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| **Course Code** | 18CSE310J | **Course Name** | Quantum Computation | **Course Category** | *E* | *Professional Elective* | L | T | P | C |
| 2 | 0 | 2 | 3 |

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| **Pre-requisite Courses** | *Nil* | | **Co-requisite Courses** | *Nil* | | **Progressive Courses** | *Nil* |
| **Course Offering Department** | | *Computing Technlogies* | | | **Data Book / Codes/Standards** | *Nil* | |

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| **Course Objectives:** | | | *The purpose of learning this course is to:* | |  | **Learning** | | |  | **Program Learning Outcomes (PLO)** | | | | | | | | | | | | | | |
|  |  |
| **1 :** | *Gain knowledge about quantum computing and quantum mechanics* | | | |  | 1 | 2 | 3 |  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| **2 :** | *Analyze the Quantum Circuits* | | | |  | Level of Thinking (Bloom) | Expected Proficiency (%) | Expected Attainment (%) |  | Engineering Knowledge | Problem Analysis | Design & Development | Analysis, Design, Research | Modern Tool Usage | Society & Culture | Environment & Sustainability | Ethics | Individual & Team Work | Communication | Project Mgt. & Finance | Life Long Learning | PSO - 1 | PSO - 2 | PSO – 3 |
| **3 :** | *Utilize Open source Qiskit for quantum programing* | | | |  |  |
| **4 :** | *Learn about Grover and deustch Jozsa quantum algorithms* | | | |  |  |
| **5 :** | *Utilize the quantum concept and explore its applications* | | | |  |  |
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| **Course Outcomes (CO):** | | | | *At the end of this course, learners will be able to:* | |  |
| **CO-1 :** | *Identify the need of quantum computing and quantum mechanics* | | | | | *4* | *70* | *75* |  | *1* | *3* | *-* |  | *-* | *-* | *-* | *-* |  |  | *-* | *-* | *-* | *-* | *-* |
| **CO-2 :** | *Explore the Quantum gates and Quantum Circuits* | | | | | *4* | *70* | *75* |  | *2* | *3* | *1* | *-* | *-* | *-* | *-* | *-* |  |  | *-* | *-* | *-* | *-* | *-* |
| **CO-3 :** | *Develop the quantum programs for circuit optimization.* | | | | | *4* | *60* | *70* |  | *2* | *3* | *-* | *3* | *-* | *-* | *-* | *-* | *-* | *-* | *-* | *-* | *-* | *-* | *-* |
| **CO-4 :** | *Incorporate the Quantum algorithms Deustch Jozsa and Grover* | | | | | *4* | *70* | *80* |  | *2* | *3* | *-* | *3* | *-* | *-* | *-* | *-* | *-* | *-* | *-* | *-* | *-* | *-* | *-* |
| **CO-5 :** | *Demonstrate the different Quantum simulators and real time applications* | | | | | *4* | *70* | *75* |  | *1* | *3* | *-* | *3* | *-* | *-* | *-* | *-* | *-* | *-* | *-* | *-* | *-* | *-* | *-* |

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| Duration (hour) | | 12 | 12 | 12 | 12 | 12 |
| **S-1** | SLO-1 | *Need for Quantum Computing and fundamental concepts* | *Fubini Study metric* | *Quantitative measures of circuit* | *Introduction to Grover algorithm* | *Introduction to quantum applications* |
| SLO-2 | *Vector spaces, Probability* | *Geometry of quantum states* | *Analysis of quality of Circuits* | *Detailed walk through on Grovers algorithm* | *Research challenges of quantum* |
| **S-2** | SLO-1 | *Complex numbers and mathematical preliminaries* | *Tutorial style problem solving session* | *Circuit optimization* | *Quantum Amplitude Estimation* | *Introduction to QC Models* |
| SLO-2 | *Postulates of quantum mechanics* | *Physical Realization of Models* |
| **S**  **3-4** | SLO-1 | ***Lab 1:*** *Python basics* | ***Lab 4:*** *Quantum hardware and Simulators* | ***Lab 7:*** *Quantum circuits* | ***Lab 10 :*** *Quantum teleportation in Qiskit* | ***Lab 13:*** *project presentation and demo*  *(use case developed)* |
| SLO-2 |
| **S-5** | SLO-1 | *Bra-ket notations* | *Complexity classes* | *Tutorial style problem solving sessions* | *Tutorial-problems analysis* | *Tech landscape* |
| SLO-2 | *Measurements* | *Turing machine* | *Problem solving session* | *VQE* |
| **S-6** | SLO-1 | *Composite systems* | *Turing machine concepts* | *Introduction to quantum algorithms* | *Programming concepts in Qiskit* | *Tutorial-problems* |
| SLO-2 | *Bells theorem* | *Quantum gates* | *Deustch Jozsa algorithm* | *Analysis of Qiskit* | *Problem solving session* |
| **S**  **7-8** | SLO-1 | ***Lab 2:*** *Navigation on Circuit composer and Qiskit in Quantum Lab* | ***Lab 5:*** *implement single and multiple qubit gates* | ***Lab 8:*** *Visualization tools (State vector and Q-Sphere)* | ***Lab 11:*** *Implementation of Grovers algorithm* | ***Lab 14:*** *Project thesis preparation* |
| SLO-2 |
| **S-9** | SLO-1 | *Entanglement* | *Quantum circuits* | *Oracles and Phase kick back* | *Exploring Qiskit* | *Discussion of different use cases* |
| SLO-2 | *Programming in quantum* | *Use case in logistics* |
| **S-10** | SLO-1 | *Pure and Mixed states* | *Quantum circuits design* | *Deustch Jozsa Algorithm-details* | *Analysis of exercises created by NPTEL* | *Use case in ML and image processing* |
| SLO-2 | *Block sphere* | *Usage of IBM composer* | *Use case in finance and quantum cryptography* |
| **S**  **11-12** | SLO-1 | ***Lab 3:*** *Project preparation phase 1*  *(Analysis of problem statement related to quantum computing)* | ***Lab 6:*** *Project preparation phase 2*  *(Design of the project based on problem statement)* | ***Lab 9:*** *Project preparation phase 3*  *(Implementation of quantum problem statement in cloud environment)* | ***Lab 12:*** *Project preparation phase 4*  *(Testing of the software implemented)* | ***Lab 15:*** *Project report submission (Thesis of use case developed)* |
| SLO-2 |

