Curriculum

Ph.D.

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Indian Institute of Technology Jodhpur

Ph.D. (Physics)

Cat.	*Course Number: Course Title*	*L-T-P*	*Credits*		*Cat.*	*Course Number: Course Title*	*L-T-P*	*Credits*
I Semester					**II Semester**			
E	*Electives*				E	*Electives*		
	Total					*Total*		
III Semester					**IV Semester**			
H	**PH799 Ph.D. Thesis**				H	**PH799 Ph.D. Thesis**		
	Total					*Total*		
V Semester					**VI Semester**			
H	**PH799 Ph.D. Thesis**				H	**PH799 Ph.D. Thesis**		
	Total					*Total*		
VII Semester					**VIII Semester**			
H	**PH799 Ph.D. Thesis**				H	**PH799 Ph.D. Thesis**		
	Total					*Total*		

Electives

Semester I				**Semester II**			
PH751	Nuclear Physics: Principles & Applications	3-0-0	3	PH760	Material and Device Characterization	3-0-0	3
PH752	Biomolecular Information Processing	3-0-0	3	PH761	Astrophysics	3-0-0	3
PH753	Biomolecular Information Processing	3-0-0	3	PH762	Quantum Computation and Information	3-0-0	3
PH754	Magnetism and Superconductivity	3-0-0	3	PH763	Quantum Coding and Cryptography	3-0-0	3
PH755	Particle Physics	3-0-0	3	PH764	Electronic Transport in Mesoscopic System	3-0-0	3
PH756	General Theory of Relativity	3-0-0	3	PH765	Vacuum Systems and Thin film Technology	3-0-0	3
PH757	Quantum Field Theory	3-0-0	3	PH766	Relativistic Quantum Mechanics		
PH758	Semiconductor Device Technology	3-0-0	3	PH767	Classical and Quantum Optics	3-0-0	3
PH759	Understanding Scanning Tunneling Microscope	3-0-0	3	PH768	Applications of Interaction of Radiation with Matter	3-0-0	3

S.No.	*Category*	*Category Title*	Students with	*Total Courses*	*Total Credits*
1	E	*ELECTIVES*	Master's Degree	4	12
			Bachelor's Degree	10	30
2	H	Thesis	-	-	-

Course Title	***Nuclear Physics: Principles & Applications***	Course No.	**PH751**			
Focus Group	Physics	Structure	3	0	0	3
Offered for	Ph.D. students	Status			*Elective*	
Pre-requisite	*Consent of Teacher*	To take effect from	*July 2014*			

Objectives

1. Learning the fundamentals of Nuclear physics.
2. To provide knowledge of the important and current applications of nuclear physics.

Learning Outcomes

1. Understanding the fundamental principles of nuclear physics.
2. The students will become familiar with the applications of nuclear physics.

Course Content

Basic concepts of special theory of relativity, Wave-particle duality, Uncertainty relation & Schrodinger equation; Particle in one-dimensional box, Tunnelling effect

General properties of nucleus, Radioactive decay, Binding energy, Liquid drop model, Semi-empirical mass formula, Meson theory of nuclear forces

Tunnel theory of alpha decay, Beta decays and weak interactions, Nuclear reactions, Interaction of alpha & beta particles, gamma radiation and neutrons with matter

Biological effects of radiation, Absorbed dose, Equivalent dose, Effective dose, Radiation in the environment, Risk to occupationally exposed workers

Nuclear fission and fusion, chain reaction, Physics of nuclear reactors, Nuclear astrophysics: Synthesis of elements

Radiocarbon dating

Industrial uses: Tracing, Gauging, Food preservation

Nuclear medicine, Nuclear forensic

Reference Books

1. R. W. Hertzberg, “Deformation and Fracture Mechanics of Engineering Materials,” John Wiley & Sons, 1996 .
2. C. R. Brooks and A. Choudhury, “Failure Analysis of Engineering Materials,” McGraw-Hill, 2002 .
3. W. D. Callister, “Materials Science and Engineering; An Introduction,” 7th Edition, John Wiley & Sons,2007.
4. D. Broek, "Elementary Engineering Fracture Mechanics", Springer; 3rd edition, 1986
5. Kathleen Mills, Metals Handbook: Volume 12: Fractography (Asm Handbook) , 1987
1. W. T. Becker, R. J. Shipley ,ASM Handbook: Volume 11: Failure Analysis and Prevention (ASM Handbook) (ASM Handbook), 2002

Course Title	***Biomolecular Information Processing***	Course No.	**PH752**			
Focus Group	Physics	Structure	3	0	0	3
Offered for	PhD students	Status	*Core*		Elective	
Pre-requisite	*Consent of Teacher*	To take effect from	*July 2013*			

Objectives

To understand various biological processes where ever information processing prevails (such as in enzymatic, peptide based, DNA based, RNA based reaction processes and so on). To understand these processes means to understand the inherent nature of these materials. The various biochemical and bio-catalytic activities of these materials can lead to use these materials in systems where logical control brings better stability and better efficiency. Here artificial systems based on analogous synthetic system will also be discussed.

