Department of Physics
Course structure and Syllabus for Int. M.Sc. in Physics (2020)
Minimum credit required: 210
Minimum duration: 10 Semesters
Maximum duration: 14 Semesters

Semester	Credit	Semester	Credit
I	21	VI	22
II	22	VII	23
III	21	VIII	21
IV	22	IX	21
V	22	X	19

Semester I

Course Code	Course Name	L-T-P	CH	CR	Remark
PI 101	Physics-I	2-1-0	3	3	GE for Non-Major
PI 103	General Physics-I	2-1-0	3	3	CORE for Physics Major
CI 101	Chemistry-I	2-1-0	3	3	GE
MI 101	Mathematics-I	2-1-0	3	3	GE
BI 101	Biology-I	2-1-0	3	3	GE
PI 197	Physics Lab –I	0-0-3	6	3	CORE for Physics Major GE for Non-Major (Chemistry & Biology)
BI 107	Biology Laboratory	0-0-3	6	3	GE
EG 110	Communicative English (Language Proficiency)	3-0-0	3	3	AEC
Total credits			27	**21**	

Semester II

Course Code	Course Name	L-T-P	CH	CR	Remark
PI 102	Physics-II	2-1-0	3	3	GE for Non-Major
PI 104	General Physics-II	2-1-0	3	3	CORE for Physics Major
CI 102	Chemistry-II	2-1-0	3	3	GE
BI 102	Biology-II	2-1-0	3	3	GE
MI 102	Mathematics-II	2-1-0	3	3	GE
PI 198	Physics Lab-II	0-0-3	6	3	CORE for Physics Major
CI 105	Chemistry Lab	0-0-3	6	3	GE
ES 103	Environmental Studies	4-0-0	4	4	AEC
Total credits			28	**22**	

Course Code	Course Name	L-T-P	CH	CR	Remarks
PI 197	Physics Lab-I	0-0-3	6	3	GE for Non-Major (Mathematics)

Semester III

Course Code	Course Name	L-T-P	CH	CR	Remarks
PI 201	Physics III	2-1-0	3	3	Non-Major

Course Code	Course Name	L-T-P	CH	CR	Remarks
PI 203	Classical Mechanics	2-1-0	3	3	CORE
PI 217	Mathematical Physics-I	2-1-0	3	3	CORE
CI 201	Chemistry III	3-0-0	3	3	GE
MI 201	Mathematics III	2-1-0	3	3	GE
PI 297	Physics Lab-III	0-0-4	8	4	CORE
NS 106	NSS	0-0-2	4	2	SEC
CS 535	Introduction to Scientific Computing	2-0-1	4	3	AEC
Total credit			28	**21**	

Semester IV

Course Code	Course Name	L-T-P	CH	CR	Remarks
PI 205	Electromagnetism	2-1-0	3	3	CORE
PI 214	Electronics	2-1-0	3	3	CORE
PI 325	Thermodynamics and Statistical Physics	2-1-0	3	3	CORE
PI 218	Modern Physics	2-1-0	3	3	CORE
PI 298	Physics Lab-IV	0-0-4	8	4	CORE
	Elective I	2-1-0	3	3	DSE
DM 101	Disaster Management	2-1-0	3	3	SEC
Total credit			26	**22**	

Semester V

Course Code	Course Name	L-T-P	CH	CR	Remarks
PI 303	Physical and Geometrical Optics	2-1-0	3	3	CORE
PI 202	Introductory QM	2-1-0	3	3	CORE
PI 315	Mathematical Physics II	2-0-1	3	3	CORE
PI 309	Analog Electronics and communications	2-1-0	3	3	CORE
PI 204	Atomic and Nuclear Physics	2-0-1	3	3	CORE
PI 308	Laser Physics	2-1-0	3	3	DSE
PI 399	Physics Lab-V	0-0-4	8	4	CORE
Total credits			**26**	**22**	

Semester VI

Course Code	Course Name	L-T-P	CH	CR	Remarks
PI 307	Basic Material Science	2-1-0	3	3	CORE
PI 317	Basic Computation Techniques	2-1-0	3	3	CORE
PI 314	Measurement Physics	2-1-0	3	3	CORE
	Elective II	2-0-1	3	3	DSE
PI 311	Waves and Accoustics	2-1-0	3	3	CORE
	Open Elective	2-1-0	3	3	
PI 300	Project cum Physics Lab-VI	0-0-4	8	4	
Total credits			**26**	**22**	

List of elective papers

1. **PI 220 Renewable Energy**
2. **PI 221 Nanomaterial Fundamentals and application**
3. **PI 222 Earth Science**

- **Minimum credit for B.Sc. (Physics) (for lateral exit from Int. M.Sc.)= 130**

Semester VII

Course Code	Course Name	L-T-P	CH	CR	Remarks
PI 403	Electromagnetic Theory I	2-1-0	3	3	
PI 413	Advanced Classical Mechanics	2-1-0	3	3	
PI 414	Quantum Mechanics –I	2-1-0	4	3	
PI 416	Condensed Matter Physics and Material Science	2-1-0	3	3	
PI 499	Physics and Computational Lab	0-1-3	7	4	
PI 405	Semiconductor Devices	2-1-0	3	3	
PI 400	Physics Lab-VII	0-0-4	8	4	
Total credits				**23**	

Semester VIII

Course Code	Course Name	L-T-P	CH	CR	Remarks
PI 552	Quantum Mechanics-II	2-1-0	3	3	
PI 310	Statistical Physics	2-1-0	3	3	
PI 551	Electromagnetic Theory II	2-1-0	3	3	
PI 417	Advanced Mathematical Physics	2-0-1	4	3	
PI 302	Analog and Digital Electronics	2-1-1	5	4	
PI 450	Seminar	0-0-1	2	1	
PI 498	Physics Lab-VIII	0-0-4	8	4	
Total credits				**21**	

Semester IX

Course Code	Course Name	L-T-P	CH	CR	Remarks
PI 559	Project-1	0-0-6	12	6	To be carried out under the guidance of a faculty member
PI 402	Nuclear and Particle Physics	2-1-0	3	3	
PI 553	Atomic and Molecular Spectroscopy	2-1-0	3	3	
	Elective I	2-1-0	3	3	
	Elective II	2-1-0	3	3	
	Open Elective	2-1-0	3	3	
Total credits				**21**	

Semester X

Course Code	Course Name	L-T-P	CH	CR	Remarks
PI 500	Project-1I	0-0-10	20	10	To be carried out under the guidance of a faculty member
	Elective III	2-1-0	3	3	
	Elective IV	2-1-0	3	3	
	Open Elective	2-1-0	3	3	
Total credits				**19**	

Elective Courses are offered by the department in Semester IX and Semester X: Minimum of Four is to be chosen from any specialization.

Course Code	Course Name	L-T-P	CH	CR	Remarks
	Astrophysics				
PI 564	Introductory Astrophysics	2-1-0	3	3	
PI 565	Elements of GTR and Cosmology	2-1-0	3	3	
	Condensed Matter Physics				
PI 510	Advanced Condensed Matter Physics and Materials Science	2-1-0	3	3	
PI 554	Soft Condensed Matter Physics	2-1-0	3	3	
	Electronics				
PI 507	Digital Signal Processing	2-1-0	3	3	
PI 508	Digital Communication System	2-1-0	3	3	
PI 516	Microprocessors and Digital Signal Processing Based Systems	2-1-0	3	3	
PI 517	Microwave Systems and	2-1-0	3	3	

	Antenna Propagation				
High Energy Physics					
PI 501	Quantum Field Theory	2-1-0	3	3	
PI 540	Particle Physics	2-1-0	3	3	
Photonics					
PI 557	Photonics	2-1-0	3	3	
PI 559	Nanophotonics	2-1-0	3	3	

Plasma Physics					
PI 521	Fundamentals of Plasma Physics	2-1-0	3	3	
PI 525	Nonlinear Plasma Physics	2-1-0	3	3	
Nano-Science					
PI 562	Quantum Effects in low Dimensional Systems	2-1-0	3	3	
PI 563	Physics of Nano Devices	2-1-0	3	3	

Total Credit (UG + PG): 130 + 84 =214

Terminology
Core papers (CORE)
Generic Elective (GE)
Discipline Specific Elective papers (DSE)
Ability Enhancement Compulsory (AEC)
Skill Enhancement Course (SEC)

Detailed Syllabi

Semester-I

PI 101: PHYSICS-I (L2-T1-P0-CH3-CR3)

Course objectives: This course is intended for the students of the first semester of Integrated M.Sc. and Integrated B.Sc. B.Ed. from the departments of Mathematics, Chemistry and MBBT. This is the first of the three basic physics courses offered to them. The primary objective of the course is to offer those non-physics-major students the overview of important physics concepts which are needed for a general understanding at the undergraduate level, and also to offer concepts which are important and relevant for their major subjects. This course consists of elements of coordinate systems, vectors and matrices, introductory mechanics and properties of matter.

Learning outcome: As an outcome of this course, learners are expected to get an idea of the basics of coordinate systems, vectors and matrices, introductory mechanics and properties of matter. Learners will get a detail of the coordinate systems: plane polarized, cylindrical and spherical; along with various vector and scalar properties. The extensive use of vectors and matrices in solving various problems in an intended learning outcome. Learners are also expected to understand the basic mechanics in both inertial and non-inertial frames, motion under a central force and the mechanics of a system of particles. The simple properties of matter, which are relevant for all the students will also be described in this course.

Course Content:

Coordinates, Vectors and Matrices:

Coordinate systems, plane polar, cylindrical and spherical polar; line element, surface element and volume element; gradient, divergent and curl.

Line, surface and volume integrals.

Properties of matrices; complex conjugate matrix, transpose matrix, hermitian matrix, unit matrix, diagonal matrix, adjoint of a matrix, self-adjoint matrix, cofactor matrix, symmetric matrix, anti-symmetric matrix, unitary matrix, orthogonal matrix, trace of a matrix, inverse matrix, eigenvalue, diagonalization of matrices.

Mechanics:

Work-energy theorem, conservative forces and potential energy; energy diagram; non-conservative forces; motion in non-inertial frames; uniformly rotating frame; centrifugal and Coriolis forces.

Motion under a central force.

System of particles; centre of mass, equation of motion of the centre of mass; laboratory and centre of mass frame of references; elastic and inelastic collisions; linear and angular momentum and their conservation laws; fixed axis rotation; moment of inertia; theorem of parallel and perpendicular axes; compound pendulum, Kater's and bar pendulum.

Properties of Matter:

Elasticity; elastic constants; Hooke's law; torsional oscillation; bending of a beam; cantilever; surface tension; viscosity; kinematics of moving fluids.

Text Books:

1. Spiegel M., *Vector Analysis: Schaum's Outlines Series*, 2nd edition (McGraw Hill, 2017).
2. Potter M. C., Goldberg J., *Mathematical methods*, 2nd edition (Phi Learning Pvt. Ltd., 2008).
3. Mathur, D. S., *Mechanics*, (S. Chand & Co. Ltd., 2000).
4. Kleppner, D. and Kolenkow, R., *Introduction to Mechanics*, (McGraw-Hill, 1973).

Reference Books:

1. Harper C., *Introduction to Mathematical Physics*, 1st edition (Phi Learning Pvt. Ltd., 2008).
2. Chow, T. L., *Mathematical Methods for Physicists: A concise introduction*, 1st edition (Cambridge Univ. Press, 2000).
3. Takwale R., Puranik P., *Introduction to Classical Mechanics*, (McGraw Hill, 2017).
4. Young, H. D. and Freedman, R. A., *University Physics*, 12th edition (Pearson, 2009).

PI 197: Physics Lab –I (L0-T0-P3-CH6-CR3)

Course objective: This course is designed for the Integrated M.Sc. and Integrated B.Sc. B.Ed. from the department of Physics to familiarize the different components and equipment use in physics practical among them. This course is also design to perform some experiments related to general properties of matter, mechanics, magnetism etc.

Learning outcome: After completion of the course students will be able to use the different components and equipment in physics practical. Students will also able to work effectively and safely in the laboratory environment independently and as well as in teams.

Course contents:

1. Laboratory related components:
    a. Laboratory safety measures; handling of chemical; electrical and electronics items and instruments; handling of laser and laser related instruments and experiments; handling of radioactive samples and related instruments; general safety measures etc.
2. Familiarization with equipment and components:
    a. Familiarization of different Electrical and Electronics components and hence identification & determination of values of unknown components
    b. Familiarization of different optical and hence show different optical behavior & pattern by using different optical components and optical sources (white light, laser, sodium light etc.)
    c. Familiarization of Microsoft excel, Origin and other software for data analysis
    d. Soldering and de-soldering of components in a circuit board.

3. Use of equipment:
    a. Multimeter and its uses
    b. Function generator and its uses
    c. CRO and its use to measure the wavelength, frequency, amplitude etc. of a given electrical signal.
4. Study the variation of time period with distance between center of gravity and center of suspension for a bar pendulum and,
    a. determine

a) radius of gyration of the bar about its axis through its center of gravity and perpendicular to its length and,
b) value of g

5. Determine the moment of a given magnet and horizontal component of Earth's magnetic field using magnetometers
6. Determine g through Kater's Pendulum
7. Find the refractive index of a given prism with the help of a spectrometer.
8. To determine the surface tension of the given liquid (water/CC14) by capillary tube method.
9. To measure the focal length of a given lens using (a) Bessel's method and (b)Magnification method.
10. To study elastic and inelastic collisions using suspended spherical balls of different materials.
11. Determination of Young's modulus of the given wire by torsional oscillation (Searl's method)

PI 103: General Physics I **(L2-T1-P0-CH3-CR3)**

Course Objective: This course is intended for the students of the first semester of Integrated M.Sc. and Integrated B.Sc. B.Ed. from the department of Physics. The primary objective of this course is to offer the Physics-major students an introduction to the elementary concepts of Mechanics, Properties of Matter and Mathematical Physics, before they are offered the full-fledged courses on Classical Mechanics and Mathematical Methods in a few of the next semesters. These concepts are also important for them for their laboratory courses.

Learning outcome: As an outcome of this course, learners are expected to get introductory ideas of Mechanics, Properties of Matter and Mathematical Physics. In the Mechanics part, the learners will get an overview of the work, energy and force; systems of particles; rigid body dynamics and basic properties of matter. In the Mathematical Physics section, the learners are expected to learn about various coordinate systems; Line, surface and volume integrals with physical examples; properties of matrices and differential equations.

Course Content:

Introductory Mechanics and Properties of Matter:

Work, Energy and Force: Work-energy theorem, conservative forces and potential energy, energy diagram, non-conservative forces, motion in non-inertial frames, uniformly rotating frame, centrifugal and introductory concept of Coriolis forces.

System of particles: Centre of mass, equation of motion of the centre of mass, laboratory and centre of mass frame of references, Elastic and inelastic collisions, linear and angular momentum and their conservation laws.

Rigid body dynamics: Fixed axis rotation, moment of inertia, theorem of parallel and perpendicular axes, calculation of moment of inertia for bodies of different shapes, compound pendulum, Kater's and bar pendulum, calculation of the acceleration due to gravity.

Properties of matter: Elasticity, elastic constants, Hooke's law, torsional oscillation, bending of a beam, cantilever, surface tension, viscosity, kinematics of moving fluids.

Introductory Mathematical Physics:

Coordinate systems: plane polar, cylindrical, spherical polar, line element, surface element and volume element in different coordinate systems, gradient, divergent and curl.

Integrals: Line, surface and volume integrals with physical examples.

Properties of matrices: complex conjugate matrix, transpose matrix, hermitian matrix, unit matrix, diagonal matrix, adjoint of a matrix, self-adjoint matrix, cofactor matrix, symmetric matrix, anti-symmetric matrix, unitary matrix, orthogonal matrix, trace of a matrix, inverse matrix, eigenvalue and diagonalization of matrices.

Differential equations: Ordinary differential equations and their solutions.

Text books:

1) Mathur, D. S., Mechanics, (S Chand & Co Ltd, 2000)
2) Kleppner, D. and Kolenkow, R., Introduction to Mechanics, (McGraw-Hill Book Co., Inc, 1973)
3) Spiegel M., *Vector Analysis: Schaum's Outlines Series*, 2nd edition (McGraw Hill Education, 2017)
4) Potter M. C., Goldberg J., *Mathematical methods*, 2nd edition (Phi Learning Pvt. Ltd-New Delhi, 2008)

Reference books:

1) Takwale R., Puranik P., *Introduction to Classical Mechanics*, (McGraw Hill Education 2017)
2) Young, H. D. and Freedman, R. A., University Physics, 12th edition (Pearson, 2009)
3) Harper C., *Introduction to Mathematical Physics,* 1st edition *(*Phi Learning Pvt. Ltd-New Delhi, 2008)
4) Chow, T. L., *Mathematical Methods for Physicists: A concise introduction*, 1st edition (Cambridge Univ. Press, 2000)

Semester-II

PI 102: PHYSICS-II **(L2-T1-P0-CH3-CR3)**

Course Objectives: The main objective of the course is to introduce basic concepts on Special Theory of Relativity, Electromagnetism and Electronics.

Learning outcome: It is expected that after successfully completing the course, the student has a good idea on relativity, electricity, magnetism and electronics.

Course Content:

Special Theory of Relativity:

Frames of reference, relative velocity and accelerations, Concept of ether, Michelson-Morley experiment, elements of special theory of relativity, the postulates, Galilean and Lorentz transformations, equivalence of mass and energy, time dilation, length contraction, simultaneity, Doppler effect, twin paradox.

Electromagnetism:

Coulomb's law (electric), electric field due to a system of charges, Gauss's law in differential and integral forms, electric dipole, its electric field and potential, capacitance of parallel plates.

Coulomb's law (magnetic), Biot-Savart law, force on a current and on moving charges in a B-field.

Electronics:

Kirchhoff's law, network theorem, nodal analysis, mesh analysis, maximum power transfer theorem, series circuits, parallel circuits (DC analysis only), semiconductors, p-type, n-type semiconductors, p-n junction, diode, triode.

Text Books:

1. Beiser A., *Concepts of Modern Physics,* 6th edition (Tata McGraw Hill, 2008).
2. Rakshit, P. C. and Chattopadhaya, D., *Electricity and Magnetism,* (New Central Book Agency, 2012).
3. Robbins, A. H. & Miller, W. C., *Circuit Analysis* (Delmar Cengage Learning, 2003).

Reference Books:

1. Resnick, R., *Introduction to Special Relativity*, 1st edition (Wiley, 2007).
2. Griffith, D. J., *Introduction to Electrodynamics*, 3rd edition (Prentice Hall of India, 1999).
3. Edminister, J. A., *Electrical Circuits- Schaum's Outline series*, 2nd edition (McGraw Hill,1983).

PI 198: Physics Lab -II
(L0-T0-P3-CH6-CR3)

Course objective: This course is designed for 2nd semester Integrated M.Sc. and B.Sc.-B.Ed. students. In this course eexperiments are introduced mainly to cover the basic physics related to electronics, thermodynamic, sound and optics, electricity etc..

Learning outcome: After completion of this course students will have a good foundation in the fundamentals related to the experiments included in this course and their advanced applications.

1. Design LCR series and parallel circuits and to measure resonant frequencies.
2. To prove Thevenin's and Norton's theorem
3. Determine the force between two current carrying conductors.
4. Study the I-V characteristics of a Diode
5. Study of Lissajous Figure of two different waves using CRO and find out the unknown frequency of an electrical signal.
6. To determine the thickness of thin film using interferometric method.
7. Determine the mechanical/ Electrical equivalent of heat by Joule's Calorimeter.
8. Determine the coefficient of linear expansion of the given metal sample by optical lever method.
9. Determine of the co-efficient of viscosity of water by Poiseulle's method
10. Determine the wavelength of the given source of light using Fresnels' Biprism
11. Measurement of frequency of an unknown tuning fork using a sonometer.
12. To determine the coefficient of self-inductance of a coil by Rayleigh's D.C. Bridge method

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PI 104: General Physics II **(L2-T1-P0-CH3-CR3)**

Course Objectives: The main objective of the course is to introduce the detailed concepts on Electrostatics, Magnetostatics, Special Theory of Relativity and Electronics.

Learning outcome: It is expected that after successfully completing the course, the student has a good idea on electromagnetism, relativity and electronics.

