DEPARTMENT OF PHYSICS

INDIAN INSTITUTE OF TECHNOLOGY
(INDIAN SCHOOL OF MINES) DHANBAD

SYLLABUS

OF

MASTER OF SCIENCE (M.Sc.) IN PHYSICS

Effective from the Session
2019-2020

M. Sc. in PHYSICS (2 Years)

COURSE STRUCTURE

SEMESTER-I

Sl. No.	Course Code	Course Name	L	T	P	Credit
1	PHC501	Classical Mechanics and Special Theory of Relativity	3	1	0	11
2	PHC502	Methods of Mathematical Physics	3	1	0	11
3	PHC503	Optics and Optical Instrumentation	3	0	0	9
4	PHC504	Electronics	3	0	0	9
5	PHC505	Numerical Methods and Computer Programming	3	0	0	9
6	PHC506	Experimental Physics I	0	0	2	2
7	PHC507	Experimental Physics II	0	0	2	2
Total			**15**	**2**	**4**	**53**

SEMESTER-II

Sl. No.	Course Code	Course Name	L	T	P	Credit
1	PHC508	Quantum Mechanics	3	1	0	11
2	PHC509	Electrodynamics and Radiation theory	3	0	0	9
3	PHC510	Atomic and Molecular Physics	3	1	0	11
4	PHC511	Condensed Matter Physics	3	0	0	9
5	[*To Elect*]	Open Elective I†	3	0	0	9
6	PHC512	Experimental Physics III	0	0	2	2
7	PHC513	Experimental Physics IV	0	0	2	2
Total			**15**	**2**	**4**	**53**

SEMESTER-III

Sl. No.	Course Code	Course Name	L	T	P	Credit
1	PHC514	Statistical Mechanics	3	1	0	11
2	PHC515	Laser Physics and Technology	3	0	0	9
3	PHC516	Nuclear and Particle Physics	3	0	0	9
4	[*To Elect*]	Departmental Elective I‡	3	0	0	9
5	[*To Elect*]	Departmental Elective II‡	3	0	0	9
6	PHC517	Computation and Simulation	0	0	2	2
7	PHC518	Experimental Physics V	0	0	2	2
Total			**15**	**1**	**4**	**51**

SEMESTER-IV

Sl. No.	Course Code	Course Name	L	T	P	Credit
1.	[*To Elect*]	Open Elective II†	3	0	0	9
2.	[*To Elect*]	Departmental Elective III‡	3	0	0	9
3.	PHC519	Thesis Unit I	0	0	0	9
4.	PHC520	Thesis Unit II	0	0	0	9
Total			**6**	**0**	**0**	**36**

†**Open Electives**: The subjects to be floated as 'Open Electives' in a semester will be declared from the following table before semester registration. Students may choose one from the declared subjects available from own department or any other subject available from sister departments.

Sl. No.	Course Code	Course Name	L	T	P	Credit
1	PHO501	Astrophysics and Cosmology	3	0	0	9
2	PHO502	Nonlinear Optics	3	0	0	9
3	PHO503	Physics of Nanomaterials	3	0	0	9
4	PHO504	Optoelectronic Materials and Devices	3	0	0	9

‡**Departmental Electives**: The subjects to be floated as 'Departmental Elective' in a semester will be declared from the following table before semester registration. Students should choose any one subject from the declared list of subjects for each Departmental Elective. To float a subject at least 25% students of the actual strength of the M.Sc. (Physics) class (number of students enrolled in M.Sc. in Physics) has to opt the subject. Only the floated courses subject to the above condition will be available to students of sister departments as open electives.

Sl. No.	Course Code	Course Name	L	T	P	Credit
1	PHD501	Advanced Quantum Mechanics	3	0	0	9
2	PHD502	Computational Physics	3	0	0	9
3	PHD503	High Energy Physics	3	0	0	9
4	PHD504	Biophysics	3	0	0	9
5	PHD505	Thin Film and Vacuum Technology	3	0	0	9
6	PHD506	Characterization Techniques	3	0	0	9
7	PHD507	Plasma and Space Physics	3	0	0	9
8	PHD508	Fibre Optics and Applications	3	0	0	9
9	PHD509	Advanced Condensed Matter Physics	3	0	0	9
10	PHD510	Quantum Computation and Information	3	0	0	9

COURSE CONTENT

SEMESTER-I

PHC501	CLASSICAL MECHANICS AND SPECIAL THEORY OF RELATIVITY		(310)
Course Philosophy	Classical mechanics relates more closely to ordinary language than relativity or quantum mechanics. It presents answers to the macroscopic world quite efficiently. On the other hand special theory of relativity contradicts many principles of classical theory and explains motion of particles at high speeds.		
Learning outcome	By studying classical mechanics one gets the idea about the inadequacy of mechanics while dealing with subatomic particles or particles with speeds comparable to the speed of light. Classical Mechanics also helps the student to prepare for the modern physics courses like Quantum Mechanics.		
Unit No.	**Topic**	**No. of lectures**	**No. of tutorials**
1.	**Lagrangian Formulation**: Mechanics of a system of particles, constraints and generalized Coordinates and momenta, gyroscopic forces, Jacobi integral, Gauge invariance, D'Alembert's principle, Calculus of Variation and Lagrange's equations. Lagrangian formulation of continuous system, variation and end points, Action integrals, Principle of least action	8	3
2.	**Central force:** Equations of motion, orbits: closure and stability of circular orbits, Virial theorem, Kepler problem, Collision and scattering in a central force field	6	2
3.	**Hamiltonian formulation**: Legendre transformations, Hamilton equations, cyclic coordinates and conservation theorems, Canonical transformations, Poisson theorem, Poisson brackets, Angular momentum, Hamilton-Jacobi theory, Generating functions, Properties, group properties	8	3
4.	**Rigid body kinematics and Dynamics**: Orthogonal transformations, Euler angles, Coriolis effect, angular momentum and kinetic energy, tensors and dyadic, inertia tensor, Euler equations, applications, heavy symmetrical top.	6	2
5.	**Small oscillations**: Eigenvalue problem, frequencies of free vibrations and normal modes, forced vibrations, two-coupled oscillations, normal modes and co-ordinates, dissipation	5	1
6.	**Special theory of relativity**: Minkowski world and Lorentz transformations, world lines, Relativistic Mechanics of Mass Points, Lorentz covariance of the new conservation laws, Relativistic analytical mechanics, Relativistic force, Lagrangian and Hamiltonian of a relativistic particle.	6	2
Total 52		**39**	**13**

Text Books:

1. Classical Mechanics, Goldstein, Safkoand Poole; Pearson; 2002.
2. Classical Mechanics: Systems of Particles and Hamiltonian Dynamics; Greiner; Springer-Verlag, 2004.
3. Introduction to Special Relativity; Robert Resnick; John Wiley; 1965.

Reference Books:

1. Classical Mechanics; Ranaand Joag; Tata McGraw Hill; 1991.
2. Classical Mechanics; Gupta, Kumar and Sharma; Pragati Prakashan; 2010.
3. Classical Mechanics of Particles and Rigid Bodies; Gupta; John Wiley and Sons; 1988.

PHC502	**METHODS OF MATHEMATICAL PHYSICS**		**(310)**
Course Philosophy	To sketch the ideas and emphasize the relations which are essential to the study of physics and related fields.		
Learning Outcome	The approach incorporate contents required for the basic & advanced level of understanding and active learning on problem solving skills of physics students. The mathematical methods given herewith are not quoted under most general assumptions, but are customized to the more restricted applications required in almost all areas of physics.		
Unit No.	**Topics**	**No. of lectures**	**No. of tutorials**
1	**Special Functions:** Generating functions; Recurrence relation; Associate Legendre, Bessel, Hermite and Laguerre equations and their solutions; Physical applications; Green's function and its applications.	10	3
2	**Complex Variables:** Analytic functions of a complex variable, Contour integrals, Cauchy's Integral theorem and formulae, Calculus of residues, Application of complex variables.	7	2
3	**Tensors:** Transformation properties, Metric tensor, Raising and lowering of indices, Contraction, Symmetric and anti-symmetric tensors.	5	2
4	**Group Theory:** Definition, Properties, Transformations, Multiplication table, Examples. Tensors: Transformation properties, Metric tensor, Raising and lowering of indices, Contraction, Symmetric and anti-symmetric tensors.	6	2
5	**Laplace transform:** Laplace transform and its properties, Laplace inverse transform, Laplace transform of derivatives, Application of Laplace transform.	5	2
6	**Fourier transform:** Sine, Cosine and Complex transforms with examples, Definition, Properties and Representations of Dirac Delta Function, Properties of Fourier Transforms, Transforms of derivatives, Parseval's Theorem, Convolution Theorem, Discrete Fourier transform, Introduction to Fast Fourier transform.	6	2
Total 52		**39**	**13**

Text Books:

1. Mathematical Methods for Physicists; Arfkenand Weber; Academic Press; 2010.
2. Mathematical Methods for Physics and Engineering; Riley, Hobson, Bence; Cambridge University Press; 2002.
3. Group Theory and Quantum Mechanics; Tinkham; Dover Publications; 2003.
4. Elements of Group Theory for Physicists; Joshi; New Age; 1997.

Reference Books:
1. Essential Mathematical. : Methods For Physicists; Arfkenand Weber; Academic Press; 2005
2. Applied Mathematics For Engineers And Physicists; Pipes; Mcgraw-Hill Book Company; 1970
3. Introduction To Mathematical Physics; Harper; PHI Learning; 2009
4. Mathematical Physics: Advanced Topics; Joglekar; Universities Press; 2006
5. Mathematical Methods for Physics; Wyld; Westview Press; 1999
6. Mathematical Methods in Physical Sciences; Boas; Wiley India Pvt Ltd; 2006

PHC503	**OPTICS AND OPTICAL INSTRUMENTATION**	**(300)**
Course Philosophy	To teach students about basis of optical instrumentation	
Learning Outcome	After attending this course, students will learn the following different type of detectors and their uses, different types of imaging systems, interferometric techniques and their uses in testing optical components and Holography and HOEs.	
Unit No.	**Topics**	**No. of lectures**
1	Modern Optical Elements-Imaging by Lenses of varying diameters, thick and thin lenses, overview of optical aberrations produced by lenses, GRIN lenses, Blazed and Ronchi Grating, Different types of Prisms-Right Angle, Porro, Dove Prism, Penta Prism, Constant deviation prisms - Abbe and Pellin-Broca Prism	7
2	Optoelectronic devices-Detectors, Thermal and Quantum detectors, Efficiency, Different types of Thermal and Quantum detectors, Photodiodes, PMT, Electro- and acusto-optic effects and modulators, Charge Couple Device (CCD) and Complementary Metal-Oxide Semiconductor (CMOS) device	6
3	Specialized Interferometry-Interferometer principles, Path different introduced by thin film, Young's fringes, Newton, Michelson and Twyman-Green Interferometer and their applications, lateral shearing interferometer, Radial, rotational and reversal shear interferometer, Multi-beam, multi-pass and multi-wavelength interferometer and their applications, Common path interferometer.	9
4	Phase measuring Techniques-Temporal and spatial phase shifting using Phase shifting Interferometry (PSI), Advantages and disadvantages of PSI over conventional interferometry, Fast Fourier Transform	3
5	Imaging Systems-Ordinary Microscopy and their limitation for use in study of biological specimen, BF, DF and PL-Microscopy, Interference microscopy- Differential Interference Contrast (DIC) its pros and cons, Photoluminiscence-Fluorescence and Phosphorescence, emission and absorption spectra, measurement of fluorescence using fluorimeter and spectrofluorometer, confocal microscopy	6
6	Basics of Holography and its applications in recording different types of holograms, Speckle and its use in speckle photography and speckle shearing interferometry, Holographic Optical Element (HOE)-Hololens and holomirror, Computer generated hologram (CGH).	8
Total		**39**

Text Books:

1. Optical Shop Testing; D. Malakara, Wiley and Sons, Inc. 2007.
2. Optics and Optical Instrumentations; B.K. Johnson, Dover, 1960.
3. Principles of Optics; M. Born and E. Wolf; Cambridge University Press; 1999.
4. Optical Metrology, Kjell J. Gåsvik, John Wiley and Sons Ltd., 2002.