Learning Outcomes

1. One can understand the concept of unconventional computing
2. Having this knowledge an alternate machine for computing can be created

Course content:

1. *Biomolecular computing systems: Unconventional computing to smart materials:* Overview of the conventional computing system, comparison of unconventional system with unconventional computing systems.
2. *Peptide based computation:* Introduction, peptide based replication networks, template assisted replication, theoretical prediction of the network connectivity, *De Nevo* designed synthetic networks, uniform design of all two input gates, requirement of symmetry and order for constructing logic gates, experimental logic gates, adaptive networks and triggered chemically and by light.
3. *Biomolecular electronics and protein based optical computing:* Introduction, biomolecular and semiconductor electronics a comparision, Bacteriorhodopsin as a photonic and holographic material, light induced and branched photocycle3D optical memory, efficient algorithm for data processing,
4. *Enzyme based information processing:* Introduction, enzyme based logic systems producing pH changes as output signals, interfacing of enzyme logic systems with modified electrode with signal processing polymers, switchable biofuel cells, processing of injury biomarkers with modified electrodes.
5. *Enzyme logic digital biosensors:* Introduction, enzyme based logic systems for identification of injury conditions, multiplexing of injury code for parallel operation of enzyme logic gates, mimic of biochemical pathways for complex Biocomputing, application of filter system for digitalization of information
6. *Information security applications based on biomolecualr systems:* Introduction, molecular and biomolecualr keypad locks, antibody encryption and steganography, bio-barcode

Reference Books

1. Biomolecular information processing by Evgeny Katz, Wiley-VCH publication
2. Molecular and supramolecular information processing from molecular switches to logic systems by Evgeny Katz, Wiley-VCH publication
3. Principles of computational cell biology by V. Helms
4. Molecular Switches by B. L. Feringa and W. R. Browne

Course Title	**Biomolecular Information Processing II**	Course No.	**PH753**			
Focus Group	Physics	Structure (LTPC)	3	0	0	3
Offered for	PhD students	Status			*Elective*	
Pre-requisite	*Consent of Instructor*	To take effect from				

Course objective

1. To understand various biological processes where ever information processing prevails (such as in enzymatic, peptide based, DNA based, RNA based reaction processes and so on).
2. To understand the associated biochemical and bio-catalytic activities of these materials, which can lead to use these materials in systems where logical control brings better stability and better efficiency.
3. To understand natural systems to fabricate analogous artificial systems.

Learning Outcomes

1. One can understand the concept of unconventional computing
2. One can think of creating an alternate computing machine

Course Contents

1. *Biomolecular computing systems:* Introduction, DNA as a tool for molecular programming, DNA structure, review of DNA reaction, birth of DNA computing: Adleman's experiment and extension, Hamiltonian path problem via DNA computing, other models of DNA computing, computation using DNA tiles algorithmic assembly via DNA tiling lattices, source of errors, algorithmic error correction schemes for tiling, challenges in DNA based biomolecular computation
2. *Biomolecular finite automata:* Introduction, biomolecular finite automata, theoretical models of a molecular Turing machine, the first realization of an autonomous DNA based finite automaton, three symbol three state DNA based automata, molecular crypto system for images by DNA computing, molecular computing device for medical diagnosis and treatment *in vitro*, DNA based automaton with bacterial phenotype output, molecular computing with plant cell phenotype, biomolecular plant cell phenotype
3. *In vivo* information processing using RNA interference: Introduction, regulatory pathways as computation, a computation versus a computer, prior work on synthetic biomolecular computing circuit, RNA interference based logic, logic circuit blueprint, experimental confirmation of the computational core, building the sensory module, direct control of siRNA by mRNA inputs, complex transcriptional regulation using RNAi-based circuits
4. Bacteria based cellular computing circuits for sensing: Introduction, cellular computing circuits, genetic toolbox, engineered gene regulation, oscillators, witches, AND logic gates, edge detector, transition to *in silico* rational design, transition from enzyme computing to bacteria based Biocomputing
5. Logic of decision making in environmental bacteria: Introduction, building models for biological networks, formulation and simulation of regulatory networks, stochastic versus deterministic models, graphical models, Boolean analysis of regulatory networks, translating biological networks into logic circuits, from digital networks to workable models

Reference Books

1. Biomolecular information processing by Evgeny Katz, Wiley-VCH publication
2. Molecular and supramolecular information processing from molecular switches to logic systems by Evgeny Katz, Wiley-VCH publication
3. Principles of computational cell biology by V. Helms
4. Molecular Switches by B. L. Feringa and W. R. Browne

Course Title	***Magnetism and Superconductivity***	Course No	**PH754**			
Focus Group	Physics	LTPC	3	0	0	3
Offered for	Ph. D.	Type	Elective			
Pre-requisite	Consent of Teacher	To take effect from				

Objectives

Introduce magnetism and superconductivity principles and their applications

Learning Outcomes

The students will develop insight into the key principles and applications of Magnetism & Superconductivity, and their relevance to current developments in physics.