Course Content:

Electrostatics:

<u>Coulomb's law and Gauss's law with applications:</u> Coulomb's law (electric), electric field due to a system of charges, Gauss's law in differential and integral forms with applications, electric dipole, its electric field and potential, capacitance of parallel plate.

Magnetostatics:

<u>Coulomb's law and Biot-Savart law with applications:</u> Coulomb's law (magnetic), the Biot-Savart law, current carrying conductors in a magnetic field.

Special Theory of Relativity:

<u>Basic developments and concepts:</u> Frames of reference, relative velocity and accelerations, concept of ether, Michelson Morley experiment and its result, elements of special theory of relativity, the postulates, Galilean and Lorentz transformations, time dilation, length contraction, Doppler effect, twin paradox.

<u>Mass-energy equivalence:</u> Equivalence of mass and energy, concept of the electronvolt unit and relevant examples with fundamental particles.

Electronics:

<u>Circuit analysis:</u> Network theorem, nodal analysis, mesh analysis, maximum power transfer theorem, series circuits, parallel circuits (DC analysis only).

<u>Semiconductors</u>: p-type and n-type, p-n junction, diode, triode, LED, solar cell.

<u>Text books:</u>

1) Griffith, D. J., *Introduction to Electrodynamics*, 3rd edition, (Prentice-Hall of India, 1999)
2) Purcell E.M., Electricity and Magnetism, 3rd edition , Cambridge University Press; 3 edition
3) Beiser A., *Concepts of Modern Physics*, 6th Edition (Tata McGraw-Hill 2008)
4) Robbins, A. H. & Miller, W. C., *Circuit Analysis*, (Delmar Cengage Learning., 2003).

<u>Reference books:</u>

1) Rakshit, P. C. and Chattopadhaya, D., *Electricity and Magnetism*, (New Central Book Agency, 2012)
2) Resnick, R., *Introduction to Special Relativity*, 1st edition (Wiley 2007)
3) Edminister, J.A., *Electrical Circuits- Schaum's Outline series*, 2nd edition (McGraw Hill, 1983)

<u>Semester-III</u>

PI 201: Physics-III **(L2-T1-P0-CH3-CR3)**

<u>Course Objectives:</u>
The main objective of the course is to introduce the detailed concepts on modern physics.

<u>Learning outcome:</u>
It is expected that after successfully completing the course, the student has a good idea on quantum mechanics.

<u>Course Content:</u>

Particle properties of waves: Wave particle duality, Photoelectric effect, Black body radiation, Plank radiation law, Rayleigh-Jeans law, Stefan's law.

Atomic physics: Rutherford model, Bohr model, hydrogen atom (quantum numbers and spectral series; qualitative), X-ray, Moseley's law, Basics of Lasers. Basics particle physics: elementary forces and particles.

Limitations of classical physics: Qualitative discussions of the problem of the stability of the nuclear atom. The photo-electric effect. Franck-Hertz experiment and the existence of energy levels. Experimental evidence for wave-particle duality, X-ray diffraction and Bragg law. Compton scattering. Electron and neutron diffraction. Einstein and de Broglie's relations ($E = h\gamma$, $p = h/\lambda$).

Schrodinger equation: The concept of the wave function as a probability amplitude and its probabilistic interpretation. Plane wave solutions of the one-dimensional time-dependent Schrodinger equation for a particle in free space and elementary derivation of the phase and group velocities (quantitative discussion of wave packets is not required).

Uncertainty relation: The position-momentum uncertainty relation and simple consequences. Solutions of the one-dimensional Schrodinger's equation for an infinite square well potential; qualitative treatment of the finite well (derivation not required). Linear harmonic oscillator.

Text Books:

1. Beiser, A., *Concepts of Modern Physics* (McGraw-Hill, 2002).
2. Krane, K. S., *Modern Physics* (Wiley).

Reference Books:

1. Beiser, A., Perspectives *of Modern Physics* (McGraw-Hill Inc.,US).
2. Thornton, S. T. and Rex, A., Modern Physics for Scientists and Engineers (Cengage Learning; 4 edition).
3. Gautreau, R. Schaum's Outline of Modern Physics, (McGraw-Hill; 2 edition).
4. Young, H.D. and Freedman, R.A., *University Physics,* 12^{th} edition, (Pearson, 2009).

PI 203: Classical Mechanics (L2-T1-P0-CH3-CR3)

Course objective:

Objective of this course is to introduce concepts and principles of mechanics. Motion of objects will be studied by using Newtonian as well as Lagrangian and Hamiltonian formulation.

Course Outcome:

Students will understand concepts of generalized coordinates and constrained motion. They will be able to apply Newtonian as well as Lagrangian and Hamiltonian mechanics to describe motion of physical systems, including systems involving central potential.

Course Content:

Mechanics of a particle: Conservation theorems for a particle, motion of a particle under damping forces, motion of a particle under central force, motion of a body in a resisting medium, Kepler's laws of planetary motion, moving co-ordinate systems, Galilean transformation, Coriolis force, Foucault's pendulum.

Mechanics of a System of Particles: Centre of mass and its motion, conservation theorems for a system of particles, collision problems, constraints, generalised co-ordinates, configuration space, principle of virtual work, D'Alembert's principle.

Lagrangian Formulation: Lagrange's equation, the rules of forming Lagrange's equation, Lagrange's equations for non-conservative forces, spherical and cylindrical co-ordinates, Hamilton's principle and Lagrange's equation, application of Lagrange's equation, motion of charged particle in an electromagnetic field, superiority of Lagrange's approach over Newtonian approach.

Hamiltonian Formulation: Phase space, Hamiltonian function and Hamiltonian equation, Application of Hamiltonian equation, Harmonic oscillator, compound pendulum, cyclic co-ordinates, Liouville's theorem, Routh's procedure.

Text Books:

1. Upadhyaya, J. C., *Classical Mechanics*, (Himalayan Publishing House).
2. Gupta, S. L., Kumar, V. and Sarma, H. V., *Classical Mechanics*, (Pragati Prakashan).

Reference Books:

1. Goldstein, H., *Classical Mechanics*, (Narosa, 2001).
2. Rana N. C., and Joag, P. S., *Classical Mechanics*, (Tata McGraw-Hill, 1991).
3. Takwale, R. G. and Puranik, P. S., *Introduction to Classical Mechanics*, (Tata McGraw-Hill, 1978).
4. Panat, P. V., *Classical Mechanics*, (Narosa Publishing House).

PI 217: Mathematical Physics-I **(L2-T0-P1-CH4-CR3)**

Course Objectives: The main objective of the course is to introduce the fundamental methods of mathematical physics and develop required mathematical skills to study various physical problems in Classical and Quantum mechanics, Electrodynamics and other areas of theoretical physics, in particular in higher dimensions.

Learning outcome: Upon completion of the course, the students should be able to understand basic theory of vectors analysis, curvilinear coordinate systems, differential equations, matrices, Fourier series and probability theory. Successful students should be able to apply methods of vector differentiation and integrals as well as separation of variables to solve differential equations, Expansion of Fourier and Taylor series, various integrals to special functions, solve differential equations using matrix methods and use basic probability theory to analysed experimental data.

Course Content:

Scalar and vector fields, differentiations, divergence and curl; integrations, Greens, Gauss's and Stokes theorems and their applications, transformations of coordinate systems and vector components, metric coefficients, curvilinear coordinates, expressions for grad., div., and curl, Helmholtz equation in three-dimensions and separable variables in various coordinate systems, matrices and determinants.

Beta, gamma and error functions, relationship between the beta and gamma functions, reduction of some classes of integrals to gamma functions, Sterling's formula; derivation of values of gamma functions.

Fourier series: Evaluation of coefficients, graphical representations, even and odd functions, properties of Fourier series, Fourier integrals.

Elements of probability: Mathematical probability, compound probability, total probability, sample space, random variables, expectation value, averages, mean, standard deviation, binomial distribution, normal distribution; variance, covariance and correlation; theory of errors, central limit.

Random Process: Random variables to random process, statistical averages, stationary processes.

Text Books:

1. Harper, C., *Introduction to Mathematical Physics*, *(*Prentice Hall, 2009).
2. Arfken, G. B., and Weber, H. J., *Mathematical Methods for Physicists*, (Elsevier Ltd, Oxford, 2005).
3. Spiegel, M. R., *Vector Analysis*, Schaum's outline series, (Tata McGraw-Hill 1979).

Reference Book:

1. Morganeau, H. and Purphy, C. M., *The Mathematics of Physics and Chemistry,* (Young Press, 2009).

PI 297: Physics Lab-III **(L0-T0-P4-CH8-CR4)**

Course objective: This laboratory course is designed for the third semester students of Integrated M.Sc. in physics. This course contains the experiments related to optics, thermodynamics, electricity and electronics.

Learning outcome: After completion of this course students will be able to learn practically the interference and diffraction, thermocouple, Wheatstone bridge principles and Op-Amp. This course will motivate the students to develop small experiments related to these techniques and develop their physical understanding.

Course content:

1. To observe the rotation of the plane of polarization of monochromatic light by a given solution and to determine the specific rotation of sugar solution using a Polarimeter.
2. Determine the wavelength (λ) of the given monochromatic light by using Lloyd's mirror.
3. To measure thermo e.m.f. of a thermocouple as a function of temperature and find inversion temperature.
4. To measure the radius of curvature of a given concave mirror and to measure the refractive index of a liquid by this method.
5. To measure the inductance of a given inductor using Anderson bridge.
6. To measure the capacitance of a capacitor by de-Sauty method and to find permittivity of air.
7. To study Op-Amp. characteristics:
    a. To get data for different input bias current,
    b. To measure and null the output offset voltage.
8. Determine the efficiency of the given solar cell for different intensity and different frequency of light sources.

9. Measure the elasticity of the given sample by Newton's ring method.

Semester-IV

PI 205: Electromagnetism **(L2-T1-P0-CH3-CR3)**

Course Objectives:

(a) It offers a precious scope of learning and enjoying the basics of electrostatics, electrodynamics and magnetism methodologically

(b) It opens inner stimulations to students to look creatively at the physical world from electromagnetic perspectives.

(c) It develops a multi-disciplinary capability to understand and solve all sorts of fundamental problems driven by electricity, magnetism, and so forth.

Learning outcomes:

(a) A full completion of the course is expected to build up strong creativity, analytical capability and innovativeness in the students.

(b) It enables to realize and enjoy the philosophical mysteries of electromagnetism via exercises of mathematical physics, vector operation, electricity and magnetism.

(c) It illuminates the physical universe from a new perspective of electromagnetic origin eventually after the applicability of the considered models skilfully.

Course Content:

Electrostatics in vacuum: Coulomb's law, Electric field due to a system of charges, Field lines, flux and Gauss's law, Gauss's law in differential form, the electric dipole and its electric field and potential, the couple and force on, and the energy of, a dipole in an external electric field, Gauss's law in integral form, field and potential due to surface and volume distributions of charge, force on a conductor, the capacitance of parallel plate, cylindrical and spherical capacitors, electrostatics in the presence of dielectric media, Modification to Gauss's law, polarisation, the electric displacement, relative permittivity, capacitance and energy in the presence of dielectric media.

Magnetic effects in the absence of magnetic media: the B-field, steady currents: the B-field set up by a current, the Biot-Savart law, the force on a current carrying conductor and on moving charges in a B-field, the magnetic dipole and its B-field, the force and couple on, and the energy of, a dipole in an external B-field, energy stored in a B-field.

Gauss's law in integral form, simple cases of the motion of charged particles in electric and magnetic fields.

Text Books:

1. Griffith, D. J., *Introduction to Electrodynamics*, 3rd edition, (Prentice-Hall of India, 1999).
2. Purcell, E. M., *Electricity and Magnetism*, Berkely Physics Course, Vol. 2 (McGraw-Hill, 1965).
3. Matveev, A.N., *Electricity and Magnetism*, (Mir Publishers, 1986).

PI 214: Electronics **(L2-T1-P0-CH3-CR3)**

Course Objectives: This course is designed to cater to basic concept of electronics. It has the objective to enable the students to understand and acquaint the basic idea and operating principle of day-to-day electronic devices; thereby inculcating their pursuit for higher studies.

Learning Outcomes: After the completion of this course, a student should have acquired the knowledge with facts and figures related to this field for better understanding in higher versions of electronic devices

Course Content:

Series and Parallel Resonant circuits (Detailed AC analysis)
Introduction to Three Phase Circuits. Two port n/w, Z-parameter, Y-parameter, Transmission.
Semiconductors: p and n Type Semiconductors. Energy Level Diagram, Mobility and conductivity, transport phenomenon due to donor and acceptor impurities, Fermi level, Hall Effect, conductivity measurement Conductivity and Mobility.
Diodes: Barrier Formation in pn Junction Diode (Simple Idea). Current Flow Mechanism in Forward and Reverse Biased Diode (Recombination, Drift and Saturation of Drift Velocity). Derivation of Mathematical Equations for Barrier Potential, Barrier Width and Current for Step Junction. pn junction and its characteristics. Static and Dynamic Resistance. Diode Equivalent Circuit. Ideal Diode. Load Line Analysis of Diodes and Q-point.
Two-terminal Devices and their Applications: (1) Rectifier Diode. Half-wave Rectifiers.
Centre-tapped and Bridge Full-wave Rectifiers Calculation of Ripple Factor and Rectification.
Efficiency. Qualitative idea of C, L and π - Filters. (2) Wave shaping circuits (3) Zener Diode and Voltage Regulation. (4) Photo Diode, (5) Varactor Diode.

Bipolar Junction Transistors, n-p-n and p-n-p transistors. Characteristics of CB, CE and CC Configurations. Current gains α, β and γ and Relations between them. Load Line Analysis of transistors. DC Load line and Q-point. Physical Mechanism of Current Flow. Active, Cutoff, and saturation Regions. Transistor in Active Region and Equivalent Circuit.

Fundamental of Digital Circuits, Combinational Circuits.

Text Books:

1. Robbins, A. H. & Miller, W.C., *Circuit Analysis*, (Delmar Cengage Learning., 2003).
2. Hayt, W. H. & Kemmerly, J. E., *Engineering Circuit Analysis*, (McGraw Hill, New York, 1993).
3. Millman, J., Halkias, C.C. and Jit, S., *Electronic Devices and Circuits*, (McGraw Hill Education,India, 2016).
4. Kumar, A., *Fundamentals of Digital Electronics* (PHI Learning Pvt. Ltd., 2003).

Reference Books:

1. Toro,V. Del, *Electrical Engineering Fundamentals*, (Prentice Hall, 1994).
2. Edminister, J.A., *Electrical Circuits- Schaum's Outline series*, 2nd edition (McGraw Hill,1983).
3. Smith, R.J. and Dorf, R.C., *Circuits, Devices and Systems*, (John Wiley & Sons, 1992).
4. Morris, J. *Analog Electronics*, (Arnold Publishers, 1991).
5. Mottershead, A. *Electronic Circuits and Devices*, (Prentice Hall, 1997).
6. Streetman, B.G. & Banerjee, S., *Solid State Electronic Devices*, (Pearson Prentice Hall, 2006).
7. Bhargava, N. N., Kulshreshtha D.C. & Gupta S.C., *Basic Electronics & Linear Circuits*, (Tata McGraw Hill, 2006).

8. Boylestad, R. & Nashelsky, L. *Electronic Devices and Circuit Theory*, 8th edition, (Pearson Education, India, 2004).
9. Malvino A. P., *Electronic Principals*, (Glencoe, 1993).

PI 325: Thermodynamics and Statistical Physics (L2-T1-P0-CH3-CR3)

Course Objectives: The course introduces the fundamental ideas of thermodynamics including thermodynamic systems and properties, relationship among thermo-physical properties, the laws of thermodynamics and their applications in various physical thermo dynamical systems. The course also accounts for methods using the basic probability theory to derive phenomenological laws of physics using microscopic description. This course will provide essential tools required to study thermo dynamical systems.

Learning outcome: Upon completion of the course, the students should be able to explain fundamental concepts relevant to thermodynamics and thermo dynamical systems, work, power and heat in thermodynamic systems, explain thermo dynamical laws in Isolated, Closed and Open systems and the concept of Entropy. Students will be able to explain phase transitions and derive thermo dynamical laws form microscopic description in ideal fluid systems.

Course Content:

Macroscopic description of the state, extensive and intensive variables, temperature, thermodynamic variables (pressure, temperature, etc.), thermal equilibrium, equation of state.

Thermal conductivity, zeroth law of thermodynamics**,** temperature scales; work, heat and internal energy, the Gibbs-Duhem relation.

Thermodynamic processes: reversible, irreversible, quasi-static, adiabatic, isothermal.

First law of thermodynamics**,** specific heat capacity, enthalpy, kinetic theory of gases and Maxwell-Boltzmann statistics; calculation of pressure, kinetic interpretation of temperature, mean free path, Maxwell's distribution, equi-partition of energy; heat engines.

The second law of thermodynamics, Carnot cycle and Kelvin temperature scale, Clausius' theorem, entropy and its physical interpretation, entropy change for simple processes.

Free energies: Helmholtz free energy, Gibbs free energy, Legendre transformations, conditions of equilibrium, Maxwell's relations, phases and phase transitions, equilibrium between two-phases, general equilibrium conditions, the Clausius-Clapeyron equation, phase transformation of substances, Van der Walls gas and the liquid gas transition, thermodynamics of magnetic systems, The third law of thermodynamics.

Microscopic versus macroscopic points of view, kinetic theory of gases, concept of ensembles, micro-canonical, canonical, grand-canonical ensembles, partition function, postulates of classical statistical mechanics, derivation of thermodynamics from statistical mechanics principles, equation of state for ideal and real gases, Gibbs paradox.

Text Books:

1. Callen, H. B., *Thermodynamics and Introduction to Thermostatistics,* 2nd edition, (Wiley Student Edition).
2. Reif, F., *Fundamentals of Statistical and Thermal Physics,* (Tata McGraw-Hill, 1985).
3. Zemansky, M. W. and Dittman, R. H., *Heat and Thermodynamics,* 7th edition, (Tata McGraw-Hill International, 2007).

PI 218: Modern Physics **(L2-T0-P1-CH4-CR3)**

Course Objective: The basic Course Objective of this course is to teach the students the various important topics of Modern Physics. They have to learn about the particle-like properties of electromagnetic radiation and wave-like properties of particles. They have to learn about one-dimensional time independent Schrödinger equation and it's solutions in simple problems. Moreover they are to learn different models of the atom and finally they should study about the expansion of universe and related topics.

Learning Outcome: The Learning Outcome of this course is that after finishing the course the students will be familiar with various important topics of Modern Physics. They will learn about the particle-like properties of e.m. radiation and wave-like properties of particles. They will learn about one-dimensional time independent Schrödinger equation and it's solutions in simple problems. Moreover they will be familiar with different models of the atom. Finally they are expected to learn about the expansion of universe and related topics.

Course content:

Particle-like properties of electromagnetic radiation: Electromagnetic spectrum, electromagnetic waves, blackbody radiation, the photoelectric effect, the Compton effect, Bremsstrahlung and X-ray production.

Wave-like properties of particles: deBroglie hypothesis, uncertainty relationships for classical waves, Heisenberg uncertainty relationships, wave packets.

One-dimensional time independent Schroedinger equation, probabilities and normalization, applications to the free particle, particle in a box (1-D and 2-D), the simple harmonic oscillator.

Models of the atom: Thompson model, Rutherford model, line spectra, Bohr model, Franck-Hertz experiment, the correspondence principle, deficiencies of Bohr atomic model, vector model, intrinsic spin, Stern-Gerlach experiment, hydrogen atom energy levels, Zeeman effect, fine structure, electronic states in many-electron atoms, X-rays.

Expansion of universe, background radiation, big bang cosmology, the future of the universe.

Text Books:

1. Krane, K. S., *Modern Physics*, (John Wiley & Sons, 1983).
2. Bernstein, J., Fishbane, P. M. and Gasiorowicz, S. G., *Modern Physics*, 1st edition, (Prentice-Hall, 2000).

PI 298: Physics Lab-IV **(L0-T0-P4-CH8-CR4)**

Course objective: This laboratory course is designed for the fourth semester students of Integrated M.Sc. in physics. This course contains the experiments related to optics, Laser, optical fibre, quantum mechanics thermodynamics, characterization of semiconductor material and devices, etc.