Reference Books:

1. Fundamental of Optics, Jenkins and White, 2001.
2. Optics, A. Ghatak, Tata McGraw Hill, 2005.
3. Optics, E. Hecht, Addison-Wesley, 2001.
4. Introduction to Applied Optics, P. Banerjee and T.C. Poon, CRC Press, 2003.
5. Fourier Optics, J. W. Goodman, Viva Books Pvt. Ltd., New Delhi, 2007.
6. Modern Optical Engineering, W.J. Smith, McGraw-Hill, 1966.
7. Fundamental of Photonics, B. E. A. Saleh, M. C. Teich, Wiley, 2007.
8. Elements of Modern Optical Design, Donal C O 'Shea, Wiley Interscience, 1985.
9. Advanced Light Microscopy, Vols. 1-2, M. Pluta, Elsevier, 1988.

PHC504	**ELECTRONICS**	**(300)**
Course Philosophy	Course is about basic and advanced electronic circuits that covers both Analog and Digital.	
Learning Outcome	Students will be familiarizing with the realistic picture of the working principle behind Analog and Digital electronic devices.	
Unit No.	**Topic**	**No. of Lectures**
1.	Network theorems, p-n junction diodes, metal-semiconductor junction diodes, BJT/JFET devices and their characteristics, Homo and Heterojunction devices.	5
2.	Number systems, Transistor as a switch, Basic logic gates, universal gates, Boolean Algebra, De Morgan's laws, Karnaugh map, Arithmetic circuits, Flip-Flops, Registers, Synchronous, Asynchronous, Counters, A/D and D/A conversion, Multiplexer, Demultiplexer.	12
3.	Ideal amplifier, Feedback theory, Oscillators, Differential amplifier and its transfer characteristics, operational amplifier and its frequency response, Op-amp as adder, subtractor, differentiators, integrators, logarithmic amplifier, Applications of op-amp, Solution of differential equations, Active filters, Multivibrators, 555 timer based circuits.	10
4.	Amplitude and Frequency modulation, Demodulation techniques, Bandwidth requirements, Pulse communication, Digital communication, frequency and time division multiplexing.	7
5.	Digital logic families, Basic concepts of Integrated Circuits, Semiconductor Memories, Basics of Microprocessors and Microcontrollers.	5
	Total	**39**

Text Books:

1. Millman's Electronic Devices and Circuits; Millman; Tata Mgraw Hill; 2007.
2. Digital Principles and Applications: Leach and Malvino; Tata Mgraw Hill; 2006.
3. Semiconductor Devices: Physics and Technology: S.M. Sze (John Wiley), 2007.
4. Electronic Devices and Circuits (SIE); Cathey; McGraw-Hill Education (India) Ltd; 2008.

Reference Books:
1. Electronic Device and Circuit Theory, R.L. Boylestadand, L.Nashelsky, Pearson 2013.
2. Integrated Electronics: Millman and Halkias (Tata McGraw Hill) 2010.
3. Microelectronics: Millman and Grabel (Tata McGraw Hill), 1999.
4. Electronic Devices and Circuits; Gupta; S. K. Katariaand Sons; 2010.
5. Electronic Fundamentals and Applications: Int. and Discrete Systems; Ryder; PHI Learning; 2009.
6. Hand Book of Electronics; Gupta and Kumar; Pragati Prakashan; 2010.
7. Electronics: Fundamentals and Applications; Chattopadhyay and Rakshit; New Age Internl.; 2010.

PHC505	NUMERICAL METHODS AND COMPUTER PROGRAMMING	(300)
Course Philosophy	▪ To introduce students with the numerical procedures of fundamentals of mathematical operations and tools for computer programming; ▪ To prepare them for coding in any language for applications in any physical field or subject.	
Learning Outcome	Upon completion of the course a student will numerically be able to accomplish the methods of approximation and errors, roots of equations, curve fitting, interpolation methods, calculus, Fourier approximation, and computer programming in suitable languages.	
Unit No.	**Topics**	**No. of lectures**
1	**Methods of approximation and errors**: Truncation and round-off errors; Accuracy and precision.	5
2	**Roots of Equations**: Bracketing methods (false position and bisection), Iteration methods (Newton-Raphson). Systems of linear algebraic equations: inversion and LU decomposition methods. Gauss elimination method.	7
3	**Curve fitting:** Least squares regression, linear and nonlinear regressions.	4
4	**Interpolation Methods:** interpolating polynomials. Newton's divided difference.	4
5	**Numerical differentiation and integration:** Trapezoidal and Simpson's rules.	4
6	**Ordinary differential equations:** Euler's method, Runge-Kutta methods. Boundary value and Eigenvalue problems. Partial differential equations: Laplace's equation and solutions. Few applications.	6
7	**Fourier approximation:** Introduction, Discrete Fourier and Fast-Fourier transforms.	4
8	**Computer Programming:** Some computer programs in suitable languages, based on above topics.	5
Total		**39**

Text Books:
1. Shastry, S.S., "Numerical Methods", Prentice Hall Inc., India, 1998.
2. Richard L. Burden and J. Douglas Faires, “Numerical Analysis”, Brooks/Cole, Cengage Learning
3. Noble Ben, "Numerical Methods", New York International Publications, New York, 1964.
4. Numerical Analysis with Algorithms and Programming; Santanu Saha, CRC press, 2016

Reference Books:
1. Buckingham R.A., "Numerical Methods", Sir Isaac Pitman Sons. Ltd., London, 1957.
2. Uri M. Ascher and Chen Greif, “A first Course in Numerical Methods” SIAM, 2011.
3. Bakhvalov, N .S., "Numerical Methods", Mir. Pub., Moscow, 1977.
4. Numerical recipes in C++ or Fortran

PHC506	**EXPERIMENTAL PHYSICS I**	**(002)**
Course Philosophy	▪ To familiarize students with basic experiments of electronics; ▪ To increase observational and analytical power of students.	
Learning Outcome	Students will learn: 1) Basic circuitry of electronics experiments on bread board. 2) Basic physics of working mechanism of each experiment. 3) To enhance experimental capability and instrument handling.	
Practical Unit No.	**Tentative Title of Experiments**	**Tentative No. of classes**
1 1.	Study of rectification of an alternating voltage source through bridge rectifier	2
2 2.	Study of free running (Astable) Multivibrator using 555 timer	2
3 3.	Study of R.C. coupled amplifier and hence to measure its voltage gain	2
4 4.	Study of Planck’s constant and work function of materials	2
5 5.	Study of operational amplifier	2
6	Study of series and parallel connections in solar cell (PV) module etc.	2
Total (Tentatively 24 hours)		**12**

Text Books:
1. An Advanced Course in Practical Physics by D. Chattopadhyay, P. C. Rakshit; New Central Book Agency (P) Ltd., 2007 (8e)
2. A Textbook of Advanced Practical Physics by S. K. Ghosh; New Central, 2000 (4e)
3. Electronic Principles; A. Malvino and David J. Bates; Mcgraw Higher Ed; 2006.

Reference Books:
1. Advanced practical physics for students, by B. L. Worsnop and H. T. Flint; Littlehampton Book Services Ltd., 1951 (9e)
2. Advanced Practical Physics, V-I and II by Chauhan and Singh; Pragati Prakashan
3. Physical Methods, Instruments and Measurements, Vol. 1-4, Edited by Yuri M. Tsipenyuk; Russian Academy of Sciences, Russia
4. Handbook of Physical Measurements, by Judith Hall, Judith Allanson, Karen Gripp, Anne Slavotinek; Oxford, 2e (2006)

PHC507	EXPERIMENTAL PHYSICS II		(002)
Course Philosophy	▪ To familiarize students with basic experiments of optics, modern physics, magnetism etc. ▪ To increase observational and analytical power of students.		
Learning Outcome	Students will learn: 1) Basic physics of working mechanism of each experiment. 2) Practical aspects of light interference, diffraction, atomic physics, magnetism etc. 3) To enhance experimental capability and instrument handling.		
Practical Unit No.	**Tentative Title of Experiments**	**Tentative No. of classes**	
1 1.	To determine diameter of thin human hair by diffraction method using optical bench	2	
2 2.	Study of variation of refractive index of the material of the prism with wavelength of light	2	
3 3.	Study of minimum deviation of prism and to find wavelength of unknown line from that curve	2	
4 4.	Michelson interferometer to find wavelength of unknown light	2	
5 5.	Study of discrete atomic energy levels by Frank & Hertz experiment	2	
6	Study on B-H curve of ferromagnetic materials etc.	2	
Total (Tentatively 24 hours)		**12**	

References:

1. An Advanced Course in Practical Physics by D. Chattopadhyay, P. C. Rakshit; New Central Book Agency (P) Ltd., 2007 (8e)
2. A Textbook of Advanced Practical Physics by S. K. Ghosh; New Central, 2000 (4e)
3. Advanced Practical Physics, V - I and II by Chauhan and Singh; Pragati Prakashan

SEMESTER-II

PHC508	QUANTUM MECHANICS		(310)
Course Philosophy	Course introduces the methods to do the mechanics of atomic and subatomic particles.		
Learning Outcome	Familiarizing students with the theoretical framework of non-relativistic quantum mechanics and its applications to simple problems.		
Unit No.	**Topics**	**No. of lectures**	**No. of tutorials**
1	**Schrödinger Equation:** Solution of harmonic oscillator and hydrogen atom problems.	4	1
2	**Linear Vector and Representation Theory**: Linear vector space, Dirac notations of Bra - Ket, Matrix representation of Observables and states, Determination of eigenvalues and eigen state for observables using matrix representations for harmonic oscillator, Change of representation and unitary transformations, Coordinate and momentum representations, Equations of motion in Schrödinger and Heisenberg pictures	12	3
6	**Theory of Angular Momentum:** Symmetry, invariance and conservation laws, relation between rotation and angular momentum, commutation rules, Matrix representations, addition of angular momenta and Clebsch-Gordon coefficients, spin-orbit coupling and fine structure, Pauli spin matrices.	6	3
6	**Time-Independent Perturbation theory:** Time-independent Perturbation theory (non-degenerate and degenerate) and applications to fine structure splitting, Zeeman effect (Normal and anomalous), Stark effect.	6	2
7	**Variational method** and applications to helium atom and simple cases	4	1
8	**WKB approximation** and applications to simple cases.	3	1
9	**Time-dependent Perturbation theory**, Fermi's Golden rule, selection rule, Semi-classical theory of interaction of atoms with radiation.	4	2
Total 52		**39**	**13**

