	CBCS Based M.Sc. Applied Physics Course Structure (w.e.f., Session 2019-20)				
S. No.	**CODE**	**COURSE NAME**	**Category**	**L-T-P**	**CREDITS**
	SEMESTER-I				
1	**PH401**	Classical Mechanics and Relativity	**C**	4-0-0	4
2	**PH403**	Electrodynamics	**C**	4-0-0	4
3	**PH405**	Quantum Mechanics-I	**C**	4-0-0	4
4	**PH407**	Mathematical Physics	**C**	4-0-0	4
5	**PH409**	Statistical Physics	**C**	4-0-0	4
6	**PH411**	Physics Laboratory-I	**C**	0-0-8	4
		TOTAL		**20-0-8**	**24**
		Total Contact Hours		28	
	SEMESTER-II				
1	**PH402**	Quantum Mechanics-II	**C**	4-0-0	4
2	**PH404**	Solid State Physics	**C**	4-0-0	4
3	**PH406**	Electronics	**C**	4-0-0	4
4	**PH408**	Physics Laboratory-II	**C**	0-0-8	4
5	**PH410/ PH412**	Matlab Programming / Design and Simulation Experiments in Physics	**SEC**	0-0-4	2
6		**DSE-I**	**DSE**	3-0-0	3
7		**DSE-II**	**DSE**	3-0-0	3
		TOTAL		**18-0-12**	**24**
		Total Contact Hours		30	
	SEMESTER-III				
1	**PH501**	Atomic and Molecular Physics	**C**	4-0-0	4
2	**PH503**	Nuclear and Particle Physics	**C**	4-0-0	4
3	**PH505**	Applied Optics	**C**	2-0-0	2
3	**PH507**	Physics Laboratory-III	**C**	0-0-8	4
4	**PH509**	Computational Physics	**SEC**	3-0-2	4
5		**DSE-III**		3-0-0	3
6		**Generic Elective***	**GE***	3-0-0	3
		TOTAL		**19-0-10**	**24**
		Total Contact Hours		29	
	SEMESTER-IV				
1	**PH502**	Project	**Project**		20
					20
	Total credits for all semesters				**92**
	*** GENERIC ELECTIVE (GE): Course taken from other Departments**				

S.No.	**CODE**	**COURSE NAME**	**CREDITS**
DISCIPLINE SPECIFIC ELECTIVES (DSE-I)			
1	**PH414**	Semiconductor Physics and Devices	3
2	**PH416**	Thin Film Technology and Vacuum Science	3
3	**PH418**	Optical Fiber Communications	3
DISCIPLINE SPECIFIC ELECTIVES (DSE-II)			
1	**PH420**	Nanoscience and Nanotechnology	3
2	**PH422**	Soft Electronic Materials and Devices	3
3	**PH424**	Laser Systems and Applications	3
DISCIPLINE SPECIFIC ELECTIVES (DSE-III)			
1	**PH511**	Characterization of Solid State Materials	3
2	**PH513**	Selected Topics in Photonics	3
3	**PH515**	Nanophotonics and Nanoplasmonics	3

New course structure will be effective from admissions in 2019-2020. School/Department will not be bound to run all the courses. Minimum number of students may be fixed to run any elective course.

SEMESTER-I

PH401-CLASSICAL MECHANICS AND RELATIVITY

4-Credits (4-0-0)

Classical Mechanics: Degrees of freedom, generalized co-ordinates and constraints, D'Alembert's principle, Lagrange equations, Hamilton's principle, generalized momenta, cyclic coordinates and conservation laws, independent coordinates and their orthogonal transformations, Euler's theorem, moment of inertia tensor, principal axis transformation, force free motion of a rotating body and methods of solving the Euler equations, Hamilton's equations, Legendre transformations, Poisson brackets and Liouville's theorem, Hamilton-Jacobi theory, motion in a central force field, Kepler's problem and its solutions, scattering, motion in a non-inertial frame, coriolis force.

Relativity: Postulates, Lorentz transformations, time dilation, length contraction, velocity addition, relativistic momentum, mass-energy equivalence, energy and momentum, invariants and conserved quantities, Newton's equations of motion in relativistic form, general theory of relativity, consequences and applications of relativity in astronomy.

Texts/References

1. H. Goldstein, **"Classical Mechanics",** Narosa Publishing House (**2001**)
2. N. C. Rana and P. S. Joag, **"Classical Mechanics",** Tata McGraw-Hill (**1991**)
3. L. D. Landau and E. M. Lifshitz, **"Mechanics",** Butterworth-Heinemann (**1977**)
4. I. C. Percival and D. Richards, **"Introduction to Dynamics",** Cambridge University Press (**1983**)
5. J. V. Jose and E. J. Saletan, **"Classical Dynamics: A Contemporary Approach",** Cambridge University Press (**2002**).

PH403- ELECTRODYNAMICS

4-Credits (4-0-0)

Review of Basic Electromagnetic Theory, Laplace and Poisson equations, Boundary Value Problems; uniqueness theorem, method of images, Green function method, Orthogonal functions and expansions, separation of variables, solution of Laplace/Poisson equation in spherical, cartesian and cylindrical coordinates, multipole expansion, Multipole expansion, macroscopic electrostatics, dielectrics and boundary conditions, boundary value problems with dielectrics, molecular polarizability and electric susceptibility, models for molecular polarizability, electric-field enhancement, **Vector and Scalar Potentials:** Gauge transformations, Lorentz gauge, Coulomb gauge, **Electromagnetic Waves:** EM waves in vacuum and Matter, Absorption and Dispersion, Guided Waves, TE and TM Waves, Retarded potentials, Jefimenko's Equations, Lienerd-Wiechert Potentials, The fields of a moving point charge, Dipole radiation, radiation from accelerated charges, applications to communication and radar.