Course Content

Review of basic magnetostatics: Magnetic field, magnetic moment, magnetic dipole etc.

Magnetization and magnetic materials: Magnetic induction and magnetization, Susceptibility and permeability, hysteresis loops.

Atomic origins of magnetism: Solution of Schrodinger equation for a free atom, quantum numbers and their physical meanings, Electron spin in many body reference, spin-orbit coupling- Russell-Saunders coupling, Hund's rule, jj coupling, Zeeman and anomalous Zeeman effect.

*Diamagnetism:*Diamagnetic susceptibility, diamagnetic materials, Superconductivity and related effects, superconducting materials and their applications.

*Paramangetism:*The Curie-Weiss law, Langevin theory of paramagnetism, Pauli paramagnetism and use of paramagnets.

Ferromagnetism and ferrimagnetism: Magnetic domains, domain walls, hysterization and magnetization, ferromag and ferrimag materials and their applications.

Antiferromagnetism: Weiss theory of antiferromagnetism, susceptibility above and below T_N, application of antiferromagnets.

Device applications: Magnetic data storage, magneto-optic recording- Kerr effect, Faraday effect etc., magnetic semiconductors, exchange mechanisms, spin transistors etc.

Reference Books

1. Culity B. D. and Graham, C. D., *Introduction to magnetic materials*.
2. David, J.,*Introduction to magnetism and magnetic materials*.
3. Kittel, C., *Introduction to solid state physics*.
4. Goodenough, J., *Magnetism and the chemical bond*.

Course Title	***Particle Physics***	Course No	**PH755**			
Focus Group	Physics	LTPC	3	0	0	3
Offered for	Ph. D.	Type	Elective			
Pre-requisite	Consent of Teacher	To take effect from				

Objectives
Learning the fundamentals of Elementary Particle Physics.

Learning Outcomes
The successful students will become familiar with the basic concepts of Feynman calculus, QED, QCD and weak interactions.

Course Content
A preview of Particle Physics: Historical introduction of particle physics, Classification of particles, Elementary particle dynamics, Relativistic Kinematics, Symmetries, Groups and Conservation laws.
Bound States: Light quark mesons, Baryons, Magnetic moments, Masses.
Feynman Calculus: Decays and scattering, Decay rates, Cross sections, The Golden Rule, Higher order diagrams
Quantum Electrodynamics (QED): Feynman rules for QED, Electron-Muon scattering, Electron-Electron scattering, Compton scattering, Casimir's trick, Mott and Rutherford scattering, Pair annihilation, Renormalization.
Quantum Chromodynamics (QCD): Elastic electron-proton scattering, Feynman rules for QCD, Pair annihilation in QCD, Asymptotic freedom.
Weak Interactions: Parity violation and the V-A form of the weak interaction, interpretation of the coupling G, Nuclear β-decay, Muon and pion decay, Charged current neutrino-electron scattering, neutrino quark scattering, Observation of weak neutral current, Neutral current neutrino-quark scattering, Cabibbo angle.
Electroweak Interactions: Weak isospin and hypercharge, basic electroweak interactions, Effective current-current interactions, Feynman rules for electroweak interactions, neutrino-electron scattering, electroweak interference in electron-positron annihilation.

Reference Books

1. David Griffiths, *Introduction to Elementary Particles*, Wiley-Vch, 2010.
2. Abraham Seiden, *Elementary Particles*, Pearson, 2009.
3. Halzen, F. and Martin, A. D., *Quarks and Leptons*, Wiley-India, 2011.

Course Title	***General Theory of Relativity***	Course No	**PH756**			
Focus Group	Physics	LTPC	3	0	0	3
Offered for	Ph. D.	Type	Elective			
Pre-requisite		To take effect from				

Objectives
To give the student a basic understanding of the General Theory of Relativity and its importance for modern physics.

Learning Outcomes
1. Will give detailed insight regarding theory and dynamics related to gravity.
2. The students will be able to apply the theory of general relativity in many fields of physics for example in astrophysics and cosmology.

Course Content
Review of special theory of relativity–vector and tensor–particle dynamics–electrodynamics – energy momentum tensor – relativistic hydrodynamics.
Principle of equivalence–gravitational forces–geodesic–affine connection–Newtonian limit.
Tensor algebra–tensor density–transformation of affine connection–covariant differentiation–gradient, divergence, curl–parallel transport–curvature tensor–Bianchi identity–Ricci tensor–curvature scalar–Killing vectors and symmetries Einstein's field equation
Schwarzschild solution–Birkhoff's theorem - geodesic equation in Schwarzschild space time–Precession of perihelion of mercury – bending of light rays – gravitational red shift.
Stellar equilibrium–White dwarfs– neutron stars–comoving coordinates – Schwarzschild blackholes – collapse to a blackholes.
Friedmann-Robertson-Walker solution – our Universe.