Text Books:

1. Introduction of Quantum Mechanics; David J. Griffiths; Pearson Education; 2010
2. Quantum Mechanics: An introduction, W. Greiner, Springer (India) Pvt. Ltd., 2001
3. Quantum Mechanics: Theory And Applications, 1e; Ghatak and Lokanathan; Kluwer Academic Publishers; 2004

Reference Books:

1. Quantum Mechanics; Schiff; Tata McGraw Hill; 2010
2. Principles of Quantum Mechanics; Shankar; Springer; 2006
3. Modern Quantum Mechanics; Sakurai; Pearson; 1994
4. Quantum Mechanics 2nd Ed; Bransden and Joachain; Pearson; 2000;

5. Principles of Quantum Mechanics; Dirac; Oxford University Press, Usa; 1982
6. Quantum Mechanics, 3rd Edition; Merzbacher; John Wiley; 2005
7. Feynman Lecture, Vol. 3, Addison-Wesley, 2005
8. Quantum Mechanics; V. K. Thankappan; New Age International Pub; 1993

PHC509	**ELECTRODYNAMICS AND RADIATION THEORY**	**(300)**
Course Philosophy	The course content covers the propagation of electromagnetic waves in linear media (vacuum, dielectric, and conductor).	
Learning Outcome	It familiarizes students with different principles and phenomena when electromagnetic wave propagates in different media.	
Unit No.	**Topics**	**No. of lectures**
1	**Maxwell's Equations:** Displacement current, Maxwell's equations, Vector and Scalar potentials, Gauge transformations, Coulomb gauge, Lorentz gauge, Inhomogeneous wave equation and solution by Green's function, Electromagnetic energy and momentum, Conservation laws,. Covariance of electrodynamics: Transformation of sources and fields, Electromagnetic field tensor and Maxwell's equations.	13
2	**Electromagnetic Waves:** Plane wave propagation in vacuum and in a dielectric medium, Polarization, Reflection and Refraction at dielectric interfaces, Plane wave propagation in conductor, Dispersive media, Normal and Anomalous dispersion, Wave propagation in one dimension, Group velocity, Phase velocity, Wave guides and Resonant Cavities, Plane wave propagation in wave guides, Classification of fields, Plane wave propagation in resonant cavities, Resonant modes and Power losses in cavities.	16
3	**Radiation:** Field of a localized oscillating source, Liénard-Wiechert potentials, Electromagnetic fields due to an accelerated charge and a uniformly moving charge, Power radiated by an accelerated charge at low and high velocity, Angular distribution of power radiated by an accelerated charge, Bremsstrahlung, Synchrotron, and Cerenkov Radiation, Reaction Force of Radiation fields.	10
Total		**39**

Text Books:

1. Classical Electrodynamics; Jackson; John Wiley; 2007
2. Classical Electrodynamics; Greiner; Springer; 1998
3. Introduction to Electrodynamics; Griffiths; PHI Learning; 2009

Reference Books:

1. Classical Electricity and Magnetism; Panofsky and Phillips; Dover Publications, Inc.; 1990
2. Foundations of electromagnetic theory; Reitz, Milford and Christy; Pearson; 2009
3. Electrodynamics; Gupta, Kumar and Sharma; Pragati Prakashan; 2010
4. Classical Electromagnetic Theory; Vanderlinde; John Wiley and Sons; 1993

PHC510	ATOMIC AND MOLECULAR PHYSICS		(310)
Course Philosophy	Atomic and molecular physics topics covered here deals with the observation and interpretation of radiation absorbed or emitted by atoms or molecules. This information can lead into the knowledge of structure and properties of the atom/ molecule.		
Learning outcome	The course will enable the student to get an idea about atomic and molecular spectra, spin orbit interaction, fine and hyperfine structure of spectral lines, Zeeman and Stark effects, line broadening mechanisms, Raman spectra and Mossbauer spectroscopy.		
Unit No.	**Topic**	**No. of lectures**	**No. of tutorials**
1.	Vector atom model, Quantum states of one electron atoms-Atomic orbitals, Hydrogen spectrum-Pauli's principle.	4	1
2.	Spin orbit interaction and fine structure in alkali Spectra, intensity rules – Equivalent and non-equivalent electrons. Interaction energy in LS and jj Coupling – Hyperfine structure	6	3
3.	Zeeman effect – Splitting of spectral lines in presence of weak and strong magnetic field, Stark effect, Two electron systems.	6	2
4.	Broadening of spectral lines– Line broadening, Doppler and Lorentz Broadening mechanisms.	3	1
5.	Molecular spectra, Rotational spectra of diatomic molecules as a rigid rotator using Schrodinger wave equation and non-rigid rotator, intensity of rotational lines, Frank-Condon principle.	6	2
6.	Vibrational-rotational spectra, vibrational energy of diatomic molecule-Diatomic molecule as a simple harmonic oscillator, Effect of anharmonicity, Energy levels and spectrum-Morse potential, energy curve-Molecules as vibrating rotor-Vibration spectrum of diatomic molecule. Raman spectroscopy, Rotational and vibrational Raman spectra of diatomic molecules.	8	3
7.	Effect of Nuclear spin on intensities of Rotational Raman spectra; Mossbauer spectroscopy.	6	1
Total 52		**39**	**13**

Text Books:

1. Introduction to Atomic Spectra; White; Mcgraw-Hill Education; 1934.
2. Atomic Spectra And Atomic Structure; Herzberg; Dover; 2008
3. Physics of Atoms and Molecules: Bransden and Joachain; Pearson; 2006.
4. Atomic & Molecular Spectra; Raj Kumar, KedarNath Ram Nath, New Delhi, 1997.

Reference Books:

1. Fundamentals of Molecular Spectroscopy; Banwell; Mcgraw-Hill Education (India) Ltd; 2000.
2. Introduction to Molecular Spectroscopy; Barrow; Mcgraw-Hill Education; 1962.
3. Lasers - Fundamentals and Applications: Thyagrajan & Ghatak; Springer; 2010.
4. Chemical Applications of Group Theory; Cotton; Wiley India Pvt Ltd; 2009.
5. Modern Spectroscopy; Hollas; Wiley India Pvt Ltd; 2010.

PHC511	CONDENSED MATTER PHYSICS	(300)
Course Philosophy	To introduce students with fundamental physical science of solid matters; To prepare them for advanced studies in similar fields and research in materials science	
Learning Outcome	Students will learn the physics of crystalline, thermal, electronic, semiconducting, superconducting and magnetic properties of solid state materials.	
Unit No.	**Topics**	**No. of lectures**
1	**Crystallography:** Elementary concepts of point and space group and its relevance to crystal structure. Interaction of X-rays with matter, Elastic scattering from a perfect lattice. The reciprocal lattice and its applications to diffraction techniques. The Laue, powder and rotating crystal methods; Crystal structure factor and intensity of diffraction maxima, Extinctions due to lattice centering. Introduction to quasi crystals.	9
2	**Defects in Crystals:** Point defects, line defects and planer (stacking) faults. Role of defects in crystal growth. The observation of imperfections in crystals.	3
3	**Lattice Dynamics**: Vibration of lattice with two atoms per unit cell, Quantisation of lattice vibrations, Interaction of electromagnetic waves and particle waves with phonons.	4
4	**Electronic Properties of Solids**: Band theory; Nearly free electron, Tight-bonding, cellular and pseudopotential methods. Fermi surface, Landau levels, Cyclotron resonance.	5
5	**Semi-conductor Physics**: Degenerate and non-degenerate semiconductors, Carrier densities in doped semiconductors, Conductivity of semiconductors, Hall effect (Classical), Semiconductor Heterostructures and Superlattices. Junction capacitance of a PN junction, Metal semiconductor junction, Luminescence, Photo conductivity and Optical absorption.	7
6	**Superconductivity and Superfluidity**: Meissner effect, Thermodynamics of superconductors, Type-I and type-II superconductors. Vortex, Londoné equation, Coherent length, Cooper pair, Josephson effects. Magnetic properties; Introduction to superfluidity.	6
7	**Magnetism:** Spin waves and magnons, Ferri- and antiferro-magnetic order, Exchange interaction, Domains and Bloch-wall energy. Magnetoresistance, Giant magneto resistance; Magnetic Resonance.	5
Total		39

Text Books:

1. Solid State Physics; Ashcroft andMermin; Brooks/Cole; 2003.
2. Principles of Electronic Materials and Devices, S. O. Kasap, McGraw Hill Company, Inc., 2006.
3. Solid State Physics-Structure and Properties of Materials; Wahab; Narosa; 2000.

Reference Books:

1. Introduction of Solids; Azaroff; Tata McGraw Hill; 1984.
2. Crystallography Applied to Solid State Physics; Vermaand Srivastava; New Age; 1991.

3. Introduction to Solid State Physics; Kittel; Wiley India Pvt Ltd; 2007.
4. Element of X-ray Diffraction, B. D. Cullity, Addison-Wesley Publishing Company, Inc. Reading, MA, USA, 1956.
5. Solid State Physics (Introduction to the theory), James Patterson, Bernard Bailey, Springer-Verlag Berlin Heidelberg, 2010.
6. Elementary Solid State Physics, M. Ali Omar, Addison-Wesley, 1994.

