Appendix - VI (I)

DEPARTMENT OF PHYSICS

Scheme of Examinations and Syllabus for
the M.Sc. Physics Degree Program

Approved by the Board of Studies in Physics on 22 March 2024

(From 2024 admission onwards)

Cochin University of Science and Technology
Cochin - 682 022

Website: http://physics.cusat.ac.in

Preamble:

Physics is one of the fundamental scientific disciplines that deal with the universe's fundamental laws ranging from nano to cosmic scale. It is one of the oldest academic disciplines that emerged during the 17th century and continues to be a dynamic and evolving field. The knowledge of physics is indispensable to deepen our understanding of the world around us and for technological advancements that can shape our lives in profound ways. Scientifically advanced people are a prerequisite for a society to become a developed one in every aspect. Becoming a developed nation depends upon creating a critical mass of researchers who work on some of the forefront areas of scientific knowledge. Building quality manpower in fundamental subjects such as physics is essential for a society to create a strong foundation in science and technology and advance further.

The Department of Physics of Cochin University of Science and Technology envisions carrying out this mission by navigating students through quality advanced training in Physics and engaging in good scientific research through its M.Sc. program. The Department is known for its collaborative and inclusive research environment that can help students develop a scientific temper, enabling them with skills useful for teaching, research, and industrial careers. The students are trained to develop excellent analytical and computational skills, which are imperative for success in any field in today's world.

Our M.Sc. syllabus is designed with the view that a student completing the course will have mastery of several specialized fields in physics. This is achieved through providing advanced elective topics in both theoretical and experimental physics. An entire semester devoted to Project work and seminars complements the advanced courses to give the students a firsthand experience in scientific research. The program is crafted to align with the latest trends and technological advancements in education. An increased focus on learning and using various computational tools in the curriculum ensures that the students are equipped for today's digital age.

Program Specific Outcomes: M.Sc. Physics

PSO1: Attain mastery of advanced topics in Physics as per the aptitude of students.

PSO2: Acquire excellent analytical and computational skills.

PSO3: Equip the students to take up scientific research and teaching in academia/industry as a career and engage in lifelong learning.

PSO4: Gain hands-on experiance on advanced scientifi

c experiments and instrumentation.

PSO5: Acquire excellent abilities in various aspects of science communication.

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Scheme

Semester – I

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
24-318-0101	Mathematical Physics	C	50	50	100	4
24-318-0102	Classical Mechanics	C	50	50	100	4
24-318-0103	Electrodynamics	C	50	50	100	4
24-318-0104	Quantum Mechanics - I	C	50	50	100	4
24-318-0105	Advanced Experiments in Physics Lab - I	C	100	-	100	3
	Total		300	200	500	19

Semester – II

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
24-318-0201	Quantum Mechanics – II	C	50	50	100	4
24-318-0202	Statistical Mechanics	C	50	50	100	4
24-318-0203	Atomic and Molecular Spectroscopy	C	50	50	100	4
24-318-0204	Advanced Electronics	C	50	50	100	4
24-318-0205	Advanced Experiments in Physics Lab - II	C	100	-	100	4
	Total		300	200	500	20

Semester – III

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
24-318-0301	Nuclear and Particle Physics	C	50	50	100	4
24-318-0302	Solid State Physics	C	50	50	100	4
24-318-03xx	Elective – I *	E	50	50	100	4
24-318-03yy	Elective – II *	IE	50	50	100	4
24-318-0304	Advanced Experiments in Physics Lab - III	C	100	-	100	4
	Total		300	200	500	20

Semester – IV

Course Code	Name	C/E	Marks Distribution			
			Cont. eval.	End semester	Total	Credit
24-318-0401	Major Project[@]	C	200	200	400	16
24-318-0402	Online course (MOOC) **	E	-	100	100	2
24-318-04zz	Elective – III (Online Mode) *	E	50	50	100	4
	Total		250	350	600	22

Total credit requirement for the Program: 80

There will be no end semester examination for the lab courses and they will have only continuous evaluation.

* Elective - I and Elective - III (Online mode) are Departmental elective courses. i.e offered by the faculty members of the Department. Elective – II is the interdepartmental elective (IE) course. Replace *xx*, *yy* and *zz* with selected elective course codes. Classes and continuous evaluation of Elective-III will be conducted fully in online mode so that students who do major project in other institutions have no difficulty attending it. The mode of end semester examination of Elective-III will be decided by the Department Council before the examination.

@Regarding the Major Project the following directions may be followed:

(a) The major project can be done within the department/other departments in CUSAT or in an external institution of National/International reputation. i.e. institutions like, IISc Bangalore, Various IIT's, IISERs, Central Universities, CSIR laboratories, NITs, TIFR, Raman Research Institute, IIA, inter university centres like IUCAA, NPOL, ISRO, DRDO, IIEST, industrial organization, etc and any other equivalent institution.

