SIR PADAMPAT SINGHANIA UNIVERSITY

Udaipur

SCHOOL OF ENGINEERING

Course Curriculum of Ph.D. Degree Programme

In

Physics

(Batch-2018-19)

Credit Structure

Category	Credits
Departmental Major Subjects	6
Research Methodology	3
Total	9

Course Structure: Ph.D. Degree (2018-19)

(Departmental Major Subjects)

S.No.	Course Code	Course Title	L	T	P	Credit(s)
1	PH-601	Elementary Quantum Mechanics	3	0	0	3
2	PH-602	Theoretical Atomic & Molecular Physics-I	3	0	0	3
3	PH-603	Nonlinear Dynamics-I	3	0	0	3
4	PH-604	Advanced Quantum Mechanics	3	0	0	3
5	PH-605	Theoretical Atomic & Molecular Physics II	3	0	0	3
6	PH-606	Nonlinear Dynamics II	3	0	0	3

Note:

1. The candidate has to select two courses of 3 credits each from the departmental major subjects and a compulsory Research Methodology (common to all PhD Scholars) course of 3 credits.
2. The following combinations of major subjects shall be allowed depending on the required prerequisites: S. Nos. 1&4, S. Nos. 2&5, S. Nos. 3&6, S. Nos. 1&2, S. Nos. 1&3.

Detailed Syllabus for Ph.D. Degree Programme
in
Physics

Semester – I

(Departmental Major Subject)

PH-601	L – T – P - C
Elementary Quantum Mechanics	3 – 0 – 0 - 3

Objective: *The objective of this course is to introduce the fundamentals of quantum mechanics & its applications to study the various properties of atoms, molecules & solids.*

Course Content

The quantum concept, Postulates of quantum mechanics Schrodinger equation: Derivation & Solution, Physical interpretation of wave function, Expectation values, Probability current density, Ehrenefest's theorem, Uncertainty principle, Complementarity principle.

One-dimensional problems: Wells & barriers, Harmonic oscillator by Schrodinger's equation, Applications of Schrodinger equation in Spherical Symmetric System: Rigid Rotator & Hydrogen Atom, Degeneracy.

Operators in QM: Orthogonal sets, Completeness, Different type of operators, Eigen values & Eigen functions, Operator formalism in QM, Commutation Algebra, Commutatively & simultaneous Eigen functions. Hilbert space, Operators as matrix, Matrix form of wave function, Schrodinger, Heisenberg & Interaction matrix representation, Dirac's Bra & Ket vectors, Direct sum & product of Hilbert space, Co-ordinate & momentum representation.

Identical particles, Symmetric & anti-symmetric wave functions, Particle exchange operator, Pauli exclusion principle, Spin angular momentum, Stern-Gerlach experiment, Spin matrices for electron, Commutation relations.

Angular momentum operator, Spin angular momentum, Total angular momentum operators, Commutation relations of total angular momentum, Eigen values of J^2 & J_z, J_+ & J_-, J_x & J_y, Addition of angular momentum, CG coefficients, Wigner-Eckart theorem.

Approximate methods- Time independent perturbation theory, Non-degenerate & degenerate cases, Applications: – normal He atom, perturbed harmonic oscillator, Zeeman Effect & Stark effect.

Text/Reference books:

1. Quantum Mechanics. Schiff L I. 3rd Ed. McGraw-Hill. 1968.
2. Quantum Mechanics Theory & Applications. Ghatak A. K. & Lokanathan S. 3rd Ed. McMillan India Limited. 1997.
3. Quantum Mechanics: A modern approach. Das A. & Milissionos A.C. 1st Ed. Gordan & Breach Science Publishers.2010.
4. Quantum Mechanics An Introduction. Grenier W. 4th Ed. Springer.2001.
5. Modern Quantum Mechanics. Sakurai J.J.2nd Ed. Addison-Wesley. 2010.

Detailed Syllabus for Ph.D. Degree Programme
in
Physics

Semester – I

(Departmental Major Subject)

PH-602	L – T – P - C
Theoretical Atomic & Molecular Physics - I	3 – 0 – 0 - 3

Objective: *The objective of this course is to introduce the physical structure & behavior of atoms & molecules.*

Course Content

Interaction of One-Electron Atoms with Electromagnetic Radiation: Dipole approximation, Einstein Coefficients, Selection Rules, Line Intensities, Lifetimes, Line Shapes, & Line Widths, The Photoelectric effect, Fine structure, Hyperfine Structure. The Stark Effect, the Zeeman Effect; Two- Electron Atoms: Ground State, Excited States, Auger Effect, Resonances; Many-Electron Atoms: The Central Field Approximation, Thomas-Fermi Model, Atom Interferometry; Molecules: The Born-Oppenheimer Approximation, the Hydrogen Molecule, Diatomic Molecules, Electronic Structure, Rotational & Vibrational Structure, Polyatomic Molecules.