PHC512	**EXPERIMENTAL PHYSICS III**	**(002)**
Course Philosophy	▪ To familiarize students with basic experiments of materials science, electronics and spectroscopy; ▪ To increase observational and analytical power of students.	
Learning Outcome	Students will learn: 1) Basic physics of working mechanism of each experiment. 2) Some techniques to find out physical parameters of materials. 3) To enhance experimental capability.	
Practical Unit No.	**Tentative Title of Experiments**	**Tentative No. of classes**
1 1.	Study of compressibility of a given liquid by ultrasonic diffraction grating method	2
2 2.	Study of diffusion potential and band gap of P-N junction	2
3 3.	Study of h-parameters of the transistor	2
4 4.	Study of Silicon-Controlled Rectifier (SCR) characteristics	2
5 5.	Study of Curie temperature of a given ferroelectric material	2
6	Study of g-factor by electron spin resonance method etc.	2
Total (Tentatively 24 hours)		**12**

References:

1. An Advanced Course in Practical Physics by D. Chattopadhyay, P. C. Rakshit; New Central Book Agency (P) Ltd., 2007 (8e)
2. A Textbook of Advanced Practical Physics by S. K. Ghosh; New Central, 2000 (4e)
3. Advanced Practical Physics, V - I and II by Chauhan and Singh; Pragati Prakashan

PHC513	**EXPERIMENTAL PHYSICS IV**	**(002)**
Course Philosophy	▪ To familiarize students with fundamental experiments of optics and spectroscopy; ▪ To increase observational and analytical power of students.	
Learning Outcome	Students will learn: 1) Basic physics of working mechanism of each experiment. 2) Some techniques to determine few physical parameters and constants, and how to correlate them with the physical phenomena. 3) To enhance experimental capability.	
Practical Unit No.	**Tentative Title of Experiments**	**Tentative No. of classes**
1 1.	Study of Zeeman effect and calculate the line separation	2
2 2.	Study of e/m ratio using oil drop method	2
3 3.	Double slit experiment to find out slit width and separation	2
4 4.	Study of absorption spectrum of Iodine vapour with constant deviation spectrometer and the to determine energy levels of iodine molecule, force constant etc.	2

5 5.	Study of Hydrogen spectrum and hence determine the Rydberg's constant	2
6	Study of band gap of a given material using UV-visible absorption spectrum.	2
Total (Tentatively 24 hours)		**12**

References:

1. An Advanced Course in Practical Physics by D. Chattopadhyay, P. C. Rakshit; New Central Book Agency (P) Ltd., 2007 (8e)
2. A Textbook of Advanced Practical Physics by S. K. Ghosh; New Central, 2000 (4e)
3. Advanced Practical Physics, V - I and II, by Chauhan and Singh; Pragati Prakashan

SEMESTER-III

PHC514	**STATISTICAL MECHANICS**		**(310)**
Course Philosophy	Systems, made up of large number of constituent particles are characteristic by many emergent properties which are understood by the laws of statistical mechanics. The course is meant to introduce these laws to the students.		
Learning Outcome	Students will be conversant with the general notions of Statistical Mechanics viz. ensemble theory. Using this approach they should be able to calculate properties of systems with many particles. They will also have the idea of the statistical basis of phase transitions and critical phenomena.		
Unit No.	**Topics**	**No. of lectures**	**No. of tutorials**
1.	Phase space, trajectories and density of states, Liouville's theorem	2	1
2.	Ensemble Theory: Microcanonical, Canonical and Grand canonical ensembles, partition function, calculation of statistical quantities, Energy and density fluctuations	8	3
3.	Density matrix, statistics of ensembles, statistics of indistinguishable particles	4	1
4.	Maxwell-Boltzman, Fermi-Dirac and Bose-Einstein statistics, properties of ideal Bose and Fermi gases, Bose—Einstein condensation.	6	3
5.	Cluster expansion for a classical gas, Virial equation of state	4	1
6.	Introduction of ising model: one, two and three dimensions; Exact solutions in one dimension	4	1
7.	Landau theory of phase transition, critical indices, dimensional analysis.	4	1
8.	Correlation of space-time dependent fluctuations, Fluctuations and transport phenomena, Brownian motion, Langevin theory, Fluctuation dissipation theorem, The Fokker Planck equation.	7	2
Total 52		**39**	**13**

Text Books:

1. Statistical Mechanics: R. K. Pathria; Elsevier; 2002.

2. Fundamentals of Statistical and Thermal Physics; Reif; McGraw-Hill; 1965.
3. Thermodynamics and Statistical Mechanics; Greiner; Springer; 2007.

Reference Books:

1. Statistical Mechanics: K. Haung; Wiley Eastern; 2003.
2. Modern Theory of Critical Phenomena: Shang Keng Ma; Levant Books; 2007.
3. Statistical Mechanics: Landau and Lifshitz; Butterworth-Heinemann; 1976.
4. Introduction to Phase Transitions and Critical Phenomena; H. Eugene Stanley; Oxford University Press; 1987.

PHC515	**LASER PHYSICS AND TECHNOLOGY**	**(300)**
Course Philosophy	Laser, the light extraordinary, has so many applications in various field even having further potential and hence it has urgent need to familiarize lasers & their technical advances to the students so that students be ready to apply coherent light to solve various problems in areas such as scientific, industrial, healthcare etc.	
Learning Outcome	Through this course students will learn following: 1) Fundamental principles of stimulated emission and how to convert it into coherent light emission. 2) The manipulation of light i. e. mode selection, continuous and pulsed generation, spectral narrowing etc. 3) Applications of various lasers in various fields including scientific research to common use.	
Unit No.	**Topics**	**No. of lectures**
1	**Overview**: Gaussian beam, Monochromaticity, Directionality, Coherence; Atomic energy levels.	4
2	**Energy distributions and laser design**: Einstein's quantum theory of radiation; Boltzmann distribution, Population inversion, Rate equations, Stability conditions, Three level and four level lasers; Issues in designing a laser; Pumping mechanisms; Stable and unstable resonators, Laser Cavity, Longitudinal and Transverse Modes, Mode Selection, Gain in a Regenerative Laser Cavity; Q-switching, Mode locking, Laser amplification, Frequency conversion, Pulse expansion, Pulse shortening – Pico-second and Femto-second operations, Spectral narrowing and Stabilization.	15
3	**Laser systems:** Basics of tunable, ultrafast and power lasers; *Gas lasers*: He-Ne, He-Cd, Ar, Kr ion, CO_2, Excimer lasers; *Solid state lasers*: Diode pumped solid state lasers, Lamp pumping and thermal issues; Ruby, Nd-YAG, Fibre lasers; *Semiconductor lasers*: Laser materials, Laser structure, Frequency control of laser output, Modern diode laser, Quantum cascade lasers, p-Ge lasers, Vertical-cavity surface-emitting laser.	14
4	**Applications of laser**: Laser cooling; Laser barcode scanner, Laser trimming, Cutting, Welding, Drilling and Tracking, Pattern formation by laser etching; LIDAR; Laser-tissue interaction, Laser surgery; Holography, Interferometry, Microscopy.	6
Total		**39**

Text Books:

1. Laser Fundamentals, by William T. Silfvast, Cambridge University Press, 2008.

2. Principles of Lasers, by Orazio Svelto; Springer, 2009.
3. Lasers – Theory and Applications, by K. Thyagarajan and A. K. Ghatak; Macmillan India, Delhi, 1981.

Reference Books:

1. Laser Physics, by Simon Hooker and Colin Webb; Oxford, 2010.
2. Lasers, by A. E. Siegman; University Science Books, 1986.
3. Laser Application in Surface Science and Technology, by H. G. Rubahn; John Wiley and Sons, 1999.
4. Laser Physics, by P. W. Milonni, J. W. Eberly; John Wiley and Sons, 2010.
5. Laser Cutting: Guide for manufacturing, by C. L. Caristan; Society of Manufacturing Engineers, 2004.
6. Optical Electronics, by Ghatakand Thyagarajan, Cambridge.
7. Essentials of Optoelectronics, by A. Rogers, Chapman Hall.
8. Lasers and Non-Linear Optics, B. B. Laud; New Age International, New Delhi, 1991.
9. Laser Spectroscopy: Basic Concepts and Instrumentation, by Demtroder; Springer, 2004.

PHC516	**NUCLEAR AND PARTICLE PHYSICS**	**(300)**
Course Philosophy	▪ To establish a foundation of nuclear science and technology within physics students; ▪ To prepare them for higher studies and research in the relevant fields.	
Learning Outcome	After attending the course a student will be acquainted with various important aspects of nuclear science and related techniques like nuclear systematics, stability, two nucleon problems, detectors and accelerators, nuclear reactions and elementary particles.	
Unit No.	**Topics**	**No. of lectures**
1	**Nuclear systematics and stability:** Masses, sizes, spins, angular momenta, magnetic moments, parity, quadrupole moments, energetics and stability against particle emission, Gamow's theory of Alpha decay, Fermi theory of Beta decay, Gamma decay, Internal conversion, Nuclear isomerism.	8
2	**Two Nucleon Problems:** Nature of nuclear forces, Meson theory of nuclear forces, Deuteron problem, Nucleon-Nucleon scattering, scattering length, coherent and incoherent scattering, Effective range theory.	8
3	**Detectors and Accelerators:** Gas-Filled Ionization Detectors, Proportional counter, G.M. counter, Semiconductor Detectors, Solid State Scintillation Counters, Synchrotrons, Linear Accelerators, Colliding / Beam Accelerators.	8
4	**Nuclear Reactions:** Conservation laws, Classification, Compound Nucleus theory, Continuum and Statistical theories, Cross-sections, Breit-Wigner formula, Direct Reactions.	7
5	**Elementary particles:** Leptons, Mesons and Baryons, concept of antiparticle, discrete symmetries and conservation laws, Weak interactions (nuclear and particle decays, neutrinos etc.). Isospin and strangeness, Gellmann-Nishijima formula, quark model, colour, resonances, SU(3) classification, flavour of standard model.	8
Total 39		**39**

Text Books:

1. Nuclear Physics; I. Kaplan; Narosa; 2006.
2. Quarks and Leptons; Halzen and Martin; Wiley India Pvt Ltd; 2008.

Reference Books:

1. Atomic and Nuclear Physics; Vol.2, S N Ghoshal; S. Chand; 1994.
2. Structure of the Nucleas; Preston and Bhaduri; Westview Press; 1993.
3. Theory of Nuclear Structure; Pal; Affiliated East West Press; 2000.
4. Introductory Nuclear Physics; Wong; PHI Learning; 2010.
5. Theory of Nuclear Structure; Gupta; Alpha Publication; 2011.
6. Nuclear and Particle Physics; Burcham and Jobesl; Longman Publishing Group; 1994.
7. Quarks and Leptons: Halzen and Martin; Wiley India Pvt Ltd; 2008.
8. Symmetry Principles Particle Physics; Gibson and Pollard; Cambridge University Press; 2010.
9. Symmetry Principles in Particle Physics; Emmerson; Oxford University Press; 1972.
10. Introduction to High Energy Physics; Perkins; Cambridge University Press; 2010.