Reference Books

1. Weinberg, S., *Gravitation and Cosmology: Principle and Applications of the General Theory of Relativity*, John Willey & Sons, 1972.
2. Hartle, J. B., *Gravity*, Pearson education, 2011.

Course Title	***Quantum Field Theory***	Course No	**PH757**			
Focus Group	Physics	LTPC	3	0	0	3
Offered for	Ph. D.	Type	Elective √			
Pre-requisite	Consent of Teacher	To take effect from				

Objectives

1. To have an appreciation for the subject of quantum field theory.
2. To have an understanding of why quantum field theory occupies an important place in understanding various aspects of modern research.

Learning Outcomes

1. Understanding the introductory principles of quantum field theory.
2. The students will become familiar with concepts such as relativistic equations, renormalization and Feynman diagrams.

Course Content

Classical field theory: Lagrangian and Hamiltonian formalisms; Noether's theorem. This introduces the concept of symmetries in a consistent fashion.

Need for quantum field theory: particles and fields; canonical quantization; path integrals. The traditional approach to quantization is via the canonical route, while the modern developments, in gauge fields, rely on the path integral approach.

Spinor fields: Dirac equations, Lorentz invariance. A fundamental relativistic quantum equation is the Dirac equation. This treats space and time on an equal footing.

Electromagnetic fields: Maxwell's equations. The primal quantum object is light. Here we study the Lorentz invariance of Maxwell's equations and some of their consequences to Quantum Electrodynamics.

Electromagnetic vacuum: Harmonic oscillator; Casimir effect; Unruh effect; Lamb shift. The modes of a field can be described by the harmonic oscillator. This initiates the study into the phenomena of the Casimir and Unruh effects. Lamb shift, an experimental evidence of the existence of quantum vacuum fluctuations, will also be studied.

Relativistic evolutions: Introduction to Klein-Gordan equation, Dirac equation. Klein-Gordan equation was introduced, historically, to obtain a relativistic analogue of the Schrodinger equation. This leads to the problem of negative energy solutions, which are resolved by resorting to quantization of the field. This provides a simple illustration to the celebrated Spin-Statistics theorem. We also study the quantization of the Dirac field.

Self-energies and renormalization: An introduction. Here we study phenomena such as electron self-energy and vacuum polarization.

Feynman diagrams: perturbation theory; Wick's theorem. This is a standard diagrammatic method for performing Lorentz covariant perturbation theory.

Reference Books

1. Peskin, M. E. and Schroeder, D. V., An *Introduction to Quantum Field Theory*, Frontiers in Physics, 1995.
2. Milonni, P. W., *The Quantum Vacuum*, Academic Press, 1994.

Course Title	***Semiconductor Device Technology***	Course No	**PH758**				
Focus Group	Physics	LTPC	3	0	0	3	
Offered for	Ph. D.	Type	Elective				
Pre-requisite		To take effect from					

Objectives

To understand basic properties of semiconductors, physical principles and operational characteristics of semiconductor devices, and advanced device issues relevant to state-of-the-art integrated-circuit technologies.

Learning Outcomes

This course familiarizes with the physical concepts behind the solid state electronics devices.

Course Content:

Physics and Properties of Semiconductors: crystal structure, energy bands, statistics, Fermi level, carrier concentration at thermal equilibrium, carrier transport phenomena, Hall effect, recombination, optical and thermal properties, basic properties for semiconductor operation.

Device Processing Technology: oxidation, diffusion, ion-implantation, deposition, lithography, etching and interconnect.

p-n Junction: depletion region, diffusion, generation-recombination, current-voltage characteristics, junction breakdown, charge storage and transient behavior.

Bipolar transistor: transistor action and dependence on device structure, charge control switching model, Ebers-Moll Model, current-voltage characteristics, non-ideal and limiting effects at extremes of bias.

State-of-the-Art Bipolar Transistor Technology: poly-si emitters, narrow base, structural tradeoffs in optimizing performance.

Metal-Semiconductor Contacts: equilibrium, idealized metal semiconductor junctions, nonrectifying (ohmic) contacts, Schottky diodes, tunneling.

Metal-Oxide-Silicon System: MOS structure, capacitance, oxide and interface charge (charging of traps, tunneling through oxide).

*MOS Field-Effect Transistor:*threshold voltage, derivation of current-voltage characteristics, dependence on device structure.

State-of-the-Art MOS Technology: small-geometry effects, mobility degradation due to channel and oxide fields, velocity saturation, hot-electron effects.

Modern CMOS Technologies: CMOS Process flow starting from Substrate selection to multilevel metal formation, comparison between bulk and SOI CMOS technologies.

Reference Books

1. Donald , A. N., *Semiconductor Physics and Devices*, Tata McGraw-Hill, 2007.
2. Sze, S.M., *Physics of Semiconductor Devices*, John Wiley & Sons, 2001.
3. James,P., Deal, M. and Griffin P., *Silicon VLSI Technology*, Prentice Hall, Electronics and VLSI series, 2000.
4. Ben, G. S. and Kumar, B. S., *Solid State Electronic Devices*, Pearson Education Asia, 2007.