(b) If a student wants to do his/her project in an external institution he/she has to find the supervisor from a nationally/internationally reputed institution like as mentioned above. A consent letter/email from the external supervisor should be produced to the Department Head/Coordinator of the batch. The consent letter can be considered by the Department council/Department Head and approval can be given to the student to pursue the project with the supervisor concerned.

(c) An internal faculty in charge must be assigned by the Department Council/Department Head to each student who is doing the project in other institutions/departments.

(d) The internal faculty in charge will periodically monitor the progress of the students assigned to him/her.

(e) Continuous evaluation of the project must be done by the supervisor. In the case of projects done outside the department, this can be done either by the external supervisor alone or by internal faculty in charge (in cases where the external supervisor is not able produce an official evaluation statement) or by both the internal and external supervisors together.

(f) The department shall arrange a mid-term presentation for all students. This will form a part of the continuous evaluation.

(g) The students must submit a report at the end of the project, which is duly signed and recommended by the supervisor on or before the date stipulated by the Department. For projects done outside, the report must be duly signed by the external supervisor.

(h) The end semester evaluation in the form of a presentation followed by viva based on the project will be done in the Department by a committee appointed by the Department Council/Department Head.

** Online course 24-318-0402 can be selected by the students from a set of courses approved by the Department Council. The Department can recommend courses from reputed platforms like Swayam (UGC), Coursera, CUSAT - MOOC etc. The following guidelines will be applicable for the online course.

(a) A sub-committee appointed by the Department council can approve a set of courses that the students in the Department can take. This will be based on considerations such as the length of the course, the relevance of its content to the program, etc. The list of approved courses will be notified to the students before the beginning of the first semester. The students are allowed to choose a course from this approved set only.

(b) The credit given by the department for such a course will be two regardless of its duration.

(c) Students may register and complete the online course at their convenience during the two year period of the program but before the submission of the final project report.

(d) At the end of the course, the student should produce a valid document regarding the successful completion of the Course and stating his/her marks/grades. The Department Council will ascertain that the document produced is satisfactory and recommend awarding two (2 only) credits for the course along with the marks/grades obtained.

(e) If a student fails a course, he/she may take the same or another approved course after informing the council.

Syllabus

Semester I

24-318-0101: Mathematical Physics

Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective:

This course introduces different mathematical tools used in physics to the students. The course aims to prepare the students for understanding and applying various mathematical formalisms. The material covered in this course is very important for students as the mathematical techniques introduced find applications in every branch of physics and other quantitative sciences.

Course Outcome:

CO	CO Statement	CL
CO1	Demonstrate an understanding of the meaning of gradient, divergence and curl. Work with them in different coordinate systems, and solve problems involving scalar and vector fields	Understand, Apply
CO2	Demonstrate an understanding of basic tensor analysis	Understand
CO3	Solve problems involving calculus of functions of a complex variable	Apply
CO4	Solve a second order linear differential equation	Apply
CO5	Solve important partial differential equations such as Laplace equation, wave equation and Poisson equation by the method of separation of variables	Apply
CO6	Solve algebraic & differential equations, and calculate definite integrals numerically	Apply
CO7	Solve basic problems in probability and demonstrate a deep understanding of the Binomial, Poisson and Gaussian probability distributions	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	3	1	0	1
CO2	1	3	1	0	1
CO3	1	3	1	0	1
CO4	1	3	1	0	1
CO5	1	3	1	0	1
CO6	1	3	1	0	1
CO7	1	3	1	0	1

Module I

Review of vector calculus. Orthogonal curvilinear coordinates, cylindrical and spherical polar coordinates. Vector integration and integral theorems. Tensor analysis: Contravariant and covariant vectors, Basic operations with tensors, Quotient law, The line element and metric tensor.

Module II

Complex numbers, functions of a complex variable, mapping, branch lines and Riemann surface. Calculus of functions of a complex variable, elementary functions of z. Complex integration. Series representations of analytic functions. Integration by the method of residues, evaluation of real definite integrals.

Module III

Solution of linear second order differential equations. The Euler linear equation. Solutions in power series - Frobenius method, Bessel's equation. Simultaneous equations. Partial differential equations, Solutions of Laplace's and wave equation, solution of Poisson's equation - Green's function method, Laplace and Fourier Transform methods.

Module IV

Numerical methods: Interpolation. finding roots of equations, graphical methods, method of linear interpolation, Newton's method. Numerical integration, the rectangular rule, The trapezoidal rule, Simpson's rule. Numerical solutions of differential equations, Euler's method, Runge-Kutta method, equations of higher order, system of equations. Least-squares fit.
Probability theory - definitions and sample space. Random variables and probability distributions. Calculating expectation and variance. The Binomial, Poisson and Gaussian distributions.

Text Books:

1. Mathematical methods for physics and engineering, K. F. Riley, M. P. Hobson and S. J. Bence, Cambridge Universality Press (2006).