PHC517	**COMPUTATION AND SIMULATION**	**(002)**
Course Philosophy	▪ To provide hands on experience of computation through programming and simulation of specific physical phenomena; ▪ To equip the students with various tools of computation and simulation to be useful in advanced studies, research or any other relevant career.	
Learning Outcome	Students will be trained in programming various useful mathematical operations and functions using specially MATLAB. They will also get some experience on operating and running simulation programmes.	
Practical Unit No.	**Tentative Title of Experiments***	**Tentative No. of Classes**
1	MATLAB program to generate the Fibonacci series	1
2	MATLAB program to verify the number entered is prime number or not	1
3	MATLAB program to find the factorial of a number	1
4	MATLAB program to find the roots of quadratic equation	1
5	MATLAB program for a simple text-mode calculator	1
6	MATLAB program to calculate e^x by series user defined function.	1
7	MATLAB program to generate data of a mathematical function and store the data in to a file.	1
8	MATLAB program for loading data created in an external program	1
9	MATLAB program to create a simple table and a simple plot.	1
10	MATLAB program to plot trigonometric functions	1
	* Subject to the availability of other softwares, e.g. ANSYS, COMSOL, the plan of experiments may change.	
Total (Tentatively 20 hours)		**10**

Reference:

1. Essential MATLAB for Engineers and Scientists, 3rd Ed, by Brian Hahn and Daniel Valentine, Elsevier (Butterworth-Heinemann)

PHC518	EXPERIMENTAL PHYSICS V	(002)

Course Philosophy	▪ To make students acquainted with some important experiments of Fibre and Optical physics; ▪ To increase observational and analytical power of students.	
Learning Outcome	Students will learn: 1) Basic physics of working mechanism of each experiment. 2) Techniques to study optical phenomena and their applications. 3) To enhance experimental capability and instrument handling skill.	
Practical Unit No.	**Tentative Title of Experiments**	**Tentative No. of classes**
1	1. Study of Verdet constant of a given material by Faraday rotation	2
2	2. Study of microbending loss of optical fibre	2
3	3. Study of numerical aperture of a given multimode fibre	2
4	4. Study on Mach Zehnder interferometer and to find flatness of a flat object	2
5	5. Study of Pockel's effect using electro-optic cell; Study of contact angle of liquid on glass surface	2
6	Study of particle size determination using laser light diffraction etc.	2
Total (Tentatively 24 hours)		**12**

References:

1. An Advanced Course in Practical Physics by D. Chattopadhyay, P. C. Rakshit; New Central Book Agency (P) Ltd., 2007 (8e)
2. A Textbook of Advanced Practical Physics by S. K. Ghosh; New Central, 2000 (4e)
3. Advanced Practical Physics, V - I and II, by Chauhan and Singh; Pragati Prakashan

SEMESTER-IV

PHC519	THESIS UNIT I	(000)

Course Philosophy	Exposure to current research areas.
Learning Outcome	After completion of the project, students will learn the physical origin of the research problem, and techniques to address.
Description	
At the beginning of the semester students will be allotted supervisors (faculty members) from the same department. A student should decide the topic of research oriented project and dissertation in consultation with the supervisor and conduct research work throughout the semester under the guidance of him / her. Originality of the work is not necessarily a binding condition. Evaluation will be done based on two components: (i) dissertation submitted to the department, and (ii) seminar presentation of the project work done and viva-voce.	

PHC520	THESIS UNIT II	(000)
Course Philosophy	Exposure to current research areas.	
Learning Outcome	After completion of the project, students will learn the physical origin of the research problem, and techniques to address.	
Description		
At the beginning of the semester students will be allotted supervisors (faculty members) from the same department. A student should decide the topic of research oriented project and dissertation in consultation with the supervisor and conduct research work throughout the semester under the guidance of him / her. Originality of the work is not necessarily a binding condition. Evaluation will be done based on two components: (i) dissertation submitted to the department, and (ii) seminar presentation of the project work done and viva-voce.		

OPEN ELECTIVES

PHO501	ASTROPHYSICS AND COSMOLOGY	(300)
Course Philosophy	▪ To provide a glimpse of the ever mysterious and stirring world of space and related phenomena to the beginners or to the curious students of any discipline other than physics; ▪ To motivate students to choose a career in related areas of physics; ▪ To prepare a base for an ambitious physics student who wants to go to advanced studies or research in relevant fields.	
Learning Outcome	The course conveys basic to rather advanced level knowledge on exciting and important aspects related to astrophysics, general relativity and cosmology.	
Unit No.	**Topics**	**No. of lectures**
1	**Fundamentals of Astrophysics:** Overview of major contents of universe, Mass, length and time scales in astrophysics, Celestial coordinates, Astronomy in different bands of electromagnetic radiation, Interaction of radiation with matter , Black body radiation, Basic knowledge of stellar atmospheres, Binaries, variable stars, Compact objects , Evolution of a stars: White Dwarfs, Neutron stars, Supernovae, Pulsar, Stellar black holes, clusters, open and globular clusters, Shape, size and contents of our galaxy, Normal and active galaxies.	16
2	**General Relativity:** Foundations of general relativity, Riemannian geometry of Euclidean signature manifolds: tensors on Euclidean manifolds and their transformation laws; Christoffel symbol and Riemann tensor; geodesics; general properties of the Riemann tensor. Einstein's equation Schwarzschild and Kerr space-times	12
3	**Cosmology:** Introduction**,** observational tests, the early universe, the microwave background, dark matter and dark energy**.** Cosmological models: principles of homogeneity and isotropy; Newtonian cosmology, FRW metric; open, closed and flat universes; relation between distance, red-shift and scale factor.	11
Total		**39**

Text Books:

1. Theoretical Astrophysics, Padmanabhan T., Vols.1-3, Cambridge University Press, 2005.
2. Astrophysics for Physicists, Arnab Rai Choudhuri, Cambridge University Press.
3. Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity, Steven Weinberg
4. An Introduction to Cosmology, 3rd Edition, Narlikar.
5. The Early Universe: E. Kolb and M.S. Turner.

Reference Books:

1. The Physical Universe, Shu, F., University of California, 1982.
2. Astrophysical Concepts, 3rd ed, Harwit, M. Springer-Verlag, 2006.
3. The Classical Theory of Fields, 2nd ed., Landau, L.D. and Lifshitz, E.M., Pergamon Press, 1995.
4. Gravity: Introduction to Einstein's General Relativity, Hartle, J. B., Pearson Education, 2003.
5. Physical Cosmology, Peebles, P. J. E., Princeton University Press, 1993.

PHO502	**NONLINEAR OPTICS**	**(300)**
Course Philosophy	The course content covers the propagation of electromagnetic waves in nonlinear media.	
Learning Outcome	Students will be learning different nonlinear processes as an outcome under light matter interaction in nonlinear media classically as well as quantum mechanically. In addition, they will also have knowledge about the working principle of many optical devices based on nonlinear phenomena.	
Unit No.	**Topics**	**No. of lectures**
1	**Introduction:** Origin of nonlinearity, Brief review of electromagnetic waves, Polarization, Diffraction, Anisotropic media, Light propagation through anisotropic media, Nonlinear polarization, Nonlinear susceptibility, Wave equation.	06
2	**Nonlinear Processes:** ***Second order nonlinear effects***: Second harmonic generation (SHG), Phase matching techniques, Periodically poled materials and their applications in nonlinear optical devices, Parametric fluorescence, Parametric amplification, Three wave mixing, Sum and Difference frequency generation, Parametric oscillation.	13
3	***Third order nonlinear effects***: Third harmonic generation (THG), Self-phase modulation, Cross-phase modulation, Four wave mixing, Optical phase conjugation, Kerr effect, Self-focusing and Self-defocusing. Spontaneous and Stimulated Raman Scattering, Hyper-Raman effect, Higher-order Raman processes,	10
4	**Quantum-mechanical description**: Use of Density matrix and Perturbative approach to nonlinear optical susceptibilities. Multiphoton processes.	05
5	**Devices**: Electro-optic effect, Electro-optic modulators. Photorefractive effect, Acousto-optic effect, Acousto-optic modulators. Magneto-optic effect. Faraday effect, Magneto-optic modulator, Quantum detectors.	05
Total		**39**

Text Books:

1. Nonlinear Optics, R.W. Boyd, Academic press, Elsevier, 2008.

2. Quantum Electronics, Amnon Yariv, John Wiley and Sons, 1989.
3. Fundamentals of Nonlinear Optics, P. E. Powers, CRC Press, 2011.
4. Handbook of Nonlinear Optics, R. L. Sutherland, 2003.

Reference Books:

1. Nonlinear Optics; Nicolaas Bloembergen; World Scientific Pub Co Inc; 1996
2. Laser and Nonlinear Optics; B. B. Laud; New Age; 1991
3. Principles of Nonlinear Optics, Y. R. Shen, A Wiley Inter-science Publication, 1984.
4. Light-Matter Interactions, W. T. Hill and C. H. Lee, Wiley-VCH, 2007.
5. Essentials of Nonlinear Optics, Y. V. G. S. Murthy and C. Vijayan, Wiley, 2014.
6. Essentials of Lasers and Nonlinear Optics; Baruah; PragatiPrakashan; 2000.

PHO503	**PHYSICS OF NANOMATERIALS**	**(300)**
Course Philosophy	▪ To introduce the students with science and technology involved with the viable materials at nanoscale; ▪ To get the students ready for research in advanced fields of materials science and to be a professional in development and production industry.	
Learning Outcome	Upon completion a student will know about: ▪ Properties of nanomaterials; ▪ Physical and chemical sciences working behind the properties exhibited by the materials at nanoscale; ▪ Various physical and chemical techniques of synthesis and fabrication of nanomaterials and nanostructures; ▪ Some typical technologically important nanomaterials.	
Unit No.	**Topics**	**No. of lectures**
1	**Introduction:** Band Structure, Density of States (DOS) in bands, Variation of DOS with energy, Variation of DOS and band gap with size of crystal; Joint Density of States, Dimensional dependence of DOS of Fermi gas electrons. Electron confinements in infinitely deep and finite square well potentials; Physical concepts of circular, parabolic and triangular well potentials.	9
2	**Quantum size effect:** Properties of nanoparticles, Characteristic lengths, Clusters, Magic Numbers; Quantum well, Quantum wire, Quantum dot; Energy subbands; Conduction electrons and dimensionality; Properties dependent on DOS. Electrical transport properties, Diffusive and ballistic regime, Single electron tunnelling, Excitons, Optical absorption in quantum well; Surface plasmon resonance; Nanomagnetism; Nanomechanical properties.	10
3	**Preparation of nanomaterials and nanostructures**: Classification, Top-down and Bottom-up approach, Overview of different fabrication and synthesis techniques such as Ball Milling, Chemical bath Deposition, Electrodeposition, Sol-Gel, Anodization technique, Photolithography, E-beam lithography, Hot-embossing Technique, Physical Vapor Deposition, Glancing angle deposition, Pulsed Laser Deposition, Molecular Beam Epitaxy. Growth mechanisms of nanocrystals and nanostructures.	12
4	**Typical nanomaterials**: Graphene, Fullerenes and Carbon Nanotubes; Supramolecular structures; Nanocomposites, Zeolites.	8
Total		**39**

Text Books:

1. Introduction to Nanotechnology, Poole and Owners, Wiley India Pvt Ltd, 2007.
2. Nanostructures and Nanomaterials: Synthesis, Properties, and Applications, Cao; World Scientific Publishing Company, 2011.
3. Introduction to Nanoscience and Nanotechnology, Chattopadhyay and Banerjee, PHI Learning Pvt. Ltd., 2009.
4. Nanoscience and Nanotechnology – Fundamentals to Frontiers: By M. S. Ramachandra Rao, S. Singh; Wiley, 2013.
5. Chemistry of Nanomaterials: Synthesis, Properties and Applications, Rao, Muller and Cheetham, Wiley VCH; 2004.