Course Title	***Principles Scanning Tunneling Microscope***	Course No	**PH759**			
Focus Group	Physics	LTPC	3	0	0	3
Offered for	Ph. D.	Type	Elective			
Pre-requisite	Solid State Physics, Quantum Mechanics	To take effect from				

Objectives

To understand the principles behind scanning tunneling microscope

Learning Outcomes

1. One can get acquainted and operate scanning tunneling microscope.
2. Understanding of various surface will be easier

Course Content

Overview: Tunneling an elementary model, probing electronic structure in atomic scale, spatially resolved scanning spectroscopy, lateral resolution, origin of atomic resolution in STM, tip-sample interaction effects

*Imaging Mechanism:*atom-scale tunneling, perturbation approach, image force, the square-barrier problem, modified Bardeen approach, effect of image force on tunneling, tunneling matrix elements, tip wavefucntions, Green's function and tip wavefunctions, wavefunctions at surfaces, related model, concept of surface states, field emission spectroscopy, atom-beam diffraction, first principles theoretical studies

*Imaging crystalline surfaces:*types of STM images, surfaces with one-dimensional corrugation, surface with tetragonal, hexagonal or trigonal symmetry, corrugation inversion, the S-wave-tip model

*Imaging atomic states and role of atomic force in tunneling:*Slater atomic wavefnctions, profiles of atomic states as seen by STM, Na-atom tip model, images of surfaces: Independent orbital approximation, effect of atomic force in STM, attractive atomic force as a tunneling phenomenon, attractive atomic force abd tunneling conductance

*Tip-sample Interactions and scanning tunneling spectroscopy:*Local modification of sample wavefunction, deformation of tip and sample surface, electronics for spectroscopy, nature of the spectra, tip-treatment for spectroscopy studies, The Feenstra parameter, ex situ and in situ determination of tip DOS

Reference Books

1. Chen, C. J., *Introduction to Scanning Tunneling Microscopy*, Oxford University
2. Weisendanger, R., *Scanning Probe Spectroscopy and Microscopy*, Cambridge University
3. Ashcroft, N. W., and Mermin, N. D., *Solid State Physics*, Halt, Rinehart and Winston, 1976.

Course Title	***Materials and device characterization***	Course No	**PH760**			
Focus Group	Physics	LTPC	3	0	0	3
Offered for	Ph. D.	Type	Elective √			
Pre-requisite	Consent of Teacher	To take effect from				

Objectives
Introduction to the different characterization tools for materials and devices.

Learning Outcomes
The students will be able to understand the concepts and theory underlying the modern techniques employed to determine semiconductor material and device parameters.

Course Content
Introduction to materials characterization and their necessity including physical, chemical and electrical characterization.
Structural and crystallographic characterization-X-ray, neutron and electron diffraction, LEED, RHEED, characterization of crystalline and non-crystalline materials.
Microscopy techniques- Geometrical optics and optical microscopy, Scanning electron and Transmission electron microscopy.
Optical spectroscopy: UV-Vis and FTIR spectroscopy, Raman spectroscopy with introduction vibrational spectroscopic concepts.
Magnetic measurement techniques: SQUID magnetometer, temperature and field dependent magnetic measurements using PPMS and SQUID, introduction magnetic imaging techniques such as MRI and NMRI.
*Electrical measurement:*Drude model introduction, Four probe resistivity measurements, Van der Pauw method, Hall measurement, PN junction measurements, Schottky barriers, Thermally stimulated current spectroscopy.
Low temperature measurements: Introduction to cryogens, Dewars, He-4/3 cryostat, Dilution cryostat, Adiabatic demagnetization, Resistance themometry.
Nuclear Magnetic Resonance (NMR), Mossbauer spectroscopy techniques: Principle, method, experiments for material characterization, X-ray photoelectron/Auger spectroscopy measurements.

Reference Books
1. Schroder, D. K., *Semiconductor material and device characterization.*
2. Zhang, S., Li, L. and Kumar, A., *Materials characterization techniques.*
3. Egerton, R., *Physical principles of electron microscopy: An introduction to TEM, SEM and AEM.*

Course Title	***Astrophysics***	Course No	**PH761**			
Focus Group	Physics	LTPC	3	0	0	3
Offered for	Ph. D.	Type	Elective √			
Pre-requisite	Consent of Teacher	To take effect from				

Objectives

1. To make them familiar with the basic ideas needed to understand the astrophysical phenomena.
2. To elucidate the nature and properties of compact astrophysical objects.

Learning Outcomes

1. The students will have the idea how astrophysical observations, measurements can be carried out and how the observational data can be interpreted.
2. The students will be acquainted with the physics of compact objects.

Course Content

Celestial coordinates - brightness - absolute and relative magnitude - astronomical distance measurement- sources of astronomical information – astronomy in different bands of electromagnetic radiation.

Properties of Sun: Estimate of surface temperature, luminosity, radius, mass - sun's spectrum - composition of sun.

