POST GRADUATE DEPARTMENT OF PHYSICS

UNIVERSITY OF KASHMIR, SRINAGAR

(Course Curriculum M.Sc Physics SEMESTER-IV)

Academic years 2021, 2022 and 2023

SEMSESTER-IV

Type of Course	Course Code	Title of Course	No. of Credits
Core (CR)			
CR	PHY18401CR	Particle Physics	04
CR	PHY18402CR	Computational Methods in Physics	04
CR	PHY18403CR	Project	04
Discipline Centric Electives (DCE)			
DCE	PHY18404DCE	Astrophysics - II	02
DCE	PHY18405DCE	Atmospheric Physics - II	02
DCE	PHY18406DCE	Quantum Field Theory - II	02
DCE	PHY18407DCE	High Energy Physics	02
DCE	PHY18408DCE	Neutrino Physics	02
DCE	PHY18409DCE	General Relativity	02
Generic Electives (GE)			
GE	PHY18410GE	Modern Communication Systems	02
GE	PHY18411GE	Astronomical Techniques	02
Open Electives (OE)			
OE	PHY18412OE	Atmospheric Science	02

Table 1: Semester - IV Course Details

Title:Particle Physics **(Course Code:PHY18401CR)**

Max.Marks:100 **Int. Assessment:** 20 **Ext. Examination:** 80 **Credits:** 04

Course Outcome: The course aims to provide a comprehensive understanding of elementary particles, their interactions, and the theoretical frameworks that govern their behavior. Students will gain insights into the strong, weak, and electroweak interactions, as well as the quark structure of hadrons, contributing to a deeper understanding of particle physics and the Standard Model.

Learning Outcome: Outcome: Upon completion of the course, the student should be able to:

- Explore particle classification schemes, including the Gellmann-Nishijima scheme and the eightfold way.
- Examine invariance principles such as the parity and conservation laws.
- Investigate tests of parity conservation and charge conjugation invariance.
- Understand baryon and lepton conservation, CPT invariance, and CP violation.
- Explore the V-A theory and coupling constant in weak interactions.
- Study phenomena such as neutron decay, muon decay, and pion decay.
- Understand electroweak interactions, predicting and discovering W/Z bosons.
- Explore weak isospin, hypercharge, and the effective current-current interaction in electroweak interactions.
- Learn Feynman rules for electroweak interaction and electron-positron annihilation.
- Study the quark structure of hadrons, including the baryon decuplet and baryon octet.
- Explore quark spin, color, and the magnetic moment of baryons.
- Investigate light pseudoscalar and vector mesons, as well as mesons built of heavy quarks.
- Understand lepton and quark scattering, including electron-positron annihilation to hadrons, electron-muon scattering, neutrino-electron scattering, and lepton-nucleon scattering.
- Explore deep inelastic scattering and the structure of quarks. (o) - Explore strange particles and strongly decaying resonances.
- Understand the particle content of the Standard Model.

- Explore the nature of fundamental interactions within the Standard Model.
- Discuss inadequacies of the Standard Model.

Unit-I

Overview of Elementary particles: Overview of particle discoveries, particle classification schemes, the Gellmann-Nishijima scheme, the eight fold way, the quark model. Invariance principles and conservation laws: the parity operation, parity of particles and antiparticles, tests of parity conservation, charge conjugation invariance, charge conservation and gauge invariance, baryon and lepton conservation, CPT invariance, CP violation.

Unit-II

Weak Interactions: V-A theory, coupling constant, neutron decay, muon decay, pion decay, CP invariance and violation, Charged weak interactions, neutral weak interactions, Cabibo mixing, CP violation; the neutral kaon system. Electroweak Interactions: prediction and discovery of W /Z , weak isospin and hypercharge, the basic electroweak interaction, the effective current-current interaction, Feynman rules for electroweak interaction, Electron-positron annihilation

Unit-III

Quark structure of hadrons: the baryon decouplet, quark spin and colour, the baryon octet, magnetic moment of baryons, the light pseudoscalar mesons, the light vector mesons, mesons built of heavy quarks. Lepton and quark scattering: electron positron annihilation to hadrons. electron-muon scattering, neutrino-electron scattering, lepton-nucleon scattering, deep inelastic scattering and quarks.