2. Mathematical Methods for Physicists Paperback (7th Edition), Arfken, Elsevier (2012).

Reference Books:

1. Mathematical Methods for Physicists: A Concise Introduction, Tai L. Chow, Cambridge University Press (2001).

24-318-0102: Classical Mechanics

Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective:

The course aims to develop an understanding of Lagrangian and Hamiltonian formulation which enables the students for simplified treatments of many complex problems in classical mechanics and provides the foundation for the modern understanding of dynamics. In a detailed way, since this course forms the foundation for the study of many areas of Physics such as Quantum mechanics, it apprises the students about Lagrangian and Hamiltonian formulations. The course aims:

- To define the concepts of Lagrangian Mechanics.
- To interpret the concepts of Hamiltonian Mechanics and explain generating function, canonical transformation, Poisson brackets. To formulate the method of Hamilton-Jacobi techniques.
- To illustrate the dynamics of a rigid body and non-inertial frames of reference.
- To formulate the method of Hamilton-Jacobi and action-angle variable techniques.
- Understanding the basics of non-linear dynamics in physics and their applications

Course Outcome:

CO	CO Statement	CL
CO1	Understanding the drawback of Newtonian formulation of mechanics. Construct Lagrangian for different physical systems and Lagrange's equation of motion and solve it. (Module 1)	Understand
CO2	Understanding the Hamiltonian formalism in solving physics problems and understanding the Poisson bracket method in tackling physical problems. Understanding the Hamiltonian-Jacobi formulation and its applications. (Module 2)	Understand
CO3	Understanding the techniques for solving the problems of rigid body mechanics based on Lagrange's formulation (Module 3)	Understand
CO4	Understanding the basic characteristic features of non-linear dynamics (Module 4)	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	3	3	0	1
CO2	3	3	3	0	0
CO3	2	2	2	0	1
CO4	2	3	3	0	2

Module I

Lagrangian formulation: Mechanics of a system of particles(brief review)- Constraints - Generalized coordinates - D'Alembert's principle and Lagrange's equations - Calculus of variations and Derivation of Lagrange's equations from it. Symmetry properties and Noether's theorem. Application of Lagrange's equation to Central force problem - equivalent one dimensional problem - classification of orbits - the differential equation for orbits - Kepler problem.

Module II

Hamiltonian Mechanics: Hamilton's equation from variation of principle (Principle of least action with fixed end points), cyclic coordinates. Equations of canonical transformation - examples. Poisson Brackets- Equations of motion , angular momentum Poisson Bracket relations. Hamilton-Jacobi equation - harmonic oscillator problem - Hamilton's characteristic function.

Module III

Rotational dynamics: Independent coordinates of a rigid body. Orthogonal transformations - Euler angles - rigid body equations of motion- angular momentum and kinetic energy of motion about a point- inertia tensor- Solving rigid body problems and Euler equations of motion- torque free motion of a rigid body- symmetric top. Rate of change of a vector, centrifugal and Coriolis forces.

Module IV

Nonlinear dynamics and chaos: Historical overview, FIxed points and stability, Linear stability analysis, Classification of Bifurcations, Chaotic trajectories, Liapunov exponent, Lorentz map, Logistic map: Cobweb diagram; Fixed points, Onset of chaos, Poincare maps, Fractals and dimensionality : Cantor set, Sierpinski carpet. (Sections from Text book 2)

Text Books:

1. H. Goldstein, C. Poole and J. Safko , Classical Mechanics, Third Edition, Pearson (2011).
2. Nonlinear Dynamics and Chaos: With Applications to Physics, Biology, Chemistry and Engineering. SH Strogatz, CRC Press, 2018.

Reference Books:

1. V. B. Bhatia , Classical Mechanics, Narosa (1997).
2. Landau and Lifshitz, Mechanics Vol. I, 3rd Edition, Butterworth-Heinemann (1976).
3. Rana and Joag, Classical Mechanics, McGraw-Hill Education (India) Pvt Limited, (2001).

24-318-0103: Electrodynamics

Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective:

The course aims to develop the fundamental concepts in classical electrodynamics. For students who are already familiar with the basics of electromagnetism, Maxwell's equations will be introduced and they will be equipped with advanced mathematical methods to tackle various boundary value problems in electrodynamics. By introducing the time dependent fields, the connection between magnetic and electric fields and the role of special theory of relativity in understanding the electromagnetic phenomena is also explained. The main objectives of the course are:

- To explain the various techniques for solving the boundary value problems.
- Investigate various consequences of Maxwell's equations. Viz. Gauge invariance, conservation laws and boundary conditions of electromagnetic fields at an interface.
- Application of Maxwell's equations for the study of propagation of electromagnetic waves in various media.
- To understand and develop the theory of wave guides and electromagnetic radiation phenomena.
- To look at the close relationship between electromagnetic phenomena and special theory of relativity.