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| **Learning**  **Resources** | *1. Quantum Computation and Quantum Information. M. A. Nielsen and I. L. Chuang, Cambridge University Press*  *2. Presskil Lecture notes: Available online: http://www.theory.caltech.edu/~preskill/ph229/*  *3 MichaelA. Nielsen and Issac L. Chuang," Quantum Computation and Information, Cambridge, 2002*  *4. Mikio Nakahara and Tetsuo Ohmi,"Quantum Computing", CRC Press, 2008*  *5. N. David Mermin,"Quantum Computer Science", Cambridge, 2007*  *6.* [*https://qiskit.org/*](https://qiskit.org/) | *7. An Introduction to Quantum Computing. P. Kaye, R. Laflamme, and M. Mosca, Oxford University Press, New York*  *8. Quantum Computer Science. N. David Mermin:, Cambridge University Press*  *9. Quantum Cryptography. D. Unruh:, Available online: https://courses.cs.ut.ee/all/MTAT.07.024/2017\_fall/uploads/*  *10. NIST Post Quantum Cryptography, Available online: https://csrc.nist.gov/projects/post-quantum-cryptography/round-2-submissions*  *11. Quantum Algorithms for Cryptographically Significant Boolean Functions - An IBMQ Experience. SAPV Tharrmashastha, D. Bera, A. Maitra and S. Maitra, Springer 2020.*  *12. Quantum Algorithm Zoo. https://quantumalgorithmzoo.org/*  *13. Handbook of Applied Cryptography. A. J. Menezes, P. C. van Oorschot, and S. A. Vanstone. CRC Press*  *14.* Chap 2,3,4 of Quantum Computing Explained by David McMahon (if available)  15. https://qiskit.org/learn/intro-qc-qh  *16.* [*https://github.ibm.com/dmadan07/Grover-ex*](https://github.ibm.com/dmadan07/Grover-ex)  *17.* [*https://qiskit.org/documentation/machine-learning/*](https://qiskit.org/documentation/machine-learning/)  *18.* [*https://qiskit.org/documentation/finance/*](https://qiskit.org/documentation/finance/)  *19.* [*https://qiskit.org/textbook/ch-algorithms/index.html*](https://qiskit.org/textbook/ch-algorithms/index.html)  *20.* [*https://cds.cern.ch/record/1522001/files/978-1-4614-6336-8\_BookBackMatter.pdf*](https://cds.cern.ch/record/1522001/files/978-1-4614-6336-8_BookBackMatter.pdf) |

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| **Learning Assessment** | | | | | | | | | | | |
|  | Bloom’s  Level of Thinking | Continuous Learning Assessment (50% weightage) | | | | | | | | Final Examination (50% weightage) | |
| CLA – 1 (10%) | | CLA – 2 (15%) | | CLA – 3 (15%) | | CLA – 4 (10%) | |
| Theory (5%) | Practice (5%) | Theory (7.5%) | Practice (7.5%) | Theory (7.5%) | Practice (7.5%) | Theory (5%) | Practice (5%) | Theory (25%) | Practice (25%) |
| Level 1 | Remember | 20% |  | 15% |  | 15% |  |  |  | 15% |  |
| Level 2 | Understand | 20% |  | 25% |  | 25% |  | 25% |  | 20% |  |
| Level 3 | Apply | 45% | 30% | 40% | 35% | 40% | 40% | 20% | 20% | 45% | 30% |
| Level 4 | Analyze | 15% | 40% | 20% | 35% | 20% | 30% | 20% | 50% | 20% | 35% |
| Level 5 | Evaluate |  | 30% |  | 30% |  | 30% | 25% | 30% |  | 35% |
| Level 6 | Create |  |  |  |  |  |  |  |  |  |  |
|  | Total | 100 % | 100 % | 100 % | 100 % | 100 % | 100 % | 100% | 100% | 100% | 100% |  |

# CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

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| **Course Designers** |  |  |
| Experts from Industry | Experts from Higher Technical Institutions | Internal Experts |
| Prabha Narayan , *QKRISHI* |  | *Gayathri.M*  *Assistant Professor,*  *Ctech.* |