DEPARTMENT OF COMPUTING TECHNOLOGIES

Honors in Quantum Computing

Curriculum for Honors in Quantum Computing					
Course Code	Course Title	Hours/ Week			C
		L	T	P	
Foundation Courses					
21HCSF010	*Quantum Computation*	*3*	*0*	*2*	*4*
21HCSF011	*Quantum Machine Learning*	*3*	*0*	*2*	*4*
Professional Electives (To choose any Four)					
21HCSE030	*Quantum cryptography*	*2*	*1*	*0*	*3*
21HCSE031	*Quantum Natural Language Processing*	*2*	*1*	*0*	*3*
21HCSE032	*Quantum Communication*	*2*	*1*	*0*	*3*
21HCSE033	*Quantum Sensing*	*2*	*1*	*0*	*3*
21HCSE034	*Classical and quantum information theory*	*2*	*1*	*0*	*3*
21HCSE035	*Quantum computation and Information Processing*	*2*	*1*	*0*	*3*
21HCSE036	*Quantum Mechanics*	*2*	*1*	*0*	*3*
	Total Learning Credits				**20**

Course Code	21HCSF010	Course Name	QUANTUM COMPUTATION	Course Category	F	Foundation Course	L	T	P	C
							3	0	2	4

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

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*Gain knowledge about quantum computing and quantum mechanics*
CLR-2 :	*Analyse the Quantum Circuits*
CLR-3 :	*Utilize Open source Qiskit for quantum programming*
CLR-4 :	*Learn about Grover and deustch Jozsa quantum algorithms*
CLR-5 :	*Utilize the quantum concept and explore its applications*

Program Learning Outcomes (PLO)

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	1 Engineering Knowledge	2 Problem Analysis	3 Design & Development	4 Analysis, Design, Research	5 Modern Tool Usage	6 Society & Culture	7 Environment & Sustainability	8 Ethics	9 Individual &Team Work	10 Communication	11 Project Mgt. & Finance	12 Life Long Learning	13 PSO - 1	14 PSO - 2	15 PSO – 3
CLO-1 :	*Identify the need of quantum computing and quantum mechanics*	*1*	*3*	-		-	-	-	-			-	-	-	-	-
CLO-2 :	*Explore the Quantum gates and Quantum Circuits*	*2*	*3*	*1*	-	-	-	-	-			-	-	-	-	-
CLO-3 :	*Develop the quantum programs for circuit optimization.*	*2*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	-	-
CLO-4 :	*Incorporate the Quantum algorithms Deustch Jozsa and Grover*	*2*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	-	-
CLO-5 :	*Demonstrate the different Quantum simulators and real time applications*	*1*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	-	-

Unit-1 **9 Hours**

Need for Quantum Computing and fundamental concepts, Vector spaces, Probability, Complex numbers and mathematical preliminaries, Postulates of quantum mechanics, Bra-ket notations, Measurements, Composite systems,Bells state,Entanglement,Bloch sphere, Pure and Mixed states

Unit-2 **9 Hours**

Geometry of quantum states, Complexity classes, Turing machine, Turing machine concepts, Quantum gates, Quantum circuits, Quantum circuits design,

Unit-3 **9 Hours**

Quantitative measures of circuit, Analysis of quality of Circuits, Circuit optimization, Introduction to quantum parallelism, Deustch Algorithm, Deutsch Jozsa algorithm,

Unit-4 **9 Hours**

Introduction to Grover algorithm, Detailed walk through on Grovers algorithm, geometric visualization of Grovers iterations, grovers search applied to unstructured database, quantum Teleportation, shor algorithm, quantum Fourier transform

Unit-5 **9 Hours**

Introduction to quantum applications, Research challenges of quantum, Introduction to QC Models, Physical Realization of Models,Varitional quantum eigen solver, quantum cryptograpgy-bb84 protocol,discussion of different use cases in quantum finance and quantum optimization.(QAOA)

LAB EXPERIMENTS:

Lab 1: *Python basics*
Lab 2: *Navigation on Circuit composer and Qiskit in Quantum Lab*
Lab 3: *Project preparation phase 1*
(Analysis of problem statement related to quantum computing)
Lab 4: *Quantum hardware and Simulators*
Lab 5: *implement single and multiple qubit gates*
Lab 6: *Project preparation phase 2*
(Design of the project based on problem statement)
Lab 7: *Quantum circuits*
Lab 8: *Visualization tools (State vector and Q-Sphere)*
Lab 9: *Project preparation phase 3*
(Implementation of quantum problem statement in cloud environment)
Lab 10 : *Quantum teleportation in Qiskit*
Lab 11: *Implementation of Grovers algorithm*
Lab 12: *Project preparation phase 4*
(Testing of the software implemented)
Lab 13: *project presentation and demo*
(use case developed)
Lab 14: *Project thesis preparation*
Lab 15: *Project report submission (Thesis of use case developed)* *30 Hours*

Learning Resources	*1.Quantum Computation and Quantum Information. M. A. Nielsen and I. L. Chuang, Cambridge University Press* *2.Quantum Computing ,Vishal Sahni, Tata McGraw-Hill Publishing Company Limited,2007.* *3. Mikio Nakahara and Tetsuo Ohmi,"Quantum Computing", CRC Press, 2008* *4. N. David Mermin,"Quantum Computer Science", Cambridge, 2007* *5. https://qiskit.org/* *6.An Introduction to Quantum Computing. P. Kaye, R. Laflamme, and M. Mosca, Oxford University Press, New York*	*7. Quantum Computer Science. N. David Mermin:, Cambridge University Press* *8. 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.*

	Bloom's Level of Thinking	Formative CLA – 1 Average of unit test (45%)		Life Long Learning CLA – 2 Practice (15%)		Summative Final Examination (40% Weightage)	
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	15%	-	-	%	15%	-
Level 2	Understand	20%	-	-	30%	20%	-
Level 3	Apply	35%	-	-	35%	35%	-
Level 4	Analyze	30%	-	-	35%	30%	-
Level 5	Evaluate	%	-	-	%	%	-
Level 6	Create	%	-	-	%	%	-
	Total	100 %		100 %		100 %	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Prabha Narayanan Qkrishi	Dr.Jayakumar Vaithiyashankar , Presidency University,Bengaluru.	Dr.M.Gayathrii, SRMIST
		Dr.R.Thilagavathy, SRMIST