Course Outcome:

CO	CO Statement	CL
CO1	Will get familiarized with the various boundary value problems and learn different techniques for its solutions (Module 1)	Understand
CO2	The introduction of conservation laws and investigation of the propagation of electromagnetic waves in various media leads to a clear understanding and applications Maxwell's equations (Module 2)	Understand
CO3	Will learn some of the other important consequences of Maxwell's equations by studying: 1. Electromagnetic wave propagation in wave guides and conducting media. 2. The electromagnetic radiation phenomena (Module 3).	Understand
CO4	Will understand the important concepts involved in special theory of relativity and its intimate connection to the electrodynamics phenomena (Module 4).	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	2	2	1	1
CO2	1	2	2	1	1
CO3	1	2	2	1	1
CO4	1	2	2	1	1

Module I

Review of vector calculus, Multipole expansion- electrostatic multipole moments - energy of a charge distribution in an external field. Boundary value problems, Introduction to Green's function, formal solution with Green's functions, electrostatic potential energy. Method of images- point charge near a grounded conducting sphere-point charge near a charged insulated conducting sphere - conducting sphere in an uniform electric field. Laplace equation in spherical polar coordinates- boundary value problem with azimuthal symmetry.

Module II

Maxwell's equations. Vector and scalar potentials - gauge transformations - Lorentz gauge, Coulomb gauge. Poynting's theorem and conservation of energy and momentum, complex Poynting vector. Boundary conditions for the electric and magnetic fields at an interface - Plane electromagnetic wave in a non-conducting medium, linear and circular polarization, reflection and refraction at a dielectric interface, polarization by reflection and total internal reflection.

Module III

Waves in conducting or dissipative medium-skin depth. Cylindrical cavities and wave guides, metallic wave guides, modes in a rectangular wave guide, resonant cavities. Green's function for wave equation. Simple radiating systems- fields and radiation of a localized oscillating source - electric dipole field and radiation, magnetic dipole and electric- quadrupole fields.

Module IV

Special theory of relativity - Postulates of relativity, Lorentz transformations, four vectors, addition of velocities, four velocity, relativistic momentum and energy, mathematical properties of space-time, matrix representation of Lorentz transformation. Dynamics of relativistic particles. Lagrangian and Hamiltonian of relativistic charged particle, motion in a uniform static electric and magnetic fields, magnetism as a relativistic phenomenon, transformation of the electromagnetic field, electromagnetic field tensor.

Text Books:

1. J. D. Jackson, Electrodynamics, 3rd Edition, Wiley (2009).
2. Introduction to Electrodynamics, D. J. Griffiths, 4th Edition, Cambridge University Press (2017).

Reference Books:

1. The Classical theory of fields - L D Landau and E M Lifshitz Pergamom Press Ltd (1971)
2. Electrodynamics - M. Chaichian, I. Merches, D Radu and A. Tureanu, Springer Verlag, (2016)
3. Classical Electrodynamics - W Greiner , Springer Verlag , New York (1998)

24-318-0104: Quantum Mechanics I

Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective:

The primary aim of the course is to provide an introduction to the mathematical formulation of Quantum Mechanics along with its physical principles. In addition, this course discusses some of the important time-independent 1D and 3D problems in Quantum Mechanics. The general objectives of course are:

- To formulate Quantum Mechanics using abstract mathematical structure of linear vector spaces.
- Describe the postulates of Quantum Mechanics and discuss the concepts of state, observables and time evolution in Quantum Mechanics.
- Discuss Schrodinger and Heisenberg formulations of Quantum Mechanics.
- Discuss various 1-dimensional and 3-dimensional time independent problems in quantum mechanics

Course Outcome:

CO	CO Statement	CL
CO1	Students will get an understanding of linear vector spaces which are fundamental to quantum mechanics . They will also learn concepts and properties of inner-product, basis, linear operators (in particular Hermitian operators) (Module I)	Understand
CO2	A thorough understanding of the postulates of quantum mechanics and other key concepts is obtained through the 2 nd module. The connection between classical and quantum physics is also elaborated in this module. (Module II)	Understand
CO3	Students will solve various 1-dimensional time independent problems in quantum physics. This will help them to formulate such problems and understand the general properties of solutions (Module III).	Understand, Apply
CO4	The student will learn to solve various 3-dimensional time independent problems in Quantum Mechanics. Study of angular momentum and atomic structure will be crucial to understand other subjects like spectroscopy. Quantum Theory of scattering is introduced (Module IV).	Apply, Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	1	2	0	0
CO2	2	2	2	0	1
CO3	2	2	2	0	0
CO4	2	3	2	2	0

Module I

Linear Vector Spaces: de Broglie's hypothesis: matter waves and experimental confirmation; Linear vector spaces: inner product, Hilbert space, Wave Functions; Linear operators: Hermitian operators, Projection operators, Commutator algebra, Unitary operators, Eigenvalues and Eigen vectors of a Hermitian operator; Basis: Representation in discrete bases, Matrix representation of kets, bras, and operators, Change of bases and unitary transformations, Matrix representation of the eigenvalue problem, Representation in position bases.