Learning outcome: After completion of this course students will be able to learn practically the experiments using laser, optical fibre etc.. In this course students will also learn how to use the optical bench. This course will motivate the students to develop small experiments related to these techniques and develop their physical understanding.

Course content:

1. To determine the resistivity of the given semiconductor sample by Four Probe method.
2. To determine the susceptibility of the given sample by Quince tube method.
3. To determine the Planck constant using different wavelength of light using Planck constant kit.
4. To study interference and diffraction with a laser beam at a single slit, double slit, three slits and four slits, and measure the slit separations.
5. To measure the spot size of a beam from a He-Ne laser and a diode laser and to calculate the M parameter.
6. To study the p-n junction characteristics and obtain output voltage at different frequencies.
7. To study connector losses in optical fibers:
    a. loss due to diameter mis-match,
    b. loss due to lateral off-set,
    c. loss due to angular misalignment
8. To measure the refractive index of a sample with a Michelson interferometer.
9. Determination of the focal length and hence the power of a convex lens by displacement method on an optical bench.
10. To find out the velocity of ultrasonic waves in a medium using ultrasonic interferometer.

Semester-V

PI 303: Physical and Geometrical Optics **(L2-T1-P0-CH3-CR3)**

Course Objective: This course targets to impart an overall understanding of fundamental concepts of geometrical and wave optics. Various defects of images and their reduction methods will be introduced. The course will provide in depth discussion of the wave properties of light, primarily interference, diffraction, polarization and discusses some common experimental tools used to measure such phenomena.

Learning Outcome: At the end of the course, students will be able to understand basic concepts and calculations of geometrical and physical optics. They will be able to apply the laws of reflection and refraction to plane and spherical surfaces and will be able to understand and recognize aberrations. Students are expected to understand wave propagation of light as well as to explain fringe patterns of various experiments and observations.

Course Content:

Basic Geometric Optics: law of reflection, reflection from planar and curved surfaces, Snell's law; refraction at the planar and curved surfaces, thin lens, prisms.

Matrix methods: matrix optics concepts and basic matrices, cascading matrices: thin lens, thick lens, principal planes and imaging, study of a compound lens.

Aberrations: monochromatic and chromatic aberrations, Seidel aberrations: spherical aberration, coma, astigmatism, field curvature and distortion, chromatic aberrations, examples.

Polarization: light as a transverse wave, linear and circular polarizations, methods of producing and analyzing polarized light, linear polarizers and wave plates, Fresnel reflection and transmission coefficients, total internal reflection, Jones vectors and matrices for the ploarizer and wave plate, Stokes vectors and Muller matrices.

Interference: division of wavefront and amplitude, intensity distribution in an interference pattern, visibility of fringes, Young's double-slit interferometer, Michelson interferometer, Rayleigh interferometer, multiple beam interference: Fabry-Perot etalon and interferometer, resolving power.

Diffraction: Fresnel-Huygens theory of diffraction, Fresnel and Fraunhofer regions of diffraction, diffraction at a straight edge, Fraunhofer diffraction at the slit, circular and rectangular apertures, resolving power of a telescope, diffraction at multiple slits, grating, resolving power of a grating.

Holography: recording and reconstruction of a wave, characteristics of the diffracted waves from the hologram, diffraction efficiency, types of the holograms, zone plate analogy of the hologram.

Fourier Optics: simple concepts.

Text Books:

1. Subrahmanyam, N., Lal, B. and Avadhanulu, M. N., *A Textbook of Optics*, (S. Chand & Co. Ltd., 2012).
2. Mathur, B. K. and Pandya, T. P., *Principles of Optics*, (Tata McGraw-Hill International, 1981).

3. Chakraborty, P. K., *Geometrical and Physical Optics*, 3rd edition, (New Central Book Agency(P) Ltd., 2005).

Reference Books:

1. Hecht, E., *Optics*, 4th Edition, (Addison-Wesley Pub. Co., 2001).
2. Born, M. and Wolf, E., *Principles of Optics*, 7th edition, (Pergamon Press Ltd, 2000).
3. Jenkins, F. A. and White, H. E., *Fundamentals of Optics*, 4th edition, (Tata McGraw-Hill International, 1981).
4. Sirohi, R. S., *Wave Optics and Applications*, (Orient Longman, 1993).

PI 202: Introductory Quantum Mechanics (L2-T1-P0-CH4-CR3)

Course Objective: The basic Course Objective of this course is to teach the students the various introductory topics of Quantum Mechanics. They have to learn about the origin of quantum theory and inadequacy of classical ideas. They are to learn about wave-particle duality and de Broglie's hypothesis with related experiments. Students have to learn about uncertainty relation, wave function and its probabilistic interpretation. Finally they have to learn about Schrodinger equation and it’s solutions in various simple situations.

Learning Outcome: The Learning Outcome of this course is that after finishing the course the students will be familiar with the various introductory topics of Quantum Mechanics. They are expected to learn about the origin of quantum theory and inadequacy of classical ideas. They will learn about wave-particle duality and de Broglie's hypothesis with related experiments. Students are expected to learn about uncertainty relation, wave function and its probabilistic interpretation. Finally they will learn about Schrodinger equation and it's solutions in various simple situations.

Course Content:

Origin of quantum theory, inadequacy of classical ideas, Planck's quantum hypothesis, photoelectric effect, Compton scattering.

Wave-particle duality, deBroglie's hypothesis, experimental evidence for deBroglie's hypothesis, Davisson-Germer experiment, Thompson experiment.

Simple consequences of uncertainty relation, wave function and its probabilistic interpretation, wave packet and uncertainty relation.

Schrodinger equation, solution of one-dimensional Schrodinger equation for an infinite square well potential, reflection and transmission at potential steps, qualitative treatment of barrier penetration for simple rectangular barriers.

The quantum harmonic oscillator.

Text Books:

1. Schiff, L. I., *Quantum Mechanics*, 3rd edition, (McGraw-Hill, New Delhi, 1968).
2. Ghatak, A. and Lokanathan, S., *Quantum Mechanics*, 5th edition, (Macmillan, 2004).

Reference Books:

1. Merzbacher, E., *Quantum Mechanics*, 2nd edition, (John Wiley, New York, 2005).
2. Richtmyer, F. K., Kennard E. H. and Lauritsen, T., *Introduction to Modern Physics*, 5th edition, (McGraw-Hill, 1976).
3. Waghmare, Y. R., *Fundamentals of Quantum Mechanics*, 1st edition, (Wheeler publishing, 1996).

4. Mathews, P. M. and Venkatesan, K., *A Textbook of Quantum Mechanics*, 2nd edition, (Tata McGraw-Hill, 1976).

PI 315: Mathematical Physics-II **(L2-T1-P0-CH3-CR3)**

Course Objectives: The main objective of the course is to introduce the uses of differential equations, special functions and integral transforms to study various physical problems in different branches of physics like Quantum Mechanics, Atomic and molecular physics, electrodynamics etc..

Learning outcome: Upon completion of the course, the students should be able to solve the ordinary and partial differential equations, differential equations with special functions and their uses in physics. Students will also learn the use of integral transforms in physical problems.

Course Content:

Ordinary differential equations, second-order homogeneous and inhomogeneous equations, Wronskian, general solutions, adjoint of a differential equation, ordinary and singular points, series solution, Legendre, Hermite, Laguerre and the associated polynomials, their differential equations, generating functions, Bessel functions, spherical Bessel equations, integral representation of special functions.

Generating functions, Recurrence relations, Rodrigue's formulae and orthogonality of the special functions, Sturm Liouville problem, elements of hyper-geometric functions, Gauss hyper-geometric and confluent hyper-geometric equations, Dirac delta function, Green function.

Partial differential equations in physical problems: Laplace's equation, Poisson's equation, Heat flow equations, Wave equations, Helmholtz equations, solutions of these equations, eigenvalue problems, boundary value problems, method of separation of variables.

Integral transforms: Laplace transform, Hankel transform, Mellin transform, Fourier transform.

Properties of Laplace and Fourier transforms, application of Laplace and Fourier transforms.

Text Books:

1. Harper, C., *Introduction to Mathematical Physics, (*Prentice Hall, 2009).
2. Arfken, G. B., and Weber, H. J., *Mathematical Methods for Physicists*, (Elsevier Ltd, Oxford, 2005).
3. Spiegel, M. R., *Vector Analysis*, Schaum's outline series, (Tata McGraw-Hill 1979).

Reference Book:

1. Morganeau, H. and Purphy, C. M., *The Mathematics of Physics and Chemistry,* (Young Press, 2009).

PI 309: Analog Electronics & Communications **(L2-T1-P0-CH3-CR3)**

Course Objectives: This course is designed to aquatint the realm of pure and applied part of analog electronics and communication systems. It has the objective to enable the students to understand and impart the basic idea and operating principle of analog as well communication gadgets; thereby inculcating their pursuit for real field implementation.

Learning Outcomes: After the completion of this course, a student should have acquired the knowledge with facts and figures related to this field for better understanding in higher versions of electronic and communication devices.

Course content :

Op-Amp with and without feedback: Open loop considerations-inverting, non-inverting, differential, feedback-voltage follower, Practical op-amps: Offset considerations-input offset voltage, input bias current, input offset current, thermal drift, effect of power supply voltage, other temperature sensitive parameters, noise, CMRR, maximum common mode input voltages, op-amp instrumentation circuits.

Linear Applications: Op-amp as ac amplifiers, summing and averaging circuits, integrators, differentiators, voltage-current converter, current-to voltage converter, analog computers, voltage regulators.

Introduction to communication systems: Elements of a Communication System, terminologies in Communication systems, basics of signal representation and analysis. Noise: external, internal, noise calculations, noise figure. Amplitude modulation techniques: Theory and generation of AM, DSBSC, SSB, VSB.

Angle modulation techniques: theory, practical issues and generation of Frequency Modulation (FM) and Phase.

Radio transmitters and receivers: Introduction to – AM, SSB, FM Transmitters. Receiver Types: tuned radio-frequency (TRF) and superheterodyne receiver, AM and FM Receivers.

Radiation and propagation of waves -Electromagnetic Radiation, Effects of the Environment, Propagation of Waves - Ground (Surface) Waves, Sky Waves and Space Waves.

Text Books:

1. Gayakward, R.A., *Op-Amps and Linear Integrated Circuits*, 3rd Edition, (PHI, 2001).
2. Kennedy, G., Bernard D. and Prasanna, S. R. M., *Electronic Communication Systems*, (McGraw-Hill Global Education India, 5th edition, 2011).

Reference Books:

1. Hambley, A. R., *Electronics*, 2nd Edition, (Prentice Hall, 2000).
2. Horowitz, P. and Hill, W. *The Art of Electronics*, 2nd Edition, (Cambridge University Press, 1995).

PI 204: Atomic and Nuclear Physics **(L2-T1-P0-CH3-CR3)**

Course objective: The main objective of this course is to introduce the fundamental ideas of atomic and nuclear physics which includes property of nuclei, radioactivity, nuclear reactions, nuclear radiation detection processes and fundamental of atomic physics.

Learning outcome: After completion of this course students will be familiar with the fundamentals of atomic and nuclear physics. After this course students will be able to take advanced course on atomic and molecular physics and Nuclear and particle physics.

Course content:

Atomic Physics: The Bohr model of the hydrogen-like atom, brief account of the Sommerfeld model, electron spin; Stern-Gerlach experiment, space and spin quantization, the vector model of the atom, spin-orbit interaction, fine structure of spectral lines, LS and jj coupling, the Zeeman effect, Paschen-Back effect, Stark effect, scattering of light: Rayleigh scattering formula, colour of the sky, polarisation of the scattered light.

Nuclear Physics: General properties of nuclei, concept of nuclear size, spin, parity, magnetic dipole moment and electric quadropole moment of nuclei, nuclear forces and stability of nuclei, concept of packing fraction and binding energy, binding energy curve and its significance.

Natural radioactivity and radioactive decay: Type of radioactive decays, theory of radioactive disintegration, radioactive constants, mean-life of a radio element, radioactive equilibrium, half-life of a radio element, determination of decay constant and half-life.

Nuclear reactions: Types of nuclear reactions, conserved quantities of nuclear reaction, energies of nuclear reaction, Q-value, exoergic & endoergic reactions, nuclear fusion and fission reactions.

Detectors: Principles of detection of charge particles, construction and working principle of gas-filled detectors, ionization chamber, its construction and working principle, interaction of γ-particle with matter, construction and working principles of a scintillating detector.

<u>Text Books:</u>

1. Krane, K. S., *Introductory Nuclear Physics*, (John Wiley, New York, 1987).
2. White, W. H., *Introduction to Atomic Spectra*, (McGraw-Hill, 1934).

<u>Reference Books:</u>

1. Green, A. E. S., *Nuclear Physics*, (McGraw-Hill Book Company, Inc., New York, 1955).
2. Srivastava, B.N., *Basic Nuclear Physics and Cosmic Rays,* (Pragati Prakashan, Meerut, 2011).

PI 308: Laser Physics **(L2-T1-P0-CH3-CR3)**

<u>Course objective:</u> The laser physics paper has been designed by keeping following objectives in mind

- Fundamental of lasing actions starting from Einstein's rate equations will be discussed thoroughly
- Physics of three and four level laser systems that are vital to learn the working of various laser systems will be discussed elaborately
- Various techniques that are used to increase the output power from laser systems are included
- The course further incorporates different important applications of lasers in various fields

<u>Learning outcome:</u>

Students taking the course on Laser physics is expected to learn the physics behind lasing actions from all kinds of lasers. Furthermore, he/she understands various parameters that will determine the nature of light (in terms of its coherence property, output power and wavelength) emitting from a laser system. Besides, the students learn important applications of laser in various fields starting from material science to biological science.

<u>Course content:</u>

Planck's Law, Absorption, spontaneous emission and stimulated emission, Einstein's A & B coefficients, two-level atomic systems, light amplification, threshold condition.

Line broadening mechanism, pumping methods and laser rate equations, variation of laser power around threshold, optimum output coupling.

Modes of a rectangular cavity and open planar resonator, the quality factor (Q-factor), the ultimate bandwidth of laser, mode selection, Q-switching, mode locking, modes of a confocal resonator, general spherical resonator.

Properties of laser beam; propagation of Gaussian beam and ABCD matrix.

Some laser systems like He-Ne laser, ruby laser, neodymium-based lasers, CO_2 laser, dye laser, fiber laser, semiconductor laser, DFB lasers, DH lasers.

Generation of ultra-fast optical pulses, pulse compression, femto-second laser and its characteristics.

Some applications of lasers like laser cooling, laser tweezers, material processing.

Text Books:

1. Ghatak, A. K. and Thyagarajan, K., *Optical Electronics*, (Cambridge University Press, 2009).
2. Svelto, O., *Principles of Lasers*, 3rd edition, (Springer, 2007).
3. Milonni, P. W. and Eberly, J. H., *Laser Physics*, (John Wiley & Sons, 2010).

Reference Books:

1. Yariv, A., *Quantum Electronics*, 3rd edition, (Wiley Eastern Ltd.).
2. Davis, J. H., *Introduction to Low Dimension Physics*, (Cambridge University Press, 1997).
3. Siegman, A. E., *Lasers*, (University Science Books, 1986).

PI 399: Physics Lab-V (L0-T0-P4-CH8-CR4)

Course objective: This course is designed for Integrated M.Sc. fifth semester students**.** The main objective of this course is to provide experimental as well as theoretical understanding of different physical phenomenon related to changing of temperature and electromagnetic properties of matter, development of different circuit using IC, different optical phenomena, atomic spectra etc.

Learning outcome: Learning outcome: After completion of this course students will be able to understand the theory related to the experiment and their application in their future course of time. This course will also motivate the students to develop small experiments related to these techniques and develop their physical understanding.

Course content:

1. To find out the magneto-resistance of the semiconductor sample as a function of magnetic field and to plot the graph between magnetic field vs. potential developed using magneto-resistance set-up.
2. To plot the gain – bandwidth relation for a negative feedback amplifier using IC 741.
3. To find out the Curie temperature of the given ferromagnetic material ($BaTiO_3$) using Curie temperature kit.
4. To study Malus' law of polarization.
5. To measure optical nonlinearity using z-scan method.
6. To find out the value of Boltzmann constant using Boltzmann Constant kit.
7. To find out the Rydberg constant by observing the Balmer series of Hydrogen using spectrophotometer.
8. To study diffraction at a circular aperture and find the resolving power of a given lens used as an objective of a telescope.
9. a. Develop a clipping and a clamping circuit and determine the output voltage with different DC bias voltage applied.

b. Design and develop a full wave and a half wave rectifier circuits and find out the ripple factor of the circuits.

10. To study the temperature dependence of Hall coefficient of a semiconductor sample using Hall effect set-up.

Semester-VI

PI 307: Basic Material Science **(L2-T1-P0-CH3-CR3)**

Course objective: Provides an overview of Materials Science as a basis for understanding how structure/property/processing relationships are developed and used for different types of materials. Gives the beginning student an appreciation of recent developments in materials science within the framework of this course.

Learning outcome: Be able to qualitatively describe the bonding scheme and its general physical properties, as well as possible applications. Be able to qualitatively derive a material's elastic property. Be able to do simple crystallography and diffusion problems.

Course content:

Fundamentals of crystallography: Bravais lattice, unit cell, crystal systems, Miller indices of crystal planes and directions, point groups.

Typical crystal structures: Simple (sc) cubic, body centered (bcc) cubic and face centered (fcc), cubic and structures, Hexagonal closed packed (hcp), Diamond and Zinc blende (ZnS) closed packed structures, packing factors, NaCl, CsCl and cubic perovskite and wurtzite structures.

Structure of solids: linear and planar density, ligancy, packing efficiency, closed pack planes and directions, voids.

Crystal imperfections*:* point imperfections (vacancies and interstitials), Frenkel and Schottky defects, dislocations, grain boundary, grain growth and surface energy calculation.

Crystal binding: Primary and secondary bondings, bond length and bond energy, van der Waals bonding, inert gas crystals, ionic, covalent and metallic bondings, Madelung constant, Madelung energy.

Phase and phase transformation: Melting point of crystalline and amorphous solids, degrees of freedom, phase rule, binary alloys, nucleation and phase transformation.

Elastic properties, Young, bulk and rigidity moduli, yield stress, Poisson's ratio, compressibility, creep and fatigue, plasticity.

Diffusion*:* Fick's first and second laws, thermal diffusion.

Text Books:

1. Callister, W. D., *Materials Science and Engineering*, 5th edition (John Wiley, 2000).
2. Raghavan, V., *Materials Science and Engineering*, 4th edition (Prentice Hall India, 1991).
3. Kittel, C., *Introduction to Solid State physics,* 7th edition, (Wiley Eastern Ltd.,1996).
4. Burns, G., *Solid State Physics*, (Academic press, 1995).
5. Dekker, A. J., *Solid State Physics,* (Macmillan India Ltd., 2003).
6. Ashcroft, N. W. and Mermin, N. D., Solid State Physics, (Saunders, 1976).

Reference Books:

1. Smith, W. F., *Principles and Materials Science and Engineering*, 2nd edition (Tata McGraw-Hill Inc., 1990).

2. Patterson, J. D. and Bernard, B., *Introduction to the Theory of Solid State Physics*, 2nd edition, (Springer, 2007).
3. Ghatak, A. K. and Kothari, L.S., *Introduction to Lattice Dynamics*, (Addison-Wesley, 1972).
4. Hall, H. E. and Hook J. R., *Solid State Physics*, 2nd edition, (Wiley, 1991).
5. Azaroff, L. V., *Introduction to Solids*, (Tata McGraw-Hill, 1977).
6. Mathur, D. S., Properties of Matter, (S. Chand & Co., 2010).

PI 317: Basic Computation Techniques **(L2-T1-P0-CH3-CR3)**

Course Objective: To develop computer programming skills in C language and finally to train the students in devekoping algorithms for solving elementary physics problems.

Learning outcome: Become skilled in C language programming and develop algorithms and programs to tackle physics problems.

Course content:

Introduction to computers.

Programming using FORTRAN; programming using C and C^{++}

Simple programming examples from calculus; solution of simple algebraic equations, solution of simple differential equations.