Course Code	21HCSF011	Course Name	**QUANTUM MACHINE LEARNING**	Course Category	F	**Foundation Course**	L	T	P	C
							3	**0**	**2**	**4**

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

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*Gain knowledge about quantum computing, quantum mechanics and analyse the quantum circuits*
CLR-2 :	*Learn about the fundamentals of Machine Learning*
CLR-3 :	*Utilize Qiskit for supervised learning*
CLR-4 :	*Learn unsupervised learning with Qiskit*
CLR-5 :	*Utilize the quantum neural networks with Pennylane*

Program Learning Outcomes (PLO)

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	1 Engineering Knowledge	2 Problem Analysis	3 Design & Development	4 Analysis, Design, Research	5 Modern Tool Usage	6 Society & Culture	7 Environment & Sustainability	8 Ethics	9 Individual &Team Work	10 Communication	11 Project Mgt. & Finance	12 Life Long Learning	13 PSO - 1	14 PSO - 2	15 PSO – 3
CLO-1 :	*Identify the need of quantum computing and quantum gates*	*1*	*3*	-		-	-	-	-			-	-	-	-	-
CLO-2 :	*Compare Classical vs. Quantum Machine Learning*	*2*	*3*	*1*	-	-	-	-	-			-	-	-	-	-
CLO-3 :	*Develop the Quantum Machine Learning programs*	*2*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	-	-
CLO-4 :	*Incorporate the Unsupervised learning with Qiskit*	*2*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	-	-
CLO-5 :	*Demonstrate the QNN, QCNN, QGAN using Qiskit and Pennylane*	*1*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	-	-

Unit-1 **9 Hours**

Introduction to Quantum Computing- Introduction to Superposition- Classical superposition- Quantum superposition- What is a Qubit?- Mathematical Representation on Qubits- Bloch Sphere- Quantum Gates- Entanglement- Multi-Qubits states-CNOT gate

Unit-2 **9 Hours**

Classical vs. Quantum Machine Learning- Examples of Typical Machine Learning Problems- The Three Ingredients of a Learning Problem- Risk minimization in Supervised Learning- Training in Unsupervised Learning- Methods in Machine Learning-
Linear Models- Neural Networks- Graphical and Kernel methods

Unit-3 **9 Hours**

Introduction to Quantum Machine Learning- Four approaches to QML-Parameterized quantum circuits (PQC)- Quantum Information Encoding- Training parameterized quantum circuits- Supervised learning- Quantum variational classification- Quantum kernel estimation- Quantum feature map and kernels- Quantum Support Vector classification (QSVM)

Unit-4 **9 Hours**

Introduction to Unsupervised learning- Principle Component Analysis- Clustering- Classifiers used in QML- Problem solving session- QML programming concepts in Qiskit- Analysis of Qiskit- Analysis of exercises created by Qiskit- Discussion about IBM Qiskit Summer School Challenge exercises 2022 and 2023

Unit-5 **9 Hours**

Introduction to Quantum Neural Networks- Quantum Convolutional Neural Networks (QCNN)- Hybrid QNN- Problem solving session on a real dataset- Classical Generative Adversarial Networks (GAN)- Quantum Generative Adversarial Networks (QGAN)-
QGAN in Qiskit- Problem Solving session- Pennylane and AWS Quantum Braket introduction- Use cases in QML

LAB EXPERIMENTS:

1. *Introduction to Qiskit with some exercises*
2. *Develop circuit composer in Qiskit lab*
3. *Demonstrate Quantum gates using Qiskit*
4. *Python basics and Project preparation phase 1 (Analysis of problem statement related to quantum computing)*
5. *Implement single and multiple qubit gates using python*
6. *Project preparation phase 2 (Design of the project based on problem statement using Qiskit or Pennylane)*

7. *Implementation of QML algorithms* 8. *Implementation of Quantum classifiers* 9. *Implementation of QSVM and Project preparation phase 3(Implementation of quantum problem statement in Qiskit or Pennylane)* 10. *Implementation of Quantum K Nearest Neighbour* 11. *Implementation of different QML models* 12. *Project presentation phase 4 demo (use case developed) and thesis preparation* 13. *Implementation of Quantum Neural Networks* 14. *Implementation of QCNN in healthcare applications* 15. *Project report submission (Thesis of use case developed)* *30 Hours*

Learning Resources	1. *Quantum Computation and Quantum Information. M. A. Nielsen and I. L. Chuang, Cambridge University Press* 2. *Ciaran Hughes, Joshua Isaacson, Anastatsia Perry, Ranbel F. Sun, Jessica Turner, "Quantum Computing for the Quantum Curious", Springer, 2021* 3. *Maria Schuld and Francesco Petruccione, "Machine Learning with Quantum Computers", Second Edition, Springer, 2021* 4. *Maria Schuld and Francesco Petruccione, "Supervised Learning with Quantum Computers", Springer, 2018* 5. *Peter Wittek, "Quantum Machine Learning – What Quantum Computing Means to Data Mining", Elsevier* 6. *Michael A. Nielsen and Issac L. Chuang," Quantum Computation and Information, Cambridge, 2002* 7. *Mikio Nakahara and Tetsuo Ohmi,"Quantum Computing", CRC Press, 2008* 8. *N. David Mermin, "Quantum Computer Science", Cambridge, 2007* 9.*https://qiskit.org/* 10. *https://qiskit.org/documentation/machine-learning/*	11.*An Introduction to Quantum Computing. P. Kaye, R. Laflamme, and M. Mosca, Oxford University Press, New York* 12. *Quantum Computer Science. N. David Mermin:, Cambridge University Press* 13. *Quantum Algorithm Zoo. https://quantumalgorithmzoo.org/* 14. *Quantum Algorithm Zoo. https://quantumalgorithmzoo.org/* 15. *https://qiskit.org/textbook/ch-algorithms/index.html* 16. *Course | 8.370.1x | MIT Open Learning Library* 17. *https://github.ibm.com/dmadan07/Grover-ex* 18. *https://qiskit.org/documentation/finance/* 19. *https://qiskit.org/textbook/ch-algorithms/index.html* 20. *https://cds.cern.ch/record/1522001/files/978-1-4614-6336-8_BookBackMatter.pdf* 21. *The Story of Shor's Algorithm, Straight From the Source | Peter Shor - YouTube* 22. *Janani A (Resource Website) (google.com)* 23. *https://www.youtube.com/watch?v=3-c4xJa7Flk (IBM Qiskit Summer School – 2023 tutorials)*