Fundamental of radiative transfer: Radiative flux - the specific intensity - radiative transfer - optical depth - plane parallel atmosphere - the gray atmosphere problem - formation of spectral line – opacity – calculation of opacity.

Properties of stars: Colour and surface temperature - stellar spectra - spectroscopy parallax - the Hertzsprung-Russel diagram - size, mass and temperature of stars.

Stellar formation and evolution: Hydrostatic equilibrium - virial theorem - Jeans' crieria for star formation- brown dwarf - stellar structure equations.

Nucleosynthesis inside stars: Possibility of nuclear reactions in stars – Nuclear reaction rates – important nuclear reactions in stars - evolution of stars with different masses.

White dwarf - equation of state for degenerate gas - polytropicEoS - Lane-Emden equaion – Chandrasekhar mass limit.

Supernova - neutron star – neutron drip – TOV equation – pulsars – magnetic dipole model of pulsars – nonvacuum pulsar model – glitch – cooling of neutron stars – neutron stars in binary.

Reference Books

1. Arnab Rai, C., *Astrophysics for physicists*, Cambridge University Press, 2010.
2. Morison Ian, *Introduction to astronomy and cosmology*, Willey and Sons ltd, 2008.
3. Stuart, L. S., and Saul, A. T., *Black Holes, White Dwarfs, and Neutron Stars*, WILLEY-VCH Verlag GmbH & Co. KgaA, Weiheim, 2004.

Course Title	***Quantum Computation and Information***	Course No	**PH762**			
Focus Group	Physics	LTPC	3	0	0	3
Offered for	Ph. D.	Type	Elective			
Pre-requisite		To take effect from				

Objectives

1. To have an appreciation for the classical and quantum aspects of information theory.
2. To have an understanding of the exciting world of quantum computation and information.

Learning Outcomes

1. Understanding the fundamental principles of quantum information.
2. The students will become familiar with some modern applications of quantum mechanics.

Course Content

Introduction to Quantum Mechanics: Concepts of Hilbert space; basic postulates.

Quantum Computation: Quantum logic gates; quantum Fourier transform; quantum algorithm; physical realization of quantum computers.

Classical Information and Communication: What is information and how can it be used? Concepts of communication channels; Shannon entropy; coding theory and communication complexity.

Quantum Information: What is information theory from the perspective of quantum mechanics? Quantum entropy; quantum mutual information; fidelity.

Entanglement: An introduction. Concepts of entanglement and nonlocality in multi-qubits.

Quantum Communication: Quantum channel; channel capacity; dense coding; teleportation; data compression; complexity.

Some Further Applications: Quantum copying, deletion.

Some Unconventional Models of Computing: Brief introduction to cellular computation and communication; chaos based computing; DNA computing.

Reference Books

1. Michael A. Nielsen and Isaac I. Chuang, *Quantum Computation and Quantum Information*, Cambridge University Press, Cambridge, 2000.

Course Title	***Quantum Cryptography and Coding***	Course No	**PH763**			
Focus Group	Physics	LTPC	3	0	0	3
Offered for	Ph. D.	Type	Elective			
Pre-requisite	Consent of Teacher	To take effect from				

Objectives

1. This course is aimed at introducing the students to the fascinating field of cryptography and coding, with specific emphasis on the quantum aspects of it.
2. It is structured highlights that a number of facets of these theories have some parallel with the more familiar classical world.

Learning Outcomes

1. Understanding the fundamental principles of quantum cryptography and coding.
2. The students will become familiar with the modern aspects of the theory, including its experimental implementation.

Course Content

What is cryptography? Various aspects of modern cryptography; number theoretic concepts.

Classical Coding Theory: Concepts of entropy, mutual information and related aspects; Shannon's coding theorem.

Basic concepts of Quantum Mechanics: From the perspective of information and cryptography: Hilbert space, states, operators: Hermitian and Unitary, simple measurements.

Some basic no-go theorems: With implications to cryptography.

Some basic applications pertinent to quantum cryptography: Entanglement, teleportation, dense coding.

Various Quantum Cryptography protocols: Quantum Key Distribution protocols: BB84, B92, Ekert protocol, Goldenberg-Vaidman, counterfactual quantum cryptography; protocols of quantum dialogue; Quantum secret sharing protocol; Quantum cheating and cryptography; Protecting information and QKA (quantum key agreement); Shor's factoring algorithm and modern cryptography; Experimental progress in quantum cryptography.

Quantum Coding: Quantum aspects of Shannon coding theorem.

Books:

1. Nielsen, M. A and Chuang, I. I., *Quantum Computation and Quantum Information*, Cambridge University Press 2000.

2. Jaeger, G., *Quantum Information,* Springer 2007.

Course Title	***Electronic Transport in Mesoscopic Systems***	Course No	**PH764**			
Focus Group	Physics	LTPC	3	0	0	3
Offered for	Ph. D.	Type	Elective √			
Pre-requisite	Consent ofTeacher	To take effect from				

Objectives

To understand the electronic transport mechanism in mesoscopic systems.