Unit-IV

Strong Interactions: the evidence for quarks and colour charge, strange particles, strongly decaying resonances. Standard model: particle content of the Standard Model, nature of fundamental interactions, Inadequacies of SM, unification of electroweak and strong interactions

Text Books:

1. Introduction to elementary particles by David J. Griffiths, John Wiley and Sons.
2. Quarks and Leptons by F. H. Halzen and J. D. Martin, John Wiley and Sons.

References:

1. Introduction to high energy physics by D. H. Perkins

Title: Computational Methods in Physics **(Course Code: PHY18402CR)**

Max.Marks:100 **Int. Assessment:** 20 **Ext. Examination:** 80 **Credits:** 04

Course Outcome: This course provides a comprehensive exploration of computer science, beginning with foundational concepts such as computers, interpreters, and operating systems. The focus shifts to C programming in Unit I, covering program characteristics, data types, variables, expressions, and control statements, supplemented by case studies and programming exercises. Unit II delves into arrays, functions, pointers, structures, unions, and file management, emphasizing practical application through case studies. Units III and IV extend the learning to algorithm development in C, addressing linear and non-linear equations, matrix operations, eigen-values, eigen-vectors, interpolation, cubic spline fitting, numerical differentiation and integration, and solving second-order differential equations using methods like Runge-Kutta. Overall, the course aims to impart a solid foundation in C programming and algorithmic problem-solving.

Learning Outcome:

- Understand the fundamental concepts of computer programming, including the role of computers, interpreters, and operating systems.
- Demonstrate proficiency in C programming by grasping characteristics, character set, identifiers, and keywords.
- Apply knowledge of data types, constants, variables, and arrays in C programming, including proper declaration and use.
- Utilize expressions, statements, symbolic constants, operators, and expressions effectively in C programs.
- Demonstrate proficiency in using library functions, handling data input/output, and employing error diagnostics and debugging techniques.
- Gain proficiency in program structure, including the use of structures, unions, pointers, and operations on pointers.
- Solve problems related to file management in C and understand the role of the preprocessor in programming.
- Apply algorithmic thinking to develop solutions for linear equations, non-linear equations, matrix inversion, eigenvalues, and eigenvectors using C programming

Unit-I

Computers, Interpreters and Operating system, Types of programming languages, C programming, Programme Characteristics, C character set, identifiers and key words, Data types, Constants, Variables and Arrays Declaration, Expressions, Statements, Symbolic constants, Operators and Expressions, Library functions, Data input and output, Error Diagnostics, Debugging Techniques, Control statements, Case studies, Programming exercises

Unit-II

Arrays, Character Arrays and Strings, User defined functions, Function properties, Recurrsion, Programme Structure, Structure and Unions, Pointers, Pointer Declaration, Operation on pointers, Pointers and one dimensional arrays, Arrays of pointers, User defined data types, File management in C, Preprocessor, Guidelines for developing a C programme, Case studies, Programming exercises

Unit-III

Developing algorithms and Computers programs in C-Language to solve following problems:
(1) Interpolation with equally spaced and unequally spaced points
(2) Cubic Spline fitting
(3) Numerical Differentiation and Integration
(4) Second order differential equation by Runge-Kutta method and other method

Unit-IV

Developing algorithms and Computers programs in C-Language to solve following problems:
(1) Interpolation with equally spaced and unequally spaced points
(2) Cubic Spline fitting
(3) Numerical Differentiation and Integration
(4) Second order differential equation by Runge-Kutta method and other method

Text Books:

1. Introductory methods of numerical analysis by Sastry
2. Numerical analysis by Rajaraman
3. Numerical recipes by Press Teukolsky Vetterming and Flannery.
4. Programming in ANSI C, Balaguruswamy