	Bloom's Level of Thinking	Formative CLA – 1 Average of unit test (45%)		Life Long Learning CLA – 2 Practice (15%)		Summative Final Examination (40% Weightage)	
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	15%	-	-	%	15%	-
Level 2	Understand	20%	-	-	30%	20%	-
Level 3	Apply	35%	-	-	35%	35%	-
Level 4	Analyze	30%	-	-	35%	30%	-
Level 5	Evaluate	%	-	-	%	%	-
Level 6	Create	%	-	-	%	%	-
	Total	100 %		100 %		100 %	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Karthick Ganesh and Janani Ananthanarayanan, BOSONQ PSi	Dr. Jayakumar Vaithiyashankar , Presidency University, Bengaluru. *IBM Quantum Educator, IBM Qiskit Advocate*	Dr. M. Gayathri, Assistant Professor, CTECH
		Dr. S. Nalini Assistant Professor, CTECH

Course Code	21HCSE030	Course Name	QUANTUM CRYPTOGRAPHY	Course Category	E	Professional Elective	L	T	P	C
							2	1	0	3

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

Course Objectives:	The purpose of learning this course is to:
CLR-1	*Develop a comprehensive understanding of foundational quantum information concepts and their application to secure communication*
CLR-2	*Gain proficiency in utilizing entanglement for advanced quantum cryptographic applications*
CLR-3	*Develop strategies to enhance cryptographic security from imperfect information.*
CLR-4	*Understand the process of information reconciliation and its importance in ensuring the integrity and correctness of distributed keys.*
CLR-5	*Master advanced quantum cryptographic protocols and their security implications.*

Course Outcomes (CO):	At the end of this course, learners will be able to:	Program Learning Outcomes (PLO)														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		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
CO-1	*Understand and apply fundamental quantum information concepts, including qubits, density matrices, and quantum measurements.*	*1*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-2	*Utilize entanglement for cryptographic purposes, understanding its properties and applications.*	*2*	*1*	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-3	*Implement privacy amplification and randomness extraction to enhance cryptographic security.*	*1*	*2*	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-4	*Comprehend the essential principles of secure key distribution, including the theoretical foundations and practical implementations.*	*3*	2	2	-	-	-	-	-	-	-	-	-	-	-	-
CO-5	*Design and evaluate quantum key distribution and other advanced quantum cryptographic protocols.*	*3*	2	2	-	-	-	-	-	-	-	-	-	-	-	-

Unit-1: Foundations of Quantum Information	**9 Hours**
Qubits and Quantum States: Introduction to qubits, Superposition and quantum gates, Bloch sphere representation, Density Matrices: Representation of mixed states, Purity and mixedness, Quantum Measurements: Projective measurements, POVMs (Positive Operator-Valued Measures), Measurement postulates	
Unit-2: The Power of Entanglement	**9 Hours**
Introduction to Entanglement: Definition and properties of entangled states, Purifications: Concept of purifying mixed states, Bell Nonlocality: Bell's theorem and Bell inequalities, Implications for quantum cryptography, Monogamy of Entanglement: Entanglement constraints and their implications, Cryptographic significance	
Unit-3 From Imperfect Information to Near Perfect Security	**9 Hours**
Privacy Amplification: Techniques to enhance security from partial information, Protocols for privacy amplification, Randomness Extractors: Generating high-quality randomness from weak sources, Applications in cryptography	
Unit-4 Quantum Key Distribution	**9 Hours**
Secure Key Distribution: Fundamentals of key distribution, Information reconciliation, Quantum Cryptography beyond Key distribution: Coin flipping, Two-party cryptography, Oblivious Transfer, Bit commitment, Kitaev's Lower Bound on Strong Coin Flipping	
Unit-5 Quantum Key Distribution Protocols	**9 Hours**
Quantum Key Distribution Protocols: BB84 QKD, A modified Protocol, Security of BB84 key distribution, Correctness of BB4 key distribution, Quantum Cryptography using Untrusted Devices: DIQKD protocol, Security of DIQKD, Testing EPR pairs	

Learning Resources	1. Nielsen, M. A., & Chuang, I. L. (2010). Quantum Computation and Quantum Information: 10th Anniversary Edition. Cambridge University Press 2. Thomas Vidick, Stephanie Wehner (2023), Introduction to Quantum Cryptography. Cambridge University Press 3. Michael Aaron Nielsen, Quantum Information Theory. 1998.

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life Long Learning CLA-2 – (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	30%	-	30%	-	30%	-
Level 2	Understand	30%	-	30%	-	30%	-
Level 3	Apply	20%	-	20%	-	20%	-
Level 4	Analyze	20%	-	20%	-	20%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Jithesh Lalwani, Founder and CEO, Artificial Brain, Pune	Nishant K Pathak, Senior Research Fellow, IIT Delhi	Dr. G. K. Sandhia, SRMIST
Karthick Ganesh, Founder, KwantumG Research Labs, Bengaluru.	Dr.Jayakumar Vaithiyashankar , Presidency University, Bengaluru. IBM Quantum Educator, IBM Qiskit Advocate	Dr. G. Ramya, SRMIST

Course Code	21HCSE031	Course Name	QUANTUM NATURAL LANGUAGE PROCESSING	Course Category	E	Professional Elective	L	T	P	C
							2	1	0	3

Pre-requisite Courses	Co-requisite Courses	Progressive Courses
Nil	*Nil*	*Nil*

Course Offering Department	Data Book / Codes/Standards
Computing Technologies	*Nil*

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*Gain knowledge about natural language processing and quantum computing*
CLR-2 :	*Learn about the fundamentals of quantum natural language processing*
CLR-3 :	*Acquire knowledge about statistical natural language processing and sequence labelling*
CLR-4 :	*Analyse about probabilistic approaches of NLP*
CLR-5 :	*Gain insights about real time applications*