Learning Outcomes

1. Students will be able to understand the principle involved in a nanodevice.
2. It will help students to fabricate devices in better way

Course Content

*An atomistic view of electrical resistance:*Energy level diagram, what makes electrons flow, the quantum of conductance, potential profile, Coulmb blockade, towards Ohm's law

*Schrodinger equation and Self-consistent field:*Hydrogen atom, Method of finite differences, the self-consistence field procedure, relation to the multi-electron picture, bonding, multi-electron picture, basis functions as a computational tool, basis function as a conceptual tool, equilibrium density matrix

*Band Structure:*Examples of 1D and 2D solids, common semiconductors, effect of spin-orbit coupling, Quantum wells, wires, dots, and nanotubes, density of states, minimum resistance of a wire, velocity of a sub-band electron.

*Capacitance and Level broadening:*Model Hamiltonian, electron density/density matrix, quantum vs electrostatic capacitance, open systems, local density of states, life time, what constitutes a contact?

*Coherent and Non-coherent transport:*Density matrix, inflow/outflow, transmission, overview of non-coherent transport, why does an atom emit light? Inflow/outflow, some ideas on phonons, atoms to transistor, quantum transport equations, physics of Ohm's law, where is the heat dissipated? Where is the voltage drop?

Reference Books

1. Datta, S.,*Quantum transport: atoms to transistor*, Cambridge University,2011.
2. Rinehart and Winston, *Solid State Physics*, Halt, 1976.
3. Zwanzig, R., *Non-equilibrium statistical mechanics*, Oxford University Press.

Course Title	***Vacuum Systems and Thin Film Technology***	Course No	**PH765**			
Focus Group	Physics	LTPC	3	0	0	3
Offered for	Ph. D. students	Type	Elective			
Pre-requisite		To take effect from				

Objectives

To understand basic concept of vacuum science and thin film depositions & characterizations.

Learning Outcomes

1. This course familiarizes with the physical concepts behind the thin film depositions by CVD and PVD systems.
2. Knowledge about vacuum pumps and gauges.
3. Familiar with thin film characterization techniques such as XRD, SEM, AFM, PL and electrical measurements

Course Content:

Vacuum technology: Production of Vacuum - Mechanical pumps, Diffusion pump, Getter and Ion pumps, Cryopumps, Pressure Measurements Gauges, Leak Detection.

Physical Vapor Deposition: Hertz Knudsen equation; mass evaporation rate; Knudsen cell, Directional distribution of evaporating species, Evaporation of elements, compounds, alloys, Raoult's law; e-beam, pulsed laser and ion beam evaporation, Glow Discharge and Plasma, Sputtering–mechanisms and yield, DC and RF sputtering, Bias sputtering, magnetically enhanced sputtering systems, reactive sputtering, Hybrid and Modified PVD- Ion plating, reactive evaporation, ion beam assisted

*Chemical Vapor Deposition***:** reaction chemistry and thermodynamics of CVD; Thermal CVD, laser & plasma enhanced CVD, Chemical Techniques - Spray Pyrolysis, Electro-deposition, Sol- Gel and LB Techniques, Nucleation & Growth: capillarity theory, atomistic and kinetic models of nucleation, basic modes of thin film growth, stages of film growth & mechanisms, amorphous thin films, Epitaxy–homo, hetero and coherent epilayers, lattice misfit and imperfections, epitaxy of compound semiconductors.

Film Formation and Structure: Capillarity Theory, Atomistic Nucleation Processes, Cluster Coalescence and Depletion, Experimental Studies of Nucleation and Growth, Grain Structure of Films and Coatings

Methods for characterization of film properties: chemical composition, microstructure, optical, mechanical and electrical properties

Reference Books

1. Ohring, M., *The materials science of Thin films*, Academic Press Ltd.
2. Chopra K. L., *Thin Film Phenomena, McGraw-Hill Book Company.*

Course Title	**Relativistic Quantum Mechanics**	Course No.	**PH 766**				
Focus Group	Physics	Structure (L-T-P:C)	3	0	0	3	
Offered for	Ph.D. Students	Type	Elective				
Pre-requisite							

Objectives

To obtain an understanding of the key concepts of relativistic quantum mechanics including scattering theory, inter-relations between symmetry & conservation laws and relativistic wave equations

Learning Outcomes

1. The students will acquire a working knowledge of scattering theory.
2. The students will have a deep understanding of the Klein Gordon and Dirac equations, their significance, transformation properties and applications.