Text/Reference books:

1. Physics of Atoms & Molecules. Bransden B. H.& Joachain C. J. 2nd Ed. Pearson Education.2003.
2. Intermediate Quantum Mechanics. Bethe H. A. & Jackiw R. 3rd Ed. Perseus Books.1997.
3. Atoms, Molecules & Photons . Demtroder W. 2nd Ed. Springer.2010.

Detailed Syllabus for Ph.D. Degree Programme
in
Physics

Semester – I

(Departmental Major Subject)

PH-603	L – T – P - C
Nonlinear Dynamics - I	3 – 0 – 0 - 3

Objective: *The objective of this course is to introduce various fundamental principles, theoretical procedures, numerical techniques & technological applications of nonlinear dynamical systems. It also highlights the current advances in this emerging area of interdisciplinary research.*

Course Content

Dynamical systems: linear & nonlinear dynamical systems, working definition of nonlinearity & effects of nonlinearity.

Linear oscillators & predictability: free oscillations, damped oscillations, damped & force oscillations.

Nonlinear oscillators: free oscillations, damped oscillations, forced oscillations, primary resonances & jump phenomenon, secondary resonances - sub harmonic & super harmonic, nonlinear oscillations & bifurcations.

Qualitative features of dynamical systems: Autonomous & non-autonomous systems, equilibrium points, phase space & phase space trajectories, stability of equilibrium points, attractors & repellors, Criterion for stability of equilibrium points & classification of equilibrium points, periodic attractors, quasi periodic attractor, chaotic attractor, concept of dissipative & conservative dynamical systems.

Simple bifurcations: Saddle node bifurcation, pitchfork bifurcation, transcritical bifurcation, Hopf bifurcation.

Chaos in discrete dynamical systems: equilibrium points of logistic map & their stability, periodic solutions, chaotic solution & sensitivity on initial condition, bifurcation diagram, construction of Coweb diagram, strange attractor & self similarity in Henon-map, period doubling route to chaos in Henon map.

Route to chaos: Period-doubling route to chaos, quasiperiodic route to chaos, intermittence route to chaos, type-I intermittence & standard bifurcations in maps.

Chaos in dissipative nonlinear oscillators: Bifurcation & chaos in Duffing oscillator, intermittent transition, quasiperiodic route & strange non-chaotic attractors, period doubling & bifurcation in Lorenz equations, introduction to other chaotic oscillators-driven Van der Pol oscillator, damped & driven pendulum, Morse oscillator & Rossler oscillator, necessary conditions for the occurance of chaos in discrete & continuous dynamical systems.

Chaos in nonlinear electronic circuits: linear & nonlinear electronic circuit elements, linear circuit-resonant RLC circuit, nonlinear circuits-Chua's diode & bifurcation & chaos in circuit containing Chua's diode, chaos in simplest dissipative circuit-MLC circuit & its stability analysis, analytical & numerical studies, other useful nonlinear circuits: RL diode circuit, Hunt's nonlinear circuit, p-n junction diode oscillator & Colpitt's oscillator.

Characterization of periodic & chaotic motions: Lyapunov exponents, computation of Lyapunov exponents for maps & continuous dynamical systems, power spectrum, autocorrelation & dimension of attractor & criterion for chaotic motion. Advances in chaotic dynamics: time-series analysis, chaotic scattering, controlling of chaos, synchronization of chaos (only brief introductions).

Text/Reference Books:

1. Nonlinear Dynamics: Integrability, chaos & patterns. Lakshmanan M. & Rajasekhar S. 1st Ed. Springer Verlag. 2012.
2. Chaos & nonlinear Dynamics. Hillborn R. C. 2nd Ed. Oxford University Press. 2001.
3. Nonlinear oscillations, dynamical systems & bifurcation of vector fields. Guckenheimer J. & Holmes P. 6th Ed. Springer Verlag, New York.2002 .
4. Chaotic & fractal dynamics. Moon F. C. John Wiley & Sons. 1992.
5. Chaos-An introduction to dynamical systems. Alligwood K. Sauer T. & Yorke J. A. 2nd Ed. Springer Verlag. New York. 2000.
6. Chaos in dynamical systems. Ott E. 2nd Ed. Cambridge University Press. 2002.

Detailed Syllabus for Ph.D. Degree Programme
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Physics

Semester – I

(Departmental Major Subject)

PH-604	L – T – P - C
Advanced Quantum Mechanics	3 – 0 – 0 - 3

Objective: *The objective of this course is to introduce various approximate methods, scattering theory & fundamentals of relativistic quantum mechanics & its applications to study the various properties of atoms, molecules & solids.*

Course Content

Approximate methods: Variational method, WKB approximation, Applications of Variational & WKB method, Time dependent perturbation theory, Harmonic perturbation, Fermi's golden rule, Transition probabilities, Adiabatic & Sudden approximation, Semi classical treatment of radiation.