Texts/References

1. D. J. Griffith, **"Introduction to Electrodynamics"**, Prentice Hall India (**2009**)
2. J. D. Jackson, **"Classical Electrodynamics"**, Wiley India Pvt. Ltd. (**2000**)
3. J. R. Reitz, F. J. Milford & Frederick, **"Foundations of Electromagnetic Theory",** Narosa Publishing House (**1986**)
4. S. Ramo, J. R. Whinnery and T. V. Duzer, **"Fields and Waves in Communication Electronics"**, J. Wiley (**1965**)
5. E. C. Jordan and K. G. Balsain, **"Electromagnetic Waves and Radiating Systems",** Prentice Hall India (**1968**)
6. Edward M Purcell, **"Berkley Physics Course on Electricity and Magnetism",** Tata McGraw Hill Education Pvt. Ltd, Vol. 2 (**2008**).

PH405-QUANTUM MECHANICS-I

4-Credits (4-0-0)

Review of Origin of Quantum Mechanics, Schrodinger equation, Continuity equation, Ehrenfest Theorem, Solutions and applications of time-independent Schrodinger equation for infinite, square, step, rectangular, triangular and double potential wells, tunneling, simple harmonic oscillator; Operator methods, Dirac's bra and ket algebra, matrix representation and change of basis, expectation value, Hermitian operator, commutation relation, linear momentum operator, Motion in three dimensions, central potential problem, orbital angular momentum operators, spherical harmonics, addition of angular momenta and Clebsch-Gordan coefficients, eigenvalues of orbital angular momentum operators, matrix representation, angular momentum and rotations, raising and lowering operators; Hydrogen atom, helium atom; Invariance principle and conservation laws for linear momentum, energy, and angular momentum, parity; Fundamental theory of scattering: Born approximation and its applications to square well potential and Yukawa potential, partial wave analysis, phase shifts, optical theorem, scattering by square well potential and rigid sphere, electron-electron scattering.

Texts/References

1. R. Eisberg and R. Resnick, **"Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles"**, Wiley (**2010**)
2. L. I. Schiff, **"Quantum Mechanics"**, Tata McGraw-Hill (**2010**)
3. E. Merzbecker, **"Quantum Mechanics"**, John Wiley & Sons (**1970**)
4. A. Ghatak and S. Lokanathan, **"Quantum Mechanics: Theory and Applications"**, Kluwer Academic Publishers (**2004**)
5. H. C. Verma, **"Quantum Physics"**, Surya Publications (**2006**)
6. A. Beiser, **"Concepts of Modern Physics",** Tata McGraw-Hill (**1999**)

PH407-MATHEMATICAL PHYSICS

4-Credits (4-0-0)

Scalar and vector field, gradient of a scalar field, divergence & curl of vector field, Gauss's divergence theorem, Stokes's theorem, orthogonal curvilinear co-ordinates, cylindrical and spherical polar co-ordinates, elementary ideas about tensors, matrix algebra, solution of linear algebraic equations, characteristic equation and diagonal form, eigenvectors and eigen values, Cayley-Hamilton theorem, functions of matrices, application in solving linear differential equation, complex variables, Cauchy-Riemann conditions, singularities, Cauchy's theorem, Taylor and Laurent expansions, residue theorem, evaluation of definite integrals, series summation, gamma and beta functions, symmetries & groups, multiplication table and representations, permutation group, translation and rotation groups, second order linear ordinary differential equations with variable coefficients, solution by series expansion, Legendre Polynomial, Bessel Function, Hermite and Lagauerre Polynomials and their solutions, physical applications, generating functions, recursion relations, Laplace transforms, Fourier series and transforms, Dirac's delta functions, Green's functions, Sturm-Liouville equation.

Texts/References

1. P. Dennery and A. Krzywicki, **"Mathematics for Physicists"**, Dover Publications (**1996**)
2. G. B. Arfken and H. J. Weber, **"Mathematical Methods for Physicists"**, Academic Press, London (**2001**)
3. E. Kreyszig, **"Advanced Engineering Mathematics"**, 5th edition, Wiley Eastern (**1991**).
4. L. A. Pipes and L. R. Harvill, **"Applied Mathematics for Engineers and Physicists"**, McGraw-Hill, New Delhi (**1970**)
5. M. R. Spiegel, "**Schaum's Outline Series of Theory and Problems"**, McGraw-Hill, New York, (**1968**)
6. P. K. Chattopadhyay, "**Mathematical Physics"**, New Age International Publishers (**2004**)

PH409-STATISTICAL PHYSICS

4-Credits (4-0-0)

Review of basic thermodynamics, laws of thermodynamics, thermodynamic potentials, foundation of statistical mechanics, random walk, probability distribution, central limit theorem, macroscopic and microscopic states, relationship between statistics and thermodynamics, entropy and Gibb's paradox, phase space, Liouville`s theorem, ensemble theory, microcanonical, canonical, and grand canonical ensembles, partition functions, formulation of quantum statistics, quantum mechanical ensemble theory, density matrix, system composed of indistinguishable particles, Maxwell-Boltzmann, Bose-Einstein, Fermi-Dirac distributions, mono-atomic and diatomic gases, ideal Bose and Fermi gases, thermo dynamical behaviour, Bose-Einstein condensation, elementary excitations in liquid helium II, Boltzmann transport theory, H-theorem, calculation of kinetic coefficients, elementary concepts of plasma kinetic theory, Fluctuations: Thermodynamic fluctuations, Brownian motion, Einstein and Lengevin theory of Brownian motion.

Texts/References

1. F. Reif, **"Fundamentals of Statistical and Thermal Physics", McGraw Hill (1965).**
2. R. K. Patharia, **"Statistical Mechanics"**, Pergamon Press (**1996**)
3. K. Huang, **"Statistical Mechanics"**, John Wiley & Sons (**1983**).
4. J. K. Bhattacharjee, **"Statistical Mechanics: Equilibrium and Non-Equilibrium Aspects"**, Allied Publishers Pvt. Ltd. (**2001**).
5. L. D. Landau and E. M. Lifshitz, **"Statistical Mechanics",** Butterworth-Heinemann **(1980**).