Module II

Postulates of Quantum Mechanics: Postulates of Quantum Mechanics: State of a System, Probability Density, Superposition Principle, Observables as Operators, Position and Momentum operators, Position and Momentum representation of state vector, Connecting the position and momentum representations, Measurement in quantum mechanics, Expectation values, Commuting operators and Uncertainty relations; Time evolution of the state: Time-independent potentials and Stationary States, Time evolution operator, infinitesimal and finite Unitary Transformations; Conservation of probability; Time evolution of expectation values: Ehrenfest theorem; Poisson's brackets and commutators; Matrix and Wave mechanics.

Module III

Time independent 1D problems: Discrete, continuous and mixed spectrum; symmetric potentials and parity; Infinite square well potential; Symmetric potential well; Finite square well potential: Scattering and bound state solutions; Free particle; Delta function potential; Harmonic oscillator.

Module IV

Time independent 3D problems: Free particle in 3-dimensions: spherically symmetric solution; Particle in a 3D box; Schrodinger equation in presence of central Potential; Orbital angular momentum: eigen values and eigen functions of of L^2 and L_z ; Hydrogen Atom. [Text Book: Nourdine Zettili]. Scattering Theory: Kinematics, Scattering Cross Section, Green's function and Scattering am- plitude. Born approximation and its validity, Born series [Text Book: Mathews and Venkate- san].

Text Books:

1. Nourdine Zettili, Quantum Mechanics Concepts and Applications, 2nd edition, Wiley, 2009.
2. Mathews and Venkatesan, Textbook of Quantum Mechanics, 2nd edition, Tata McGraw Hill, 2010.

Reference Books:

1. David Griffiths, Introduction to Quantum Mechanics, 2nd edition, Prentice Hall, 2004.
2. J. J. Sakurai, Modern Quantum Mechanics, Revised edition, Addison-Wesley,1994
3. R. Shankar, Principle of Quantum Mechanics, 2nd edition, Kluwer Academic, 1994
4. V.K. Thankappan, Quantum Mechanics, 4th edition, New Age International, 1985

Semester II

24-318-0201: Quantum Mechanics II

Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The course aims to provide an introduction to advanced level topics in quantum mechanics. These include quantum theory of angular momentum, approximate methods for solving time dependent and time independent problems and an introduction to relativistic and multi-particle quantum mechanics. The general objectives are:

- To formulate a quantum theory of the total and the spin angular momentum of quantum particles.
- Formulate the time independent perturbation theory to find energy eigen values and eigen functions of problems that are not exactly solvable.
- Introduce WKB approximation and variational method for time-independent potentials.
- Introduce time-dependent perturbation theory to solve problems where potential is dependent on time.
- Formulate relativistic quantum mechanics
- Introduce the multi-particle quantum systems and their wave-functions. Discuss indis- tinguishably of identical particles.

Course Outcomes

CO	CO Statement	CL
CO1	Students will get a complete understanding of the total and the spin angular momenta of fundamental particles. They will also understand how angular momenta will add in a combined system. This is crucial to understand spectroscopy (Module I)	Understand
CO2	Students will be able to apply approximate methods like the perturbation theory, WKB method and variational method to solve time-independent problems that are not exactly solvable (Module II)	Understand
CO3	Perturbative approach to solve time-dependent problems will be understood. Various applications like Fermi's Golden rule, semi-classical theory of radiation will also be introduced (Module III)	Understand, Apply
CO4	Student will understand to formulate a relativistic theory of quantum mechanics and also multi particle quantum mechanics (Module IV)	Apply, Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	2	2	2	0
CO2	2	3	2	0	1
CO3	2	3	2	0	0
CO4	2	2	2	2	1

Module I

Quantum Theory of Angular Momentum: Review of Orbital angular momentum; General theory of angular momentum: Commutation relations, eigenvalues, Matrix representation of angular momentum; Spin angular momentum: Pauli spin matrices and their properties, Two component wave function, Pauli's equation; Addition of Angular momentum and Clebsch-Gordan coefficients.

Module II

Time Independent Perturbation theory: Time-independent perturbation theory: Non degenerate perturbation theory, The Stark effect, Degenerate perturbation theory: Spin Orbit Coupling, Fine structure; Variational method; WKB method, Bound states for potential wells, Transmission probability for tunnelling through a potential barrier.

Module III

Time Dependent Perturbation theory Schrodinger and Heisenberg Pictures of Quantum Mechanics; The interaction Picture and Time- dependent perturbation theory: Transition probability; Constant perturbation; Harmonic perturbation; Adiabatic and Sudden approximations. Interaction of atoms with radiation: Transition rates for absorption and stimulated emission of radiation, Dipole approximation, Electric dipole selection rules.

Module IV

Relativistic and Multi Particle Quantum Mechanics Klein-Gordon equation: Free particle solutions, Probability density. Dirac equation: Dirac matrices, Plane wave solutions, Spin of Dirac particle, Negative energy solutions.[Mathews and Venkateshan]
Many Particle Systems: Interchange symmetry; Systems of distinguishable non-interacting particle. Systems of identical particles: Exchange degeneracy, Symmetrization postulate; Constructing symmetric and anti-symmetric wave functions, Pauli's exclusion principle [Nourdine Zettili].