Program Learning Outcomes (PLO)

Course Learning Outcomes (CLO): *At the end of this course, learners will be able to:*		1 Engineering Knowledge	2 Problem Analysis	3 Design & Development	4 Analysis, Design, Research	5 Modern Tool Usage	6 Society & Culture	7 Environment & Sustainability	8 Ethics	9 Individual &Team Work	10 Communication	11 Project Mgt. & Finance	12 Life Long Learning	13 PSO - 1	14 PSO - 2	15 PSO – 3
CLO-1 :	*Identify the need of NLP and quantum computing*	1	3	-		-	-	-	-			-	-	-	-	-
CLO-2 :	*Exploring the difference of Classical machine learning and. Quantum Natural Language Processing*	2	3	1	-	-	-	-	-			-	-	-	-	-
CLO-3 :	*Analyse the statistical Q NLP and sequence labelling*	2	3	-	3	-	-	-	-	-	-	-	-	-	-	-
CLO-4 :	*Develop the probabilistic approaches using QNLP*	2	3	-	3	-	-	-	-	-	-	-	-	-	-	-
CLO-5 :	*Build real time applications using QNLP*	1	3	-	3	-	-	-	-	-	-	-	-	-	-	-

Unit-1: Introduction to NLP **9 Hours**

Introduction to Classical Natural Language Processing, NLP techniques, The different analysis levels used for NLP: morpho-lexical, Syntactic level – semantics,Pragmatics in nlp, markup (TEI, UNICODE), Applications - open problems. Introduction to Quantum Computing, Superposition and Entanglement, Single and Multi Qubit gates.

Unit-2: Introduction to Quantum Natural Language Processing **9 Hours**

Classical vs. Quantum NLP, Introduction to Quantum Natural Language Processing, Distributional word representation, QNLP basics – adjective and noun, Subject verb object sentence, DicCoCat Algorithm, String Diagram to ZX Quantum Circuit, Sentence Classification, Sentence generation.

Unit -3: *Statistical NLP and Sequence Labeling* **9 Hours**

N-grams and language models- Smoothing- text classification- Naïve Bayes classifier - Vector Semantics- TF_IDF- -word2vec - Sequence labelling -part of speech tagging- Named Entities – Named Entity Tagging- Introducing Lambeq and its features- QNLP training process- Sentence classification with lambeq – classical and quantum- Application of QNLP

Unit-4: Probabilistic Approaches **9 Hours**

Introduction to Statistical approaches to NLP tasks- Sequence labeling – Similarity Measures- Word Embeddings – skip-gram- Sentence Embeddings- Recurrent Neural Networks (RNN)- Long Short-term Memory (LSTM)- Applications using RNN and LSTM

Unit-5: Case studies **9 Hours**

Sentiment Analysis- Information Extraction- Calculating sentence similarity using a Hybrid Quantum-Classical Workflow- A Quantum search decoder for Natural Language- Quantum Enhanced Bayesian Inference for NLP tasks- A toy model for QNLP takes baby steps into the NISQ era- QNLP: Challenges and opportunities.

Learning Resources	*1.Quantum Computation and Quantum Information. M. A. Nielsen and I. L. Chuang, Cambridge University Press* *2. Ciaran Hughes, Joshua Isaacson, Anastatsia Perry, Ranbel F. Sun, Jessica Turner, "Quantum Computing for the Quantum Curious", Springer, 2021* *3. Servin Le Du, Senaida Hernandez Santana, Giannicola Scarpa ," A gentle introduction to Quantum Natural Language Processing", Computation and Language, arxiv, 2022* *4. David Peral-Garcia, Juan Cruz-Benito, Fransico Jose Garcia-Penlvo, "Comparing Natual Language Processing and Quantum Natural Processing approaches in text classification tasks", Expert Systems with Applications, Elsevier.* *4. Daniel Jurafsky and James Martin, "Speech and Language Processing: An introduction to Natural Language Processing, Computational Linguistics and Speech Recognition", Prentice Hall, 2nd Edition, 2018* *5. C. Manning and H. Schute, "Foundations of statistical Natural Language Processing", MIT Press, Cambridge, MA, 1999* *6. Mikio Nakahara and Tetsuo Ohmi,"Quantum Computing", CRC Press, 2008* *7. N. David Mermin, "Quantum Computer Science", Cambridge, 2007* *8. https://qiskit.org/* *9.* https://www.youtube.com/watch?v=rG0_SKCx09A&list=PLIMDwZY1oJSDttWv6YmK8Vv_PfB4VtDyy&index=1*10.An Introduction to Quantum Computing. P. Kaye, R. Laflamme, and M. Mosca, Oxford University Press, New York* *11. Quantum Computer Science. N. David Mermin:, Cambridge University Press* *12. Quantum Algorithm Zoo. https://quantumalgorithmzoo.org/* *13.* Introducing QNLP (ox.ac.uk)

	Bloom's Level of Thinking	Formative CLA – 1 Average of unit test (50%)		Life Long Learning CLA – 2 Practice (10%)		Summative Final Examination (40% Weightage)	
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	15%	-	%	-	15%	-
Level 2	Understand	20%	-	30%	-	20%	-
Level 3	Apply	35%	-	35%	-	35%	-
Level 4	Analyze	30%	-	35%	-	30%	-
Level 5	Evaluate	%	-	%	-	%	-
Level 6	Create	%	-	%	-	%	-
	Total	100 %		100 %		100 %	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Karthick Ganesh, BOSONQ Psi consultant, Bengaluru	Dr. Jayakumar Vaithiyashankar , Presidency University, Bengaluru. *IBM Quantum Educator, IBM Qiskit Advocate*	Dr. S. Nalini, SRMIST

Course Code	21HCSE032	Course Name	QUANTUM COMMUNICATION	Course Category	E	Professional Elective	L	T	P	C
							2	1	0	3

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

Course Objectives:	*The purpose of learning this course is to:*
CLR-1	Understand the fundamental mathematical tools essential for quantum communication.
CLR-2	Grasp the foundational concepts and principles of quantum mechanics applied in quantum communication.
CLR-3	Apply the fundamental decision theory utilized in quantum communication systems.
CLR-4	Explore the physical quantum systems and their operational principles applicable to quantum communication.
CLR-5	Develop the different notions associated with quantum information theory and I learn a few of its applications in quantum cryptography and quantum key distribution