PH411-PHYSICS LABORATORY-I

4-Credits (0-0-8)

This will be a 4-credit course with 8- contact hours where students will perform at least ten of the following experiments on Optics, Thermodynamics, Solid State Physics, Atomic Physics, Electrostatics & Electromagnetic (EM) Waves, and Mechanics**:**

1. To determine the Universal Gravitation Constant (G).
2. To study the interference fringes of (i) Equal Inclination, (ii) Equal thickness with a Michelson Interferometer.
3. To determine the speed of light with the Foucault method.
4. To study the Interference and diffraction patterns for single, double, and multiple slits.
5. Determination of wavelength of a monochromatic source with diffraction grating.
6. To determine the conductivity of wood / Masonite / Teflon.
7. To determine the dielectric constant of $BaTiO_3$.
8. To study Hall Effect and determine Hall coefficients.
9. Magneto-resistance and its field dependence.
10. To study the Electro-optic modulation with Kerr effect.
11. To study and verify Bragg diffraction with microwaves and/or X-Rays.
12. To study Electron Spin Resonance (ESR) and determine g-factor for a given spectrum.
13. To determine the Susceptibility of different materials (e.g., Gadolinium)

SEMESTER-II

PH402-QUANTUM MECHANICS-II

4-Credits (4-0-0)

Time-independent perturbation theory and applications: Harmonic oscillator, Zeeman effect, Stark effect (Non-degenerate and degenerate cases); Time-dependent perturbation theory, Schrodinger and Heisenberg picture, first order and harmonic perturbations, transition probability, Fermi's golden rule, adiabatic and sudden approximations, beta decay; Variational method: principle and application to particle in a box, simple harmonic oscillator, hydrogen atom, helium atom; WKB approximation method: principles and condition for validity, Bohr's quantization condition, applications to tunneling such as alpha particle, field emission, ammonia molecule; Symmetry in quantum mechanics: symmetric and anti-symmetric wavefunctions, identical particles, Pauli's exclusion principle, collision of identical particles, spin-statistics connection; Elements of relativistic quantum mechanics: Klein-Gordon equation and Dirac equation, Dirac matrices, spinors, positive and negative energy solutions, physical interpretation, non-relativistic limit of Dirac equation, elements of field quantization; Coherent state, squeezed state, number state, quantum entanglement, Landau symmetry, quantum cryptography, quantum computation.

Texts/References

1. P. A. M. Dirac, **"Lectures on Quantum Mechanics"**, Dover Publications (**1964**)
2. A. Messiah, **"Quantum Mechanics"**, Dover Publications, (**1999**)
3. L. I. Schiff, **"Quantum Mechanics"**, Tata McGraw-Hill, Third Edition (**2010**)
4. E. Merzbecker, **"Quantum Mechanics"**, John Wiley & Sons (**1970**)
5. J. J. Sakurai, **"Modern Quantum Mechanics"**, Addison Wesley Pub. Co (**2011**)
6. L. D. Landau and E. M. Lifshitz, **"Quantum Mechanics"**, Elsevier (**2008**)
7. Jasprit Singh, **"Quantum Mechanics: Fundamentals and applications to technology"**, Wiley-VCH Verlag (**2004**)

PH404-SOLID STATE PHYSICS

4-Credits (4-0-0)

Crystal Structure: Periodic structure and symmetry of crystals, concept of point groups, quasi-crystals, reciprocal lattice, crystal diffraction, Brillouin zones, Bragg's law, structure factor, different methods for structure determination, electron and neutron diffractions, Defects & Dislocations, point defects, dislocation, lattice vibrations, adiabatic & harmonic approximations, vibrations of mono and diatomic lattices, lattice heat capacity, Einstein and Debye models, Bloch's theorem and band structure, Kronig-Penney and tight binding model, effective mass, Elementary concept of semiconductors, intrinsic and extrinsic semiconductors,s electron and hole mobilities, impurity band conduction, p-n junction, Schottky barrier, Dielectric properties, types of polarization, local field and Clausius-Mossotti equation, dielectric constant and dielectric loss, piezo and ferroelectricity, classification of magnetic materials; dia, para, ferro and anti-ferromagnetism; Curie-Weiss law, Pauli paramagnetism, Superconductivity, Meissner effect, BCS theory, Ginzburg-Landau theory, flux quantization, field penetration and high frequency effects, Josephson junctions, soft and hard superconductors, high temperature superconductors.

Texts/References

1. C. Kittel, **"Introduction to Solid State Physics"**, Wiley (**1995**)
2. L. V. Azaroff, **"Introduction to Solids"**, Tata McGraw (**1960**)
3. M. A. Wahab**, "Solid State Physics"**, Narosa Publishing House (**1999**)
4. N. W. Ashcroft and N. D. Mermin, **"Solid State Physics"**, Holt, Rinehart and Winston (**1976**)
5. J. M. Ziman, **"Principles of the Theory of Solids"**, CBS Publishing ASIA (**1988**)
6. A. J. Dekker, **"Solid State Physics"**, Prentice-Hall (**1965**)
7. G. Burns, **"Solid State Physics"**, Academic Press, New York (**1985**)
8. M. P. Marder, **"Condensed Matter Physics"**, John Wiley & Sons (**2000**)
9. A. R. Verma and O. N. Srivastava, **"Crystallography Applied to Solid State Physics"**,New Age International Publishers (**2005**)

PH406-ELECTRONICS

4-Credits (4-0-0)