Reference Books:

1. Handbook of Nanophysics – Principles and Methods: By Klaus D. Sattler; CRC Press, 2010.
2. Materials Science and Engineering: An Introduction, W. D. Callister, John Wiley and Sons, 2006.
3. Materials Science and Engineering, V. Raghvan, PHI Learning Pvt. Ltd., 2004.
4. Nanotechnology: A Crash Course, R. Raul J. Martin-Palma, Akhlesh Lakhtakia, SPIE Press, 2010.
5. Nanoscience and Nanotechnology in Engineering, V. K. Varadan, World Scientific, 2010.
6. Introduction to Nanoscience and Nanotechnology; Gábor Louis Hornyak, Harry F. Tibbals, Joydeep Dutta, CRC Press, 2009.
7. Quantum Dots, Jacak, Hawrylak and Wojs, Springer, 1998.
8. Nanotechnology: Principles and fundamentals, Günter Schmid, Wiley-Vch, 2008.
9. Nanomaterials and Nanochemistry; C. Brchignac, P. Houdy and M. Lahmani; Springer, 2008.
10. Nanotechnology: A Crash Course, Raul J. Martin-Palma, Akhlesh Lakhtakia, SPIE Publications, 2010.

PHO504	**OPTOELECTRONIC MATERIALS AND DEVICES**	**(300)**
Course Philosophy	▪ To expose students to the field of optoelectronics; ▪ To specialize and get them ready for research and development in academics and industry.	
Learning Outcome	The students will be learnt on the physics of luminescence, semiconducting and non-semiconducting materials viable for optoelectronics, their functional mechanisms, and various kinds of optoelectronic devices like radiative recombination, photoelectric, photoconducting, stimulated emission, photoemissivity, display type and other devices.	
Unit No.	**Topics**	**No. of lectures**
1	*Elements of light*: Nature of light, Light sources, Black body, Colour temperature, Units of light, Radio metric and photometric units, Light propagation in media and waveguides, Electro-optic effects.	3
2	*Overview of luminescence*: Photoluminescence, Cathodoluminescence, Electroluminescence, Injection-luminescence.	3
	Materials:	
3	*Materials for optoelectronics*: Structural properties.	2
4	*Semiconducting materials and Heterostructures*; Electronic, transport and optical properties of semiconductors: Direct and Indirect bands; Degenerate and non-degenerate semiconductors, Doping and	10

	degeneracy; Carrier mobility in semiconductors, Electron and Hole conductivity in semiconductors; Metal-semiconductor contacts, Schottky barrier; Band bending and effect on bulk properties; Recombination processes; Excitons; Allowed, forbidden and phonon assisted optical transitions; Switching; Colour centres; Photoconductivity; Internal quantum efficiency, External quantum efficiency; Double heterojunction, Fabrication of heterojunction, Quantum wells and superlattices.	
5	*Non-Semiconducting materials*: Fibre optic materials, Lithium Niobate, Organic materials, Polymers etc.	3
	Devices:	
6	*Radiative recombination devices*: Light-emitting diodes (LED), Organic Light Emitting Devices (OLED).	2
7	*Photoelectric devices*: Photodiodes, Solar cells and Photovoltaic devices, Phototransistors, Photomultipliers, Optoisolators.	3
8	*Photoconducting devices*: Photodetectors and photoconductors, Photoresistors, Photo transistors, PIN diode, Thermal detectors, Photoconductive camera tubes, Charge-coupled imaging devices.	4
9	*Stimulated emission devices*: Injection laser diodes, Quantum cascade lasers.	2
10	*Photoemissivity device*: Photoemissive camera tube.	2
11	*Display devices*: Electro Luminescence display, Plasma display, Liquid Crystal Display (LCD), LED Display.	3
12	Introduction to Modulators, Opto-Electronic packaging, Integrated Optical Circuits (IOC).	2
Total		**39**

Text Books:

1. Optoelectronics – An Introduction to materials and devices; Jasprit Singh, McGraw-Hill, 1996.
2. Materials for Optoelectronics; Maurice Quillec, Springer Science, 1996.
3. Optoelectronic Devices and Systems; S. C. Gupta, Prentice Hall India, 2005.
4. Optoelectronics - An introduction; J. Wilson and J. Hawkes, Prentice-Hall India, 1996.
5. Semiconductor optoelectronic devices; P. Bhattacharya, Prentice Hall India, 2006.

Reference Books:

1. Optoelectronics - Advanced Materials and Devices; Pyshkin and Ballato, InTech, 2013.
2. Optoelectronic materials and device concepts; Manijeh Razeghi, SPIE, 1991.
3. Introduction to Organic Electronic and Optoelectronic Materials and Devices; Sun and Dalton, CRC Press, 2008.
4. Physics of Semiconductor Devices; Sze; Wiley, 1969.
5. Semiconductor Devices - Basic Principles; Singh; John Wiley.
6. Physics and Technology of Semiconductor Devices; Grove; Wiley, 1967.
7. Metal-Semiconductor Schottky Barrier Junction and their Applications; Sharma; Plenum, 1984.
8. Metal-Semiconductor Contact; Rhoderick and Williams; Oxford, 1988.
9. Principles of Electronic Materials and Devices; Kasap; McGraw-Hill, 2005.
10. Optical fibre communication; J. M. Senior, Prentice Hall India, 1985.
11. Optical fibre communication systems; J. Gowar, Prentice Hall, 1995.
12. Introduction to optical electronics; J. Palais, Prentice Hall, 1988.
13. Semiconductor optoelectronics; Jasprit Singh, McGraw-Hill, 1995.
14. Fiber Optics and Optoelectronics, R. P. Khare, Oxford, 2004.

EPARTMENTAL ELECTIVES

PHD501	ADVANCED QUANTUM MECHANICS	(300)
Course Philosophy	To introduce the concept of advanced concepts of quantum mechanics	
Learning Outcome	On successful completion of this course, a student should be conversant with the concepts of scattering theory, relativistic quantum mechanics and the idea of quantum field theory	
Unit No.	**Topics**	**No. of lectures**
1	**Scattering Theory:** Scattering amplitude and cross-section, Partial wave analysis and application to simple cases; Integral form of scattering equation, Born approximation validity. The optical theorem.	9
2	**Relativistic Quantum Mechanics:** The Klein-Gordon equation. The Dirac equation. Dirac matrices, spinors. Magnetic Moment and Spin of electron; Positive and negative energy solutions, physical interpretation. Nonrelativistic limit of the Dirac equation.	10
3	**Identical Particles:** Symmetric and antisymmetric wave functions: Bosons and Fermians. symmetrization postulates, Pauli's exclusion Principle. Spin-statistics connection, self consistent field approximation: Slater determinant, Hartree Fock method.	8
4	**Quantum Field Theory:** Preliminaries: why QFT? Classical Field Theory; Lagrangian formulation; Action for a scalar field; Symmetries and conservation laws, Noether's theorem; Quantum equation for field, Canonical quantization of scalar field; Dirac Field; Fock space and particle number representation.	12
Total		**39**

Text Books:

1. Relativistic Quantum Mechanics: Wave Equations, 3/Ed; W. Greiner; Springer Int.; 2006.
2. Modern Quantum Mechanics; J. J. Sakurai; Pearson; 1994.
3. Relativistic Quantum Mechanics and Quantum Fields; Katiyar; Campus Books Int.; 2009.
4. A First Book on Quantum Field Theory: Lahiri; Narosa Book Distributors Pvt Ltd; 2005.

Reference Books:

2. Relativistic Quantum Mechanics: Bjorken and Drell; McGraw-Hill; 1998.
3. Quantum Field Theory, Rev.Ed.; Mandland Shaw; Wiley; 1993.
4. Principles of Quantum Mechanics; Shankar; Springer; 2006.
5. Quantum Computation and Quantum Information: M. A. Nielsen and I. L. Chuang, Cambridge University Press.
6. An Introduction to Quantum Field Theory; Peskinand Schroeder; Westview Press; 1995.

PHD502	**COMPUTATIONAL PHYSICS**	**(300)**
Course Philosophy	▪ To acquaint the students with highly developed computational methods employed in solving complex problems in physics; ▪ To specialize them for research in theoretical physics in the forefront areas of advanced physical fields.	
Learning Outcome	After attending the course the students will be trained in the theoretical concepts and simulation of e.g. random walks, Brownian motion, percolation, Hartree-Fock and density functional theory. They will also be skilled on Monte Carlo and molecular dynamics simulations. Further they will have some useful concepts on parallel computation and MATLAB.	
Unit No.	**Topics**	**No. of lectures**
1	Theory of random walks and simulation of random walks in one, two and three dimensions. Elementary ideas and simulations of self-avoiding walks, additive and multiplicative stochastic processes, Brownian motion and fractional Brownian motion.	8
2	Percolation theory and simulation by Hoshen-Kopelman algorithm; Application to simple lattice models in Physics.	6
3	Introduction to Hartree-Fock theory and Density functional theory.	4
4	Computer Simulations: 1. Monte Carlo simulation: Basic idea, Importance Sampling, Metropolis algorithm, Markov chain, and Some applications. 2. Molecular Dynamics: Basic idea, Equation of motion; Program initialization, The force calculation, Integrating the equation of motion and Some applications. Ising model in magnetism, Bak-Tang-Wiesenfeld model in studies of self-organized criticality.	15
5	Significance of Parallel Computation in numerical calculation; Introduction to MATLAB Programming with few examples.	6
Total		**39**

Text Books:

1. Numerical Recipes: The Art of Scientific Computing; William H. Press; Cambridge University Press; 2007.
2. A Guide to Monte Carlo Simulations in Statistical Physics, D. P. Landau and K. Binder, Cambridge University Press.
3. I. Prigogine and Stuart A. Rice, New Methods in Computational Quantum Mechanics, Wiley.
4. Introduction to Computational Chemistry, Frank Jensen

Reference Books:

1. Matlab: A Practical Introduction to Programming and Problem Solving; Stormy Attaway; Butterworth-Heinemann; 2011.
2. FORTRAN 90 for Scientists and Engineers; Brian Hahn; Butterworth-Heinemann; 1990.
3. Computer Programming in Fortran 77; V. Rajaraman
4. Computational Physics, Joseph Marie Thijssen, Cambridge University Press.
5. An Introduction to Computational Physics, Tao Pang, Cambridge University Press.
6. Computer Simulation of Liquids, M. P. Allen and D. J. Tildesley, Clarendon Press.
7. D. Frankel and B. Smit, Understanding Molecular Simulation, second edition, Academic Press.
8. R. G. Parr and W. Yang, Density Functional theory of atoms and molecules.

