.
9.	Compare trapped ions and superconducting circuits.
10.	Explain the concept of quantum randomness.
11.	Explain the conceptual understanding of a qubit using the examples of spin and polarization, and clearly compare it with a classical bit.
12.	Detail the importance of entanglement in quantum system and how its properties enable capabilities not found in classical system.
13.	Discuss the conceptual reasons why a qubit in superposition offers a computational advantage over a classical bit
14.	Explain what it means for a theoretical concept like Hilbert space or an operator to be

	"only interpreted in abstract" in the context of this qualitative course.
15.	Discuss the course outcome of "Comparing classical and quantum information systems" using the key differences between bits and qubits, and their respective principles.

Unit-III

S.No	Part-A Questions
1.	Name two diPerent physical systems that can be used to implement a qubit and describe very briefly what physical property is used in each case.
2.	Define quantum decoherence in one sentence.
3.	Write the general formula for the density operator of a mixed state
4.	What is decoherence?
5.	Define scalability in quantum computing.
6.	Mention any two challenges in building quantum computers.
7.	What is error correction in quantum systems?
8.	Name two quantum hardware platforms.
9.	Define trapped ions.
10.	What is quantum noise?
11.	Why is entanglement difficult to maintain?
12.	Mention two conditions for a functional quantum system.
13.	What is meant by "isolation" in quantum computing?
14.	What is NOISE in Quantum Computing?
15.	What is Fragility.

S.No	Part-B Questions
1.	Explain the fragility of quantum systems.
2.	Describe the role of decoherence, noise, and control.
3.	Explain error correction as a theoretical necessity.
4.	Discuss scalability and stability challenges.
5.	Compare superconducting circuits and photonics as hardware platforms.
6.	Explain the importance of entanglement in building a quantum computer.
7.	What are the theoretical barriers in developing quantum computers?
8.	Explain trapped ions as a platform for quantum computing.
9.	Discuss visions and reality of quantum computing.
10.	Write a note on quantum software and its role.
11.	Explain why Decoherence is considered the main challenge in building quantum computers.
12.	Compare the Advantages and Limitations of Photonic Quantum Computers with other hardware platforms.
13.	Explain how Error management and Fault tolerance are connected in building scalable quantum systems.
14.	Discuss the Fragility of Quantum Systems due to Decoherence and Noise, with examples.
15.	Compare Superconducting circuits, Trapped ions, Photonics as hardware platforms.

Unit-IV

S.No	Part-A Questions
1.	What is Quantum Key Distribution (QKD)?
2.	Define Quantum Internet.
3.	State the role of entanglement in communication.
4.	What is quantum parallelism?
5.	Write one difference between classical and quantum gates.
6.	What is decoherence in communication?
7.	Mention one application of quantum secure networking.
8.	What is quantum error correction?
9.	Define quantum parallelism in one sentence.
10.	What is meant by "many states at once"?
11.	What is the purpose of QKB
12.	What is the conceptual goal of the Quantum Internet?
13.	What is the idea behind Quantum Parallelism?
14.	Name two challenges in Quantum Computing
15.	Why is Error correction important in Quantum Computing, from a theoretical perspective?

S.No	Part-B Questions
1.	Compare quantum information with classical information.
2.	Explain the basics of quantum communication.
3.	Describe Quantum Key Distribution (QKD).
4.	Discuss the concept of Quantum Internet.
5.	Explain the role of entanglement in communication.
6.	Describe quantum secure networking with examples.
7.	Write notes on quantum parallelism.
8.	Explain the difference between classical and quantum gates.
9.	Discuss challenges: decoherence and error correction in communication.
10.	Explain real-world importance and future potential of quantum communication.
11.	Explain the fundamentals of Quantum Communication, detailing the concept of Quantum Key Distribution (QKD) and the crucial Role of Entanglement in communication protocols.
12.	Provide an Introduction to Quantum Computing, focusing on the concept of Quantum Parallelism (Many States at Once) and contrasting it with classical computation.
13.	Discuss the Real-World Importance and Future Potential of quantum computing and communication, providing examples of the conceptual advantages they offer over classical systems.
14.	Compare and contrast the operation of Classical vs Quantum Gates, explaining how the unique properties of qubits affect the theoretical structure of quantum gates.
15.	Analyze the theoretical Challenges: Decoherence and Error Correction in the context of both quantum computing and quantum communication.

Unit-V

S.No	Part-A Questions
1.	Mention two healthcare applications of quantum computing.
2.	Write two applications of quantum sensing.
3.	Give an example of industrial use of quantum computing.
4.	Mention two companies working in quantum technologies.
5.	What is quantum optimization?
6.	Define ethical concern in quantum computing.
7.	Mention two societal challenges of quantum adoption.
8.	Name two emerging careers in quantum computing.
9.	What is the role of educational programs in quantum adoption?
10.	Write any two examples of global companies in quantum computing.
11.	How are quantum technologies relevant to Material science?
12.	Name one challenge to adoption related to human resource.
13.	What is the role of quantum technologies in precision timing?
14.	State one specific focus area for industrial case studies like IBM or Google.
15.	Give one example of am application in Healthcare for quantum technologies.

S.No	Part-B Questions
1.	Discuss the role of quantum computing in healthcare (drug discovery).
2.	Explain applications of quantum computing in material science and logistics.
3.	Discuss precision timing and sensing in quantum systems.
4.	Explain industrial case studies: IBM, Google, Microsoft.
5.	Explain the ethical, societal, and policy challenges in quantum adoption. Ethical, Societal, and Policy Challenges in Quantum Adoption
6.	Discuss challenges in adoption: cost, skills, and standardization.
7.	Write short notes on emerging quantum careers.
8.	Explain educational and research landscape of India in quantum computing.
9.	Discuss India's opportunities in the global quantum race.
10.	Write a note on real-world applications and future potential of quantum computing.
11.	Discuss the conceptual breakthroughs that quantum technologies promise in Material science and drug discovery by simulating molecular interactions.
12.	Discuss the key Challenges to adoption of quantum technologies, including cost, skills, and standardization, and suggest ways to conceptually overcome them.
13.	Analyze the contributions and focus areas of at least three major Industrial case studies (e.g., IBM, Google, Microsoft, PsiQuantum) in driving the quantum future.
14.	Elaborate on how quantum technologies fundamentally change the approach to solving complex problems in Logistics and optimization.
15.	Discuss the current industry trends in quantum technology and how they are shaping the future direction of research and commercialization.