Kirchoff's laws, Thevenin's and Norton's theorem, Superposition, Reciprocity, Compensation theorems, Source transformation, Delta and Star transformations, **Semiconductor device physics:** V-I characteristics of Diodes (Zener and Tunnel), Transistors, FET, MOSFET, SCR, Optoelectronic devices, Microwave devices, Varactor, IMPATT Diode, **Classification of amplifiers**: Operating point and its stability, Biasing of Transistor, h-parameter model of BJT, Single Stage and two stage RC coupled amplifiers and their frequency response, hybrid π- model. High frequency response, **Feedback Amplifiers**: Classification, concept of feedback, Advantages of Negative feedback in amplifiers, Emitter follower and Darlington pair. **Sinusoidal Oscillators**: Barkhausen Criterion, Phase shift Oscillator, Wien Bridge Oscillator, Hartley and Colpitts Oscillators, Crystal Oscillator. **Operational amplifier**: Differential amplifier, Characteristics, Offset error voltages and currents, frequency response, Slew Rate, CMRR, Inverting and Non-inverting amplifiers, applications, Multivibrator circuits, Timers, Voltage Controlled Oscillator, **Digital Electronics**: Logic gates, Boolean algebra and minimization techniques, Design of combinational circuits, Adder and Subtractors, Encoders, Decoders, Multiplexers, Demultiplexers, Sequential circuits, Flip Flops, Counters, Registers, A/D and D/A conversion, Microprocessor and Microcontrollers.

Text/References

1. J. Milman and C.C. Halkias, **"Electronic Devices and Circuits"**, Tata-McGraw-Hill (**2007**)
2. R. J. Higgins, **"Electronics with Digital and Analogue Integrated Circuits",** Prentice Hall (**1983**)
3. A. P. Malvino, **"Electronics: Principles and Applications",** Tata McGraw-Hill (**1991**)
4. A. P. Malvino and D. P. Leach, **"Digital Principals and Applications"**, Tata McGraw-Hill (**1977**)
5. J. Millman and A. Grabel, **"Microelectronics"**, McGraw-Hill (**1987**)
6. M. S. Tyagi **"Introduction to Semiconductor Materials and Devices"**, Wiley (**2010**)
7. S. M. Sze and K. K. Ng, "**Physics of Semiconductor Devices"**, Wiley (**2008**)
8. G. B. Clayton, **"Operation Amplifiers"**, ELBS (**1980**)

PH408- PHYSICS LABORATORY-II

4-Credits (0-0-8)

This will be a 4-credit course with 8-contact hours where students will perform at least ten of the following experiments on analog and digital Electronics**:**

1. To trace the I-V characteristic curves of diodes and transistors on a CRO, and learn their uses in electronics circuits.
2. To study regulated power supply using (a) Zener diode only (b) Zener diode with a series transistor, (c) Zener diode with a shunt transistor.
3. To study the characteristics of FET (Field Effect Transistor) and use it to design a relaxation oscillator and measure its frequency.
4. To design a multi-vibrator of given frequency and study its wave-shape.
5. Negative feedback and amplifier characteristics.
6. To design a single stage amplifier (CE) of a given voltage gain and lower cut of frequencies.
7. To design a RC coupled two stage amplifiers of a given gain and cut-off frequencies.
8. To study the characteristics of an operational amplifier.
9. To study the addition, integration and differentiation properties of an operational amplifier.
10. Use of differential amplifier and operational amplifiers in linear circuits.
11. To study the series and parallel LCR circuits.
12. Design of simple logic gates using transistors.
13. To study analog to digital (A/D) and digital to analog (D/A) conversion.
14. To design and study a digital 555 timer.
15. Pulse generator experiments.
16. To design and study a digital counter.

PH410-MATLAB PROGRAMMING

2-Credits (0-0-4)

Introduction to MATLAB, programming in Matlab, arrays, multidimensional arrays, element by element operations, polynomial operations using arrays, elementary mathematical functions, user defined functions, advanced function programming, working with data files, program design and development, relational operators and logical variables, logical operators and functions, conditional statements, loops, switch structure, debugging Matlab programs, plotting, 2-D-plotting functions, subplots, overlay plots, special plot types, regression, 3-D plots, direct MATLAB functions to solve linear algebraic equations and ordinary differential equations.

Texts/References

1. Rudra Pratap, **"Getting started with Matlab 7: A quick introduction for Scientists and Engineers"**, Oxford University Press (**2002**).
2. Peter I. Kattan, "**MATLAB for Beginners: A Gentle Approach".**
3. Amos Gilat, **"MATLAB: An Introduction with Applications"**

PH412-DESIGN AND SIMULATION EXPERIMENTS IN PHYSICS

2-Credits: (0-0-4)

Brief introduction to design and simulation software, overview of the physical principles, menus and functions; Layout design concept in 2D and 3D simulation domain for rectangular and elliptical waveguides, setting up of input electromagnetic field; Material models: constant dielectrics, lossy dielectrics, dispersive materials; Light sources: plane wave and point sources, continuous and pulsed waveforms; Boundary conditions for perfectly matched layers, perfect conductors, symmetric and periodic structures; Layout design of photonic band-gap structures, simulation with plane waves; Design and analysis with nonlinear materials; Plane wave simulation in conductors; Design and analysis of 1D and 2D photonic crystals; Introduction to scripting for structure design.

Note: Topics can be added or removed as per the availability of resources.

Text/References: Software specific

Discipline Specific Elective I

PH414-SEMICONDUCTOR PHYSICS AND DEVICES

3-Credits (3-0-0)

Bonding Forces and Energy Bands in Solids, Charge Carriers in Semiconductors, Carrier Concentrations, Drift of Carriers in Electric and Magnetic Fields, Excess carriers in Semiconductors, Fabrication of P-N Junctions, Forward and Reverse Biased Junctions,Reverse-Bias Breakdown, Transient and A-C Conditions, Band Structure Engineering, Metal-Semiconductor Junctions, Semiconductor Hetero-junctions, Photodiode, LED, Semiconductor Laser, Solar Cells, Physics of Bipolar Devices, Hot Electron Devices, Fundamentals of MOS and Field effect Devices, Review of Quantum theory of Semiconductors, Electrons and Holes in Quantum-Wells, Wires and Dots, Resonant Tunnel Diode.