Program Learning Outcomes (PLO)

Course Outcomes (CO):	*At the end of this course, learners will be able to:*	1 Engineering Knowledge	2 Problem Analysis	3 Design & Development	4 Analysis, Design, Research	5 Modern Tool Usage	6 Society & Culture	7 Environment & Sustainability	8 Ethics	9 Individual &Team Work	10 Communication	11 Project Mgt. & Finance	12 Life Long Learning	13 PSO - 1	14 PSO - 2	15 PSO – 3
CO-1	Acquire a broad understanding of the mathematical concepts behind quantum communication and computing.	3	2	-	-	-	-	-	-	-	-	-	-	1	-	-
CO-2	Recognize and design various quantum communication systems and modulation schemes	3	2	-	-	-	-	-	-	-	-	-	-	-	2	-
CO-3	Explore more advanced areas of quantum communication research.	3	-	-	-	-	-	-	-	-	-	-	-	-	-	1
CO-4	Analyze concepts of physical quantum systems and their operating pricniples	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-
CO-5	Classify the different notions associated with quantum information theory and will learn a few of its applications in quantum cryptography and quantum key distribution	3	2	-	-	-	-	-	-	-	-	-	-	-	3	-

UNIT 1: Mathematical Tools: **9 Hours**

Introduction to vector spaces, inner-product spaces, linear independence, basis, Finite dimensional Hilbert spaces, linear operators, projectors, Eigenvalue decomposition, Tensor products; Analysis and probability, limit, infimum, supremum, continuity, compact sets, convexity, dual function, probability distributions

UNIT 2:Elements of Quantum Mechanics: **9 Hours**

The notion of qubits, axioms of a closed quantum system, quantum dynamical systems, quantum measurements and POVM.

UNIT 3:Introduction to Quantum decision theory: **9 Hours**

Analysis of a quantum communication system, introduction to the Helstrom decision theory of quantum binary communication systems, decision theory of K-ary Quantum communication systems, Holevo's theorem, constellation of quantum states.

UNIT 4:Introduction to Quantum communication systems: **9 Hours**

Introduction to Glauber's representation of coherent quantum states, Quantum binary communication systems and different modulation schemes: OOK, BPSK, QAM, PSK, PPM, overview of quantum squeezed states.

UNIT 5:Introduction to Quantum Information Theory: **9 Hours**

Notion of density operators, partial trace, reduced density operator, Schmidt rank, purification of mixed states, entanglement, quantum teleportation. Introduction to classical information theory: Shannon entropy, classical channels and channel coding. Notion of von- Neumann entropy, quantum channels, accessible information and Holevo bound, transmission through a noisy quantum channel.Introduction to Quantum Cryptography and Quantum Key Distribution.

Learning Resources	1. "Quantum Communications", Gianfranco Cariolaro, Springer, 2015. 2. "Quantum Communication, Quantum Networks, and Quantum Sensing", Ivan B. Djordjevic, Academic Press, 2022.	3."Principles of Quantum Communication Theory: A Modern Approach", Sumeet Khatri, and Mark M. Wilde, 2021, Pre-release version, available freely at https://www.markwilde.com/teaching/2021-fall-qit/. 4. "Quantum Computation and Quantum Information", Michael Nielsen and Isaac Chuang, Cambridge University Press, 2010.

Bloom's Level of Thinking	Continuous Learning Assessment (CLA) - By the Course Faculty				By The CoE	
	Formative CLA-I Average ofunit test (50%)		**Life Long*Learning** CLA-II- Practice(10%)		**Summative** Final Examination (40% weightage)	
	Theory	Practice	Theory	Practice	Theory	Practice
Remember	30%	-	30%	-	30%	-
Understand	30%	-	30%	-	30%	-
Apply	20%	-	20%	-	20%	-
Analyze	20%	-	20%	-	20%	-
Evaluate	-	-	-	-	-	-
Create	-	-	-	-	-	-
Total	100 %		100 %		100 %	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Karthick Ganesh , KwantumG research Labs, BosonQ Psi consultant	Dr. Chandan, Post-Doctoral Fellow, Institute of Mathematical Sciences	Dr.Sorna Kokila, SRMIST
	Dr. Jayakumar Vaithiyashankar , Presidency University, Bengaluru. *IBM Quantum Educator, IBM Qiskit Advocate*	Dr.Ramesh, SRMIST

Course Code	21HCSE033	Course Name	QUANTUM SENSING	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	Explore a comprehensive foundation in quantum mechanics principles and mathematical formalism.
CLR-2 :	Understanding classical inference and quantum parameter estimation techniques, highlighting Bayesian and frequentist approaches.
CLR-3 :	Investigate a wide range of quantum sensing platforms and protocols, aiming to understand their capabilities and applications in sensing technology
CLR-4 :	Acquire the knowledge on advanced quantum sensing techniques, focusing on phase estimation, interferometry, and distributed sensing.
CLR-5 :	To explore advanced topics in quantum parameter estimation and their applications in quantum computing, communication, and optics

Program Learning Outcomes (PLO)

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	1 Engineering Knowledge	2 Problem Analysis	3 Design & Development	4 Analysis, Design, Research	5 Modern Tool Usage	6 Society & Culture	7 Environment & Sustainability	8 Ethics	9 Individual &Team Work	10 Communication	11 Project Mgt. & Finance	12 Life Long Learning	13 PSO - 1	14 PSO - 2	15 PSO – 3
CLO-1 :	*Apply key concepts such as superposition, density matrix, Hilbert space, Schrödinger equation, and quantum operations.*	1	3	-		-	-	-	-			-	-	-	-	-
CLO-2 :	*Perform classical and quantum parameter estimation, understand the quantum Cramer-Rao bound, and evaluate Bayesian vs. frequentist approaches*	2	3	-	3	-	-	-	-			-	-	-	-	-
CLO-3 :	*Exploring quantum sensing platforms and protocols, enabling them to design and implement advanced quantum sensing systems for various applications.*	2	3	1	-	-	-	-	-	-	-	-	-	-	-	-
CLO-4 :	*Demonstrate the quantum sensing methods, understand sensitivity limits, and utilize distributed sensing in practical scenarios.*	2	3	-	3	-	-	-	-	-	-	-	-	-	-	-
CLO-5 :	*Analysing multi-parameter estimation, advanced imaging techniques, and specialized sensing methods like microwave cavity sensing and opto-mechanical sensing.*	1	3	-	3	-	-	-	-	-	-	-	-	-	-	-

Unit-1 **9 Hours**

Introduction, quantum states -superposition, density matrix; quantum operations -unitary, quantum channel, measurement; Quantum Systems- qubits, qdits, harmonic oscillators; Distance measure of quantum states- Trace distance, Fidelity; Probabilities in quantum mechanics, Naimark's theorem.