PHD503	HIGH ENERGY PHYSICS	(300)
Course Philosophy	▪ To teach the students some high level physical concepts of sub-nuclear or particle physics; ▪ To specialize them for research on very advanced scientific problems of both experimental and theoretical physics in the area of fundamental nuclear particles and their interactions.	
Learning Outcome	The course will let the students learn about fundamental particles, their interactions and conservations laws, quark model, different symmetries, Gauge theories, quantum electrodynamics and quantum chromodynamics.	
Unit No.	**Topics**	**No. of lectures**
1	Natural units; four fundamental interactions, leptons and hadrons, historical introduction to the elementary particles, Gell-Mann eightfold way, quark model, Concept of colour, Bound states of quarks, Decays and conservation laws. Relativistic kinematics, Lorentz Covariance, Collisions.	15
2	Symmetries and groups, SU(2) of Isospin, Flavour symmetries, SU(3) flavour group, construction of hadronic wave functions, Parity, Charge conjugation, CP violation, Weak Interactions,	10
3	Gauge Theories, Lagrangians in relativistic field theory, Noether's theorem: symmetries and conservation laws, U(1) local gauge invariance and QED Lagrangian, Non-Abelian Gauge Invariance, Yang-Mills Theory, Spontaneous Breaking of Gauge symmetry, Higgs Mechanism, Feynman diagrams and elementary particle dynamics	11
4	Quantum Chromodynamics, The Standard Model, Grand Unification	3
Total		**39**

Text Books:

1. Introduction to Elementary Particles, David J. Griffiths.
2. Introduction to High Energy Physics, Donald Perkins.
3. Quarks and Leptons: An Introductory Course in Modern Particle Physics, Francis Halzen and Alan Martin.

Reference Books:

1. Elementary Particle Physics, Stephen Gasiorowicz.
2. Relativistic Quantum Mechanics, James Bjorken and Sidney Drell.
3. Modern Elementary Particle Physics; Gordon Kane.
4. Gauge Theory of Elementary Particle Physics; T. P. Cheng and L. F. Lee, Oxford University Press 1984.

PHD504	**BIOPHYSICS**	**(300)**
Course Philosophy	The content of the course introduces the basic concept of biophysics and techniques used to address the biophysical problems.	
Learning Outcome	After completion of the course, students will understand the impact of Physics to solve problems of Biological origin. In addition, they will have insight about numerous theoretical as well as experimental tools to address biological problems in cellular level.	
Unit No.	**Topic**	**No. of Lectures**
1	**Basic Concepts in Biophysics**: General organization of a cell and it's division, Kinetics and Transport processes, Molecular forces in biological structures, Physics of micro and macromolecules, Biomolecular Structures and Dynamics (Proteins, Nuclear Acids, Carbohydrates, Lipids and Membranes), Inter and Intra-molecular interactions, Molecular distribution and statistical thermodynamics, Protein folding, Introduction to Neurobiophysics, Introduction to Computational biophysics.	24
2	**Methods in Biophysics**: X-Ray diffraction, Spectroscopic techniques; Microscopic techniques, Super resolution techniques, Otoscopy, Low and high coherence interferometry, Optical Coherence Tomography (OCT), Phase Imaging, Magnetic Resonance Imaging (MRI), Computer Tomography (CT), Optical/ Magnetic tweezers, Laser Surgery.	15
Total		**39**

Text Books:

1. Essentials of Biophysics, P Narayanan, New Age International, 2005.
2. Biomedical Imaging: Principles and Applications, Ed.: Reiner Salzer, Wiley, 2012.
3. Biophysics: An introduction, Rodney M.J. Cotterill, Wiley, 2002.
4. Molecular and Cellular Biophysics, Meyer B Jackson, Cambridge, 2006.
5. Biochemistry, J. M. Berg, J. L. Tymoczko, L. Stryer, W. H. Freeman and Company, 2002.

Reference Books:

1. Biophysics: An introduction, R. Glaser, Springer-Verlag Berlin Heidelberg, 2012.
2. Biophysics, V. Pattabhi and N. Gautham, Kluwer Academic Publishers, 2002.
3. Introduction to Biophysics by Pranab Kumar Banerjee, S. Chand and Co, 2008.
4. Biophysics, Ed. W. Hoppe, Springer-Verlag, 1983.
5. Applied Biophysics, A Molecular Approach for Physical Scientist, T.A Weigh, Wiley, 2007.
6. Proteins Structure and Function, David Whitford, Wiley, 2005.
7. Introduction to Biomedical imaging, A. G. Webb, John Wiley and Sons Inc.,2003.
8. Introduction to medical imaging, N. B. Smith, A. Webb, Cambridge University Press, 2011.
9. Quantitative Phase Imaging, M. Miret. al., Progress in Optics, 57, Elsevier, 2012.
10. Magnetic Tweezers for Single-Molecule Experiments, I. D. Vilfanet. al., Ch. 13, pp. 371-395, Handbook of Single-Molecule Biophysics, Springer, 2009.

PHD505	**THIN FILM AND VACUUM TECHNOLOGY**	**(300)**
Course Philosophy	• To guide the students to the doorsteps of materials processing and device fabrication at micro and nanoscale, primarily using vacuum techniques – indispensable for miniaturization, reproducibility and reliability of the fabricated device; • To prepare students with a specialized direction of materials science and engineering ready to land up in education, research, development and production useful for both in academia and industry.	
Learning Outcome	Students will learn: a) Theories of thin film growth from nano to micro scale, b) Processes of growing thin films, c) Properties of materials at two dimensional structures and their possible applications, d) Theories and techniques of vacuum generation and measurements, e) Applications of vacuum from high pressure to ultra low pressure.	
Unit No.	**Topics**	**No. of lectures**
	Science and Technology of Thin Films	
1	Nucleation and Growth: Film formation and structure; Thermodynamics of nucleation, Nucleation theories: Capillarity model – homogeneous and heterogeneous nucleations, Atomistic model – Walton-Rhodin theory; Post-nucleation growth; Deposition parameters; Epitaxy; Thin film structure; Structural defects and their incorporation.	6
2	Preparation methods: Electrochemical Deposition (ECD); Spin coating; Physical Vapour Deposition (PVD)- thermal evaporation, electron beam evaporation, RF-sputtering; Pulsed Laser deposition (PLD); Chemical Vapour Deposition (CVD), Plasma-Enhanced CVD (PECVD), Atomic Layer Deposition (ALD), Molecular Beam Epitaxy (MBE).	6
3	Thickness measurement and monitoring: Electrical, mechanical, optical interference, microbalance, quartz crystal methods.	3
4	Properties of thin films: Electrical, mechanical, optical and magnetic.	3
5	Thin film devices: Fabrication and applications.	2
	Science and Technology of Vacuum	
6	Vacuum principles: Basic terms and concepts; Continuum and Kinetic gas theory; Pressure ranges; Types of flow; Conductance.	5
7	Vacuum generation: Vacuum pumps – a survey; Diaphragm pump, Rotary vane pump, Diffusion Pump, Turbomolecular Pump (TMP), Sorption pumps: Adsorption pumps, Sublimation pumps, Sputter-ion pumps; Cryo Pump.	7
8	Vacuum measurement: Thermal conductivity vacuum gauges, Ionization vacuum gauges.	3
9	Analysis of gas at low pressures: Residual gas analyzers, Quadrupole mass spectrometer.	2
10	Leaks and their detection: Types of leaks, Leak rate, leak size, mass flow; Leak detection methods: Pressure rise and drop tests, Tests using vacuum gauges, Bubble immersion test, Foam-spray test, Halogen and Helium leak detectors.	2
Total		**39**

Text Books:

1. Thin Film Phenomena; K. L. Chopra; McGraw-Hill; 1969.
2. Handbook of Thin Film Technology; Leon I. Maissel and Reinhard Glang; McGraw-Hill; 1970.
3. Thin Film Fundamentals; A. Goswami; New Age International Pvt. Ltd; 2007.
4. Materials Science of Thin Films; Milton Ohring; Academic Press; 2001.
5. Vacuum Science and Technology; V. V. Rao, T. B. Ghosh and K. L. Chopra; Allied Publishers, 1998.
6. Fundamentals of Vacuum Technology; Walter Umrath; Leybold, 1998.

Reference Books:

1. Thin Films; Heavens; Dover Publications Inc.; 1991.
2. Thin-Film Deposition: Principles and Practice; Smith; McGraw-Hill; 1995.
3. Thin Film Processes I; Vossen and Kern; Elsevier Science and Technology Books; 1978.
4. Thin film processes II; Vossen and Kern; Academic Press; 1991.
5. Handbook of Vacuum Science and Technology; Hoffman, Singh and Thomas; Academic Press; 1998.
6. Vacuum Technology; Roth; North Holland, 1990.

PHD506	**CHRACTERIZATION TECHNIQUES**	**(300)**
Course Philosophy	To make students acquaint with advanced materials characterization tools required for scientific research and development field.	
Learning Outcome	Students will learn: 1. Basic principles and working of each technique. 2. Methodology of data recording, analysis and interpretation of observations. 3. How and when a particular technique needs to be used to get required information.	
Unit No.	**Topics**	**No. of lectures**
1	**Microstructure Characterization techniques:** Light microscopy-bright field, dark field, phase contrast illumination, Ellipsometry, Spectral reflectance, Scanning Electron Microscope (SEM), Transmission electron microscope (TEM), Atomic force microscopy (AFM), Scanning tunnelling microscopy (STM).	6
2	**Spectroscopic techniques:** Spectrophotometry, Luminescence spectroscopy, Fourier Transform Infrared (FTIR) spectroscopy, Raman spectroscopy, Surface plasmon resonance (SPR) spectroscopy, Dynamic light scattering (DLS), Inductively Couple Plasma Mass Spectroscopy (ICPMS).	8
3	**Compositional characterization techniques:** X-ray and Ultra-7violet Photoelectron Spectroscopy (XPS and UPS), Energy Dispersive X-ray analysis (EDAX), X-ray Fluorescence Spectroscopy (XRF), Rutherford Backscattering Spectroscopy (RBS), Inductively Coupled Plasma Mass Spectrometry (ICPMS).	7
4	**Crystalline Structure characterization techniques:** X-ray diffraction (XRD), Transmission Electron diffraction (TED).	2
5	**Electrical characterization techniques:** Measurement of resistivity by four-probe method, Impedance and ferroelectric	4

	measurements, flow cyclic voltammetry.	
6	**Characterization of Mechanical Properties:** Micro / Nanoindenter, Nanoindentation and bending tests by AFM, Frictional Force Microscopy.	4
7	**Magnetic characterization techniques:** Vibrating Sample Magnetometer (VSM), Superconducting Quantum Interference Device (SQUID), and Magnetic Force Microscopy (MFM).	4
8	**Thermal characterization techniques:** Differential Scanning Calorimeter (DSC), Thermo-Gravimetric and Differential Thermal Analyzer (TG-DTA), Thermal mechanical analysis (TMA), Dynamic mechanical analysis (DMA).	4
Total		**39**

Text Books:

1. Microstructural characterization of materials, D. Brandon and W. Kaplan, John Wiley and Sons, 2013.
2. Surface Characterization Methods: Principles, Techniques and Applications; Milling; CRC Press; 1999.
3. ASM Handbook: Volume 10: Materials Characterization; George M. Crankovic; ASM International; 1986.