Semiconductor Optoelectronics: Interactions of photons with semiconductors, semiconductor based photon sources, light emitting diodes (LEDs), semiconductor-laser amplifiers, semiconductor injection lasers, semiconductor based absorbers, photodetectors (visible, infrared & THz), photoconductors, photodiodes, avalanche photodiodes, responsivity, dark current, photocurrent and noise in photodetectors, solar cells.

Texts/References

1. Rolf Enderlein, Norman J Horing, **"Fundamentals of Semiconductor Physics and Devices"**, World Scientific (**1997**).
2. Ben Garland Streetman, Sanjay Kumar Banerjee, **"Solid State Electronic Devices"**, Pearson Prentice Hall **(2006).**

3. S. M. Sze, **"Semiconductor Devices: Physics and Technology"**, 2nd Ed., John Wiley & Sons **(1969).**
4. M.S.Tyagi, **"Introduction to semiconductor, materials and devices"**, John Wiley & Sons **(2008).**

PH416-THIN FILM TECHNOLOGY AND VACUUM SCIENCE

3-Credits (3-0-0)

Pressure and Vacuum: Behavior of gases, gas transport phenomenon, viscous, molecular and transition flow regimes, measurement of pressure, pressure gauges, residual gas analyses, Vacuum: Need in research and industry, gas throughput, production of vacuum, mechanical pumps, rotary pump, diffusion pump, Getter and ion pumps, cryopumps, turbo-molecular pump, principles of low, high, and ultra high vacuum, production and measurement systems, materials for vacuum systems, design aspects of vacuum systems for different applications, leak detection, Thin Film Deposition: Thin film nucleation and growth, atomistic and kinetic models of nucleation, physical vapor deposition (PVD), chemical vapor deposition (CVD), plasmas, discharges and arcs, dc, rf, reactive and magnetron sputtering, pulsed laser deposition (PLD), epitaxy, molecular beam epitaxy (MBE), Chemical Techiques: Sol-Gel, spray pyrolysis, mechanical, Characterization of thin film and surfaces: structural, chemical, electrical, optical characterization, mechanical properties of thin films, metallic, semiconducting, insulating thin films, multilayered thin films, applications of thin films.

Texts/References

1. M. Ohring, **"Materials Science of Thin Films"**, Academic Press (**2012**)
2. K. L. Chopra, **"Thin Film Phenomena"**, Mc Graw-Hill (**1969**)
3. Eishabini-Riad, F. D. Barlow, **"Thin Film Technology Handbook"**, McGraw-Hill (**1998**)
3. D. M. Hoffman, B. Singh, J. H. Thomas, **"Handbook of Vacuum Science & Technology",** Academic Press (**1998**)
4. J. M. Lafferty (Ed.), **"Foundations of Vacuum Science & Technology",** Wiley (**1998**).

PH418-OPTICAL FIBER COMMUNICATIONS

3-Credits (3-0-0)

Basic characteristics of optical fiber, Ray path and pulse dispersion in planar optical wavguides, modes, step and graded-index, single-mode and multimode optical fibers, propagation characteristics; Signal degradation in optical fibers: absorption, scattering losses, bending loss, intermodal distortion, material dispersion, waveguide dispersion, Dispersion-induced limitations, fiber birefringence, nonlinear effects; Fiber fabrication: vapour phase deposition techniques, mechanical properties of fibers and cables, optical fiber connections: joints, couplers and isolators, microstructured optical fibers.

Brief review of sources and detectors: LED, Laser diodes, P-I-N, avalanche photodiodes, receiver designs, noise in detection process, bit-error-rate; Optical amplifiers: basic concepts, gain, gain saturation, noise, Erbium-doped fiber amplifiers, Raman fiber amplifiers, parametric amplifiers; Components of a communication system, design considerations, Analog and digital modulation,Wavelength-division multiplexing (WDM), demultiplexers, dispersion compensation and chirping, self phase modulation, optical solitons; Optical fiber directional couplers, fabrication, applications, band-pass filter, polarization controller, Fiber Bragg grating (FBG), single mode optical fiber sensors.

Texts/References

1. A. Ghatak and K. Thyagrajan, **"Introduction to Fiber Optics",** Cambridge University Press (**1998**)
2. G. Keiser, **"Optical Communications Essentials",** Mc-Graw-Hill (2003)
3. J. M. Senior, **"Optical Fiber communications",** Ed.3, Prentice-Hall (2009)
4. A. W. Snyder and J. Love, **"Optical Waveguide Theory"**, Springer (**2010**).

Discipline Specific Elective II

PH420-NANOSCIENCE AND NANOTECHNOLOGY

3-Credits (3-0-0)

Nanoscale Physics: Introduction to different nanosystems and their realization, Quantum size-effects, characteristic scale for quantum phenomena, quantum wells, quantum wires, and quantum dots, nano-clusters and nano-crystals, density of states for low-dimensional structures, Coulomb blockade, magic numbers, optical properties of nanosystems, excitons and plasmons, photo-luminescence, absorption spectra, Localized Surface Plasmons, Nanofabrication Techniques, top-down and bottom-up approaches, Chemical Techniques: Sol-Gel, spray pyrolysis, nucleation and growth of nanostructures and nanodimentional thin films, atomistic and kinetic models of nucleation, Physical Techniques: physical vapor deposition (PVD), chemical vapor deposition (CVD), dc, rf, reactive and magnetron sputtering, pulsed laser deposition (PLD), molecular beam epitaxy (MBE), Lithographic techniques, Technologically important nanostructures: Buckminster fullerene, Carbon nanotubes, Graphene and Magnetic Nanostructures, Applications of nanomaterials in Biology, Environment, and Energy.