Course Content

Scattering Theory: Differential and total scattering cross-sections, Partial wave analysis, Born approximation and its applications, Lippmann-Schwinger equation, Scattering of identical particles

Symmetries in Quantum Mechanics: Symmetry and conservation laws. Continuous and discrete symmetries, Parity, Charge Conjugation and Time reversal symmetry

Klein Gordon Equation: KG equation, The non relativistic limit, Free spin-0 particles, The charged KG field, Lagrange density and energy-momentum tensor of the KG-field, Lorentz Invariance of the KG equation, Charge conjugation and C Parity, Interaction of a spin-0 particle with an electromagnetic field, Gauge invariance of the couplings, Lagrange density and energy-momentum tensor for a KG particle in an electromagnetic field, Solution of KG equation for a square-well potential

Dirac Equation: Negative Energy Solutions, Antiparticles, Dirac Hole Theory, Feynman interpretation of Antiparticles, Gama-matrics and their properties, Lagrange density and energy-momentum tensor of the free Dirac equation, Convariance of Dirac equation, Pauli's fundamental theorem, Spinors under Lorentz transformations, Bilinear covariants, Charge conjugation, Parity & Time reversal invariance, Majorana representation of Dirac equation, Plane wave solution, Two component theory of neutrino, Spin and Helicity, Dirac particle in one-dimentional square well potential, Relativistic Hydrogen atom problem

References

1. Bjorken,J.D. and Drell,S.D., (1998), *Relativistic Quantum Mechanics*, McGraw-Hill, New York
2. Sakurai,J.J., (1967), *Advanced Quantum Mechanics*, Addison-Wesley, ________
3. Ashok,D., (2003), *Lectures on Quantum Mechanics*, Hindustan Book Agency, New Delhi

Course Title	**Classical and Quantum Optics**	Course No	**PH767**			
Focus Group	Physics	Structure (L-T-P-C)	3	0	0	3
Offered for	Ph.D. Students	Type	*Elective*			
Pre-requisite	*Consent of Teacher*					

Objectives

1. To have an appreciation for the classical and quantum aspects of light in its various manifestations
2. To have an understanding of novel applications of light matter interaction, such as masers and lasers

Learning Outcomes

1. Familiarity with the very important concept of coherent states
2. The students will become familiar with concepts such as squeezing, lasing and atom optics

Contents

Classical Optics: Geometrical Optics, General Properties of Rays, Principle of Fermat, Lagrange, Interference and Interferometers, Michelson and Mach-Zehnder Interferometer, Theory of Diffraction, Huygens-Fresnel Principle, Kirchoff's Diffraction Theory, Fraunhofer and Fresnel diffraction

Quantum Theory of Radiation: Quantum Theory of the Free Electromagnetic Field, Coherent and Squeezed States of Radiation, Radiation from a Classical Current, Coherent States, Squeezed State Physics, Quantum Distribution Theory, Q, P and W Distributions, Photon-Photon Interferometry, Photon Detection and Quantum Coherence Functions

Atom-Field Interaction: Hamiltonian, Density Matrix of Two-Level Atom with a Single Mode Field, Lasing without Inversion, Coherent Trapping, Electromagnetically Induced Transparency, Basic Concepts of Quantum Interference Phenomena, Resonance Fluorescence in the presence of Weak Driving Fields

Quantum theory of laser: Natural Line Width, Collective Effect, Quantum Theory of Damping, General Reservoir Theory, Master Equations

Books

1. Mandel, L., and Wolf, E., (1995), *Optical Coherence and Quantum Optics*, Cambridge University Press
2. Scully, M. O., and Zubairy, M. S., (1997), *Quantum Optics*, Cambridge University Press

Course Title	**Applications of Interaction of Radiation with Matter**	Course No.	**PH 768**			
Focus Group	Physics	Structure (L-T-P:C)	3	0	0	3
Offered for	Ph.D. Students	Status	*Elective*			
Pre-requisite	Consent of Teacher					

Objective

1. To provide the basic understanding of interaction of different forms radiation with matter
2. Basic scientific processes involving detection of radiation and its applications

Learning Outcomes

1. To evaluate and estimate the processes involving the radiation interaction with matter.
2. The Students will become familiar with concepts of radiation and its application modern technology

Contents

Elementary Introduction to Radiation, detection and its interaction –

(a) *Radioactivity*: alpha-decay - beta-decay - gamma-ray emission, Nucleus : Binding energy - packing fraction - Binding Energy Curve - Stability Curve, Different Nuclear Models: Liquid Drop Model and Shell Model, Fission and Fusion

(b) *Radioactive Detection and Analysis Detection of radiation*: Geiger Muller Counter and Scintillation Counter

(c) Energy loss mechanism of charged particle and Radiation: Collisional Stopper Power (Bathe's Formula): Range of alpha and beta particles

Introduction to Scattering, Generation of Radiations and its Application –

(a) Derivation of Bremsstrahlung Radiation, Synchrotron Radiation, Optical Transition Radiation and Cherenkov Radiation

(b) Scattering of Charged particle and radiation: Compton scattering, Thomson scattering, Rutherford scattering including differential scattering cross-section and pair production

(c) Applications of Radiation in Medicine (Cancer therapy): Evaluation and estimation of Bragg peak of MeV protons in human tissues

References

1. Cohen,B.L., (2005), *Concepts of Nuclear Physics*, Tata McGraw Hill Education, New Delhi
2. Jackson,J.D., (1999), *Classical Electrodynamics*, John Wiley & Sons, New Delhi