Examples of least squares curve fitting, matrix eigenvalue problems.

Text Books:

1. Gottfried, B. S., *Schaum's outline of theory and problems of programming with C*, (McGraw-Hill Professional, 1996).
2. Kanetkar, Y., *Let us C,* (BPB *Publications,* 2012).
3. Mayo, W. E. and Cwiakala, M., *Schaum's Outline of Programming With Fortran 77*, Schaum's Outline series, (McGraw-Hill, 1995).
4. Scheid, F., *Schaum's outline of theory and problems of numerical analysis*, 2nd edition, Schaum's outline series, (McGraw-Hill, 1989).

Reference Books:

1. Mathews, J. H., *Numerical Methods for Mathematics, Science and Engineering*, (Prentice Hall).
2. Narsingh Deo, *System Simulation with Digital Computers*, (Prentice Hall, 1979).

PI 314: Measurement Physics **(L2-T1-P0-CH3-CR3)**

Course objective: Measurement Physics is an important component of Physics curriculum. The course has been designed with the following objectives

- Topics that are required to interpret and analyze data in different domains of physics spanning from experimental to theoretical fields.
- Production of low temperature and the different techniques to measure it.
- Different instrumentation in electronics and the techniques to improve signal quality.

Learning outcome:

Students taking the aforesaid course will learn how to interpret data (both theoretical and experimental) and subsequently learn how the important parameters can be derived from a given set of results. The course discusses different techniques involve towards production of low temperature and the ways to measure it. Similarly, different transducers and detectors that are used in various fields will immensely help the students to understand the operational principle of these components while using them for experimental investigations. Students further learn the physics of different electronic instrumentations and the ways to improve the signal quality from any electronic circuit.

Course Content:

Data interpretation and analysis, precision and accuracy, error analysis, propagation of errors, least squares fitting, linear and nonlinear curve fitting, chi-square test, Measurement of energy and time using electronic signals from the detectors and associated instrumentation, signal processing; multi-channel analyser, Time of flight technique, coincidence measurements, true-to-chance ratio.

Transducers (temperature, pressure/vacuum, magnetic field, vibration, optical), measurement and control, ionization chamber, proportional counter, GM counters, spark chambers, cloud chamber, semiconductor detectors for charged particles and γ-ray detectors, scintillation counters, photodiodes and charge coupled device (CCD) and CMoS cameras for detection of electromagnetic radiation.

Production of low temperature below 1K, adiabatic demagnetisation and magnetic refrigerator, special properties of liquid helium, temperature below 10^{-6}K, nuclear demagnetisation, measurement of low temperatures.

Op-amp based, instrumentation amp, feedback, filtering and noise reduction, shielding and grounding, Fourier transforms, lock-in detector, box-car integrator, modulation techniques.

Text Books:

1. Sayer, M. and Mansingh, A., *Measurement, Instrumentation and Experiment Design in Physics and Engineering*, (Prentice-Hall India, 2000).
2. Nakra, B. C. and Chaudhry, K. K., *Instrumentation Measurement and Analysis* (Tata McGraw-Hill, 1985).

Reference Books:

1. Knoll, G. F., *Radiation, Detection and Measurement*, 3rd edition, (John Wiley & Sons, 2000).
2. Jones, B. E., *Instrumentation measurement and feedback* (Tata McGraw-Hill, 1978).

PI 311: Waves and Acoustics **(L2-T1-P0-CH3-CR3)**

Course Objectives: The paper ***waves and acoustics*** has been designed to disseminate followings to the students

- To understand the physics behind different types of harmonic waves. Fourier analysis of different harmonics waves is also discussed in the paper.
- Different types of waves such as transverse and longitudinal waves and their propagation in medium are discussed thoroughly.
- Important phenomenon of acoustic waves including superposition, interference, beats, Doppler effect are also discussed in this paper.

- To learn quality of acoustic waves, its applications in various fields and how sound waves are recorded and reproduced.

Learning outcome: Students taking this course will acquire the knowledge on the physical treatment of different harmonic waves. He/she should be able to analyze any harmonic waves mathematically. Also, students learn various important phenomena of acoustic waves and their applications in diverse fields of research.

Course content:

Vibrations: Potential energy vs. displacement relation, concept of equilibrium, development of simple harmonic oscillation (SHO) and other anharmonic terms from force equations, damped oscillation, critical damping, Q-factor of an oscillator, forced vibration, resonance, low and high frequency responses, eigen frequency and normal modes, energy transfers between modes, coupled pendulum, Lissajous figures, anharmonic oscillator, Fourier series and Fourier coefficients, Fourier analysis in some simple cases.

Waves: Progressive wave in one-dimension and in three-dimensions, wave equation, plane wave and spherical wave, intensity, dispersion, group velocity, phase velocity, speed of transverse waves in a uniform string, eigen frequencies and eigen modes for plucked and struck strings, speed of longitudinal waves in a field, energy density and intensity of waves.

Superposition of waves: Superposition principle, interference in space and energy distribution, beats, combinational tones, production, detection and applications of ultrasonic waves, Doppler effect, shock waves.

Acoustics: Vibrations in bounded system, normal modes of a bounded system, harmonics, quality of sound, noise and music, intensity and loudness, bel and phon, principle of sonar system, acoustic transducers and their characteristics, recording and reproduction of sound, measurement of velocity, frequency and intensity, acoustics of halls, reverberation and Sabines formula.

Text Books:

1. Chattopadhyay, D., *Vibration, Waves and Acoustics*, (New Central Book Agency, 2010).
2. Main, I. G., *Vibrations and Waves in Physics*, 2nd edition (Cambridge University Press, 1984).

Reference Books:

1. Randall, R. H., *An Introduction to Acoustics*, Sect. 7-21, 7-22, (Addison-Wesley, 1951).
2. Wood, A. B., *A Textbook of Sound*, 3rd Edition, (Bell & Sons, 1955).
3. Crawford, F. S., *Waves*, *Berkeley Physics Course*, Vol. 3, (Tata McGraw-Hill, 1968).
4. Pain, H. I., *The Physics of Vibrations and Waves*, 6th edition (John Wiley & Sons Ltd., 2005).

PI 300: Project cum Physics Lab-VI **(L0-T0-P4-CH8-CR4)**

Course objective: Main objective of this course is to motivate the students towards research related to both experiments and theory.

Learning outcome: After completion of this course students will be able to design and carry out scientific experiments. Students will be able to learn how to report their results in the form of a report.

List of elective papers:

1. PI 220: Renewable Energy
2. PI 221: Nanomaterial Fundamentals and application
3. PI 222: Earth Science

PI 220: Renewable Energy **(L2-T1-P0-CH3-CR3)**

Course Objectives: The main objective of the course is to illustrate the importance of renewable energy sources and make the students understand the concepts of various energy generation and storage systems.

Learning outcome: It is expected that after successfully completing the course, the student will have a good understanding of various small and large scale renewable energy sources. They will also learn to harness electricity utilizing these renewable energy sources.

Course content:

Fossil fuels and Alternate Sources of energy: Fossil fuels and nuclear energy, their limitation, need of renewable energy, non-conventional energy sources. An overview of developments in Offshore Wind Energy, Tidal Energy, Wave energy systems, Ocean Thermal Energy Conversion, solar energy, biomass, biochemical conversion, biogas generation, geothermal energy tidal energy, Hydroelectricity.
Solar energy: Solar energy, its importance, storage of solar energy, solar pond, non-convective solar pond, applications of solar pond and solar energy, solar water heater, flat plate collector, solar distillation, solar cooker, solar green houses, solar cell, absorption air conditioning. Need and characteristics of photovoltaic (PV) systems, PV models and equivalent circuits, and sun tracking systems.
Wind Energy harvesting: Fundamentals of Wind energy, Wind Turbines and different electrical machines in wind turbines, Power electronic interfaces, and grid interconnection topologies. Ocean Energy: Ocean Energy Potential against Wind and Solar, Wave Characteristics and Statistics, Wave Energy Devices.
Electromagnetic and Piezoelectric Energy Harvesting, Energy storage and conversion devices: fuel cells, batteries, supercapacitors.
Environmental issues and Renewable sources of energy, sustainability.

Text Books:

1. H. P. Garg and Jai Praksh, *Solar Energy Fundamentals and Applications*, TMH, 2000.
2. J. Twidell and T. Weir, *Renewable Energy Resources*, E & F N Spon, 1986.
3. G. Boyle, (Ed.), *Renewable Energy, Power for a Sustainable Future*, The Open University/Oxford University Press, 1996.
4. R. O. Hayre, S. W. Cha, W. Colella and F. B. Prinz, *Fuel Cell Fundamentals*, Wiley, 2008.
5. B. E. Logan, *Microbial Fuel Cells*, Wiley, 2007.
6. G.D Rai, *Non-conventional energy sources*, Khanna Publishers, New Delhi, 2011.
7. M P Agarwal, *Solar energy*, S Chand and Co. Ltd., 1983.
8. Suhas P Sukhative, *Solar energy: principles of thermal collection and storage*, Tata McGraw - Hill Publishing Company Ltd, 3rd Ed. 2008.

Reference Books:

1. A. Luque and S. Hegedus (Eds.), *Hand book of Photovoltaic Science and Engineering*, 2nd Edn., John Wiley, 2011.
2. P Jayakumar, *Solar Energy: Resource Assessment Handbook*, *2009.*
3. P. Takahashi and A. Trenka, *Ocean Thermal Energy Conversion*, John Wiley, 1994.
4. C. Y. Wereko-Brobby and E. B. Hagan, *Biomass Conversion and Technology*, John Wiley, 1997.
5. J. F. Walker and N. Jenkins, *Wind Energy Technology*, John Wiley and Sons, 1997.
6. D. D. Hall and R. P. Grover, *Biomass Regenerable Energy*, John Wiley, 1987.
7. T. Jiandong, Z. Naibo, W. Xianhaun, H. Jing, and D. Huishen, *Mini Hydropower*, John Wiley, 1996.

PI 221: Nanomaterial Fundamentals and Applications (L2-T1-P0-CH3-CR3)

Course Objectives: The main objective of the course is to introduce the basic concepts on nanostructures and the quantum mechanical analysis of such structures. In addition, processing and characterization techniques will also be taught.

Learning outcome: It is expected that after successfully completing the course, the student will understand the physics behind the exciting properties of nanostructures. They will also learn the techniques to use nanostructures in various devices.

Course content:

Nanoscale systems: Length scales, 1D, 2D and 3D nanostructures (nanodots, nanowires, nanorods, thin films,), Band structure and density of states of materials at nanoscale, Size effects in nano systems, Quantum confinement: Applications of Schrodinger equation- Infinite potential well, potential step, potential box, quantum confinement of carriers in 3D, 2D, 1D nanostructures and its consequences.
Synthesis of nanostructured materials: Top down and Bottom up approach, Photolithography. Ball milling. Gas phase condensation. Vacuum deposition. Physical vapor deposition (PVD): Thermal evaporation, E-beam evaporation, Pulsed Laser deposition. Chemical vapor deposition (CVD). Sol-Gel. Electro deposition. Spray pyrolysis. Hydrothermal synthesis. Preparation through colloidal methods. MBE growth of quantum dots.

Characterization: X-Ray Diffraction, Optical Microscopy, Scanning Electron Microscopy, Transmission Electron Microscopy, Atomic Force Microscopy, Scanning Tunnelling Microscopy.
Properties of nanomaterials: Dielectric constant for nanostructures. Excitons in direct and indirect band gap semiconductor nanocrystals, absorption, emission and luminescence. Optical properties of heterostrctures and nanostructures. Electron transport in nanostrcutures, thermionic emission, tunneling and hoping conductivity. Defects and impurities: Deep level and surface defects. Mechanical and thermal properties of nanomaterials.

Applications: Applications of nanoparticles, quantum dots, nanowires and thin films for photonic devices (LED, solar cells). Single electron devices. CNT based transistors. Micro Electromechanical Systems (MEMS), Nano Electromechanical Systems (NEMS).

Text Books:

1. C.P. Poole, Jr. Frank J. Owens, *Introduction to Nanotechnology* (Wiley-Interscience, May 2003).
2. S.K. Kulkarni, *Nanotechnology: Principles & Practices* (Capital Publishing Company, 2007).

3. K.K. Chattopadhyay and A. N. Banerjee, *Introduction to Nanoscience and Technology* (PHI Learning Private Limited, 2009).
4. Richard D. Booker, Earl Boysen, *Nanotechnology* (John Wiley and Sons, 2005).

Reference Books:

1. M. Hosokawa, K. Nogi, M. Naita, T. Yokoyama, *Nanoparticle Technology Handbook* (Elsevier, 2007).
2. Bharat Bhushan, *Handbook of Nanotechnology* (Springer-Verlag, Berlin, 2004).
3. Cao Guozhong and Wang Ying, *Nanostructures and Nanomaterials –Sysnthesis, Properties and Applications*, World Scientific Publishing, 2nd edition, 2011.
4. Dieter Vollath, *Nanomaterials: An Introduction to Synthesis, Properties and Applications*, Wiley, 2008.
5. *Nanoscale Materials in Chemistry*, edited by Kenneth J. Klabunde & Ryan Richards, John Wiley & Sons, 2nd edition, 2009.
6. *Nanomaterials: Synthesis, properties and Applications*, Ed. A. S. Edelstein and R.C.Cammarata, IOP (UK, 1996). Characterization of nanophase materials: Ed. Z.L.Wang, Willey-VCH (New York, 2002).
7. *Naostructured Materials*, Ed. Jackie Yi-Ru Ying (Academic Press, Dec 2001).
8. *Nanotechnology: Basic Science and emerging technologies*, Ed. Michael Wilson, K.Kannangara, G. Smith, M. Simmons, and C. Crane (CRC Press, June 2002).

PI 222: Earth Science **(L2-T1-P0-CH3-CR3)**

Course Objectives: This course is designed so as to familiarize the realm of inner earth structure with a bit touch on earthquake dynamics. It has the objective to enable the students to understand and impart the basic idea of earth processes and their evolution dynamics; thereby inculcating their spirit for hazard mitigation.

Learning Outcomes: After the completion of this course, a student should have acquired the fundamental knowledge with adequate facts and illustrations and thereby gathered the requisite expertise in mitigating hazard.

Course content:

Structure: The Solid Earth: Mass, dimensions, shape and topography, internal structure, Magnetic field, Gravity field, Thermal structure and Heat Flow. Earth's Interior.
The Hydrosphere: The oceans, their extent, depth, volume, chemical composition. River systems.
The Atmosphere: variation of temperature, density and composition with altitude, clouds.
The Cryosphere: Polar caps and ice sheets. Mountain glaciers.

Dynamical Processes: Concept of plate tectonics, sea-floor spreading and continental drift. Earthquake and earthquake belts, Seismic waves, Volcanoes and Tsunamis.
The Atmosphere: Atmospheric circulation. Weather and climatic changes and. Cyclones.
I Climate: Earth's temperature and greenhouse effect, The Indian monsoon system.

Geophysical Exploration: Basic principles of Gravity, Magnetic, Electrical and Seismic Explorations.

Reference Books:

1. *Planetary Surface Processes*, H. Jay Melosh, Cambridge University Press, 2011.

2. *Consider a Spherical Cow: A course in environmental problem solving*, John Harte.University Science Books.
3. *Holme's Principles of Physical Geology*. 1992. Chapman & Hall.
4. Emiliani, C, 1992. Planet Earth, Cosmology, *Geology and the Evolution of Life and Environment*. Cambridge University Press.

Semester-VII

PI 403: Electromagnetic Theory-I **(L2-T1-P0-CH3-CR3)**

Course Objectives:

(a) It offers a precious scope of learning and enjoying the basics of electrostatics, electrodynamics and magnetism methodologically in both the non-relativistic and relativistic regimes.

(b) It opens inner stimulations to students to look creatively at the physical world from electromagnetic and wave communicative perspectives.

(c) It develops a broad mind setup to understand and solve all sorts of applied problems driven by electricity, magnetism, and so forth.

Learning outcomes:

(a) A full completion of the course is expected to build up strong creativity, analytical capability and innovativeness in the students.

(b) It enables potentiality improvement via diversified exercises of mathematical physics, vector operation, and electromagnetism.

(c) It shows the physical universe from a new perspective of electromagnetic origin eventually after judging the applicability of the various model theories competently.

Course Content:

Review of Electrostatics and magneto-statics: Electrostatic and magnetostatic fields in matter, Method of images, boundary value problems, Laplace equation in rectangular, cylindrical and spherical coordinates, multipole expansion, Gauge transformation, Coulomb and Lorentz gauges, Maxwell's equations, conservation of energy and momentum in electrodynamics, Poynting Theorem, Maxwell's stress tensor.

Wave equation, reflection, refraction and propagation of electromagnetic waves in dispersive media, wave equation in a conducting medium.

Wave-guides and cavity resonance, EM wave propagation of various types of EM modes in different types of wave guides.

Text Books:

1. Griffiths, D. J., *Introduction to Electrodynamics*, (Prentice Hall India, 2009).
2. Jackson, J. D., *Classical Electrodynamics*, 3rd edition, (Wiley, Eastern Ltd, 1998).

Reference Books:

1. Ritz, J. R. and Millford, F. J., *Foundations of Electromagnetic Theory*, (Prentice Hall India).
2. Slater, J. C., and Frank, N. H., *Electromagnetism*, (Dover Publications, 2011).
3. Miah, W., *Fundamentals of Electromagnetism*, (Tata McGraw-Hill, 1982).
4. Feynman, R. P., *Feynman Lecture Series Volume II*, (Addison Wesley Longman, 1970).

PI 413: Advanced Classical Mechanics (L2-T1-P0-CH3-CR3)

Course Objective:

The course aims to develop the ability of students to apply basic methods of classical mechanics towards solutions of various problems, including motion of oscillatory systems and that of rigid bodies. They will be familiarised with various methods of classical mechanics and will learn how to apply them to formulate equations of motion.

Learning Outcome:

After completion of the course, students will be able to use the calculus of variations to solve real physical problems. They will be able to describe and understand the motion of mechanical systems using Lagrange and Hamilton formalism. Students will understand Poisson brackets, canonical transformations and will be able to solve small oscillation problems.

Course Content:

Variational Principles: Derivation of Euler-Lagrange differential equation, Hamilton’s principle and its deduction, derivation of Lagrange’s equation from Hamilton’s principle, modified Hamilton’s equation (vibrational principle) and derivation of Hamilton’s principle from it, principle of least action, method of Lagrange’s undetermined multipliers.

Two-body Central Force Problems: Reduction of two-body problems to equivalent one body problem, equation of motion under central force, equation for an orbit, inverse square law of force, Kepler's laws of planetary motion and their deduction, Virial theorem, scattering in a central force field and Rutherford scattering.

Canonical Transformations and Brackets: Canonical and Legendre transformations, generating function, procedure for application of canonical transformation, condition for canonical transformation, bilinear invariant condition, integral invariant of Poincaré, Poisson brackets and Lagrange’s brackets and their properties, relation between Poisson and Lagrange’s brackets, application of Poisson bracket to mechanics, Liouville’s theorem.

Hamilton-Jacobi Theory: Hamilton-Jacobi (HJ) equation, Hamilton’s characteristic and principal function, HJ equation for Hamilton’s characteristic function, solution of Kepler's problem by HJ method, action-angle variable and harmonic oscillator problem, separation of variables in HJ equation, transition from classical to quantum mechanics.

Mechanics of a Rigid Body: Generalised co-ordinates of a rigid body, body and space reference system, Eulerian angles, orthogonal transformations, infinitesimal rotations, kinematics of a rigid body, moving frame of reference, Euler equation, spinning top, gyroscope.

Small Oscillations: One dimensional oscillator; stable, unstable and neutral equilibriums, Normal co-ordinates and normal modes, Two coupled pendulum, double pendulum, vibration of a linear triatomic molecule, general case- system with 'n' degrees of freedom.

Text Books:

1. Upadhyaya, J. C., *Classical Mechanics*, (Himalayan Publishing House).
2. Goldstein, H., *Classical Mechanics*, (Narosa Publishing House).