Texts/References

1. C. P. Poole, "Introduction to Nanotechnology", Wiley-IEEE (2003)
2. T. Pradeep, "Nano: The Essentials", McGraw-Hill (2007)
3. H.S.Nalva (editor),"Handbook of Nanostructured Materials and N anotechnology", Academic Press (1999)
4. S. K. Kulkarni, "Nano Technology Principles and Practices", Capital Publishing Company (2006)
5. Silvana Fiorito, "Carbon Nanotubes", Pan Stanford Publishing (2007)
6. Richard Booker and Earl Boysen, "Nanotechlongy",Wiley (2005)
7. M. Ohring, "Materials Science of Thin Films", Academic Press (2012)

PH422-SOFT ELECTRONIC MATERIALS AND DEVICES

3-Credits (3-0-0)

Difference between Inorganic and Organic semiconductors, Small molecules and Polymers, Optical Properties of few small molecules and polymers: concept of highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO) levels, Absorption spectra, photoluminescence spectra, photoluminescence excitation spectra, Jablonski diagram.

Thin Films: Growth behavior, luminescent properties, spectroscopic ellipsometry & optical constants, routes of degradation and environmental stability of soft organic thin films.

Devices: Transparent conducting oxides (TCOs) for device application. Optical and electronic properties (absorption, resistivity, workfunction) of indium tin oxide (ITO).

Orgainc Solar Cells (OSC) structures & characteristics (efficiency, fill factor) concept of donor and acceptor layers, sandwich, bulk hetrojunction and dye sensitized solar cell. Organic light emitting diodes (OLED) structure: Hole injecting, hole transporting, hole blocking, light emitting and electron transporting layers, fabrication of OLED and its characteristics, CIE coordinates, White light sources.

Design and fabrication of device: Patterning of ITO, its surface treatment, evaporation and coating processes, encapsulation, major challenges in device fabrication, optical outcoupling and approaches, Commercialization issues for solar cell and display devices: Efficiency, life time, size, weight & cost. resolution, brightness, colour Gamut, aspect ratio, contrast ratio, power consumption.

Texts/References

1. H. G. Tompkins, **"A User's guide to Ellipsometry"**, Academic Press (**1993**).
2. R. M. A. Azzam and N. M. Bashara, **"Ellipsometry and Polarized Light"**, Elsevier (**1988**).
3. W. Brutting, **"Physics of Organic Semiconductors"**, Wiley-VCH (**2005**).

PH 424-LASER SYSTEMS AND APPLICATIONS

3-Credits (3-0-0)

Interaction of radiation with matter, spontaneous and stimulated emission, Einstein coefficients, optical amplification and population inversion, lineshape functions, homogeneous and inhomogeneous broadening, Threshold condition; CW operation of laser; Critical pumping rate; Population inversion and photon number in the cavity around threshold; Output coupling of laser power. Optical resonators; Cavity modes; Mode selection; Pulsed operation of laser: Q-switching and Mode locking: Experimental techniques, Different laser systems: Nd:YAG/Nd:Glass Lasers, Tunable Ti-Sapphire Laser, Alexandrite Laser, Fiber Lasers, He-Ne Laser, Argon-ion Laser, He-Cd Laser, Excimer Lasers, Carbon dioxide Laser, Copper Vapor Laser, Free-electron Laser, Short Pulsed Lasers, Laser applications in medicine and surgery, materials processing, optical communication, metrology and LIDAR and holography.

Texts/References

1. K. Thyagrajan and A Ghatak, **"Lasers: Fundamentals and Applications", Springer (2010)**
2. O. Svelto, D. C. Hanna, **"Principle of Lasers"**, Springer **(1998)**
3. K. F. Renk, **"Basics of Laser Physics"**, Springer **(2012)**
4. B. B. Laud, **"Lasers and Non-Linear Optics",** Wiley **(1991).**

SEMESTER III

PH 501-ATOMIC AND MOLECULAR PHYSICS

4-Credits (4-0-0)

Quantum states of an electron in an atom, electron spin, Stern-Gerlach experiment, spectra of H, He, and alkali metals, relativistic corrections for energy levels of hydrogen, two electron atom, j-j and L-S coupling, Zeeman effect, Paschen-Back and Stark effects, X-ray spectra, spectral line width and intensities, Molecular symmetry, electronic, rotational and vibrational energy levels in molecules, Franck-Condon principle and selection rules, Fluorescence, Phosphorescence, and Photoluminescence, bond dissociation energies, molecular orbitals and models, ESR, NMR, FTIR, Surface Enhanced Raman Spectroscopy (SERS), Mössbauer Spectoscopy, Spectroscopic Instrumentation.

Text/References

1. H. E. White, **"Introduction to Atomic Spectra",** McGraw-Hill (**1934**)
2. C. N. Banwell and E. McCash, **"Fundamentals of Molecular Spectroscopy",** McGraw-Hill (**1994**)
3. J. M. Hollas, **"Basic Atomic and Molecular Spectroscopy",** Royal Society of Chemistry (**2002**)
4. V. K. Jain, **"Introduction to Atomic & Molecular Spectroscopy",** Narosa Publishing House (**2011**)
5. G. Aruldhas, **"Molecular Structure and Spectroscopy",** PHI Learning Pvt. Ltd. **(2004).**

PH 503-NUCLEAR AND PARTICLE PHYSICS

4-Credits (4-0-0)

Fundamental forces and interactions in nature, Review of elementary nuclear properties, Radioactive decay processes, Nuclear Reactions, reactions induced by neutron, proton, alpha particles, beta particles and gamma radiation, reactions at ultra-high energies, theory of compound nucleus formation and its limitations, Accelerators & Detectors, Nuclear Models: Semi-empirical mass formula, liquid-drop model, shell model, validity, limitations, and experimental evidence of shell structure in nuclei, nuclear fission and fusion, collective model, unified model, meson theory, Elementary Particles: Classification, symmetries and conservation laws, isospin, hypercharge, strangeness, parity etc, quark model, Gell-Mann-Nishijima formula, C (Charge conjugation), P (Parity), and T (Time Reversal) invariance and applications of symmetry arguments to particle reactions, parity non-conservations in weak interactions.