References:

1. Numerical analysis by Rajaraman

Title: Project **(Course Code: PHY18403CR)**

Max.Marks:100 **Int. Assessment:** 20 **Ext. Examination:** 80 **Credits:** 04

Course Outcome:

Learning Outcome: Learn

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Description

The students will work intensively on a topic of her/his choice, while interacting on regular basis with the project supervisor. The project should consist of any innovative topic in Physics which, in principle, should lead to some training for further research on the topic. The student should present the most recent and novel research happenings in the field. The curriculum shall consist of the preparation and submission of a project report and then oral presentation and viva-voce before a committee consisting of internal and external examiners. The distribution of marks for the various component of this curriculum shall be as follows;

Category	**Total Marks**
Internal Assessment (By Supervisor)	20
Contents of Project Report	20
Tour	10
Presentation/Viva-voce (External)	50
Total	100

Title: Astrophysics - II **(Course Code: PHY18404DCE)**

Max.Marks:50 **Int. Assessment:** 10 **Ext. Examination:** 40 **Credits:** 02

Course Outcome: Students will be able to learn how to apply the laws of physics to explain the birth of the universe, the birth and death of planets, stars, nebulae, galaxies, and other celestial objects. After finishing the course student is expected to account for the theoretical basis for our modern cosmological view of the universe, including the beginning at Big Bang and the development up to early galaxy formation. They also learn how the universe originated in the past (Big Bang theory) and what are the different phases. They learn about the experimental tests upon which the cosmological theories are built up. The different cosmological parameters for understanding the observed universe. Going through Friedmann model Students will acquire knowledge about where the Universe came from and where it's headed.

Learning Outcome: Upon completion of the course, the students should:

- Understanding the size and shape of the Milky Way galaxy
- Grasping the Hubble classification system for galaxies.
- Exploring the types of forces acting on stars within a stellar system.
- Defining the time of relaxation in the context of stellar dynamics
- Investigating the masses of double galaxies using observational methods.
- Understanding the cosmological principle and its implications for the large-scale structure of the universe
- Familiarizing with the Robertson-Walker equation and its significance in cosmology.
- Understanding Einstein's field equation and its role in describing the gravitational interaction in cosmology.

Unit-I

The Milky Way galaxy, size and shape, rotation curve of galaxy, radio observation and spiral structure, star counts, interstellar extinction. Hubble classification of galaxies. Stellar dynamics, types of forces on a star in the stellar system, Tidal radii, star star encounter, time of relaxation determination of time of relaxation, application to Galaxy & star cluster. Masses of double galaxies, Masses of cluster of galaxies by virial theorem observational determination of masses, clusters of galaxies, Missing mass problem.

Unit-II

Cosmology, cosmological principle, Newtonian cosmology, deceleration parameters critical density, Robertson walker equation and its properties, solution of Robertson-Walker equations. Einstein field equation in cosmology, Energy tensor of Universe, solution of Friedman's equation, Einstein de-sitter model, open model, particle horizon, Event horizon.Thermal History of the Universe, Temperature red shift relation, distribution in the early Universe, relativistic and non- relativistic limits, decoupling of matter and radiation, Cosmic microwave background radiation (CMBR)

Text Books:

1. Introduction to Cosmology by J. V. Narlikar
2. Modern astrophysics by B. W. Caroroll and D. A. Ostlie, Addison-Wesley Pub.

References:

1. Structure foundation in universe by T. Padmanabhan, Cambridge University Press
2. Stellar dynamics by S. Chandrashekhar
3. Stellar evolution by Kippenhahn
4. Quasars and active galactic nuclei by A. K. Kembhavia and J. V. Narlikar. Cambridge University Press.
5.