Text Books:

1. Nourdine Zettili, Quantum Mechanics Concepts and Applications, 2nd edition, Wiley, 2009
2. Mathews and Venkatesan, Textbook of Quantum Mechanics, 2nd edition, Tata McGraw Hill, 2010.
3. Walter Greiner, Relativistic Quantum Mechanics Wave Equations, 3rd Edition, Springer, 2000 (Module IV)

Reference Books:

1. J. J. Sakurai, Modern Quantum Mechanics, Revised edition, Addison-Wesley,1994.
2. Walter Greiner, Relativistic Quantum Mechanics Wave Equations, 3rd Edition, Springer, 2000 (Module IV)
3. R. Shankar, Principle of Quantum Mechanics, 2nd edition, Kluwer Academic, 1994
4. David Griffiths, Introduction to Quantum Mechanics, 2nd edition, Prentice Hall, 2004

5. V.K. Thankappan, Quantum Mechanics, 4th edition, New Age International, 1985 (Module IV)

24-318-0202: Statistical Physics

Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective:

This course introduces students to the fundamental principles of equilibrium statistical physics. The focus is on developing a formalism to derive macroscopic or emergent quantities of various physical systems. The course is a very relevant one for students at a Master's level, as the formalism introduced underpins all of material science and other branches where one is interested in the collective behavior of a system.

Course Outcome:

Upon completion of this course, a student should be able to -

CO	CO Statement	CL
CO1	Differentiate between systems in equilibrium and out of equilibrium	Understand, Analyse
CO2	Demonstrate an understanding of the terminology, concepts and principles of describing equilibrium properties of physical systems	Understand
CO3	For a given ideal system, derive various macroscopic quantities - either using a classical or a quantum setting - using the principles learned	Apply
CO4	Derive the macroscopic properties of ideal quantum gases	Apply
CO5	Develop a basic understanding of various aspects of the statistical physics of systems with interaction between its constituent components	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	2	2	1	1
CO2	1	2	2	1	1
CO3	1	2	2	1	1
CO4	1	2	2	1	0
CO5	1	2	2	1	0

Module I

Features of macroscopic systems: Concept of equilibrium, Irreversibility and approach to equilibrium, Basic probability concepts: Statistical ensembles, Mean values and fluctuations, Statistical description of a system of particles, Micro and macro states, The microcanonical ensemble.

Module II

Thermal Interaction, Distribution of energy between macroscopic systems, Systems in contact with a heat reservoir, Canonical ensemble and the Boltzmann distribution, Partition function and Free energy, Paramagnetism, Ideal gas in canonical ensemble - mean energy and mean pressure, harmonic oscillator, Grand Canonical ensemble.

Module III

Canonical distribution in the classical approximation: Phase space of classical systems, Ideal gas, entropy of mixing and Gibbs paradox, Maxwell velocity distribution, harmonic oscillator, The equipartition theorem and its applications, Liouville's theorem.

Module IV

Statistical physics of ideal quantum gases: Ideal Fermi gas at zero and non-zero temperatures, Fermi-Dirac and Bose-Einstein integrals, Ideal Bose gas - Bose-Einstein condensation, Density operator.
Interacting systems: 1D Ising model, Mean field approach, Phase transitions, Critical point and critical exponents, Universality, Renormalization group approach (Qualitative ideas).

Text Books:

1. Statistical Physics, Berkeley Physics Course, Volume 3, F. Reif, Tata- McGraw-Hill (2008).

2. Principles of equilibrium statistical mechanics, D. Chowdhury and D. Stauffer, Wiley (2000).

Reference Books:

1. An introduction to thermal physics, Daniel V Schroeder, Pearson Education (2007).

2. Statistical Mechanics, K. Huang, Wiley India (2008).

3. Statistical Physics, Landau and Lifshitz, Elsevier (2005).

24-318-0203: Atomic and Molecular Spectroscopy

Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

Atomic and molecular spectroscopy provides a foundational understanding of quantum mechanics, which is essential for comprehending the behaviour of matter at the atomic and molecular levels. This knowledge is fundamental in physics, chemistry, and related disciplines. The objective of this course is to understand the origin of the quantized nature of atomic and molecular energy levels in a system and its applications in material characterization. The interaction between electromagnetic radiation and matter, commonly studied through spectroscopy, holds immense importance across various scientific disciplines and technological applications. This course also aims to provide detailed working principles of different laser systems, which have numerous applications in industry, material science, medicine, and telecommunications.