Nuclear Applications*: Environmental monitoring, radioactive dating, radiation detection, medical imaging (e.g., CAT Scans, MRI, NMR), elemental analysis using mass spectroscopy with accelerators, material characterization, opinion formation on the positive aspect (e.g., power generation using nuclear reactors) and negative aspect (weapons of mass destruction) in the backdrop of scientific, humanitarian, and national interests.

* The outlined topics are meant for self study followed by presentation by the student.

Texts/References

1. B. Cohen, **"Concepts of Nuclear Physics",** Tata McGraw Hill (**2008**)
2. K. S. Crane, **"Introductory Nuclear Physics"**, John Wiley & Sons (**1988**)
3. I. Kaplan, **"Nuclear Physics",** Addison Wesley Pub. Co. (**1955**)
4. R. R. Roy and B. P. Nigam, **"Nuclear physics"**, Wiley (**1967**)
5. M. G. Bowler, **"Nuclear Physics"**, Elsevier Science & Technology (**1973**)
6. R. Eisberg, R. Resnick, **"Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles"**, Wiley (**2010**).

PH505- APPLIED OPTICS

2-Credits (2-0-0)

Electromagnetic waves in a medium: Review of Maxwell's equations and propagation of electromagnetic waves, Various states of polarization and their analysis. Anisotropic media, Plane waves in anisotropic media, Uniaxial crystals, Jone's calculus, Faraday rotation, Optical activity.

Diffraction: Scalar waves, The diffraction integral, Fresnel and Fraunhofer diffraction, Diffraction of a Gaussian beam, Diffraction grating. Fourier transform by diffraction and by lens, Spatial-frequency filtering, Phase-contrast microscope.

Coherence and Interferometry: Spatial and temporal coherence, Degree of coherence, Fringe visibility, Michelson stellar interferometer, Optical beats, Multiple beam interference, Fourier transform spectroscopy.

Texts/References

1. E. Hecht, **"Optics"**, Addison Wesley Pub. Co (**2002**).
2. A. Lipson, S. G. Lipson, and H. Lipson, **"Optical Physics"**, Cambridge University Press (**2010**)
3. Ajay Ghatak, "**Optics**", McGraw-Hill (2017)

PH507-PHYSICS LABORATORY-III

4-Credits (0-0-8)

This will be a 4-credit course with 8-contact hours where students will perform the following experiments. The minimum number will be decided by the department.

1. Characteristic study of, (i) Light Emitting Diode (LED), (ii) Semiconductor Laser, and (iii) Photodetector.
2. To construct a Michelson Interferometer (with Laser) and measure the coherence path length.
3. To study the operation of a Erbium-doped fiber amplifier.
4. To study, (i) numerical aperture, (ii) the propagation loss , (iii) the bending loss of an optical fiber.
5. To study the properties of a optical fiber and learn wavelength-division multiplexing.
6. Birefringence measurement with (i) Rayleigh scattering technique, (ii) Prism coupling technique.
7. To learn the cutting and preparing of an optical fiber and to study its coupling efficiency.
8. To study signal transmission through an optical fiber.
9. To study the Atomic spectra of Hydrogen, Helium, and Hg doublet sources.
10. Deposition of nanostructured thin films/nanoparticles for different deposition parameters by using the thermal evaporation technique.
11. Deposition of nanostructured thin films/ nanoparticles by the chemical route of spin coating for various deposition parameters
12. Deposition of nanostructured thin films/nanoparticles by the technique of spin coating for different deposition parameters.
13. Measurement of the thickness of the deposited thin films of different thicknesses by profilometer.

14. **Study** of electrical properties of thin films: (i) Electrical resistivity, (ii) carrier concentration, (iii) mobility; by electrical and Hall measurements set up in Van der Pauw geometry.
15. Study of the optical properties of the thin films: (i) Transmittance, (ii) Reflectance, (iii) Optical band gap, (iv) Refractive index; by using UV-Vis spectrophotometer and ellipsometery.
16. Indexing of the given X-ray diffraction data for a material and estimation of lattice structure and other crystallographic parameters (Analysis only).

PH509-COMPUTATIONAL PHYSICS

4-Credits (3-0-2)

Computational errors - generation and propagation, convergence analysis; Roots of algebraic & transcendental Equations: Bisection method, Newton-Raphson method; Interpolation: Newton's forward and backward difference methods, La Grange's and Divided difference methods, Numerical Differentiation; Numerical Integration: Trapezoidal method, Simpson's 1/3 rule, Gaussian quadrature; System of linear equations, L-U decomposition, Solution with direct and iterative methods, Tridiagonal systems solutions, Matrix Eigenvalue Problems: Householder's method, Ordinary differential equations: Picard's method, Initial value problems: Euler method, Runge-Kutta methods, Predictor-Corrector method, Solution of simultaneous and higher order ODEs; boundary value problems: Finite difference method; Partial Differential Equations: Types, Solution of heat, diffusion, diffusion-convection, wave, Laplace and Poisson equations, solution and case study of PDEs for relevant physical systems.

Students will apply the computational methods in problems arising from various branches of physics using MATLAB.

Texts/References

1. M. K. Jain, S. R. K. Iyenger, R. K. Jain, **"Numerical Methods for Scientific and Engineering Computation"**, New age international publishers **(2003).**
2. E. Balagurusamy, **"Numerical Methods",** McGraw-Hill (**2000**).
3. G. H. Golub and C. F. Van Loan, **"Matrix Computations",** Johns Hopkins University Press **(1996).**
4. C. F. Gerald and P. O. Wheatley, **"Applied Numerical Analysis"**, Addison Wesley Pub. Co (**1980**).