Unit-2 **9 Hours**

Basic Classical Inference-Probability Concepts-Bayes' Rule-Parameter Estimation: Estimator, Deviations, Classical Cramer-Rao Bound, Maximum Likelihood Estimator-Classical Information Theory-Classical Hypothesis Testing: Hypothesis/Guess, Error Probability, Maximum Likelihood Decision-Quantum Parameter Estimation: Basic Paradigm, Single Parameter Estimation, Basic Theory, Cramer-Rao Bound, Quantum Fisher Information-Bayesian vs. Frequentist Approaches

Unit-3 **9 Hours**

Neutral atoms as magnetic field sensors- Trappedions - Rydbergatoms - Atomic clocks-Solid-state spins: Ensemble sensors-NMR ensemble sensors- NV center ensembles-Other sensors: Single electron transistors - Opto mechanics. Quantum Sensing Protocol: Quantum sensor Hamiltonian: Internal, Signal, Control Hamiltonian-The sensing protocol-Ramsey measurement-Rabi measurement-Slope and variance detection.

Unit-4 **9 Hours**

Quantum phase estimation-Quantum interferometry-Supersensitive regime and Heisenberg limit-Quantum Fisher information and quantum Cramer-Rao bound-Distributed quantum sensing-Distributed quantum sensing of in-phase displacements-General distributed quantum sensing of in-phase displacements.

Unit-5	**9 Hours**
Multi-Parameter Estimation: Basic Theory-Complex Displacement Sensing-Advanced Quantum Imaging Techniques-Advanced Quantum Imaging Techniques- Distributed Quantum Sensing: Displacement Sensing-General Review of Distributed Quantum Sensing-Networked Quantum Sensors- Microwave Cavity. Sensing Applications: Applications in Quantum Computing and Communication-Opto-Mechanical - Integration with Quantum Optics-Case Studies and Practical Applications	

Learning Resources	1. Backes et al, A quantum enhanced search for dark matter axions, Nature volume 590, pages 238-242. 2. Guo X, Breum C R, Borregaard J, Izumi S, Larsen M V, Gehring T, Christandl M, Neergaard-Nielsen J S and Andersen U L, Distributed quantum sensing in a continuous-variable entangled network, Nat. Phys. 16 281–4 3. Zheshen Zhang, Quntao Zhuang, Distributed quantum sensing, Quantum Sci. Technol. 6 043001.	4. Ivan B.Djordjevic, Quantum Communication,Quantum Networks, and Quantum Sensing, Elsevier, Academic press, 2022. 5. C.L.Degen,F.Reinhard,P.Cappellaro, Quantum sensing, Reviews of modern physics,volume 89,2017 6. http://web.mit.edu/2.111/www/notes09/spring.pdf 7. Zeki Seskir, Quantum Sensors: Principles, Types, and Applications, December 2022, DOI: 10.13140/RG.2.2.27325.54242

	Bloom's Level of Thinking	Formative CLA – 1 Average of unit test (50% Weightage)		Life Long Learning CLA – 2 Practice (10% Weightage)		Summative Final Examination (40% Weightage)	
		Theory	-	Theory	Practice	Theory	Practice
Level 1	Remember	15%	-	15%	-	15%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	35%	-	35%	-	35%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	%	-	%	-	%	-
Level 6	Create	%	-	%	-	%	-
	Total	100 %		100 %		100 %	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Karthick Ganesh, BOSONQ Psi Consultant, Bengaluru	Nishant K Pathak Senior Research Fellow, (Experimental Quantum optics) IIT Delhi	*1. Dr.R.Thilagavathy, SRMIST*
	Dr. Jayakumar Vaithiyashankar , Presidency University, Bengaluru. IBM Quantum Educator, IBM Qiskit Advocate	*2. Dr.J.Ramkumar, **SRMIST***

Course Code	21HCSE034	Course Name	**CLASSICAL AND QUANTUM INFORMATION THEORY**	Course Category	E	**Professional Elective**	L	T	P	C
							2	**1**	**0**	**3**

Pre-requisite Courses	Co-requisite Courses	Progressive Courses
Nil	*Nil*	*Nil*

Course Offering Department	Data Book / Codes/Standards
Computing Technologies	*Nil*

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*Develop knowledge in classical probability theory*
CLR-2 :	*Build Technological foundations in two level quantum system, visualization and quantum information related theorems*
CLR-3 :	*Develop analytical skills in quantum entanglement, separability criteria*
CLR-4 :	*Explore on quantum applications with Quantum teleportation and Quantum Key Distribution*
CLR-5 :	*Focus on Open Quantum Systems and quantum error mitigation/correction*

Program Learning Outcomes (PLO)

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	1 Engineering Knowledge	2 Problem Analysis	3 Design & Development	4 Analysis, Design, Research	5 Modern Tool Usage	6 Society & Culture	7 Environment & Sustainability	8 Ethics	9 Individual &Team Work	10 Communication	11 Project Mgt. & Finance	12 Life Long Learning	13 PSO - 1	14 PSO - 2	15 PSO – 3
CLO-1 :	*Understand Classical probability theory*	*1*	*3*	-		-	-	-	-			-	-	-	-	-
CLO-2 :	*Equipped with various theorems related to quantum information*	*2*	*3*	*1*	-	-	-	-	-			-	-	-	-	-
CLO-3 :	*Apply the knowledge to verify and quantify entanglement*	*2*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	-	-
CLO-4 :	*Assimilate the concepts of quantum applications with quantum teleportation and quantum key distribution*	*2*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	-	-
CLO-5 :	*Enhance metrics to quantify quantum fidelity and quantum error mitigation and correction*	*1*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	-	-

Unit-1 Classical Information Theory **9 Hours**

Probability Basics probability distributions-Mean and variance-exponential, Poisson, binomial distributions-uniform, and Gaussian (normal) distributions, Shannon entropy.