Reference Books:

1. Takawale, R. G. and Puranik, P. S., *Introduction to Classical Mechanics*, (Tata McGraw Hill).
2. Rana, N. C. and Joag, P. S., *Classical Mechanics*, (Tata McGraw Hill).
3. Panat, P. V., *Classical Mechanics*, (Narosa Publishing House).
4. Gupta, S. L., Kumar, V. and Sarma, H. V., *Classical Mechanics*, (Pragati Prakashan).

PI 414: Quantum Mechanics -I **(L2-T1-P0-CH3-CR3)**

Course Objective: This course is a post-graduate level course intended for the students of the first semester of M.Sc. and seventh semester of Integrated M.Sc. from the department of Physics. This is a core course and the requisites for it are the undergraduate level courses on Modern Physics, quantum Mechanics and Mathematical Physics. The prime objective of this course is to offer the students the application of linear algebra in quantum mechanics; quantum mechanical interpretation of simple systems using various mathematical tools and a detailed study of the hydrogen atom.

Learning outcome: The learners are expected to learn the mechanism of using linear algebra to express wave functions and associated operations. The learners are also expected to revise their undergraduate knowledge on solving simple quantum mechanical systems using various mathematical techniques. Understanding how to truncate a mathematical solution (mostly in power series format) to obtain realistic solutions is one of the important ideas that the learners are supposed to be able to apply. Last but not the least, the idea of the hydrogen atom, along with understanding the quantum numbers associated, is also a crucial outcome of this course. With these concepts, the learners should be ready for the next course on "Advanced Quantum Mechanics".

Course Content:

Review of wave-particle duality, uncertainty principle, Schrodinger equation, the basic postulates of quantum mechanics, superposition principle, expectation value, Heisenberg equation of motion.

Application of Schrodinger equation to one-dimensional problem- square well potential; Quantum mechanics of simple harmonic oscillator-energy levels and energy eigenfunctions using Frobenius method.

Quantum theory of hydrogen-like atoms, time independent Schrodinger equation in spherical polar coordinates, separation of variables for the second order partial differential equation, Orbital Angular momentum in spherical polar co-ordinates and quantum numbers, Radial wavefunctions, Eigen values and eigenfunctions of orbital angular momentum.
Spin Angular Momentum and Pauli's Spin matrices.
Hilbert space formalism for quantum mechanics, Dirac notation, linear operators, Hermitian operator, projection operators, unitary operators, eigenvalues and eigen vectors of an operator.

Matrix representation of Kets, Bras and Operators, harmonic oscillator and its solution by matrix method.

Text Books:

1. Schiff, L. S., *Quantum Mechanics*, (Tata McGraw-Hill Education).
2. Ghatak, A. K. and Lokanathan, S., *Quantum Mechanics: Theory and Applications*, (Springer, 2002).

Reference Books:

1. Waghmare, Y. R., *Fundamentals of Quantum Mechanics*, (Wheeler publishing).
2. Mathews, P. M. and Venkatesan, K., *Quantum Mechanics*, (Tata McGraw-Hill Education, 2007).
3. Pauling, L., *Introduction of Quantum Mechanics*, (McGraw-Hill).
4. Dirac, P. A. M., *Principles of Quantum Mechanics*, (Oxford University Press).
5. Kemble, E. C., *The Fundamental principles of Quantum Mechanics*, (McGraw-Hill).

PI 416: Condensed Matter Physics and Materials Science (L2-T1-P0-CH3-CR3)

Course Objective: The course provides an introduction to the basic phenomena associated with condensed matter physics and materials science. The students are exposed to various theoretical aspects, techniques and experiments that would help understand condensed matter phenomena in real world systems.

Learning outcome: On completion of the course, the students should be able to connect material properties and solid state phenomena with the theoretical models. Also, the students are expected to familiarize with various experimental characterization techniques to ensure structure-property relationship.

Course content:

Review of elements of crystallography and typical crystal structures, Crystal diffraction, reciprocal lattice, atomic form factor, structure factor and Debye-Waller factor, x-ray, electron and neutron diffractions.

Lattice vibration in solids: Enumeration of modes, monoatomic linear chain, infinite and finite boundary conditions, dispersion relation, diatomic chain, acoustical and optical modes, quantization of lattice vibrations (phonons).

Einstein and Debye theory of specific heat of solids, free electron theory of metals, electronic specific heat, electrical conductivity, thermal conductivity, Wiedemann-Franz law.

Motion of electrons in periodic potential, Bloch theorem, Kronig Penney model, band theory of solids, Brillouin zones, insulators, semiconductors and metals, Fermi surface, holes, intrinsic and extrinsic semiconductors, concept of effective mass and law of mass action, Hall effect and magnetoresistance.

Inelastic neutron scattering, analysis of data by generalized Ewald construction, dispersion relations, frequency distribution function, thermal conductivity of insulators, Normal and umklapp processes, crystal imperfections, colour centres, linear and edge dislocations, Bergers' vector, thermo-luminescence.

Text Books:

1. Kittel, C., *Introduction to Solid State physics* 7^{th} Edition (Wiley, Eastern Ltd., 1996).
2. Burns, G., *Solid State Physics* (Academic press, 1995).

3. Dekker, A. J., *Solid State Physics* (Macmillan India Ltd., 2003).
4. Ashcroft, N. W. & Mermin, N. D., *Solid State Physics* (Saunders, 1976).

Reference Books:

1. Ibach, H. & Luth, H., *Solid State Physics*, (Springer-Verlag).
2. Patterson, J. D., *Introduction to the Theory of Solid State Physics*, (Addison-Wesley, 1971).
3. Ghatak, A. K. and Kothari, L. S., *Introduction to Lattice Dynamics*, (Addison-Wesley, 1972).
4. Hall, H. E. and Hook J. R., *Solid State Physics*, 2nd Edition, (Wiley, 1991).
5. Azaroff, L.V., *Introduction to Solids*, (Tata McGraw Hill, 1977).

PI 499: Physics and Computational Lab. **(L0-T1-P3-CH7-CR4)**

Cousre objective: To learn about computer hardware, operating systems and use C language program. To develop algorithms and programs of numerical techniques to solve problems in physics like Non-linear equations, linear equations, interpolation problems, differential equations, Eigen value problems, etc.

Learning outcome: Become skilled, both theoretically and practically, in computer programming, able to solve numerical problems that are frequently used in physics using computer programs.

Course content:

Numerical Analysis: Solution of non-linear equations - Newton's method, method of false position (regular falsi), solution of a system of linear equations - Gaussian elimination, iterative methods (Jacobi and Gauss-Seidel methods), Interpolation - Newton's interpolation formula, numerical differentiation and integration - Simpson's rule, trapezoidal rule, quadrature formula, numerical solution of ordinary differential equations - Euler's method, Runge-Kutta method, fitting of curves - principle of least squares.

Simulation: A system and its model, he basic nature of simulation, the simulation of continuous and discrete systems - suitable examples, stochastic simulation - generation of random numbers with different probability distributions, examples of simulation in physics.

Text Books:

1. Mathews, J. H., *Numerical Methods for Mathematics, Science and Engineering*, (Prentice Hall, 1997).
2. Narsingh Deo, *System Simulation with Digital Computers*, (Prentice Hall, 1979).

Reference Books:

1. Yashwant Kanetkar, *Let us C*, (BPB *Publications*, 2012).
2. Gottfried, B .S., *Schaum's outline of theory and problems of programming with C*, (McGraw-Hill Professional, 1996).

PI 499: Computational Laboratory (L0-T1-P3-CH8-CR4)

a. To find mean, variance, standard deviation, moments etc. for a given set of data (about 50 entries).
b. To fit a linear curve for a given set of data
c. To perform a polynomial fit for a given set of data
d. To find the roots of a quadratic equation
e. Fourier Analysis of a square.
f. To generate random numbers between 1 and 100.
g. To perform numerical integration of 1-D function using Simpson and Weddle rules
h. To find determinant of a matrix, its eigenvalues and eigen vectors
i. To simulate phenomenon of nuclear radioactivity using Monte Carlo technique.

PI 405: Semiconductor Devices (L2-T1-P0-CH3-CR3)

Course Objective: It offers an introductory course with more focus on carrier transport property and band engineering concept in solid state devices. The students are exposed to popular theoretical aspects, techniques and experiments that would help gain insight wrt semiconductor based electronic devices.

Learning outcome: On completion of the course, the students should be able to understand operation of junction devices under biasing as well as their role in electronic circuits for different applications. Also, the students are expected to develop working knowledge on operational principles of electronic components.

Course Content:

Review: Schottky diodes, Hall effect and Four Probe measurements semiconductors, Transistors as amplifiers and oscillators.

Field Effect Transistors: JFET, MESFET, MOSFET, HEMT, HBT.
Optical Devices: Solar Cells, LED, Photovoltaic Cells, Semiconductor Laser, VCSEL, SET etc.

Power semiconductor devices: SCR, UJT, thyristors, diacs, and triacs.
Display devices: Active and passive, construction of display devices, applications of LCD, ECD, PDP, ELD, Flat panel types CRT.

Semiconductor Fabrication Technique: Diffusion, Epitaxy growth, Ion Implantation, Optical and Electron lithographical Technique, etching process, dielectric and polysilicon film depositions, metallization.

Text Books:

1. Neaman D.A. and Biswas,D., *Semiconductor Devices* (Tata McGraw Hill, 2012).
2. Kano, K., Semiconductor Devices,(Prentice Hall of India, 1998).

Reference Books:

1. Milliman J. & Halkias C.C., *Integrated Electronics* (Tata McGraw Hill, 2003).
2. Milliman J. & Halkias C.C, *Electronic Devices and Circuits* (Tata McGraw Hill, 2003).
3. Malvino, A.P., *Electronic Principles*, (McGraw-Hill Education (India) Pvt Limited, 2007).
4. Allison J., *Electronic Engineering Semiconductors and Devices*, Edition 2, (McGraw-Hill,1990).

PI 400: Physics Laboratory-VII (L0-T0-P4-CH8-CR4)

Course Objective: This course provide understanding of scientific enquiry in the advanced topics related photonics, optics, microwave communication, heat and thermodynamics, nuclear Physics, condense matter physics, electronics, etc. The key learning aims in these practical classes are: consolidate subject knowledge, introduce disciplinary methods and procedures.

Learning outcome: On completion of the course, the students should be able to connect characteristics properties of the theoretical models. Also, the students are expected to familiarize with various experimental tools and characterization techniques of different experiments in physics.

Course content:

1. To design and fabricate a phase shift oscillator for the given frequency and to study the output using Op-Amp. 741/ 324 / 325.
2. Determination of thermal conductivity of a substance by Lee's method.
3. Scintillation counter:
   a. Find out the resolution and the FWHM of the given Scintillation counter
   b. Find out the gamma ray energy of the given radioactive sources
4. Determination of the Young’s modulus of a beam by four-point bending.
5. To determine the velocity of sound in (a) dry air, and (b) rods by Kundt’s tube method
6. Calculate the difference in wavelength between atomic transition lines and Zeeman lines using Zeeman effect set-up. (SES instruments Pvt. Ltd).
7. To study Talbot imaging and to obtain Talbot distances with moiré interferometry and to measure the focal length of a lens.
8. Determination of the boiling point of a liquid by platinum resistance thermometer and metre-bridge.
9. To measure the diameter of a thin wire using (a) interference, and (b) diffraction and compare the results.
10. To measure the dielectric constant and loss using microwave bench.

Semester-VIII

PI 552: Quantum Mechanics-II **(L2-T1-P0-CH3-CR3)**

Course Objective:

I. To learn the approximation techniques for solving Schrodinger equation for various physical systems and apply these techniques to real physical system of microscopic particles.

II. To understand the concept of time dependent perturbation theory and its application in absorption and emission of light by matter.

III. To learn to calculate scattering cross-section for interaction processes and relate this to the understanding of structure of atoms and particles.

IV. To acquire the concept of spin formalism of elementary particles.

V. To learn the rules of addition of angular momenta, calculate Clebsch-Gordon co-efficients and to explain spin-orbit coupling.

VI. To learn formalism of relativistic quantum mechanics and explain physical properties of elementary particles.

Learning outcome:

It is expected that after completing this course, the students will be able to

I. acquire the mathematical skill such as use of complex variables, differential equations, Gaussian integrals, linear algebra, matrix formalism etc. to solve various quantum mechanical problems.

II. draw a correlation between mathematical techniques and underlying physical concepts behind angular momenta for elementary particles, approximation techniques and scattering theory and apply to solve for atomic and molecular physics problems.

III. calculate C.G. coefficients of addition of angular momenta of two electron system **and learn matrix formalism of spin angular moenta.**

IV. apply relativistic quantum mechanics to the world of elementary particles.

Course content:

Review of angular momentum, general formalism of angular momentum, addition of angular momenta, Clebsch-Gordon coefficients.

Time-independent perturbation theory; non-degenerate case, first-order and second-order perturbations, degenerate cases, first-order Stark effect in hydrogen atom.

Time-dependent perturbation theory, Fermi’s golden rule, transition probability,WKB approximation, Ritz-variational method, Scattering theory, partial wave analysis and phase shift.

Relativistic quantum mechanics: Relativistic wave equation (Klein-Gordon and Dirac equations), elementary idea about field quantization.

Text Books:

1. Schiff, L.S., *Quantum Mechanics,* (Tata McGraw-Hill, 2004).
2. Zettili, N., *Quantum Mechanics*, (John Wiley & Sons, 2001).

Reference Books:

1. Ghatak, A. K. and Lokanathan, S., *Quantum Mechanics: Theory and Applications*, (Springer).
2. Mathews, P. M. and Venkatesan, K., *Quantum Mechanics*, (McGraw-Hill Education, 2007).
3. Pauling, L., *Introduction of Quantum Mechanics*, (McGraw-Hill).
4. Dirac, P. A. M., *Principles of Quantum Mechanics*, (Oxford University Press).

PI 310: Statistical Physics **(L2-T1-P0-CH3-CR3)**

Course Objectives: This course develops concepts in classical laws of thermodynamics and their application, postulates of statistical mechanics, statistical interpretation of thermodynamics, micro canonical, canonical and grand canonical ensembles and derive the phenomenological laws of thermodynamics from microscopic considerations. The methods of statistical mechanics are used to develop the statistics for Bose-Einstein, Fermi-Dirac and photon gases; learn concepts involved in phase transitions of various physical systems, in particular applicable to continuous phase transitions and phenomenological techniques to model phase transitions in few ideal physical systems.

Learning outcome: It is expected that after successfully completing the course, the students will to be able to explain statistical physics and thermodynamics as logical consequences of the postulates of statistical mechanics, apply the principles of statistical mechanics to selected problems, apply techniques and methodologies, language and conventions from statistical mechanics to a range of physical systems to test and communicate ideas and explanation, in particular condensed matter and low-dimensional systems in thermo dynamical limits. Students will also be able to explain equilibrium phase transitions in various physical systems.

Course content:

Review of Thermodynamics, Introduction to probability theory, Random walk, Central limit theorem and law of large numbers.

Dynamics in phase space, ergodicity and Liouville theorem, Macrostates, microstates and fundamental postulate of equilibrium statistical mechanics. Microcanonical ensemble, Boltzman definition of entropy, Canonical ensemble, partition function, calculation of thermodynamic quantities, Partition functions and few examples: Classical ideal gas, two level system, Harmonic oscillator, Paramagnetism, Curie's law, generalized expression for entropy, Gibbs entropy and mixing of entropy. Grand canonical ensemble, the grand partition function, grand potential and thermodynamic variables.

Introduction to Quantum Statistics, Density Matrix, Ideal Quantum Gases and their properties, Bose-Einstein Condensation, Black body radiation spectrum, non-interacting free Electron gas, Einstein and Debye model of specific heat, Pauli paramagnetism and negative temperature, diamagnetism, photons, phonons and White Dwarft.

Phase transitions, symmetry, order of phase transitions and order parameter, Landau's mean-field theory, Symmetry breaking. Elementary ideas on Ising, Heisenberg models of ferromagnetism, Critical point, critical exponents and their scaling.

Text Books:

1. Karder M. *Statistical Physics of Particles*, Cambridge University Press, 2007.
2. Pathria, R.K., *Statistical Mechanics*, Butterworth Heinemann, Second Edn, 1996.
3. Huang, K., *Statistical Mechanics*, 2nd Edition (Wiley,1987).
4. Reif, F., *Statistical Physics*, (Tata McGraw Hill, 2008).

Reference Books:

1. Landau and Lifshitz, *Statistical Physics*, 3rd edition (Butterworth-Heinemann;1980).
2. *Statistical Mechanics of Phase Transitions*: J. Yeomans (1992) Oxford University Press.
3. *Introduction to Modern Statistical Mechanics*: D. Chandler (1979) Oxford University Press.

PI 551: Electromagnetic Theory-II **(L2-T1-P0-CH3-CR3)**

Course objective: This course attempts to fill a special niche in the post-graduate curriculum, lying between E M Theory I and applied electromagnetism. In this course, the main concern will be with radiation phenomena associated with electromagnetic fields. Starting with a brief review of dynamic electromagnetism and electromagnetic waves, the course addresses retarded potentials and fields, antennas, interference and diffraction. The course will also treat electrodynamics by postulating special relativity and then deriving deductively many of the results that were originally obtained from experiment in the pre-relativity era.

Learning outcome: The course will provide the students sufficient preparation on macroscopic and microscopic descriptions of electromagnetic radiation with in depth understanding. Special attention will be given to the problem sets. Many problems lead the student to develop additional material, or to apply the theory to topics of contemporary interest.

Course Content:

Radiation: Retarded potentials, Hertzian dipole, antennas and arrays, half-wave dipole, Loop current element, Lenard-Wiechert potentials and electromagnetic fields of a moving point charge, electric and magnetic dipole radiations, power radiated by a moving point charge, motion of charged particles in electromagnetic fields, Cherenkov radiation, transmission lines, impedance of line, scattering and diffraction.

Four vectors, relativistic electrodynamics, field tensor, energy-momentum tensor, interdependence of electric and magnetic fields, transformation of electromagnetic fields under Lorentz transformation, invariance of Maxwell’s equations, Lagrangian for electromagnetic fields, Maxwell’s equations from least action principle.

Text Books:

1. Jordan, E. K. and Balmain, K. G., *Electromagnetic waves and Radiating systems*, (Prentice Hall, 1971).
2. Nasar, S. A., *2000 Solved Problems in Electromagnetics*, Schaum's series, (McGraw- Hill, 1992).
3. Puri, S. P., *Classical Electrodynamics*, 2nd edition, (Tata McGraw-Hill Pub., 1997).

4. Ritz, J. R. and Millford, F. J., *Foundations of Electromagnetic Theory*, (Prentice Hall India).
5. Jackson, J. D., *Classical Electrodynamics*, 3rd edition, (Wiley Eastern Ltd, 1998).
6. Panofsky, W. K. H. and Phillips, M., *Classical Electricity and Magnetism*, 2nd edition, (Addison-Wesley, 1962).
7. Griffiths, D. J., *Introduction to Electrodynamics*, (Prentice Hall of India, 2009).

PI 417: Advanced Mathematical Physics **(L2-T0-P1-CH4-CR3)**

Course objective: The main objective of this course is to introduce some advance topics of mathematical physics related to linear algebra, group theory, complex variable and tensor calculus. This course will also motivate the students to apply the mathematical techniques in developing the physical theories.

Learning outcome: After completion of this course students will know how to use matrix mechanics in quantum mechanics, use of group theory in explaining symmetry in condensed matter physics and particle physics, uses of tensor calculus in electrodynamics and general relativity. This course will also help the students to evaluate the complicated integrals using complex variables theory arises in different physical problems.

Course content:

Linear equations of homogeneous and inhomogeneous types, linear vector spaces, scalar product, linear independence, change of basis, Schmidt orthogonalisation, special matrices, diagonalization, orthogonal and unitary transformations, functions of complex variables, limit, continuity, analytic function, Cauchy formula, Laurent series, isolated and essential singularities, Contour integrations, conformal transformations.

Complex variables: Complex algebra, graphical representation, analytical functions, Cauchy-Riemann conditions, complex integrations, Cauchy's theorem, Cauchy's integral formula, residue, Cauchy's residue theorem.

Tensor analysis: Tensor in three and/or four dimensions, rank of tensors, covariant and contravariant tensors, symmetric and antisymmetric tensors, metric tensors, mathematical operations involving tensors.

