23ES31T1 –INTRODUCTION TO QUANTUM TECHNOLOGIES AND APPLICATIONS

Course Category:	Professional core	**Credits:**	3
Course Type:	Theory	**Lecture-Tutorial-Practical:**	3-0-0
Prerequisite:	• Knowledge in Introduction To Quantum Technologies And Applications	**Sessional Evaluation:** **Univ. Exam Evaluation:** **Total Marks:**	30 70 100
Course Objectives:	**Students undergoing this course are expected:**		
	• Introduce fundamental quantum concepts like superposition and entanglement. • Understand theoretical structure of qubits and quantum information. • Explore conceptual challenges in building quantum computers. • Explain principles of quantum communication and computing. • Examine real-world applications and the future of quantum technologies		

Course Outcomes:	**Upon successful completion of the course, the students will be able to:**	
	CO1	Explain core quantum principles in a non-mathematical manner
	CO2	Compare classical and quantum information systems.
	CO3	Identify theoretical issues in building quantum computers.
	CO4	Discuss quantum communication and computing concepts.
	CO5	Recognize applications, industry trends, and career paths in quantum technology.
Course Content:	**UNIT-I** **Introduction to Quantum Theory and Technologies:** The transition from classical to quantum physics, **Fundamental principles explained conceptually**: Superposition, Entanglement, Uncertainty Principle, Wave-particle duality, Classical vs Quantum mechanics – theoretical comparison, **Quantum states and measurement:** nature of observation, **Overview of quantum systems**: electrons, photons, atoms, **The concept of quantization**: discrete energy levels, Why quantum? Strategic, scientific, and technological significance, **A snapshot of quantum technologies:** Computing, Communication, and Sensing, National and global quantum missions: India's Quantum Mission, EU, USA, China. **UNIT-II** **Theoretical Structure of Quantum Information Systems**: What is a qubit? Conceptual understanding using spin and polarization, **Comparison:** classical bits vs quantum bits, **Quantum systems:** trapped ions, superconducting circuits, photons (non-engineering view),Quantum coherence and decoherence – intuitive explanation, **Theoretical concepts:** Hilbert spaces, quantum states, operators – only interpreted in abstract, The role of entanglement and non-locality in systems, **Quantum information vs classical information:** principles and differences, Philosophical implications: randomness, determinism, and observer role. **UNIT-III** **Building a Quantum Computer – Theoretical Challenges and Requirement:** What	

	is required to build a quantum computer (conceptual overview)?,**Fragility of quantum systems:** decoherence, noise, and control, **Conditions for a functional quantum system:** Isolation, Error management, Scalability, Stability, **Theoretical barriers:**Why maintaining entanglement is difficult, Error correction as a theoretical necessity, Quantum hardware platforms (brief conceptual comparison),Superconducting circuits, Trapped ions, Photonics, **Vision vs reality:** what's working and what remains elusive, The role of quantum software in managing theoretical complexities. **UNIT-IV** **Quantum Communication and Computing – Theoretical Perspective:** Quantum vs Classical Information, Basics of Quantum Communication, Quantum Key Distribution (QKD),Role of Entanglement in Communication, The Idea of the Quantum Internet – Secure Global Networking, Introduction to Quantum Computing, Quantum Parallelism (Many States at Once),Classical vs Quantum Gates, **Challenges:** Decoherence and Error Correction, Real-World Importance and Future Potential. **UNIT-V** **Applications, Use Cases, and the Quantum Future**: **Real-world application domains:** Healthcare (drug discovery),Material science, Logistics and optimization, Quantum sensing and precision timing, **Industrial case studies:** IBM, Google, Microsoft, PsiQuantum, Ethical, societal, and policy considerations, **Challenges to adoption:** cost, skills, standardization, **Emerging careers in quantum:** roles, skillsets, and preparation pathways, Educational and research landscape – India's opportunity in the global quantum race.
Text Books & References Books:	**TEXTBOOKS:** 1. Michael A. Nielsen, Isaac L. Chuang, Quantum Computation and Quantum Information, Cambridge University Press, 10th Anniversary Edition, 2010. 2. Eleanor Rieffel and Wolfgang Polak, Quantum Computing: A Gentle Introduction, MIT Press, 2011. 3. Chris Bernhardt, Quantum Computing for Everyone, MIT Press, 2019. **REFERENCE BOOKS:** 1. David McMahon, Quantum Computing Explained, Wiley, 2008. 2. Phillip Kaye, Raymond Laflamme, Michele Mosca, An Introduction to Quantum Computing, Oxford University Press, 2007. 3. Scott Aaronson, Quantum Computing Since Democritus, Cambridge University Press, 2013. 4. Alastair I.M. Rae, Quantum Physics: A Beginner's Guide, Oneworld Publications, Revised Edition, 2005. 5. Eleanor G. Rieffel, Wolfgang H. Polak, Quantum Computing: A Gentle Introduction, MIT Press, 2011. 6. Leonard Susskind, Art Friedman, Quantum Mechanics: The Theoretical Minimum, Basic Books, 2014. 7. Bruce Rosenblum, Fred Kuttner, Quantum Enigma: Physics Encounters Consciousness, Oxford University Press, 2nd Edition, 2011. 8. GiulianoBenenti, GiulioCasati, GiulianoStrini, Principles of Quantum Computation and Information, Volume I: Basic Concepts, World Scientific Publishing, 2004. 9. K.B. Whaley et al., Quantum Technologies and Industrial Applications: European Roadmap and Strategy Document, Quantum Flagship, European Commission, 2020.

	10.Department of Science & Technology (DST), Government of India, National Mission on Quantum Technologies & Applications – Official Reports and Whitepapers, MeitY/DST Publications, 2020 onward.
E-Resources:	1. IBM Quantum Experience and Qiskit Tutorials 2. Coursera – Quantum Mechanics and Quantum Computation by UC Berkeley 3. edX – The Quantum Internet and Quantum Computers 4.YouTube – Quantum Computing for the Determined by Michael Nielsen 5. Qiskit Textbook – IBM Quantum