Quantum Theory of Scattering: Collision in 3-D & scattering, Laboratory & CM reference frames, Scattering amplitude, Differential scattering cross section & total scattering cross section, General formulation of scattering theory, Born approximation, Applications of Born approximation, Partial Wave Analysis & Phase Shift, Applications of PWA, The Lippmam-Schwinger equation.

Relativistic wave equations: Klein-Gordan equation, Solution of Klein-Gordan equation, Dirac’s relativistic equation, Solution of Dirac’s equation.

Quantization of Fields: Classical approach to field theory, Second quantization, Quantum equation of field, Quantization of non-relativistic Schrödinger equation, Creation, Annihilation & Number Operators, Quantization of Klein-Gordan equation.

Text/Reference books:

1. Quantum Mechanics. Schiff L I. 3rd Ed. McGraw-Hill.1968.
2. Quantum Mechanics Theory & Applications. Ghatak A. K. & Lokanathan S. 3rd Ed. McMillan India Limited. 1997.
3. Quantum Mechanics: A modern approach. Das A. & Milissionos A.C. Gordan & Breach Science Publishers.
4. Quantum Mechanics An Introduction. Grenier W. Springer,3rd Ed. 1994.
5. Modern Quantum Mechanics. Sakurai J.J. 2nd Ed. Addison-Wesley. 2010.
6. Quantum Physics (atoms, molecules…). Eisberg R. & Resnick R. J. 2nd Ed. Wiley.1985.
7. Quantum Field Theory. Mandal F. & Shaw G. 2nd Ed. John –Willey.2010.

Detailed Syllabus for Ph.D. Degree Programme
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Physics

Semester – I

(Departmental Major Subject)

PH-605	L – T – P - C
Theoretical Atomic & Molecular Physics - II	3 – 0 – 0 - 3

Objective: *The objectives of this course to introduce various theoretical methods & approximations used to study the physical structure & behaviour of atoms & molecules.*

Course Content

The Hartree-Fock Method & the Self-Consistent Field Method; Theory of Multiplets: Electrostatic Interaction, Spin-Orbit Interaction, Interactions with External Fields; Atomic Collisions: Elastic Scattering At High Energies, At Low Energies, Corrections to Elastic Scattering, Elastic Scattering of Spin 1/2 Particles, Inelastic Scattering At High Energies, At Low Energies, Semi-classical Treatment of Inelastic Scattering, Classical Limit of Quantum Mechanical Scattering.

Text/Reference books:

1. Physics of Atoms & Molecules. Bransden B. H. & Joachain C. J. 2nd Ed. Pearson Education.2003.
2. Intermediate Quantum Mechanics. Bethe H. A. & Jackiw R. 3rd Ed. Levant Books, India.1997.
3. Atoms, Molecules & Photons. Demtroder W. 2nd Ed. Springer.2010.

Detailed Syllabus for Ph.D. Degree Programme
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Physics

Semester – I

(Departmental Major Subject)

PH-606	L – T – P - C
Nonlinear Dynamics - II	3 – 0 – 0 - 3

Objective: *The objective of this course is to introduce various fundamental principles, theoretical procedures, numerical techniques & technological applications of nonlinear dynamical systems. It also highlights the current advances in this emerging area of interdisciplinary research*.

Course Content

Chaos in Hamiltonial systems: Hamilton's equation & Hamiltonian, phase space, Liouvelles theorem & phase space distribution, constants of motion & integrable systems, pendulum & simple harmonic oscillator, non-integrable systems, KAM theorem, possible orbits in conservative systems, period doubling & chaos in conservative systems, Henon-Heiles system, standard map, periodically driven undamped Duffing oscillator.

Integrability & notion of integrability: complete integrability, complex analytic integrability, detection of integrability: Painleve analysis, Painleve analysis & Integrability of two coupled nonlinear oscillators, symmetries & integrability & its application to Henon Heiles system, a direct method for finding integral of motion, integrable systems with degrees of freedom more than two, integrable discrete systems & integrable dynamical systems on discrete lattice.

Linear & nonlinear dispersive waves: linear waves, linear nondispersive wave propagation, linear dispersive propagation, Fourier transform & solution of initial value

problem, wave packet & dispersion, nonlinear dispersive systems, Cnoidal & solitary waves.

KDV equation & solitons: Scott Russel phenomenon & KdV equation, the Fermi-Pasta-Ulam numerical experiment on an harmonic lattices, asymptotic analysis & KdV equation, numerical experiments of Zabusky Kruskal, Hirota's bilinearization method.

Text/Reference books:

1. Nonlinear Dynamics: Integrability, chaos & patterns. Lakshmanan M. & Rajasekhar S. 1st Ed. Springer Verlag. 2003.
2. Chaos & nonlinear Dynamics. Hillborn R. C. 2nd Ed. Oxford University Press. 2000.
3. Nonlinear oscillations, dynamical systems & bifurcation of vector fields. Guckenheimer J. & Holmes P. 6th Ed. Springer Verlag, New York. 2002.
4. Chaos in classical & quantum mechanics. Gutzwiller M. C.1st Ed. Springer Verlag, New York. 1990.