Title: Atmospheric Physics - II **(Course Code: PHY18405DCE)**

Max.Marks:50 **Int. Assessment:** 10 **Ext. Examination:** 40 **Credits:** 02

Course Outcome:

Learning Outcome: Upon completion of the course, the students should:

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Unit-I

Earth coordinate system (latitude, longitude, depth),Dynamic and thermodynamic variables (u,v,w,T,P,density).Forces felt by an air parcel, mathematical development of apparent forces, momentum equations,scale analysis momentum equations, the Rossby Number and geostrophic, Cyclostrophic and gradient Balance, Continuity equation, Energy equation ,Governing equations for synoptic scale.The Thermal Wind, Vertical motion, pressure coordinates,Basic equations in pressure coordinates.

Unit-II

Weather and climate, weather forecasting, Numerical weather prediction models, Global climate models, Working principle, application and circuit descriptions in blocks of the system: Ionosonde, Rdiosonde, Ozonesonde, LIDARS, DIAL, SODARS, AWS, weather Satellites, Doppler Radar, ST Radar and MST radar

Text Books:

1. McIlveen R.., Fundamentals of Climate, Chapman Hall, 1992
2. J. R. Holton, An introduction to dynamic metreology, 3rd Ed.

References:

1. he Physics of atmospheres by J. T. Houghton, 1986
2. Theory of satellite orbit in the atmosphere by King Hele
3. Weather satellite by L. F. Hubert
4. Meteorological satellite by W. K. Hedger
5. A guide to earth satellite by D. Fishlock

Title: Quantum Field Theory- II **(Course Code: PHY18406DCE)**

Max.Marks:50 **Int. Assessment:** 10 **Ext. Examination:** 40 **Credits:** 02

Course Outcome:

Learning Outcome: Upon completion of the course, the students should:

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Unit-I

The S-matrix expansion: Examples of interactions , Evolution operator, S-matrix. Wick's theorem. Feynman diagrams and Rules: Yukawa interaction: decay of a scalar. Cross section for QED processes: Electron-electron scattering. Consequence of gauge invariance. Compton scattering, Scattering by an external field. Bremsstrahlung.

Unit-II

Electromagnetic form factors: General electromagnetic vertex, Physical interpretation of form factors . Renormalization : Degree of divergence of a diagram, Regularization of self- energy diagrams, Counterterms, Ward-Takahashi identity. Observable effects of renormalization.

Text Books:

1. A first book of quantum field theory, Lahiri and Pal, Narosa Publishing House
2. Quantum field theory, Lewis H. Ryder, Cambridge University Press

References:

1. Bjorken and Drell, Relativist quantum fields
2. Itzyken and Zubair, QUantum Field Theory
3. Weather satellite by L. F. Hubert
4. Meteorological satellite by W. K. Hedger
5. A guide to earth satellite by D. Fishlock

Title: High Energy Physics **(Course Code: PHY18407DCE)**

Max.Marks:50 **Int. Assessment:** 10 **Ext. Examination:** 40 **Credits:** 02

Course Outcome: The course aims to provide a comprehensive understanding of particle classification, interactions, and advanced topics such as quarks, gluons, and Quark-Gluon Plasma. Students will gain insights into theoretical models and experimental observations related to the behavior of particles at extreme conditions, contributing to a deeper understanding of particle physics and its applications.

Learning Outcome: Upon completion of the course, the students should:

- Understand the classification of particles
- Explore the concepts of antiparticles.
- Investigate the flavors of leptons and quarks.
- Examine interactions and fields from both classical and quantum perspectives. And study the Yukawa theory of quantum exchange.
- Explore tests of parity conservation, charge conjugation invariance, and conservation laws for baryons and leptons.
- Analyze isospin in pion-nucleon systems.
- Explore the properties of quarks and gluons.
- Understand the MIT Bag model of hadrons.
- Examine the concept of Quark-Gluon Plasma (QGP) and its occurrence at high temperatures and high baryon density.
- Analyze Signals of QGP like: J/Psi suppression and production, dilepton production in QGP, photon production in Quark-Gluon Plasma.
- Study experimental information on J/Psi production and suppression in QGP and photon production in QGP.