Group theory: Group representation, reducible and irreducible representation, unitary group, special unitary group, Lorentz group, rotation group, direct product, Young Tableau, Dynkin diagrams.

Text Books:

1. Joshi, A. W., *Group Theory for Physicists*, (Wiley Eastern, 2008).
2. Brown, J. W. and Churchill, R. V., *Complex Variables and Applications*, 6th edition, (McGraw-Hill International, 1996).
3. M R Spiegel, S Lipschutz, J J Schiller and D Spellman, *Schaum's Outline of Complex Variables*.
4. Ablowitz, M. J. and Fokas, A. S., *Complex Variables, 1st South Asian paperback edition, (Cambridge University Press, 1998).*
5. Joshi, A. W., *Matrices and Tensors in Physics*.
6. Hoffman, K. and Kunze, R., *Linear Algebra*, (Prentice Hall India).

PI 302: Analog and Digital Electronics **(L2-T1-P1-CH5-CR4)**

Course Objectives: This course is designed so as to aquatint the realm of pure and applied part of digital and analog electronics. It has the objective to enable the students to understand and impart the basic idea and operating principle of digital as well as analog gadgets; thereby inculcating their pursuit for real field designing.

Learning Outcomes: After the completion of this course, a student should have acquired the knowledge with adequate facts and illustrations and thereby gathered the expertise in designing relevant application oriented schemes.

Course Content:

Op Amp non-linear applications: Voltage limiters, comparators, zero detector, Schmitt trigger, voltage to frequency and frequency to voltage converter, small-signal diodes, sample-and-hold circuits and signal generators: oscillators-square-wave, Wien bridge, phase shift.

Frequency response of an op-amp and active filter: Gain and phase shift vs. frequency, Bode plots, compensated frequency response, slew rate, active filter, first and second order low pass and high pass, Butterworth filter, band reject filter.

555 timer: monostable, astable.

Digital Electronics: Review of Boolean algebra, gates, transistor switching times, INHIBIT (ENABLE) operation, De Morgan's laws, gate assemblies, binary adders.

Combinatorial digital systems: arithmetic functions, decoder/demultiplexer, data selector/multiplexer, encoder, ROM and applications.

Sequential digital systems: flip-flops, shift registers and counters, random access memory (RAM), dynamic MOS circuits, MOS shift registers, MOS Read Only Memory, D/A and A/D systems, digital-to-analog converters, analog-to-digital converters, character generators.

Microprocessor: Architecture and Laboratory.

Text Books:

1. Kumar, A., *Fundamentals of Digital Electronics* (PHI Learning Pvt. Ltd., 2003).
2. Gayakward, R.A., *Op-Amps and Linear Integrated Circuits*, 3rd Edition, (PHI, 2001).
3. Gaonkar R.S., *Microprocessor Architecture, Programming, and Applications with the 8085*, 5th Edition, (Prentice Hall, 2002).

Reference Books:

1. Malvino A.P.and Leach D.J., *Digital Principles and Applications,* (Tata McGraw Hill 1994).
2. Milliman, J. & Halkias, C.C., *Integrated Electronics,* (Tata McGraw Hill, 2003).
3. Tocci R.J., *Digital Systems,* (Pearson/Prentice Hall, 2004).
4. Bartee T.C., *Digital Computer Fundamentals,* (Tata McGraw Hill Publishing Company, 1985).

PI 450: Seminar **(L0-T0-P1-CH2-CR1)**

Course objective: This course provide a training on how to prepare report, presentation and how to present a scientific work.

Learning outcome: After this course students will be able to prepare and present a scientific work.

PI 498: Physics Laboratory-VIII **(L0-T0-P4-CH8-CR4)**

Course Objective: This course provide understanding of scientific enquiry in the advanced topics related photonics, nonlinear optics, condense matter physics, electronics, Nuclear and particle physics, instrumentation etc. The key learning aims in these practical classes are: consolidate subject knowledge, introduce disciplinary methods and procedures.

Learning outcome: On completion of the course, the students should be able to connect characteristics properties of the theoretical models. Also, the students are expected to familiarize with various experimental tools and characterization techniques of different experiments in physics.

Course content:

1. Electron spin resonance spectrometer:
   a. To find out the Lande' g – factor of 2,2-Diphenyl-1-picrylhydrazyl sample using ESR spectrometer.
   b. To observe the E.S.R. signal of given sample (DPPH) and to measure its full width at half maximum (FWHM).
2. GM counter:
   a. Determine the resolving time of the GM counting system.
   b. Study and determine the statistical distribution low that governs nuclear decay.
   c. Determine the characteristics of a GM tube to study the variations of count rate with applied voltage and thereby determine the plateau, the operating voltage and the slope of the plateau.
   d. Determine the dead time of the GM tube using a single source.
3. To determine the coercivity, saturation magnetization and retentivity of different given samples using hysteresis loop tracer set-up.
4. To measure the impedance of a coaxial cable and a rectangular waveguide using microwave bench.
5. Determine the dielectric constant of the ferroelectric ceramic sample using the given experimental set-up.
6. Determine the electrical charge of an electron by Millikan oil drop experiment and determine the value of e/m.
7. To study response of a non-linear crystal as a function of intensity of Nd:YAG laser (532nm)
8. a. To plot intensity of Luminescence vs. Temperature glow curve using thermo-luminescence set-up.
   b. To draw the glow curve and find out the activation energy (E) of different Alkali Halide Crystals using thermo-luminescence set-up (Demonstration only)
9. To study, take a measurement and prepare a report on
   a. PL/UV-VIS Spectrophotometer
   b. Scanning Electron Microscope (SEM)
   c. X-Ray Difractometer (XRD)

Semester-IX

PI 559: Project-I **(L0-T0-P6-CH12-CR6)**

PI 402: Nuclear and Particle Physics **(L2-T0-P1-CH3-CR3)**

Course Objective:

1. To impart the basic laws and concepts of nuclear and particle physics, and build a strong foundation in these fields.

2. Nuclear physics mainly deals with the low energy process(E<10MeV) ; and introduce students to:

(a) the general properties of nuclei and nuclear structure

(b) Central and non-central nuclear forces, and scattering problem

(c) Fermi theory of beta decay and it's offshoot like neutrino physics

(d) Predictions of spin and parity by shell model

(e) Different types of nuclear reactions and detectors

3. In (elementary) particle physics (E>10 MEV), students are introduced to the smallest building blocks of the matter/universe to understand the composition of the real physical world/universe at the very basic level.

Learning Outcomes:

Upon successful completion of the course, students will be able to

1. understand better of the basic properties of nuclei and nuclear structure

2. calculate the fermi theory of beta decay for zero and non-zero mass of neutrino

3.compute the ground state spin-parity of any nuclei using shell model

4. learn the variants of nuclear reactions n detectors

5. knowledge and understanding of the elementary particle interactions

6. capability of elementary problem solving of nuclear and particle physics

7. Overall professional competency in the subject

Course Content:

Basic nuclear properties: Nuclear size determination from electron scattering, nuclear form factors, nuclear radius and charge distribution, mass and binding energy, angular momentum, parity and symmetry, magnetic dipole moment and electric quadrupole moment.

Bound state problem: properties of deuteron, Schrodinger equation and its solution for ground state of deuteron, rms radius and tensor forces, magnetic and quadrupole moments of deuteron.

Scattering problem: low energy n-p scattering and its spin dependence, effective range theory, scattering length, spin dependence (ortho & para-hydrogen), low energy p-p scattering, nature of nuclear forces, charge independence, charge symmetry and isospin formalism, evidence for saturation property, exchange character.

Fermi's theory of beta decay, Curie' Plot, electron capture, selection rules for Fermi and Gamow-Teller transitions, parity violation in -decay and Wu's experiment, two-component theory of neutrinos, neutrino helicity, concepts of neutrino mass and oscillation (solar and atmospheric neutrino puzzles), Reins and Cowen experiment, concept of double beta decay and Majorana neutrino, radioactive dating.

Evidence of shell structure, magic numbers, effective single particle potentials – square well, harmonic oscillator, Wood-Saxon with spin orbit interaction, extreme single particle model and its successes and failures in predicting ground state spin, parity, Nordheim rule.

Different types of nuclear reactions: fission, fusion, Breit-Wigner dispersion formula.

Nuclear radiation detectors: GM counter, proportional, scintillation, solid state detectors, electrostatic accelerators, cyclotron, synchrotron, linear accelerators, colliding beam accelerators.

Particle Physics: Symmetries and conservation laws, quantum numbers, strange mesons and baryons, hadron classification by isospin and hypercharge, SU(2) and SU(3), CPT theorem, CP violation in K decay, Gell-Mann Nishijima relation, quark model, coloured quarks and gluons, quark dynamics.

Text Books:

1. Krane, K. S., *Introductory Nuclear Physics*, (Wiley India Pvt. Ltd, 1998).
2. Roy R. R. and Nigam, B. P., *Nuclear Physics: Theory and Experiment*, (New Age International, 1967).
3. Wong, S. S. M., *Introductory Nuclear Physics*, 2^{nd} edition, (Wiley-VCH, 1999).

Reference Books:

1. Martin, B., *Nuclear and Particle Physics: An Introductory*, (Wiley, 2006).
2. Tayal, D. C., *Nuclear Physics*, (Pragati Prakashan, 2008).
3. Bernard L. Cohen, *Concept of Nuclear Physics*, (Tata McGraw-Hill Education Private Ltd,2011).
4. Beiser, A. and Mahajan, S., *Concept of Modern Physics*, (Tata McGraw-Hill Pvt Ltd, 2009).
2. Mohapatra, R. N. and Pal, P. B., *Massive Neutrinos in Physics and Astrophysics*, (World Scientific).
3. Giunti, C. and Kim, C., *Fundamental of Neutrino Physics and Astrophysics*, (Oxford University Press, 2007).
4. Halzen, F. and Martin, A. D., *Quarks and Leptons*, (John Wiley, 1984).
5. Griffiths, D., *Introductory to Elementary Particles*, 2^{nd} edition, (Academic Press, 2008).

6. Leo, W. R., *Techniques for Nuclear & Particle Physics Experiments*, (Springer-Verlag, 1994).
7. Knoll, G. F., *Radiation Detection and Measurement*, (John Wiley & Sons, 2010).

PI 553: Atomic and Molecular Spectroscopy **(L2-T1-P0-CH3-CR3)**

Course Objective:

I. To learn to calculate spin-orbit interaction energy and explain the fine structure of atoms and to calculate energy due to ls and jj-coupling schemes of two electron system.

II. To explain the physical concept behind rotational, vibrational and electronic spectra of diatomic molecules.

III. To understand the principles of ESR, NMR and Mossbauer spectroscopy and apply these techniques for the study of material properties.

Learning outcome:

On completion of this course, the students will be able to

I. calculate energy levels, frequencies of spectral lines of alkali and alkaline earth spectra and learn to apply quantum mechanical processes in the field of spectroscopy.

II. apply the knowledge of molecular spectroscopy as a tool in understanding the material properties and for analysing the data received from astrophysical objects.

Course content:

Atomic emission and absorption spectra (AES and ASS), series spectra in alkali and alkaline earths, LS and jj coupling in central field approximation.

Spectra of diatomic molecules, pure rotation, pure vibration; vibration-rotation and electronic spectra, Born-Oppenheimer approximation and its application to molecular spectroscopy, formation of bands, structure of bands, dissociation and pre-dissociation, valence-bond theory, molecular orbital theory, bonding and anti-bonding of electrons for equal nuclear charges, energy level of symmetric top molecules, potential energy function.

Morse potential function, Raman spectroscopy, electron spin resonance (ESR) spectroscopy, nuclear magnetic resonance (NMR) spectroscopy, Mossbauer spectroscopy.

Text Books:

1. White, H. E., *Introduction to Atomic Spectra,* (McGraw-Hill, New York, 1934).
2. Herzberg, G., *Atomic Spectra and Atomic Structure,* 2nd edition, (Dover Publications, 2010).
3. Banwell, C. N. and McCash E. M., *Fundamentals of Molecular Spectroscopy,* (McGraw-Hill, 1994).

Reference Books:

1. Kuhn, H. G., *Atomic Spectra,* (Longmans, 1969).
2. Ruark, A. E., and Urey, H. C., *Atoms, Molecules and Quanta* (McGraw-Hill, 1930).
3. Siegman A. E., *Lasers,* (University Science Books, 1986).

Elective I

Elective II

Open Elective

Semester-X

PI 500: Project-II **(L0-T0-P10-CH20-CR10)**

Elective III

Elective IV

Open Elective

Elective Papers:

Course Code	Course Name	L-T-P	CH	CR	Remarks
	Astrophysics				
PI 564	Introductory Astrophysics	2-1-0	3	3	
PI 565	Elements of GTR and Cosmology	2-1-0	3	3	

PI-564: **Introductory Astrophysics** **(L2-T1-P0-CH3-CR3)**

Course Objectives: This course is based on the basics of Astronomy and Astrophysics. The course aims at giving the students introductory idea of the sky, celestial coordinates and celestial bodies.. This course intends to train students with those basic ideas which are essential for further research, teaching and public outreach activities.

Learning Outcome: This course offers an introduction to the basic astronomy and astrophysics. It is expected that the students would be able to get adequate idea on the Astronomy & Astrophysics specialization: about the astronomical observation, stellar structure, stellar evolution, the solar system, galaxies and also about the statistical tools to be used for astrophysical analysis. This course would be beneficial for students opting a career in teaching and research in astronomy and astrophysics. This will also be very useful for students pursuing a career in Astroparticle physics.

Course content:

Celestial coordinate systems: Horizontal and Equatorial coordinate system. Telescope: Operational principle, different types and mounting. Introduction to large telescopes.

Observational characteristics: Magnitude, mass, luminosity, astrometry, photometry, spectrometry and polarimetry. Various astronomical instruments and detectors.

Stellar structure and evolution:

Herzsprung-Russel (H-R) diagram and stellar classification. Stellar spectra

Hydrostatic equilibrium. Stellar structure equations. Polytropic stars and related integral theorems. Stellar atmosphere and Saha equation. Gravitational collapse, degeneracy pressure in stars – structure of white dwarf and neutron star.

Main sequence, pre- and post-main sequence stars. Red giants. Supernova, Black holes and types.

Preliminary idea of imaging of a black hole.

Energy production in stars: Nuclear reactions, reaction rates, p-p chain and carbon-nitrogen-oxygen (CNO) cycle, Triple alpha process.

Solar System: Sun and its properties, planets and satellites, asteroids, comets and Oort's cloud, dust in the solar system, origin of the solar system-different hypotheses.

Exoplanets, their experimental detection methods.

Galaxies: classification, structure and evolution. Orbits of stars in a galaxy; linear instability. galaxy mergers. Quasars, Active galactic nuclei (AGN), Blazars.

Statistical techniques for astrophysics: Basic principles of probability and statistics, Parameter estimation and hypothesis testing, Correlated errors and multi-variate Gaussians.

Text Books:

1. Kippenhahn R. A., and Weigert, A., Stellar Structure and Evolution (Springer, Berlin, 1994).
2. Abhyankar K. D., Astrophysics: Stars and Galaxies (Universities Press, 2009).
3. Vitense, E. B., Stellar Physics (Cambridge University Press, USA, 1992).
4. Glendenning N. K., Compact Stars (Springer, Berlin, 1996)

Reference Books:

1. Chandrasekhar, S., Introduction to the Study of Stellar Structure (Dover Publications, 1958).
2. Bertin G., Dynamics of Galaxies (Cambridge University Press, USA, 1992).
3. Basu B., Chattopadhyay T., Biswas S.N.; An Introduction to Astrophysics (Prentice Hall India, 2010)

PI-565: **Elements of GTR and Cosmology** **(L2-T1-P0-CH3-CR3)**

Course Objectives: This course is based on the basics of General Theory of Relativity and Cosmology. The course aims at giving the students an idea of the principles and mathematical formulation of those topics. This course intends to train students with those basic ideas which are essential for further research, teaching and public outreach activities.

Learning Outcome: This course offers an insight to the elements of the General Theory of Relativity and Cosmology. The idea of tensors, development of the Einstein Field Equation and its solution form an integral part of the developments in Physics in the 20^{th} century. Cosmology offers the collective study of the universe: from its birth to the modern age and into the future. This course would be beneficial for students in understanding the evolving field of relativity and cosmology. This course is also a pre-requisite for students opting for a career in theoretical astrophysics.

Course content:

Tensor Analysis: Covariant and contravariant tensors, quotient rule, metric tensor. Christoffel symbol, covariant derivative of contravariant and covariant tensors, equations of geodesics, Rhemmann-christeffel tensor, Ricci tensor, scalar curvature, Einstein tensor.

Elements of General Theory of Relativity: Principle of equivalence, Principle of General Congruence. Einstein Field Equation, low velocity and weak field approximation of Einstein field equation, Gravitational waves.

Solution of EFE: Static and Schwarzschild solution of Einstein equation, exterior and interior

solutions, Schwarzschild singularity & concept of black hole. Planetary orbits: advance of perihelion of mercury; bending of light: gravitational lensing and microlens, gravitational red shift.

Large-scale structure of universe: Cosmological principle, elements of Newtonian cosmology.

Cosmological Models: Friedman-Robertson-Walker (FRW) metric, Hubble’s law, Einstein universe, De-Sitter universe. Idea of dark matter and dark energy.

Early Universe: The big bang theory, steady state theory, Cosmic Microwave Background Radiation, decoupling of matter and radiation. Inflation.

Idea of quantum gravity and quantum cosmology. Idea of Hawking radiation. Gravitational Waves.

Text Books:

1. Misner, C., Thorne, K. S. and Wheelar, J. A., Gravitation (Freeman, 2003).
2. Kenyon, I.R., General Relativity (Oxford University Press, 1990).
3. Weinberg, S., Gravitation and Cosmology (Wiley, New York, 1972).
4. Ryden B., Introduction to Cosmology (Cambridge University Press, 2016)
5. Schneider P. , Extragalactic Astronomy and Cosmology: An Introduction (Springer, 2010)
6. Narliker, J. V., Introduction to Cosmology (Cambridge University Press, 2002).

Reference Books:

1. Schutz B., A First Course in General Relativity (Cambridge University Press, 2009)
2. Rindler W., Relativity: Special, General, and Cosmological 2nd Edition (Oxford University Press, 2006)
3. Wald R.M., General Relativity (University of Chicago Press, 1984)
4. Einstein A., Relativity - The Special and The General Theory (Fingerprint Classics, 2017)

5. Weinberg S., Cosmology (Oxford University Press, 2008).
6. Liddle, A. and Loverday, J., The Oxford Companion to Cosmology (Oxford University Press, 2008)
7. Bondi H. and Roxburg I., Cosmology (Dover Publications Inc. 2010)

Course Code	Course Name	L-T-P	CH	CR	Remarks
Condensed Matter Physics					
PI 510	Advanced Condensed Matter Physics and Materials Science				
PI 554	Soft Condensed Matter Physics				

PI-510: Advanced Condensed Matter Physics and Materials Science (L2-T1-P0-CH3-CR3)

Course Objective: The aim of the proposed course is to introduce the basic notion of the condensed matter physics and to familiarise the students with the various aspects of the interactions effects. This course will be bridging the gap between basic solid state physics and quantum theory of solids. It also introduces theoretical framework such as BCS theory of superconductivity.

Learning outcome: On completion of the course, the student should be able to connect between theory and experimental macroscopic scale observations to microsopic theory.

Course Contents:
Unit-1

Fermi surface, cyclotron resonance, de Hass-Van Alphen effect, electron motion in 2-dimension, Quantum Hall effect. Elements of ferrimagnetism and antiferromagnetism. Curie-Weiss law, exchange interaction, spin waves and magnons, dispersion relation, neutron scattering from magnetic materials-structure studies, Neel's temperature.

Unit-2

Born-Oppenheimer approximation, second quantization for Fermions and Bosons. Effects of electron-electron interactions - Hartree- Fock approximation, exchange and correlation effects, screening, dielectric function of electron systems, plasma oscillations, Fermi liquid theory, elementary excitations, quasiparticles. Dielectric function of electron systems, screening, plasma oscillation. Optical properties of metals and insulators, excitons. The Hubbard model, spin-and charge-density wave states, metal-insulator transition.