Unit-2 Qubit and Quantum Information **9 Hours**

The Qubit, Pure and mixed states. Bloch sphere and Poincare sphere representation of qubits, No cloning theorem, no-deletion theorem, no-hiding theorem. No- broadcasting theorem.

Unit-3 Quantum Entanglement **9 Hours**

Product states, separable states, entangled states (maximally and partially entangled), Bell states, GHZ states monogamy of entanglement. local unitary operations on Bell states. Bell's theorem and CHSH inequality, LOCC. Separability criterion,

The Peres-Horodecki condition, Werner state, Quantification of entanglement. maximally entangled mixed states. The concept of information, information and entropy, von Neumann entropy, entanglement of formation, concurrence, negativity, quantum discord.

Unit-4 Application of quantum information **9 Hours**

Trace, distance, fidelity of quantum states, entanglement swapping, teleportation. Quantum key distribution, BB84 and Ekert protocol. Application in finance, chemistry and materials and drug design.

Unit-5 Open Quantum System **9 Hours**

Positive maps, completely positive maps, Krauss Operator. open quantum system, master equation, amplitude and phase damping. Quantum decoherence, quantum error mitigation, suppression and correction.

Learning Resources	*1. Principles of Quantum Computation and Information: A Comprehensive Textbook Giuliano Benenti & Giulio Casati & Davide Rossini & Giuliano Strini* *2. Quantum Computation and Quantum Information; Isaac Chuang and Michael Nielsen* *3. Introduction to Probability, Statistics, and Random Processes Hossein Pishro-Nik* *4. Classical and Quantum information theory: An introduction to telecom scientist, Emmanuel Dessurvire*

	Bloom's Level of Thinking	Formative CLA – 1 Average of unit test (50%)		Life Long Learning CLA – 2 Practice (10%)		Summative Final Examination (40% Weightage)	
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	15%	-	%	-	15%	-
Level 2	Understand	20%	-	30%	-	20%	-
Level 3	Apply	35%	-	35%	-	35%	-
Level 4	Analyze	30%	-	35%	-	30%	-
Level 5	Evaluate	-	-	%	-	-	-
Level 6	Create	-	-	%	-	-	-
	Total	100 %		100 %		100 %	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Karthick Ganesh, BOSONQ Psi consultant, Bengaluru	Dr. Chandan Sharma, Institute of Mathematical Sciences	Dr. V. Raghavendra, SRMIST
		Dr. Usha G, SRMIST

Course Code	21HCSE035	Course Name	QUANTUM COMPUTATION AND INFORMATION PROCESSING	Course Category	E	Professional Elective	L	T	P	C
							2	1	0	3

Pre-requisite Courses	*NIL*	Co-requisite Courses	*NIL*	Progressive Courses	*NIL*
Course Offering Department	*Computing Technologies*	Data Book / Codes/Standards	*NIL*		

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*Understanding quantum computation's historical evolution, its theoretical foundations, and its potential to redefine the approach to solving complex problems.*
CLR-2 :	*Bridge the gap between theoretical quantum computing and its practical implementation, focusing on the distinct engineering challenges in quantum versus classical environments.*
CLR-3 :	*By exploring various quantum computational models and landmark algorithms, students will understand how quantum parallelism and other uniquely quantum properties enable solutions to problems intractable in classical computing.*
CLR-4 :	*Equip students to engineer quantum systems that operate reliably despite noise, a fundamental requirement for any large-scale, practical quantum technology*
CLR-5 :	*Explore quantum entanglement, the key resource that enables quantum technologies to surpass classical limits; master its theory and applications, from Bell's inequalities to teleportation, preparing students to harness it for groundbreaking advancements*

Course Outcomes (CO):	*At the end of this course, learners will be able to:*
CO-1 :	*Explore how quantum algorithms can revolutionize key fields and evaluate their potential to transform industries.*
CO-2 :	*Compare engineering requirements for implementing quantum versus classical algorithms, and apply advanced mathematical concepts to describe quantum states, basic operations, and phenomena like superdense coding.*
CO-3 :	*Analyze key quantum algorithms to understand their operational principles, quantum parallelism exploitation, and impact on complexity classes.*
CO-4 :	*Apply operator-sum representation to model quantum noise, use distance measures to quantify quantum information integrity, and implement quantum error-correction techniques to enhance quantum system reliability.*
CO-5 :	*Apply this knowledge to design protocols for quantum teleportation and secure communication.*

Program Outcomes (PO)
(1- Low, 2 – Medium, or High-3)

	1	2	3	4	5	6	7	8	9	10	11	12
	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning
CO-1	2	3	-	-	-	-	1	-	2	-	-	2
CO-2	2	3	1	-	-	-	2	-	2	-	-	2
CO-3	2	3	-	-	-	-	2	-	2	-	-	2
CO-4	2	3	1	-	2	-	2	-	2	-	-	2
CO-5	2	3	-	-	2	-	2	-	2	-	-	2

Unit-1 **9 Hours**
History of quantum computation and quantum information, Introduction to Quantum information theory, Applications of quantum computation; Information Explosion; Speed-ups and Scale-ups in quantum and classical environments; Quantum Supremacy.

Unit-2 **9 Hours**
Engineering requirements for quantum vs classical algorithm implementation; Mathematical and Computational Perspectives: Matrices, Vectors, Probability, Linear Algebra, Approximation theory, Quantum Probability; Mathematical description of quantum states and basic quantum operations, density operator, Superdense coding.

Unit-3 **9 Hours**
Qubits and Bloch Sphere; Quantum Circuits; Adiabatic Quantum Computing; Quantum parallelism; Quantum algorithms: Shor Algorithm, Grover Algorithm, Deutsch-Jozsa algorithm, Simon's algorithm, Complexity Classes.

Unit-4 **9 Hours**
Quantum noise and quantum operations: Operator-sum representation, Linear codes, Distance measures for quantum information: Trace distance, Fidelity; Quantum error-correction: CSS code, Shor's code.