Unit-I

Particle Classification: Fermions and bosons, particles and antiparticles, free particle wave equation, lepton flavours , quark flavours. Interactions and fields: Classical and quantum picture of Interactions, Yukawa theory of quantum exchange. Parity Operation, test of parity conservation, charge conjugation Invariance, baryon and lepton conservation, isospin in pion-nucleon systems,

Unit-II

Quarks and Gluons, Bag model of hadrons, Quark Gluon Plasma, Quark Gluon Plasma at High Temperature, Quark Gluon Plasma with High Baryon Density, J/Psi suppression and production in Quark Gluon Plasma, Dilepton production in QGP, Photon production on Quark Gluon Plasma, Experimental information on J/Psi production and suppression, Experimental information on photon production.

Text Books:

1. Introduction to high energy heavy ion collisions, Cheuk Yen Wong

References:

1. Introduction to high energy physics by D. H. Perkins

Title: Neutrino Physics **(Course Code: PHY18408DCE)**

Max.Marks:50 **Int. Assessment:** 10 **Ext. Examination:** 40 **Credits:** 02

Course Outcome: The course aims to provide a comprehensive understanding of particle classification, interactions, and advanced topics such as quarks, gluons, and Quark-Gluon Plasma. Students will gain insights into theoretical models and experimental observations related to the behavior of particles at extreme conditions, contributing to a deeper understanding of particle physics and its applications.

Learning Outcome: Upon completion of the course, the students should:

- Understand the classification of particles
- Explore the concepts of antiparticles.
- Investigate the flavors of leptons and quarks.
- Examine interactions and fields from both classical and quantum perspectives. And study the Yukawa theory of quantum exchange.
- Explore tests of parity conservation, charge conjugation invariance, and conservation laws for baryons and leptons.
- Analyze isospin in pion-nucleon systems.
- Explore the properties of quarks and gluons.
- Understand the MIT Bag model of hadrons.
- Examine the concept of Quark-Gluon Plasma (QGP) and its occurrence at high temperatures and high baryon density.
- Analyze Signals of QGP like: J/Psi suppression and production, dilepton production in QGP, photon production in Quark-Gluon Plasma.
- Study experimental information on J/Psi production and suppression in QGP and photon production in QGP.

Unit-I

Introduction and Historical Overview, motivation for proposing the neutrino, first discovery by Reines and Cowan and subsequent discoveries, the number of neutrinos, neutrino properties and interactions, neutrino electron elastic scattering, neutrino-nucleon quasi-elastic scattering, neutrino-nucleon deep inelastic scattering, solar neutrinos, atmospheric neutrinos, terrestrial neutrino sources

Unit-II

Neutrino mass, neutrino oscillations, flavour oscillations in vacuum and matter, solution of the solar and atmospheric problems, limitations of oscillation experiments, direct mass searches, kinematic mass determination, double beta decay, summary of understanding now, outstanding questions and the future of experimental neutrino physics

Text Books:

1. Neutrino Physics by Kai Zubair, CRC Press
2. Current aspects of neutrino physics. Ed. by David O. Codwell, Springer Publications

References:

1. Fundamentals of neutrino physics and astrophysics by Carlo Giunti and Chung W. Kim

Title: General Theory of Relativity **(Course Code: PHY18409DCE)**

Max.Marks:50 **Int. Assessment:** 10 **Ext. Examination:** 40 **Credits:** 02

Course Outcome: Upon completion of this course, students will attain a comprehensive understanding of general relativity and its mathematical foundations. In Unit I, students will grasp the principle of general covariance, becoming proficient in tensor calculus and vector and tensor fields, including concepts such as parallel transport, connection coefficients, metric tensor, covariant derivative, geodesic equations, and the Riemann curvature tensor. Additionally, students will explore gravity in simple situations, motion along geodesics, and the symmetry properties of the Riemann tensor, gaining insight into the Bianchi identity and Ricci and Einstein tensors. In Unit II, students will delve into the Einstein equation and its solutions, studying the equation in vacuum and specific solutions like the Schwarzschild solution. The extension of the Schwarzschild solution in Kruskal-Szekeres coordinates, energy-momentum tensors, the action principle for gravitational and matter fields, and advanced topics like the Kerr solution, black holes, and gravitational waves will be covered, providing students with a solid foundation in the intricacies of general relativity.