Unit-3

Superconductivity – phenomenology, Cooper instability, BCS theory, Bogoliubov transformation-notion of quasiparticles; Ginzburg-Landau theory. Type-I and Type II superconductors — characteristic length; Flux quantization, single particle tunneling and Josephson effects, superconducting quantum interference device (SQUID); "Novel High Temperature" superconductors, superconductivity of thin films

Unit-4

Critical Phenomena: liquid-gas, paramagnetic-ferromagnetic, normal to superconductor, and superfluid transitions. Landau theory; Mean field theory, Ising and Heigenberg model, Scaling hypothesis, universality class, scaling laws, critical exponents and inequalities, renormalisation group theory, real space renormalisation group with examples.

Unit-5

Thin films and thick films, their differences, deposition techniques of thin films and thick films, physical vapour deposition (PVD), chemical vapour deposition, electroless or solution growth deposition, electrochemical deposition (ECD), screen printing of thin films. Nucleation and growth processes, structure of thin films, epitaxial growth (VPE, MBE, MOCVD, etc.), thin film thickness measurement. transport phenomena in semiconducting and insulator films, superconductivity of thin films and HTSCs (high temperature superconductor films). Applications of thin films in electronics, thin films resistors, capacitors and active devices, thin film transducers, thin film, solar cells.

Text Books:

1. P. Marder, *Condensed Matter Physics*, 2nd Edition (John Wiley & Sons, Inc, 2010).
2. C. Kittel, *Introduction to Solid State physics* 7th Edition (Wiley, Eastern Ltd., 1996).
3. H. Ibach, & H. Luth, *Solid State Physics*, (Springer-Verlag, 2011).
4. A. J. Dekker, A. J., *Solid State Physics* (Macmillan India Ltd., 2003).
5. N. W. Ashcroft, & N. D. Mermin, *Solid State Physics* (Saunders, 1976).

Reference Books:

1. Philip Phillips, Advanced solid state physics , (Overseas Press, 2008)
2. J. D. Patterson, *Introduction to the Theory of Solid State Physics*, (Addison-Wesley, 1971).
3. A. K. Ghatak, and L. S. Kothari, *Introduction to Lattice Dynamics*, (Addison-Wesley, 1972).
4. H. E. Hall, and J.R. Hook, *Solid State Physics*, 2nd Edition, (Wiley, 1991).
5. L. V. Azaroff, *Introduction to Solids*, (Tata McGraw Hill, 1977).
6. J. Solyom, Fundamentals of the Physics of Solids, Volumes 1, 2, and 3. (springer, 2007).

PI-554: Soft Condensed Matter Physics **(L2-T1-P0-CH3-CR3)**

Course Objective: The course provides an introduction to the basic phenomena that collectively define condensed matter physics, in particular, in living and non-living active matter. The students are exposed to various experiments as well as theoretical models that help in understanding physical behavior of vast pool of soft condensed matter in real world systems.

Learning outcome: On completion of the course, the student should be able to connect the theory solid state physics to micro organisms from the point of view of physical phenomena.

Course Contents:

Unit-1

Phases of soft condensed matter: Homogeneous solution and phase separation, Free energy, Osmotic pressure and Chemical potential. Colloids and Colloidal stability, sheared colloids, coagulation and flocculation, electric double layer (EDL), Poisson-Boltzmann theory, DLVO theory, polymer solutions and gels, lattice model, plastics and rubbers, Kuhn's theory, emulsions and foams, amphiphilic molecules: surfactant types and nature of packing, micelles and reverse micelles, planar bilayers, vesicles, lyophobic and lyophilic molecules, self-assembly and nanostructuring, principles and applications of Langmuir-Blodgett films, microgels, wetting-dewetting phenomena, super-hydropbobic surfaces, phospholipids and glycolipids, polyelectrolyte, polysachharides; biopolymers and biodegradable polymers.

Unit-2

Liquid crystals: types and properties, Frank free energy, Landau-de Gennes model of isotropic-nematic transition. Thermotropic and lyotropic LCs, orientational order, order parameters, Onsager equation, Landau description, optical retardation, Freedericksz transition.

Unit-3

Flow behaviour: Brownian motion and thermal fluctuation, shear thickening and shear thinning. Newtonian and Non-newtonian fluids, Ferrofluids. Diffusion and subdiffusion. Fluid flow and rheology, Implications of Marangoni effect, microfluidics, concept of glass forming and jamming, percolation model, random walks and dynamics, sandpile model, soft glassy rheology; Energy-elasticity, entropic spring, visco-elastic models, de Gennes-Taupin length, introduction to shape transitions.

Unit-4

Membrane physics: Membrane structure and membrane proteins, Bioenergetics, excitable membranes, resting potential, Hodgkin-Huxley model, ion channels, action potentials, patch clamp method. Life at low Reynold number.

Unit-5

Experimental techniques: Contact angle measurements, optical microscopy and optical profilometry, scanning probe microscopy, small angle scattering and diffraction, dynamic light scattering and diffusive wave spectroscopy, dynamics of soft matter using synchrotron x-ray and neutron scattering, rheometry, confocal microscopy.

Text Books:

1. I. W. Hamley, Introduction to Soft Matter, (Wiley, Chichester, 2000).
2. R. A. L. Jones, Soft Condensed Matter, (OUP, Oxford, 2002).
3. P. J. Collings, and M. Hird, Introduction to Liquid Crystals, (CRC Press, 1997).
4. R. Phillips, J. Kondev, and J. Theriot, Physical Biology of the Cell, (Garland Science, 2008).

Reference Books:

1. M. Kleman, and O. D. Lavrentovich, Soft Matter Physics, (Springer-Verlag, 2003).
2. S. A. Safran, Statistical Mechanics of Surfaces, Interfaces and Membranes, (AddisonWesley, Reading, MA 1994).
3. W. B. Russel, D. A. Saville, and W. R. Showalter, Colloidal Dispersions, (Cambridge University Press, New York, 1989).
4. Philip Nelson, Biological Physics: Energy, Information and Life, (Freeman, 2003).
5. D. Tabor, Gases, Liquids and Solids, (CUP, 1991).
6. R. Cotterill, Biophysics: An Introduction, (John Wiley, Singapore 2002

Course Code	Course Name	L-T-P	CH	CR	Remarks
		Electronics			
PI 508	Digital Communication System	2-1-0	3	3	
PI 517	Microwave Systems and Antenna Propagation	2-1-0	3	3	
PI 507	Digital Signal Processing	2-1-0	3	3	
PI 516	Microprocessors and Digital Signal Processing Based Systems	2-1-0	3	3	

PI 508: Digital Communication Systems **(L2-T1-P0-CH3-CR3)**

Course Objectives:

a. Understand how digital communication system works
b. Generation, transmission and receiving of digital signals in the communication system
c. An ability to design and conduct experiments

Learning outcomes:

Towards the end of the course, it is expected that the student would be able to get a basic knowledge of digital communication systems. Students will also have the idea of different modules applied in digital communication systems.

Course content:

Introduction to digital communications, sampling techniques, ESD, PSD, autocorrelation function, orthogonality.

Pulse modulation: PAM, PCM, DPCM, delta modulation, ADM.

Data transmission: FSK. PSK, DPSK, Mary modulation systems, error probability calculations.

Random process: PSD of random process, transmission of random process through linear systems, optimum filtering.

Behaviour of digital communication system in presence of noise: optimum threshold detection, OBR, carrier systems ASK, FSK, PSK and DPSK, spread spectrum systems, Optimum signal detection: Gaussian random process, optimum receiver, nonwhite channel noise.

Error control coding: block and convolution codes, combined modulation and coding, examples of typical communication systems: Modems, local area networks, computer communication, microwave, satellite, optical, cellular mobile etc.

Text Book:

1. Lathi, B. P., *Modern Analog and Digital Communication Systems*, (Oxford University Press, 2009).

Reference Books:

1. Haykins, S., *Communication systems*, 3rd edition, (Wiley India Pvt Ltd., 2006).
2. Gallager, R. G., *Principles of Digital Communication*, (Cambridge University Press, 2008).
3. Rao, P. R., *Digital Communication*, (Tata McGraw-Hill *Publishing* Co., 2007).
4. Sklar, B., *Digital Communications: Fundamentals & Applications*, 2nd edition, (Pearson Education, 2009).
5. Proakis, J. G. and Salehi, M., *Communication Systems Engineering*, (McGraw-Hill Higher Education, 2007).

PI 517: Microwave Systems and Antenna Propagation (L2-T1-P0-CH3-CR3)

Course Objective:

a. Develop understanding of the microwave systems and antennas.
b. Understanding how some practical microwave devices work.

Learning outcomes:

At the end of this course, students will have an understanding of fundamentals of microwave engineering as well as sufficient knowledge to apply it to problems of practical interests.

Course content:

Review of Maxwell's equations: Electromagnetic radiation, plane waves in dielectric and conducting media, reflection and refraction of waves.

Transmission lines, smith chart and its applications, rectangular wave guide, rectangular cavity, modes in waveguides and cavities, dielectric filled wave guides, dielectric slab guide, surface guided waves, non-resonant dielectric guide, modal expansion of fields and its applications.

Microwave semiconductor devices: Microwave transistor, microwave tunnel diode, varactor diode, Schottky diode.

MESFET: Principle of operation, MOS structure, MOSFET microwave applications, transferred electron devices: Gunn diode, LSA diode, modes of operation.
Microwave generation and amplification, avalanche effect devices: Read diode, IMPATT diode, klystron: velocity modulation process, bunching process, output power and beam loading, reflex klystron: power output and efficiency, traveling wave tubes, magnetron.
Microwave waveguide components: attenuators, phase shifters, matched loads, detectors and mounts, slotted-sections, E-plane tee, H-plane tee, hybrid tees, directional couplers, tuners, circulators and isolators, quarter wavelength transformer, multi section transformer matching section.

Lumped planar components: capacitor, inductor and balun, power dividers, directional couplers, analysis of these components using the S-parameters, microwave planar filters, planar non reciprocal devices, signal generators: fixed frequency, sweep frequency and synthesized frequency oscillators, frequency meters, VSWR meters, measurements of frequency, attenuation, VSWR and impedance.

Antenna characteristics: radiation patterns, directive gain, side lobe, back lobe, polarization, co-polarization and cross polarization level, frequency reuse, beam width, input impedance, bandwidth, efficiency, antenna types: wire, loop and helix antennas, aperture antenna-slot, waveguide and horn antenna; parabolic reflector antenna.

Microwave integrated circuits: different planar transmission lines, characteristics of microwave integrated circuits, microstrip antenna: rectangular and circular patch, feed for microstrip antennas: probe feed, microstrip line feed, aperture feed, electromagnetically fed microstrip patch.

Text Book:

1. Rizzi, P. A., *Microwave Engineering*, (Prentice-Hall, 1999).

Reference Books:

1. Pozar, D. M., *Microwave Engineering*, 3rd edition, (Wiley India Pvt. Limited, 2009).
2. Liao, S. Y., *Microwave Devices and Circuits*, 3rd edition, (Prentice-Hall of India, 2000).
3. Collin, R. E, *Foundations for Microwave Engineering*, (McGraw-Hill, 1992).
4. Griffiths, D. J., *Introduction to Electrodynamics*, (Prentice-Hall, 2009).
5. Jackson, J. D., *Classical Electrodynamics*, 3rd edition, (John Wiley & Sons, 1998).

PI 507: Digital Signal Processing **(L2-T1-P0-CH3-CR3)**

Course Objectives:

a. Develop understanding of the DSP.
b. Practical implementation of DSP

Learning outcomes:

At the end of this course, students will know concept of digital signal processing and some typical applications along with its implementation with MATLAB.

Course content:

Introduction: digital signal processor, signals and systems, sampling and quantization.

Specialized transforms: z-transform, discrete cosine transform, Hilbert transform, Fourier transform, DFT, FFTs, convolution.

Digital filters:

FIR filters-Linear phase filter, windowing method, standard and multi band, constrained least square filtering, arbitrary response filter design IIR filter- design, Butterworth, Chebyshev type I and type II, elliptical, Bessel.

Spectral analysis: Welch's method, multilayer method, Yule-Walker method, covariance methods, MUSIC and eigenvector analysis method.

Applications in real time problems like extraction of voice from noisy environment, filtering the signal using digital filters etc.

Text Books:

1. Proakis, J. G. and Manolakis, D. G., *Digital Signal Processing: Principles, Algorithms, and Applications*, 3rd edition, (Prentice Hall, 1996).
2. Mitra, S. K., *Digital Signal Processing: A Computer Based Approach*, (McGraw-Hill, 2001).
3. Lyons, R. G., *Understanding DSP*, 3rd edition, (Pearson Education, International, 2010).

Reference Books:

1. Hayes, M. H., *Digital Signal Processing*, Schaum's Outline Series, (McGraw-Hill, 1999).
2. Oppenheim, A. V. and Schafer, R. W., *Digital Signal Processing*, (Macmillan Publishing Company, New York, 1993).
3. Porat, B., *A course in Digital Signal Processing*, (John Wiley & Sons, 1996).
4. Soliman, S. S. and Srinath, M. D., *Continuous and Discrete Signals and Systems*, (Prentice Hall, 1998).
5. Sharma, S., *Signals and Systems*, (Katson Books, 2010).

PI 516: Microprocessor and Digital Signal Processing Based Systems (L1-T0-P2-CH5-CR3)

Course Objectives:

a. Develop understanding of industrial automation- software and hardware.
b. Practical interfacing

Learning outcomes:

At the end of this course, students will know how to interface hardware, acquire and process data.

Course content:

Introduction to microprocessors programming and interfacing, Transducers and sensors: Load cells, strain gauges, weighing transducers, temperature sensors (e.g. RTDs, thermocouples, semiconductor sensors, etc.), displacement sensors (e.g. LVDTs, RVDTs, encoders, linear scale etc.), proximity sensors, magnetic sensors, opto-electronic sensors, fiber optic sensors, motion transducers (velocity, vibration and acceleration), fluid transducers, pressure transducers, level transducers, etc.

The signal conditioning circuits like current booster, current to voltage converter, instrumentation amplifier, level shifter, 4-20mA current loop, etc. with their design.

The open loop, feedback loop and feed forward loop and servo controllers with details of PI, PD, PID controllers, tuning methods of the same and also auto tuning methods.

Interfacing of sensors, stepper motor designing of the signal conditioning circuits along with microcontrollers.

Text Book:

1. Hall, D., *Microprocessors and Interfacing*, 2nd edition, (Tata McGraw-Hill, 1999).

Reference Book:

1. Gaonkar R. S., *Microprocessor Architecture, Programming, and Applications with the 8085*, 5th edition, (Prentice Hall, 2002).

Course	Course Name	L-T-P	CH	CR	Remarks

Code					
High Energy Physics					
PI 501	Quantum Field Theory	2-1-0	3	3	
PI 540	Particle Physics	2-1-0	3	3	

PI 501: Quantum Field Theory (L2-T1-P0-CH3-CR3)

Course Objective: The course gives an understanding of the different classical fields and their quantisation, which describes the elementary particles and their interactions. The course also gives an understanding of Feynman's rules, a basis for calculating and understanding simple cross sections for collisions and particle production.

Course outcome: Quantum Field Theory (QFT) is the mathematical and conceptual framework for contemporary elementary particle physics. In a rather informal sense QFT is the extension of quantum mechanics (QM), dealing with particles, over to fields, i.e. systems with an infinite number of degrees of freedom. This course provides information of three of the four forces of nature and their interactions of force-carrying boson particles with matter-making fermions. It also contains quantisation of Scalar, Dirac and Vector field, interaction between the fields and renormalization theory. Towards the end of the course students would be able to deal with any kinds of elementary particle interaction specially QED, renormalization etc. The contents of this course are the prerequisite for doing research in modern particle and astro-particle physics.

Course Content:

Introduction to Fields: Lagrangian and Hamiltonian formulation of continuous systems, introduction to relativistic field theories, four-vector notations. Klein-Gordon equation, relativistic free scalar fields, Dirac equation, antiparticles, free Dirac fields, covariant formulation of Dirac equation and its gamma matrices and their algebra including trace calculations.

Quantization of Fields: Quantization of scalar fields (complex and real), Dirac fields and vector fields.

Conservation Laws and Associated Symmetries: Noether's theorem, discrete symmetries: C, P and T symmetries of free scalar, charged scalar, Maxwell and Dirac fields.

Interaction Among Fields: Interaction picture, S-matrix, wick's theorem, Feynman rules, Feynman diagrams for elementary processes, lowest order calculations for Compton scattering, Bremsstrahlung, Bhabha and Moller scatterings, renormalization.

Text Books:

1. Lahiri, A., and Pal, P. B., *Quantum Field Theory*, (Narosa Publishing House, 2017)
2. Ryder, L. H., *Quantum Field Theory*, (Cambridge University Press, 1996)
3. Halzen, F., and Martin, A. D., *Quarks and Leptons: An Introductory Course in Modern Particle Physics*, (John Wiley and Sons, 2008).

Reference Books:

1. Peskin, M. E., and Schroeder, D. V., *Introduction to Quantum Field Theory*, (Addison Wesley, 1995)
2. Weinberg, S., *The Quantum Theory of Fields* (Vol. I, II, III), (Cambridge University Press, 2005)

3. Mandl, F., and Shaw, G., *Quantum Field Theory* (John Wiley and Sons, 2010)
4. Huang, K., *Quarks, Leptons and Gauge Field*, (World Scientific, 1992)
5. Aitchison, I. J. R., and Hey, A. J. G., *Gauge Theories in Particle Physics*, (Adam Hillier, 2004)
6. Chang, S. J., *Introduction to Quantum Field Theory*, (World Scientific, 1990)

PI-540: Particle Physics **(L2-T1-P0-CH3-CR3)**

Course Objective: This course gives knowledge of fundamental particles, fundamental interaction and the range and strength of these interactions. This course is also for the understanding of fundamental particles like quarks, theory of weak different weak interactions and gauge theory of fundamental particles. It also includes a small portion of statistical data analysis.

Course outcome: This course provides some introductory and advanced knowledge of particle physics like classification of particles, fundamental interactions, quark model, parton model, weak interactions, gauge theories, statistical tools for particle physics etc. The course is developed in a way with increasing mathematical treatments and difficulties. The prerequisites of this course are mainly quantum mechanics, special theory of relativity, nuclear physics, some knowledge of elementary quantum field theory. Towards the end of the course, it is expected that the student would be able to get some introductory and some advance knowledge of elementary particles and their interactions, and gauge theories and some knowledge of statistical tools required for particle physics. All these are prerequisites for mainly research in more advanced topics of high energy physics.

Course Content

Introduction: Elementary particles, fundamental interactions (strengths and ranges), natural units. Conservation rules in fundamental interaction.

Quark Model: Quark model of mesons and baryons (quarks, gluons and colors), eightfold way of classification, symmetry groups: SU(2), SU(3), discovery of heavy quarks.

Parton Model: Probing charge distributions with electrons, form factors, e-p scattering, proton form factors, deep inelastic scattering, structure functions, partons, Bjorken scaling, QCD – dual role of gluons.

Weak Interactions: Introduction to neutrinos (postulation and discovery), V-A theory, nuclear beta decay, neutrino-quark scattering, Cabibbo angle, weak mixing angle, neutrino oscillations, CP violation.

Gauge theory: Local and global gauge theory, non-abelian gauge theory, spontaneous symmetry breaking, Higgs Mechanism, Goldstone theorem.

Statistical Tools and Data Analysis: Bayes' theorem, probability distribution functions, Monte-Carlo method, statistical tests: significance and power of a test, maximum likelihood method, examples of data analysis using the above tools in accelerator and neutrino experiments.