Reference Books:

1. Encyclopaedia of Materials Characterization - Surfaces, Interfaces, Thin Films; Brundle, Richard, Evans and Shaun; Elsevier; 1992.
2. Characterization of Semiconductor Materials - Principles and Methods; McGuire; William Andrew Publishing / Noyes; 1989.
3. Optical Techniques for Solid-State Materials Characterization, Rohit P. Prasankumar, Antoinette J. Taylor, CRC Press, 2010.
4. Foundation of Spectroscopy. Simon Duckett and Bruce Gilbert. Oxford University Press. 2005.
5. Frontier of Molecular Spectroscopy. Jaan, L. Elsevier S and T, 2008
6. Practical Handbook of Spectroscopy, James W. Robinson, CRC Press, 1991.
7. Surface and Thin Film Analysis: A Compendium of Principles, Instrumentation, and Applications, Gernot Friedbacher, Henning Bubert, John Wiley and Sons, 2011.
8. Elements of X-ray Diffraction, Cullity B D., Stock S R, Prentice Hall, Inc. 2001.
9. Scanning Electron Microscopy and X-ray Microanalysis: Third Edition, Joseph Goldstein, Springer, 2003.
10. The Principles and Practice of Electron Microscopy, Ian M. Watt, Cambridge Univ Press, 1997.
11. Principles of Thermal Analysis and Calorimetry, Peter J. Haines, RSC, 2002.

PHD507	PLASMA AND SPACE PHYSICS	(300)

Course Philosophy	▪ To introduce students with the physics of terrestrial plasmas of gaseous systems and interactions of terrestrial atmosphere with solar system; ▪ To prepare them for advanced studies and research in similar fields.	
Learning Outcome	Students will learn the physics of electron-ion interactions, fundamentals of plasmas, transport and electromagnetic wave propagation in plasma, their kinetics, applications; they will also learn the effect of solar atmosphere on the atmosphere of earth.	
Unit No.	**Topics**	**No. of lectures**
	Plasma Physics:	
1	Introduction: Debye shielding, Plasma parameters, Applications of plasma physics.	2
2	Single particle motions: Motion of charged particles in magnetic fields; Adiabatic invariants, Transit time magnetic pumping, Plasma heating; Plasma confinement schemes, Tokomak.	5
3	Plasmas as Fluids: Fluid equation of motion, Plasma approximation.	2
4	Waves in plasmas: Plasma oscillations, Electromagnetic waves in magnetized plasma, Wave propagation in cold and hot plasmas.	4
5	Diffusion and resistivity: Parameters; Collisions and discrete particle effects, Coulomb collisions, Transport processes, Conductivity, Diffusion along and across magnetic field; Fokker-Planck equation; Two-fluid and single-fluid magnetohydrodynamic (MHD) plasma models.	5
6	Equilibrium and stability: Linear waves, fluctuations in a stable plasma and instabilities in magnetized plasma; Two-stream instability.	3
7	Kinetic theory: Velocity distribution, Equations of kinetic theory, Electron plasma waves and Landau damping; Solutions of Vlasov-Maxwell equation; Cyclotron damping.	4
	Space Physics:	
8	Solar Phenomena: Structure of sun, Solar activity, Prominences, Coronal heating, Solar flares.	3
9	Solar wind: Properties, Solar wind formation, Interaction of solar wind with magnetized and unmagnetized planets.	3
10	Magnetophere: Magnetopause, Magnetotail, Magnetic reconnection, Magnetosphere, Plasma flow in the magnetosphere.	3
11	Upper ionosphere: Structure, Ionosphere, Ionospheric Irregularities, Aurora borealis; Magnetosphere-Ionosphere coupling; Wave propagation in ionosphere and in planetary magnetosphere.	5
Total		**39**

Text Books:

1. Introduction to Plasma Physics and Controlled Fusion, Vol I; Chen; Springer; 2006.
2. Elements of Space Physics, R. P. Singhal, PHI Learning, 2009.

Reference Books:

1. Basic Space Plasma Physics; Baumjohann and Treumann; World Scientific; 1996.
2. Introduction to Space Physics; Kivelson, Kivelson and Russell; Cambridge University Press, 1995.
3. Space Plasma Physics: An Introduction; Das; Alpha Science International; 2004.
4. Plasma Physics and Introductory Courses; Dendy; Cambridge University Press; 1995.
5. Introduction of Plasma Physics; Goldston and Rutherford; Taylor and Francis; 1995.
6. Fundamentals of Plasma Physics; Bittencourt; Springer; 2004.

PHD508	FIBRE OPTICS AND APPLICATIONS	(300)
Course Philosophy	▪ To educate the students about science and technology of optical fibres; ▪ To specialize and prepare them for research and development for academics and industry.	
Learning Outcome	Upon completion of the course students will be conversant on the physical principles working behind optical fibres and systems, techniques of preparation of optical fibres, components and studies of their properties, nonlinearities in properties, and various devices made out of optical fibres.	
Unit No.	**Topics**	**No. of lectures**
1	**Science of Fibre Optics** Introduction and importance of fibre optics technology, Wave propagation in Planer waveguide and cylindrical waveguides, Optical fibre-types, design and basic characteristics; Ray analysis of optical fibre, Fibre numerical aperture, Electromagnetic (modal) analysis of Step-index multimode fibres, Hybrid and linearly polarized modes, Single mode fibre, Power confinement and mode cut off, Mode field diameter, Graded-index fibre, WKB analysis, Fibre optic communication system: Concepts of WDM, DWDM; Repeaters and optical amplifiers Optimum profile.	
2	**Experimental Techniques** Fibre fabrication and characterization, Splices, Connectors and fibre cable. Loss mechanism in optical fibre. Pulse propagation, Dispersion and chirping in single-mode fibres, Dispersion compensation mechanism, Dispersion-tailored and dispersion compensating fibres, Fibre birefringence and polarization mode dispersion, Fibre bandwidth.	
3	**Nonlinear effects in optical fibre** Stimulated Raman Scattering, Stimulated Brillouin Scattering, Self Phase Modulation, Cross Phase Modulation, Optical Solitons.	
4	**Fibre based devices** Erbium-doped fibre amplifiers and lasers, Fibre Bragg gratings. Optical fibre sensors: Intensity modulated sensors, Phase modulated sensors, Spectrally modulated sensors, Optical temperature Sensor, Mach- Zehnder interferometer. Photonic crystal fibres.	
Total		**39**

Text Books:

1. An Introduction to Fiber Optics; Ghatak and Thyagarajan; Cambridge University Press; 1998.
2. G. P. Agarwal, Fiber Optic Communication Systems, John Wiley Sons, 1997.
3. John A. Buck, Fundamentals of Optical Fibers, Wiley Interscience, 2004.

Reference Books:

1. J. M. Senior, Optical Fiber Communication, Prentice Hall, 1999.
2. G. Keiser, Optical Fiber Communications, McGraw Hill, 2000.
3. K. Okamoto, Fundamentals of Optical Waveguides, Academic Press, 2000.
4. K. Iizuka, Elements of Photonics Vol I andII, Wiley-Interscience, 2002.
5. D. W. Prather et.al, Photonic Crystal, Wiley, 2009.
6. Optical Fiber Communication: Principles and Practice; Senior; Pearson; 2010.

7. Fiber Optics and Optoelectronics; Khare; Oxford University Press; 2004.
8. Photonics: Optical Electronics In Modern Communications; Amnon; Oxford University Press; 2007.

PHD509	ADVANCED CONDENSED MATTER PHYSICS	(300)
Course Philosophy	To introduce the basic theoretical background of condensed matter physics.	
Learning Outcome	A student will be acquainted with the basic theoretical knowledge that explains various phenomena of condensed matter such as superconductivity, fractional Hall effect etc.	
Unit No.	**Topics**	**No. of lectures**
1	**Many electron theory:** Introduction to many-electron wave function, Hartree-Fock theory, Second quantization formalism; Interactions of Electrons and Phonons with Photons, Exciton and Polaritons.	8
2	**Localization in Disordered Systems:** Electron Localization, Anderson localization, Mott's Localization, Hopping Conductivity.	5
3	**Correlated Systems:** Hubbard Model, Mott insulator, Kondo effect.	5
4	**Theory of Superconductivity:** Flux quantization, Macroscopic Quantum interference, Cooper Pairing, Energy gap, BCS theory; Ginzburg-Landau theory; Introduction to high temperature superconductors.	11
5	**Quantum Hall Effect:** Integer quantum Hall effect, Introduction to fractional QHE.	4
6	**Introduction to Soft Matter:** What is Soft Condensed Matter: Qualitative discussion of Colloids, Polymers, Gels, Liquid crystals.	6
Total **39**		**39**

Text Books:

1. Quantum approach to condensed matter physics, Taylor and Heinonen, Cambridge.
2. Many-Particle Physics; G.D. Mahan, Springer; 3rd ed., 2000
3. Introduction to Condensed Matter Physics, F. Duan, J. Guojun, World Scientific.
4. Soft Condensed Matter: Jones; Oxford University Press; 2002

Reference Books:

1. Advanced Condensed Matter Physics, L. M. Sander, Cambridge.
2. Basic notions of Condensed Matter Physics, P.W. Anderson, Perseus Books
3. Physics of Condensed Matter, P. K. Mishra, Academic Press, 2012.
4. Condensed matter field theory, Altland and Simmons , Cambridge
5. Quantum field theory and condensed Matter, R. Shankar, Cambridge

PHD510	QUANTUM COMPUTATION AND INFORMATION	(300)
Course	To introduce the basic knowledge about quantum computation and	

Philosophy	information.	
Learning Outcome	A student will learn a new dimension of quantum mechanics and its application in computer and the surprising quantum entanglement and quantum cryptography.	
Unit No.	**Topics**	**No. of lectures**
1	**Introduction:** Single qubit, multiple qbits, quantum gates, quantum circuits, Bell states, Bloch sphere, Density operators, Pure and mixed states, decoherence.	7
2	**Basics of quantum measurement:** Stern-Gerlach Experiment, Projective measurement, POVM measurement.	4
3	**Quantum Algorithm:** Introduction to quantum algorithms, Deutsch-Jozsa algorithm, Grover's quantum search algorithm	6
4	**Quantum Cryptography:** Cryptography, Private key distribution, introduction to quantum cryptography. Quantum key distribution, No-cloning theorem, BB84, B92 protocols. Introduction to security proofs for these protocols. Quantum teleportation	10
5	**Quantum Information:** Introduction to classical and quantum information, Examples of quantum error corrections, Shannon and Von Neumann entropy, Quantum channels and noises, Quantum correlations, EPR paradox, Bell's inequalities, Theory of quantum entanglement. Entanglement of pure bipartite states.	12
Total		**39**

Text Books:

1. Quantum Computation and Quantum Information by M. A. Nielsen and I. L. Chuang, Cambridge University Press.

Reference Books:

1. A Short Introduction to Quantum Information and Quantum Computation by M. L. Bellac, Cambridge University Press.
2. Introduction to Quantum Computation and Information, H.-K. Lo, T. Spiller, S. Popescu, World Scientific, 1998
3. Principles of Quantum Computation and Information. Vol. 1, G.Benenti, G. Casati, G. Strini, World Scientific