Learning Outcome: Upon completion of the course, the students should:

- Demonstrate a deep understanding of the principle of general covariance and its significance in the formulation of general relativity.
- Apply tensor calculus proficiently, manipulating vector and tensor fields and utilizing concepts like parallel transport and connection coefficients.
- Master the essential mathematical tools of general relativity, including the metric tensor and covariant derivative, enabling the mathematical description of gravitational phenomena.
- Analyze the geodesic equation and its application in describing the motion of particles influenced by gravity in various scenarios.
- Understand the Riemann curvature tensor, explore its symmetry properties, and grasp the importance of the Bianchi identity in the study of curved spacetime.
- Interpret and analyze the Ricci and Einstein tensors, linking them to the fundamental Einstein equation and understanding their roles in describing gravitational fields.

- Apply the Einstein equation to different scenarios, solving for specific cases such as the Schwarzschild solution and comprehending the underlying physical principles.
- Extend comprehension to advanced topics, including the Schwarzschild solution in Kruskal- Szekeres coordinates, providing insights into the geometric properties of black holes.
- Gain proficiency in dealing with energy-momentum tensors, specifically for perfect fluids, and understand their role in describing matter fields within the framework of general relativity.
- Develop knowledge of the action principle for both gravitational and matter fields, and comprehend the broader implications of solutions such as the Kerr solution and the study of gravitational waves, contributing to a comprehensive understanding of general relativity and its applications.

Unit-I

Principle of general covariance. Tensor Calculus Vector and tensor fields, Parallel transport. Connection coefficients. Metric tensor. Covariant derivative. Geodesic equation, Gravity in Simple Situations Motion along a geodesic. Riemann curvature tensor. Symmetry properties of Riemann tensor. Bianchi identity. Ricci and Einstein tensor.

Unit-II

Einstein equation, Solutions of Einstein equations, Einstein equation in vacuum, Schwarzschild solution, Schwarzschild solution extension in Kruskal-Szekeres coordinates. Energy momentum tensors, energymomentum tensor for a perfect fluid. Action principle for gravitational and matter fields. Kerr solution. Black holes. Gravitational waves.

Text Books:

1. Gravitation and cosmology: Principles and applications of GTR, S. Weinberg, Wiley
2. General theory of relativity, J. B. Hartle (Cambridge Press)

References:

1. Space time geometry by Sean Carrol, Cambridge University Press
2. General relativity by G. Wald,Cambridge University Press
3. Gravitation, foundations and frontiers by T. Padmanabhan

Title: Modern Communication Systems **(Course Code: PHY18410GE)**

Max.Marks:50 **Int. Assessment:** 10 **Ext. Examination:** 40 **Credits:** 02

Course Outcome:

Learning Outcome: Upon completion of the course, the students should:

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Unit-I

Introduction to wireless communications, example of wireless communication system, the Cellular concept and system design fundamentals, frequency reuse, Channel assignment strategies, Handoff strategies, Interference and system capacity, trunk and grade services, Methods for improving coverage and capacity in cellular system, Multiple access techniques for wireless communications FDMA, TDMA, Spread spectrum techniques, SDMA, Packet Radio, CSMA, Capacity of cellular CDMA with multiple cells and capacity of SDMA

Unit-II

Wireless systems and standards, AMPS, IS-94, GSM traffic, Examples of GSM cell, frame structure of GSM cello, details of forward and reverse CDMA channels Personal access communication systems, Personal Mobile satellite communication, Integrating GEO, LEO, MEO Satellite and terrestrial mobile systems, Rake receiver and Advanced Rake receiver

Text Books:

1. Wireless communication, principles and practice, 2nd Ed., Theodore S. Reppaport

2. Wireless digital coomunicatio, Kamilo Feher

References:

1. Electronic communication systems by Wayne Tomasi

Title: Astronomical Techniques **(Course Code: PHY18411GE)**

Max.Marks:50 **Int. Assessment:** 10 **Ext. Examination:** 40 **Credits:** 02

Course Outcome:

Learning Outcome: Upon completion of the course, the students should:

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Unit-I

Telescopes; Types of telescopes. Design and construction of a simple Optical telescopes. Schmidt telescopes. Sky charts and their importance. Solar telescopes. Detectors for optical and infrared regions. Application of CCD's to stellar imaging.

Unit-II

Astronomical photometry; Simple design of an astronomical photometer. Observing technique with a photometer Correction for atmospheric extinction. Tansformation to a standard photometric system. Astronomical spectroscopy; Spectral classification. Simple design of astronomical spectrograph. Radial velocity measurements.

Text Books:

1. C. R. Kitchin: Astrophysical Techniques
2. Heindren and Kaitchuck: Astronomical photometry

References:

1. Gordon Walker: Astronomical observations - an optical perspective, Cambridge university press.
2. Astrophysics - stars and galaxies by K. D. Abhyankar
3. C. R. Miczaika and W. M. Sinton: Tools of the astronomers
4. W. A. Hiltner: Astronomical techniques
5. Carelton: Methods of experimental physics. Vol XII A

Title: Density Functional Theory of Materials **(Course Code: PHY18410DCE)**

Max.Marks:50 **Int. Assessment:** 10 **Ext. Examination:** 40 **Credits:** 02

Course Outcome: By completing this course, students will gain a solid understanding of the theoretical foundations of electronic structure theory, from the basic many-body Schrödinger equation to the practical applications of Density Functional Theory in modelling and predicting the properties of complex systems.

Learning Outcome: Upon completion of the course, the students should:

- Apply the independent electrons approximation to simplify complex quantum systems.
- Grasp the principles of mean-field theory, the Hartree Method, and the Hartree-Fock equations for describing electron-electron interactions.
- Comprehend the transition from wave-function-based descriptions to the electron density function in Density Functional Theory.
- Understand the Hohenberg-Kohn theorem and its significance in DFT.
- Gain proficiency in solving the Kohn-Sham equations and using the local density approximation (LDA) for practical calculations.
- Analyze exchange and correlation energies in DFT and perform self-consistent DFT calculations to model complex electronic systems accurately.

Unit-I

Basic Equations for Interacting Electrons and Nuclei, Many-body Schrodinger equation, independent electrons approximation, Mean-field approximation Hartree Method, Hartree- Fock equations, Self-Consistent field method. Density functional theory: From wave-function to electron density function, Thomas–Fermi model. Hohenberg-Kohn theorem, Kohn-Sham equations, the local density approximation, Exchange and correlation energies of the electron gas, Self-consistent calculations.

Unit-II

Equilibrium structures of materials, the adiabatic approximation, Atomic Forces, Hellmann Feynman theorem, Comparison of DFT structures with X-ray crystallography. Band structures, Kohn-Sham equations for a crystal, Kohn-Sham energies and wavefunctions, Calculation of band structures and Density of States using DFT, Plane wave methods, pseudopotentials. The band gap problem. Practical implementation of DFT using Quantum Espresso.

Text Books:

1. Materials Modelling Using Density Functional Theory Feliciano Giustino , Oxford Publishers.
2. Density Functional Theory: A Practical Introduction David S. Sholl, Janice A. Steckel (John Wiley & amp; Sons)
3. Electronic Structure Calculations for Solids and Molecules: Theory and Computational Methods , Jorge Kohanoff , Cambridge University Press
4. Electronic Structure: Basic Theory and Practical Methods Richard Martin , Cambridge University Press