Course Outcomes

CO	CO Statement	CL
CO1	Describe the electronic state of atoms in terms of quantum numbers, the complexity of atomic spectra due to spin-orbit coupling, and the interpretation of term symbols. (Module 1)	Understand
CO2	Explain how atoms absorb and emit light and how this process can be affected by magnetic and electric fields. (Module 1).	Understand
CO3	Explain the contributions of transitions between rotational, vibrational and electronic states to the spectra of diatomic molecules. (Module 2)	Understand, Apply
CO4	Describe how IR and Raman spectroscopic techniques are used in molecular structure determination. (Module 3)	Apply, Analyse
CO5	Distinguish different spectroscopic techniques (absorption, fluorescence, Raman, NMR, and EPR). (Module 3)	Apply, Analyse
CO6	Write the rate equations of three-level and four-level laser systems and describe the working principle of specific laser systems. (Module 4)	Apply, Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2	2	1
CO2	3	1	2	2	1
CO3	3	1	1	2	1
CO4	3	1	1	1	1
CO5	3	1	2	1	1
CO6	3	1	3	3	1

Module I

Quantum states of electrons in atoms - Pauli's exclusion principle, calculation of spin-orbit interaction energy in one electron systems, fine structure of spectral lines in hydrogen and alkali atoms. Equivalent and non-equivalent electrons, two electron systems, interaction energy in LS and j j couplings, spectra of helium and alkaline earth elements. Normal and anomalous Zeeman effects, Stark effect, Paschen-Back effect (all in one electron system only). Hyperfine structure of spectral lines - calculation in one electron systems. Line broadening mechanisms - line shape functions for Natural, Collisional, and Doppler broadenings.

Module II

Types of molecules, rotational spectra of diatomic molecules as rigid rotor, intensity of rotational lines, The effect of isotopic substitution, energy levels and spectrum of non-rigid rotor, techniques and instrumentation for microwave spectroscopy. The vibrating diatomic molecule - simple harmonic oscillator, the anharmonic oscillator, the diatomic vibrating rotator - CO molecule. Interaction of rotation and vibrations, the vibrations of polyatomic molecules and their symmetry, the influence of rotation on the spectra of linear molecules - Electronic spectra of diatomic molecules - Born-Oppenheimer approximation, vibrational coarse structure - progressions. Intensity of vibrational transitions – the Franck- Condon principle. Dissociation energy and dissociation products. Rotational fine structure of electronic-vibrational transitions - the Fortrat diagram. Predissociation.

Module III

Raman effect - classical theory, elementary quantum theory, pure rotational Raman spectra - linear molecules, vibrational Raman spectra polarization of light and Raman effect, techniques and instrumentation of Raman and IR spectroscopy, structure determination by IR and Raman spectroscopy-simple examples, fundamentals of SERS.
Nuclear and electron spin - interaction with applied magnetic field, population of energy levels Larmor procession, NMR: NMR of hydrogen nuclei - chemical shift, techniques and instrumentation for NMR spectroscopy, medical applications of NMR - ESR spectroscopy - g factor - fine and hyperfine structure, double resonance, Basic idea of Mossbauer Spectroscopy- Recoilless emission and absorption.

Module IV

Einstein's Coefficients, Laser Fundamentals and Fabrication- Active Medium, Pumping Sources, and Optical Resonator, Phenomenon of Population Inversion, Characteristics of Laser Light, Three and Four Level Lasers - Rate Equations - Pumping Threshold, Specific Laser Systems – Ruby Laser, Nd:YAG Laser, Ti:Sapphire Laser, He-Ne Laser, Argon ion Laser, CO 2 Laser, Excimer Laser, Semiconductor Diode Lasers, Laser Applications in Industry, Material Science, Medicine, and Telecommunications.

Text Books:

1. Introduction to Atomic Spectra, H. E. White, McGraw-Hill Inc., US (1934).
2. Fundamentals for Molecular Spectroscopy, 4th Ed., C. N. Banwell and E. M. McCash, McGraw Hill Education (2017).
3. Laser fundamentals, 2nd Ed., William T Silfvast, Cambridge University Press (2008).
4. Lasers Theory and Applications, 2nd Ed., K. Thayagarajan and A.K Ghatak, Springer (2011).
5. Molecular structure and Spectroscopy (2nd Edition), G. Aruldhas, Prentice Hall of India (2007).

Reference Books:

1. Spectroscopy Vol. I, II and III, B.P. Straughan and S.Walker, Chapman and Hall (1976).
2. Introduction to Molecular Spectroscopy, G. M. Barrow, McGraw-Hill Inc.,US (1962).
3. The Physics of Atoms and Quanta (4th ed.), H. Haken and Hans C. Wolf, Springer-Verlag (1994).
4. Laser Physics, Peter W. Milonni and Joseph H. Eberly, Wiley-Blackwell (2010).
5. Optical Electronics, A.K.Gahtak and K. Thayagarajan, Cambridge University press (1989).

24-318-0204: Advanced Electronics

Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

Advanced level knowledge in electronics is essential to understand the working of computers, telecommunication systems, sophisticated analytical instruments, and other electronic appliances in our everyday life. After completion of this course, the students will be able to design different digital and analog electronic circuits for specific applications like register, counter, analog to digital converter, integrator, differentiator, comparator, waveform generators, microcontroller etc.