Discipline Specific Elective III

PH511-CHARACTERIZATION OF SOLID STATE MATERIALS

3-Credits (3-0-0)

Solid State Materials: Crystalline and amorphous solids, Elemental and Compound semiconductors, metal oxide semiconductors, organic semiconductors, insulators, superconductors, ceramics, magnetic materials, Bulk, thin films and nanostructures, smart materials, Characterization Techniques: Crystallography, X-Ray Diffraction Methods, Small angle X-Ray scattering, Electron diffraction, Neutron Diffraction, Low energy electron diffraction (LEED) and Reflection high energy electron diffraction (RHEED), X-Ray absorption spectroscopy (XAS), X-Ray Fluorescence (XRF) spectroscopy, scanning probe microscopy (AFM and STM), Electron optics, Electron Microscopy- Transmission and Scanning Electron Microscopy (TEM, SEM), X-ray photoelectron spectroscopy (XPS), Electrical characterization: Vander Pauw method, Hall measurements at low and high temperatures, Electrical conductivity and trapping parameter measurement in semiconductors and insulators, Optical characterization: UV-Visible spectroscopy, Spectroscopic ellipsometry (for determination of optical constants), photoluminescence (PL), compositional analysis employing Auger Electron spectroscopy (AES), Electron spectroscopy for chemical analysis (ESCA), Magnetic characterization: Vibrating Sample magnetometer (VSM), Superconducting Quantum Interference Device (SQUID), Thermal analysis (DTA/TGA), Nanoindentation.

Texts/References

1. R. P. Prasankumar (Editor), A. J. Taylor (Editor), **"Optical Techniques for Solid-State Materials Characterization"**, CRC Press (**2011**).
2. B. D. Cullity, S.R. Stock, "Elements of X-Ray Diffraction", Prentice Hall (2001).
3. J. F. Watts, J. Wolstenholme, **"An Introduction to Surface Analysis by XPS and AES",** Wiley **(2003**).
4. P. J Goodhew, J. Humphreys, R. Beanland, **"Electron Microscopy and Analysis",** Taylor & Francis **(2000).**

PH513-SELECTED TOPICS IN PHOTONICS

3-Credits (3-0-0)

1. Matrix method in ray tracing: Matrix formalism of axially symmetric refractive systems, Cardinal points and planes, Aberrations and their corrections, Examples of Telephoto and Zoom lens systems, Cassegrain Telescope. Matrix formalism for design of multilayered dielectric structures, Examples of Dielectric mirrors, Diffractive optical elements etc.

2. Classical Theory of Dispersion: Rayleigh Scattering, Coherent scattering and Dispersion, Dispersion Relations, Group velccity in dispersive media, Superluminal velocity and slow light.

3. Nonlinear Optics: Second and third Harmonic generation, photorefractive effect, Four wave mixing and phase conjugate mirrors, Solitons in a nonlinear medium.

4. Quantum Optics: Quantization of the Electromagnetic Field, Interference in the limit of very weak light, Plane wave modes in a linear cavity, Fluctuations in chaotic light, Sub-Poisson light, Photon anti-correlations, Entangled photons and the Bell inequality.

Texts/References

1. M. Born, E. Wolf, **"Principles of Optics"**, Pergmon Press (**1980**)
2. B. E. A. Saleh, M. C. Teich, **"Fundamentals of Photonics"**, Wiley Interscience (**1991**)
3. E. Hecht, **"Optics"**, Addison Wesley Pub. Co (**2002**).
4. A. Lipson, S. G. Lipson, and H. Lipson, **"Optical Physics"**, Cambridge University Press (**2010**)
5. Ajay Ghatak, "**Optics**", McGraw-Hill (2017)

PH515- NANOPHOTONICS AND NANOPLASMONICS

3-Credits (3-0-0)

Electromagnetics of Metals: Maxwell's Equations and EM Wave Propagation, Dielectric Function (Lorentz Drude Model and Beyond), Real Metals and Interband Transitions, dispersion, optical properties of nano materials, light propagation in nanostructures, photonic crystal, photonic bandgap engineering, photonic crystal fiber, **Surface Plasmon Polaritons (SPP):** SPP at a Single Interface, Multilayer Systems, Energy Confinement, Excitation of SPPs at Planar Interfaces through Prism and Grating Coupling, **Localized Surface Plasmons:** Localized vs. Propagating Plasmons, Mie Theory, Coupling Between Localized Plasmons, Void Plasmons and Metallic Nanoshells, **Surface Enhanced Raman Spectroscopy (SERS):** SERS Fundamentals, SERS Geometries, Enhancement of Fluorescence and Nonlinear Processes, **Applications:** Plasmonics based chemical and bio-sensors, Plasmonic Solar cells, Plasmonic Photodetectors, Plasmon Based Cancer Therapy, Overview of Silicon Plasmonics, fabrication aspects of nanophotonic devices.

Texts/References

5. Z. Zalevsky, **"Integrated Nanophotonic Devices"**, Elsevier Science (**2010**)
6. S. V. Gaponenko, **"Introduction to Nanophotonics"**, Cambridge University Press (**2010**)
7. S. Maier, **"Plasmonics Fundamentals and Applications"**, Springer (**2007**).

8. Michael Quinten, **“Optical Properties of Nanoparticle Systems”**, Wiley-VCH Verlag GmbH & Co. KGaA **(2011).**
9. H. Reather, **“Surface Plasmons on Rough and Smooth Surfaces and on Gratings”**, Springer (**1985**).

SEMESTER-IV

PH502-PROJECT

20-Credits

This will be a 20-credit course where students will prepare a written project report (in a specified format) to be submitted in the school (or GBU Library) and to be presented to the seminar committee.

1. The objective of the project may be summarized as: (i) To prepare the student for deep and detailed exploration of a selected topic of interest, (ii) To prepare the student for collecting relevant data through array of available resources e.g. published books, monograms, scientific journals, online/web material, scientific magazines etc., (iii) To prepare the student for presenting a scientific topic, subject to the scientific community in a professional way, (iv) To cultivate the habit of discussing, sharing and communicating the ideas with the scientific community, (v) Final completion of a project based on experimental/simulation/theory/fabrication or characterization etc. (vi) To promote the students to write research papers based on the outcome of the project and present the results in national/international conferences.
2. Student must interact on day to day basis with the project advisor and should report his/her progress regularly.