Title: Quantum Information Theory **(Course Code: PHY18413DCE)**

Max.Marks:50 **Int. Assessment:** 10 **Ext. Examination:** 40 **Credits:** 02

Course Outcome: This course on quantum information processing aims to equip students with a comprehensive understanding of the foundational principles and advanced concepts in quantum mechanics and quantum information theory. By delving into the postulates of quantum mechanics, students will grasp the intricacies of qubits, composite quantum systems, entanglement, and the Bell Inequality. Proficiency in density operators, distance measures, and entanglement measures will enable precise quantum state analysis, while the exploration of purification processes and isometric extensions of qubit channels enhances understanding. Students will comprehend the significance of the no-cloning theorem and gain practical skills in applying quantum circuits to protocols like entanglement distribution, super dense coding, and quantum teleportation. The course will also cover Shannon and von Neumann entropies, data processing inequalities, and quantum algorithms, providing students with a holistic understanding of quantum information processing and its real-world applications.

Learning Outcome: Upon completion of the course, the students should:

- Attain a foundational understanding of quantum mechanics postulates, including the principles of qubits, composite quantum systems, quantum entanglement, and the Bell Inequality, showcasing the ability to apply these concepts to quantum information processing.
- Master the properties of density operators, including Bloch sphere representation, projective measurement, POVM, Schmidt decomposition, and the reduced density operator. Gain proficiency in the operator sum representation and its practical applications.
- Understand and apply distance measures in quantum mechanics, such as norms, trace distance, fidelity, and their properties, while exploring the relationship between trace distance and fidelity. Gain insight into entanglement measures and the concept of purification for a density operator.
- Apply the principles of the no-cloning theorem to quantum information, showcasing an understanding of the limitations in copying arbitrary quantum states.
- Demonstrate proficiency in quantum circuits, understanding their role in quantum information processing and their applications in quantum teleportation, super dense coding, and entanglement distribution.

- Grasp the basics and properties of Shannon and von Neumann entropies, explore data processing inequalities, and comprehend coding theorems and channel capacities in the context of quantum information theory.
- Apply quantum algorithms, including parallelism, Deutsch-Jozsa, and the Quantum Fourier Transform, demonstrating their applications and understanding their efficiency in comparison to classical algorithms.
- Understand and apply mutual information concepts in the context of quantum information theory, gaining insights into information-sharing aspects between quantum systems.
- Explore elementary ideas regarding the physical realizations of quantum algorithms, gaining insight into their potential implementations and practical aspects.
- Develop a comprehensive understanding of quantum information processing, including the principles of quantum algorithms, entanglement, quantum teleportation, and quantum circuits, showcasing the ability to analyze and apply these concepts to quantum information systems.

Unit-I

Postulates of quantum mechanics, qubits, composite quantum systems, Quantum entanglement, Bell Inequality. Density Operator: General properties, Bloch sphere representation, projective measurement, POVM, Schmidt decomposition, reduced density operator. Operator sum representation and its applications. Distance Measures: Norms, Trace Distance and its properties, Fidelity and its properties, relation between Trace Distance and Fidelity. Entanglement measures. Purification: Purification of a density operator, isometric extension of single qubit channels.

Unit-II

No-Cloning theorem. Quantum Circuits. Entanglement distribution, super dense coding, quantum teleportation, optimality of these protocols, unit source capacity region. Shannon and von Neumann Entropies: Basic properties, Data Processing Inequalities, coding theorems, channel capacities. Mutual Information. Quantum Algorithms: Parallelism, Deustch-Jozsa, Quantum Fourier Transform and its applications. Physical Realizations(Elementary Ideas).

Tutorials: Analyzing some foundational papers of this field. e.g. EPR, Bell, Bennett, Shumacher.

Text Books:

1. Quantum Computation and Quantum Information: M. A. Nielson and I. Chaung , Cambridge University Press.

2. http://theory.caltech.edu/ preskill/ph219/index.htmllecture Lecture Notes by John Preskill (Caltech USA)

References:

1. Quantum Information Second Edition (Cambridge University Press): Mark Wilde
2. Quantum Information Theory: Mathematical Foundations (Springer) : M. Hayashi