Text Books:

1. Halzen, F., and Martin, A. D., *Quarks and Leptons: An Introductory Course in Modern Particle Physics*, (John Wiley and Sons, 2008)
2. Griffiths, D., *Introduction of Elementary Particles*, (John Wiley and Sons, 1987)
3. Lyons, L., *Statistics for Nuclear and Particle Physicists*, (Cambridge University Press, 1989)

Reference Books:

1. Peskin, M. E., and Schroeder, D. V., *Introduction to Quantum Field Theory*, (Addison Wesley, 1995)
2. Mandl, F., and Shaw, G., *Quantum Field Theory* (John Wiley and Sons, 2010)
3. Huang, K., *Quarks, Leptons and Gauge Field*, (World Scientific, 1992)
4. Aitchison, I. J. R., and Hey, A. J. G., *Gauge Theories in Particle Physics*, (Adam Hillier, 2004)
5. Chang, S. J., *Introduction to Quantum Field Theory*, (World Scientific, 1990)
6. Perkins, D. H., *Introduction to High Energy Physics*, (Cambridge University Press, 2000)
7. Cowan, G., *Statistical Data Analysis*, (Oxford Science Publications, Clarendon Press, 1998)
8. Sakurai, J. J., Invariance principle and elementary particles, (Princeton Univ. press, 2016)

Course Code	Course Name	L-T-P	CH	CR	Remarks
Photonics					
PI 557	Photonics	2-1-0	3	3	
PI 559	Nanophotonics	2-1-0	3	3	

PI 557: Photonics **(L2-T1-P0-CH3-CR3)**

Course objective: The **Photonics** course covers a wide spectrum of topics. The course has been designed in such a way that most of the important topics under photonics field can be taught within the stipulated period of time. A student pursuing this course is expected to learn different areas of the field that include optical modulation techniques, non-linear optical systems, photovoltaic cells, optical fiber and various form of communication devices. These are

Expected outcome: This special course is designed to provide fundamental knowledge in the field of photonics which primarily comprise of different forms of optical modulation techniques, non-linear optics, integrated optics and photovoltaic cells. Students taking this course is expected to gain knowledge on the following topics which have great interdisciplinary relevance spanning from material science to optical engineering in the future.

Non-linear photonics: Non-linear optical media, second-order and third-order non-linear optics, three-wave mixing, frequency and phase matching, self-phase modulation, self-focusing, spatial soliton, Raman amplification, Brillioun devices.

Electro-optic effects, intensity modulators, phase modulators, travelling wave modulators, Acousto- optic devices: Photoelastic effect, acousto-optic diffraction, acousto-optic modulators.

Magneto-optic devices: Magneto-optic effects, Faraday effect, magneto-optic Kerr effect, Integrated optical modulators: Phase and polarization modulation, Mach-Zehnder modulator, coupled waveguide modulator.

Photovoltaic devices: Photovoltaic device principles, equivalent circuit of solar cell, temperature effects, solar cell materials, devices and efficiencies.

Optical fiber modes and configurations, mode theory for circular waveguides, single mode and graded-index fibers, fiber materials, Attenuation in optical fibers, signal distortion in optical fibers, pulse broadening mechanism, mode coupling, design optimization of single mode fibers. Source to fiber launching, fiber to fiber joints, Non-linear effects in fibers, Raman scattering and Brillouin scattering in fibers, fiber Bragg gratings

Photonic switches, photodetectors, optical memory devices, optical communication devices.

Prerequisite qualification: Should have basic knowledge of optics, optoelectronics and electromagnetic theory,

Text Books:

1. Ghatak, A. K. and Thyagarajan, K., Introduction to Fiber Optics, (Cambridge Publisher, 2004).
2. Shen, Y. R., Principle of Non-Linear Optics, (Wiley India, 2013).
3. Chuang, S. L., Physics of Photonic Devices, (Wiley Series, 2009)

Reference Books:

1. Boyd, R. W., Non-Linear Optics, (Elsevier, 2006) Second edition.

2. Fukuda, M., Optical Semiconductor Devices, (John Wiley & Sons, 2005).

PI 559: Nanophotonics **(L2-T1-P0-CH3-CR3)**

Review of Maxwell's equations, light-matter interaction, radiating dipole, radiation pressure, spontaneous and stimulated emissions.

Optical properties of noble metals and semiconductors, Drude Somerfield theory, surface plasmon and polariton, evanescent wave, localized surface plasmon, SERS, surface plasmon based sensors.

Diffraction limit, near-field optics, super resolution spectroscopy, nanoscale optical microscopy, two photon and multi photon absorption processes, optical tweezer and vortices, phase conjugation and frequency mixing, elements of quantum communication.

Electromagnetics in mixed dielectric media, symmetries and solid state electromagnetism, 1-D, 2-D and 3-D photonic crystals, dispersion relation, photonic crystal fiber, opals, OLED, quantum well and quantum dot lasers, photo-luminescence and bio-luminescence.

Application in nano-optics and bio-photonics.

Text Books:
1. Maier, S. A., *Plasmonics: Fundamentals and Applications, illustrated* edition (Springer, 2007).
2. Boyd, R. W., *Non-Linear Optics*, 2nd edition (Elsevier, 2006).
3. Haus, J. W., *Fundamentals and Applications of Nanophotonics*, (Elsevier, 2016).

Reference Books:
1. Di Bartolo, Baldassare, Collins, John (Editors), *Nano-optics for Enhancing Light-Matter Interactions on a Molecular Scale: Plasmonics, Photonic Materials and Sub-Wavelength Resolution*, (Springer, 2012).
2. Winn, J. N., Joannopoulos, J. D. and Johnson, S. G., *Photonic Crystal: Molding the flow of Light*, (Princeton Univ. Press, 2008).
3. Shen, Y. R., *Principle of Non-Linear Optics*, (Wiley India, 2013).
4. Fukuda, M., *Optical Semiconductor Devices*, (John Wiley & Sons, 2005).
5. Chuang, S. L., *Physics of Photonic Devices*, (Wiley Series, 2009).

6. Novotny, L. and Hecht, B., *Principles of Nano-optics*, (Cambridge Univ. Press, 2009).

Course Code	Course Name	L-T-P	CH	CR	Remarks
	Plasma Physics				
PI 521	Fundamental of Plasma Physics	2-1-0	3	3	
PI 525	Nonlinear Plasma Physics	2-1-0	3	3	

PI 521: Fundamentals of Plasma Physics **(L2-T1-P0-CH3-CR3)**

Course Objective:

I. The course will help to understand the difference between ionized gas and plasma

II. To learn to use mathematical formalism such as single particle approach, fluid approach and kinetic approach to describe various plasma phenomena

III. To learn to derive dispersion relation of waves in plasma medium and understand the propagation of these waves in plasma and understand electrostatic and electromagnetic waves in plasma and their physical mechanism

IV. To understand the instabilities in plasma.

IV. To understand physical mechanism of Landau damping and its importance.

Learning outcome:

After completion of the course it is expected that the students will

I. have a strong foundation of plasma physics.

II. have understanding of charged particle motion in uniform and non-uniform electric and magnetic fields and learn about E×B drift, grad B drift, curvature drift, polarization drift, magnetic mirror etc.

III. be able to use mathematical techniques to describe normal modes in plasma and understand their behaviour.

IV. explain the concept of instabilities and analyse on the basis of dispersion relation.

Course content:

Plasma State: Ionized gas, Saha's ionization equation, Collective degrees of freedom, Definition of Plasma, Concept of Plasma temperature, Debye shielding, Quasi-neutrality, Plasma parameters, Plasma approximation, Natural existence of Plasma.

Single-particle motion: Dynamics of charged particles in electro-magnetic fields, Particle drifts, EXB drifts, Grad-B drift, Curvature drift, Polarization drift, Adiabatic invariants and their technological applications.

Kinetic theory of Plasma: Vlasov equations, Solution of linearized Vlasov equation, Langmuir waves, Ion-sound waves, Wave-particle interaction and Landau damping.

Fluid theory of Plasma: Plasma oscillations, Electron-acoustic waves, Ion-acoustic waves Electrostatic ion-waves perpendicular to magnetic field, Electromagnetic waves perpendicular to magnetic field.

Equilibrium and stability: Plasma instabilities and classification, Two-stream and gravitational instabilities.

Text Books:

1. Nicholson, D.R., *Introduction to Plasma Theory* (Wiley, USA, 1983).
2. Swanson, D. G., *Plasma Waves* (IoP, Bristol, 2003).
3. Bittencourt, J. A., *Fundamentals of Plasma Physics* (Springer, New York, 2004).
4. Bellan, P. M., *Fundamentals of Plasma Physics* (Cambridge, UK, 2006).
5. Cap, F. F, *Handbook on Plasma Instabilities* (Academic Press, New York, 1976).

Reference Books:

1. Piel, A., *Plasma Physics: An Introduction to Laboratory, Space and Fusion Plasmas* (Springer, Heidelberg, 2010).
2. Chen, F. F., *Introduction to Plasma Physics and Controlled Fusion*, 2nd ed. (Plenum, New York, 1984).
3. Kono, M. and Skoric, M. M., *Nonlinear Physics of Plasmas* (Springer, Berlin, 2010).
4. Pecseli, H. L., *Waves and Oscillations in Plasmas* (CRC Press, New York, 2013).
5. Smirnov, B. M., *Theory of Gas Discharge Plasma* (Springer, Switzerland, 2015).
6. Spitzer, L., Physics of Fully Ionized Gases (John Wiley & Sons, New York).

PI 525: Nonlinear Plasma Physics (L2-T1-P0-CH3-CR3)

Course objectives:

(a) It offers a precious scope of learning and enjoying the basics of nonlinear shielding mechanisms in various conditions.

(b) It excites inner stimulations to students to look creatively at the physical world from the nonlinear wave communicative perspectives in astrospace circumstances.

(c) It develops a broad mind setup to understand and solve different sorts of applied problems driven by nonlinear wave kinetics.

Learning outcomes:

(a) A full completion of the course is expected to build up strong creativity, analytical capability and innovativeness in the students.

(b) It enables potentiality and skill development in diversified exercises of nonlinear wave physics including fluid dynamics.

(c) It parallelly offers a remarkable scope to explore the astrophysical dark universe from a new perspective of nonlinear eigenstructure stimulation and their evolution.

Course content:

Nonlinear Debye shielding, Evacuation of the Debye sphere, Basics of exotic plasma effects: Plasma as exotic medium, Shielding in three spatial dimensions.

Weakly nonlinear processes: Concept of nonlinearity and dispersion, Weakly nonlinear and weakly dispersive waves, Wave energy alteration with dispersion and dissipation mechanisms, Shock & soliton formation, Nonlinear wave equations and asymptotic integrations.

Strongly nonlinear processes: Excitation of strongly nonlinear and strongly dispersive waves, Energy integral methods, Nonlinear coherent structures in complex plasmas, Astrophysical-cosmic-space applications.

Text Books:

1. Chen, F. F., *Introduction to Plasma Physics and Controlled Fusion*, 2nd ed. (Plenum, New York, 1984).

2. Bittencourt, J. A., *Fundamentals of Plasma Physics*, 3rd ed. (Springer, New York, 2004).
3. Bellan, P. M., *Fundamentals of Plasma Physics* (Cambridge, UK, 2006).
4. Piel, A., *Plasma Physics: An Introduction to Laboratory, Space and Fusion Plasmas* (Springer, Heidelberg, 2010).
5. Pecseli, H. L., *Waves and Oscillations in Plasmas* (CRC Press, New York, 2013).

Reference Books:

1. Swanson, D. G., *Plasma Waves* (IoP, Bristol, 2003).
2. Kono, M. and Skoric, M. M., *Nonlinear Physics of Plasmas* (Springer, Berlin, 2010).
3. Hasegawa, A., *Plasma Instabilities and Nonlinear Effects* (Springer, Berlin, 1975).
4. Davidson, R. C., *Methods in Nonlinear Plasma Theory* (Academic Press, New York, 1972).
5. Nicholson, D.R., *Introduction to Plasma Theory* (Wiley, USA, 1983).

Course Code	Course Name	L-T-P	CH	CR	Remarks
	Nano-Science				
PI 562	Quantum Effects in Low Dimensional Systems	2-1-0	3	3	
PI 563	Physics of Nano Devices	2-1-0	3	3	

PI-562: Quantum Effects in Low Dimensional Systems (L2-T1-P0-CH3-CR3)

Course Objective: The course aims to survey various ground states of condensed matter many particle systems and explore their excitations and other properties in reduced dimension. The students will learn the appropriate theoretical framework for understanding and exploring existing physical systems and with the possibilities to predict new by using microscopic physical laws.

Expected outcome: On completion of the course, the student should be able to understand the governing laws required to understand physical behaviour in micro and nano dimensional condensed matter systems.

Course Contents:

Unit 1

Quantum mechanical treatment for quantum well; parabolic well, rectangular well, triangular well, cylindrical well and spherical well; quantum wire and quantum dots; quantum size effect, size and dimensionality effects on density of states, Bohr excitons, strong and weak confinements. [6 Lecture hours]

Unit 2

Surface and its specificity, surface structure, Terrace-Ledge-Kink model, binding sites and diffusion, surface diffusion model, surface electronic state, structural defects at surfaces, Growth and epitaxy, growth modes, interfaces, surface energy and surface tension, surface plasmonics, Non-equilibrium growth, Ostwald ripening, Hall-Petch relation, grain correlated properties, Langmuir-Blodgett films, self-assembled monolayers, thermodynamics and kinetics of adsorption and desorption, lateral interaction, Chemisorption, physisorption. [8 Lecture hours]

Unit 3

Aperiodic solids and Quasicrystals, Fibonacci sequence, Penrose lattices and their extensions in 3 dimensions; Special carbon solids: Fullerene, Graphene and Carbon Nanotube - Structure, formation and characterizations; Synthesis; Density of states, Elementary electronic properties and band structure; Usual properties of Graphene – Dirac Fermion, single wall and multiwall carbon nanotube, Carbon Nanotubule based electronic devices, Transition Metal Dichalcogenide (TMDC). [5 Lecture hours]

Unit 4

Quantum mechanical modelling of materials: Hartree Fock and Density Functional Theory. Atomic pseudopotentials, Basis sets: Plane Waves and Augmented Basis sets. Plane Wave based DFT calculations. Simplified Approaches to the electronic problem: Tight binding methods;

Monte Carlo and Molecular dynamics simulations; [10 lecture hours].

Unit 5

Structure: X-ray Diffraction (XRD) patterns, Intensities of reflections, Thermal effects on diffraction patterns, Identification of phases. Effects of disorder, Strain and Crystallite size; Morphology: Scanning Electron Microscopy (SEM), Energy-dispersive and wavelength-dispersive spectrometry, Transmission Electron Microscopy (TEM), Selected Area Diffraction Patterns (SAED), Diffraction contrast to image defects;

Defect: Positron annihilation lifetime spectroscopy, defect analysis from PAS spectroscopy, defect property correlation. [10 Lecture hours].

<u>Text Books:</u>

1. G. Cao and Y. Wang, *Nanostructures and Nanomaterials: Synthesis, Properties and Applications*, 2nd edition, (World Scientific, 2011).
2. Jr. C. P. Poole, and F. J. Owens, *Introduction to Nanotechnology.* (Wiley, 2003).
3. C. Kittle, *Quantum Theory of Solids.* (Wiley, 2015).
4. N. W. Ashcroft and N. D. Mermin, *Solid State Physics.* (Cengage Learning Asia Pvt Ltd, Singapore, 2016).
5. J. Davis, *The Physics of Low-dimensional Semiconductors: An Introduction,* (Cambridge University Press, 1998).
6. J. P. Colinge and C. A. Colinge, P*hysics of Semiconductor Devices,* (Springer, 2007).
7. R. Zallen, *The Physics of Amorphous Solids* (Wiley VCH, 1998)

<u>Reference Book:</u>

1. K. Ariga, *Manipulation of Nanoscale Materials: An Introduction to Nanoarchitectonics (Royal Society of Chemistry, 2012)*
2. *W. Jones, and N. H. March, Theoretical Solid State Physics (Courier Corporation, 1985).*
3. G. Giuliani and G. Vignale*, Quantum Theory of the Electron Liquid (Cambridge Uni. Press, 2005)*
4. P. Fazekas, *Lecture Notes on Electron Correlation and Magnetism*. (World Scientific, 1999).
5. G. D. Mahan, *Many Particle Physics* (Springer Science & Business Media, 2000).
6. N. F. Mott and E. A. Davies, *Electronic Processes in Non-crystalline Materials* (Oxford *University Press, 2012)*
7. J. Solyom, *Fundamentals of the Physics of Solids, Volumes 1, 2, and 3. (springer, 2007).*

PI-563: Physics of Nano Devices **(L2-T1-P0-CH3-CR3)**

Course Objective: The course aims to connect the quantum theory of solids to deal with interacting quantum systems to design devices for their practical use with various physical properties. Emphasis is on developing coherent directions for understanding and utilizing the concepts in nanodimensions for practical applications.

Expected outcome: On completion of the course, the student should be able to understand and design the macroscopic properties of nano dimensional devices in terms of microscopic scale phenomena.

Course Contents:

Unit I

Ballistic transport; Phase coherence, Aharonov – Bohm effect; quantized conductance, Landauer formula, conductance behavior of quantum point contact; Landauer – Buttiker formula for multileads, edge states – explanation of quantum hall effect; Single electron transport – Coulomb blockade, single electron transistor (SET), molecular electronics; Kondo effect in Nanostructures. [6 Lecture hours]

Unit II

Magnons, Exchange Interactions. Magnetic Anisotropy, Order and Broken symmetry, Consequences of Broken Symmetry, Heisenberg and Ising Model, Equation of motion for Domain walls, Superparamagnetism, Stoner-Wohlfarth model, Nuclear magnetic resonance, Magnetic Resonance Imaging. [8 Lecture hours]

Unit III

Ordinary and anisotropic magneto-resistance, mechanism; Giant Magneto-resistance (GMR): basic properties, mechanism, application – spin valves and spin switches; Colossal magnetoresistance (CMR): basic properties and phase diagram, comparison with GMR; structuretolerance factor, effect of doping, charge ordering; Theoretical understanding – Double exchange mechanism, crystal field splitting and Jahn-Teller distortion, electron-phonon coupling, Application-Magnetoresistive devices, Applications of superconductors in quantum computation. [9 Lecture hours]

Unit IV

Family tree of FET: General characteristics – field dependent mobility, two region model and saturated velocity model, related field effect devices, Surface charge in MOS-capacitors; Capacitance voltage characteristics of MIS structure.

Types of MOSFET, Basic devices characteristics, Non-equilibrium conditions, linear and saturation regions, subthreshold region, mobility behaviour, temperature dependence, threshold shift, short channel effects, subthreshold current, FAMOS, VMOS; Charge coupled devices (CCD); interface trapped charge, charge storage, basic CCD structure, Charge storage and frequency response, buried channel CCD. [10 Lecture hours]

Unit V

Applications of heterojunctions, white light LED, OLED, Quantum well, quantum dot and quantum cascade lasers, photodetectors and photovoltaics. Space charge limited current, Fowler Nordheim equations, field emission devices.

Magnetic Memory, Shape memory, resistive switching, DRAM and FRAM, piezoelectric transducers and actuators, spin injection, transport and spin valve devices. [6 Lecture hours]

Text Books:

1. N. W. Ashcroft, N. D. Mermin, *Solid State Physics*, (Cengage Learning Asia Pvt Ltd, Singapore, 2016).
2. M. P. Marder, *Condensed Matter Physics* (John Wiley & Sons, 2010).
3. H. Ibach and H. Luth, *Solid State Physics* (Springer, 2009).
4. D. A. Neamen, *Semiconductor Physics and Devices*, 3 rd edition, (Tata McGraw-Hill, 2002).
5. B. G. Streetmann, *Semiconductor Devices*, (PHI, 2006).
6. M. Shur, *Physics of Semiconductor Devices*, (PHI, 1995).
7. J. Davis, *The Physics of Low-dimensional Semiconductors: An Introduction*, (Cambridge University Press, 1998).
8. J. P. Colinge, and C. A. Colinge, *Physics of Semiconductor Devices*, (Springer, 2007).

Reference Books:

1. Philip Phylips, *Advanced Solid State Physics* (Cambridge University Press, 2012).
2. W. Jones, and N. H. March, *Theoretical Solid State Physics* (Courier Corporation, 1985).
3. G. Giuliani and G. Vignale, *Quantum Theory of the Electron Liquid* (Cambridge Uni. Press, 2005).
4. P. Fazekas, *Lecture Notes on Electron Correlation and Magnetism*. (World Scientific, 1999).
5. J. Solyom, *Fundamentals of the Physics of Solids, Volumes 1, 2, and 3. (springer, 2007).*

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