Unit-5 **9 Hours**
Quantum correlations, Bell's inequalities. Theory of quantum entanglement. Entanglement of pure bipartite states. Entanglement of mixed states. Entropy and Entanglement, No Cloning Theorem, Teleportation, Quantum Computing Simulators/Environments; Quantum Information Theory..

Learning Resources	1. Eleanor Rieffel and Wolfgang Polak, QUANTUM COMPUTING - A Gentle. Introduction, The MIT Press Cambridge, Massachusetts London, England, 2011. 2. Nielsen, Michael A.; Chuang, Isaac L. (June 2012). Quantum Computation and Quantum Information (10th anniversary) .Cambridge: Cambridge University Press. ISBN 9780511992773.	

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA) - By the Course Faculty				By The CoE	
		Formative CLA-I Average of unit test (50%)		**Life Long* Learning** CLA-II- Practice (10%)		**Summative** Final Examination (40% weightage)	
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20	-	20	-	20	-
Level 2	Understand	20	-	20	-	20	-
Level 3	Apply	30	-	30	-	30	-
Level 4	Analyze	30	-	30	-	30	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Karthick Ganesh, BOSONQ Psi ,Bengaluru	Dr. Jayakumar Vaithiyashankar , Presidency University, Bengaluru. *IBM Quantum Educator, IBM Qiskit Advocate*	1. Dr S Shanmugam, SRMIST
	Dr. Chandan Sharma, Institute of Mathematical Sciences	2. Dr.P.C. Karthik, SRMIST

Course Code	21HCSE036	Course Name	QUANTUM MECHANICS	Course Category	E	Professional Elective	L	T	P	C
							2	1	0	3

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

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*Gain overall view of classical mechanics*
CLR-2 :	*Understand the limitations of classical mechanics and birth of quantum theory*
CLR-3 :	*Learn mathematical formulation and tools of quantum mechanics*
CLR-4 :	*Develop understanding of theory of angular momentum and Pauli spin matrices*
CLR-5 :	*Explore the approximate methods of solutions*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*
CLO-1 :	*Understand classical mechanics*
CLO-2 :	*Gain insights into the need for quantum theory*
CLO-3 :	*Equip with various mathematical tools for quantum mechanics*
CLO-4 :	*An understanding of practicality of angular momentum and two-level quantum system*
CLO-5 :	*Various quantum mechanical schemes to solve Schrodinger's equation*

Program Learning Outcomes (PLO)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	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
CLO-1	*1*	*3*	-		-	-	-	-			-	-	-	-	-
CLO-2	*2*	*3*	*1*	-	-	-	-	-			-	-	-	-	-
CLO-3	*2*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	-	-
CLO-4	*2*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	-	-
CLO-5	*1*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	-	-

Unit-1 Review of classical mechanics **9 Hours**

Newton's equations of motions, conservation of energy and momentum, Newtonian, Lagrangian and Hamiltonian mechanics, canonically conjugate variables, Electromagnetic fields and light, Maxwell's equations.

Unit-2 Origin of quantum theory **9 Hours**

Double slit experiment, photo-electric effect, Compton effect, wave particle duality, matter waves. Louis de Broglie's hypothesis, Black body radiation, Planck's quantum theory, Uncertainty principle, first principles of quantum mechanics, atomic structure, Rutherford, Bohr's atomic model, hydrogen atom spectrum, Stern-Gerlach experiment, spin of an electron, two-level quantum system, Classical vs Quantum mechanics

Unit -3 Mathematical formulation **9 Hours**

Mathematical formulation: Linear vector spaces, Hilbert space. Postulates of quantum mechanics, state vector, observables, measurement, uncertainty relations. Probabilities and probability amplitudes. Bra and ket vectors. Completeness, orthonormality, basis sets. Change of basis. Eigenstates and eigenvalues. Eigen basis and spectral decomposition of operators. Position and momentum representations. Wavefunctions, probability densities, probability current. Schrodinger's equation. Expectation values. Particle in a box. Potential barriers. Tunnelling. Linear harmonic oscillator: wavefunction approach and operator approach. Creation and Annihilation operators.

Unit-4 Theory of Angular momentum **9 Hours**

Motion in three dimensions Central potential problem. Orbital angular momentum operators. Eigenvalues and Eigenfunctions of orbital angular momentum operators. Spherical harmonics. Relation between rotation and angular momentum. Rotational symmetry and conservation of angular momentum. Reflection invariance and parity, Commutation rules, Matrix representations, addition of angular momenta and Clebsch-Gordon coefficients, Pauli spin matrices.

Unit-5 Approximation methods **9 Hours**

The Variational Principle (Rayleigh-Ritz Approximation), application to Helium atom. Schrodinger and Heisenberg pictures. Heisenberg equation of motion. Interaction picture. Time- independent perturbation theory. Nondegenerate and degenerate cases. Fermi's Golden rule, Semi classical theory of interaction of atoms with radiation.

Learning Resources	*1. D. J. Griffiths, Introduction to Quantum Mechanics, Second Edition (Pearson Education, Delhi,2005)* *2. P. M. Mathews and K. Venkatesan, A Textbook of Quantum Mechanics (Tata McGraw-Hill, 1977)* *3. J. J. Sakurai, Modern Quantum Mechanics* *4. Das, A., Lectures on Quantum Mechanics, Hindustan Book Agency, 2003.* *5. Shankar, R., Principles of Quantum Mechanics, Plenum Press, 1994*

	Bloom's Level of Thinking	Formative CLA – 1 Average of unit test (50%)		Life Long Learning CLA – 2 Practice (10%)		Summative Final Examination (40% Weightage)	
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	15%	-	-	%	15%	-
Level 2	Understand	20%	-	-	30%	20%	-
Level 3	Apply	35%	-	-	35%	35%	-
Level 4	Analyze	30%	-	-	35%	30%	-
Level 5	Evaluate	%	-	-	%	%	-
Level 6	Create	%	-	-	%	%	-
	Total	100 %		100 %		100 %	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Jagan Narayan Natarajan (IBM Quantum Support Engineer)	Prof. V. Subramanian, Visiting Professor, Dept. of Chemistry, IIT Madras	Dr. V. Raghavendra, SRMIST
		Dr.M.Gayathri, SRMIST