Course Outcomes

CO	CO Statement	CL
CO1	Understand the primary applications of the operational amplifier as an adder, subtractor, differentiator, integrator, comparator, and waveform generator etc. (Module 1)	Understand
CO2	Explain the working of different combinational and sequential logic circuits and its design using universal-NAND gates. (Module 2)	Understand
CO3	Explain the architecture of 8085 Microprocessor, instructions, and its working. Write assembly language program for 8085 Microprocessor (Module 3)	Understand, Apply
CO4	Understand the basics of microcontroller and programming it using open source development board Arduino (Module 4).	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	0	1	3	3	0
CO2	0	1	3	3	0
CO3	0	1	3	3	0
CO4	0	1	3	3	0

Module I

Ideal amplifier - operational amplifier - the basic operational amplifier, differential amplifier and its transfer characteristics, frequency response of operational amplifiers, adder, subtractor, Op-amp as differentiators, integrators, applications of differentiators and integrators, Solution of differential equations, general ideas about analog computation and simulation, other applications of Op-amps, filters, comparators, sample and hold circuits, waveform generators.

Module II

Combinational systems - Synthesis of Boolean functions, Boolean algebra, Universal gate - NAND, Integrated NAND circuit, Arithmetic circuits, Adder, Subtractor, BCD Addition, 2's complementary technique, Sequential systems - Flip flops-RS, JK, JK-MS, D-FF, Register, Buffer register, serial and parallel registers, Tristate switches, Tristate buffer registers, Bus organization in computers, Counters, Synchronous and Asynchronous counters, Ripple counters, Ring counter, Timing diagram, Fundamentals of D/A conversion,-Accuracy and resolution -ADC/DAC chips, Flash Converters.

Module III

Microprocessor architecture , memory, input/output, 8085 MPU, Instructions and timings, instruction classification, instruction format, instruction timing and operation status, Programming the 8085, data transfer instructions, arithmetic operations, logic operations, branch operations, examples of assembly language programs.

Module IV

Microcontroller basics, introduction to Arduino: open-source electronics prototyping, Basic ideas of Arduino, familiarize the Arduino board, IDE in PC/ laptop for Arduino programming(Sketch), data types, variables and constants, operators, control statements, loops, functions, string, serial communication, digital and analog input/output, getting input from sensors, practical applications.

Text Books:

1. Robert G. Irvine, Operational Amplifier Characteristics and Applications, 2nd Edition, Prentice Hall, New Jersey (1987).
2. John Ryder, Electronic Fundamentals and Applications (5th Edition), Prentice Hall, New Delhi, (1983).
3. A. Anand Kumar, Fundamentals of Digital Circuits (4-th Edition), Eastern Economy Edition (2019)
4. Ramesh Gaonkar, Microprocessor Architecture, Programming and Applications, Wiley Eastern Limited, New Delhi (1992).
5. Michael Margolis , Arduino Cookbook, O'Reilly Media (2011); Massimo Banzi, Getting Started with Arduino, O'Reilly Media (2009).

Reference Books:

1. Ramakant A. Gayakwad, Op-Amps and Linear Integrated Circuits (4 th Edition) Pearson Paperback (2015).
2. Milman and Halkias, Integrated Electronics, Mc. Graw Hill, (1983)
3. John Wakerly, Digital Design: Principles and Practices (4th Ed.), Prentice Hall (2005).
4. D. C. Green, Digital Electronics (5th Ed.), Pearson Education Ltd., (2005).
5. Giovanni Organtini, Arduino as a tool for physics experiments, J. Phys.: Conf. Ser. 1076 012026 (2018)
6. Web: https://www.arduino.cc/en/Guide/HomePage

Semester III

24-318-0301: Nuclear and Particle Physics

Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The course aims to develop an understanding of advanced nuclear physics with the underlying quantum mechanical principles. Also, the students can get the idea of different types of nuclear radiation detectors and their properties. The course provides the details of different elementary particles an its properties. In short, the course provides a good platform to carry forward the studies to higher levels.

Course Outcomes

After completing this course the students should be able to

CO	CO Statement	CL
CO1	Describe the basic properties of the nuclear force. (Module 1)	Understand
CO2	Explain the nucleon-nucleon scattering and its underlying principles. (Module 1)	Understand, Evaluate
CO3	Review the different nuclear models and nuclear reactions. (Module 2)	Understand, Evaluate
CO4	Discuss nuclear fission and its applications. (Module 2)	Understand, Apply
CO5	Classify different nuclear radiations and radiation detectors. (Module 3)	Evaluate
CO6	Explain the properties of the nucleus	Evaluate

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	3	2	0	1
CO2	3	3	2	2	1
CO3	3	3	2	1	1
CO4	3	2	3	2	0
CO5	3	2	2	3	0
CO6	3	2	3	2	0

Module I

Nuclear properties: Review of basic concepts, Nuclear radius, shape, spin, parity, Magnetic and electric moments, Nuclear binding energy. Nuclear two body problem, The deuteron, simple theory, spin dependence, tensor force, nucleon-nucleon scattering, partial wave analysis of n-p scattering, determination of phase shift, singlet and triplet potential, effective range theory, low energy p-p scattering.

Module II

Nuclear models, semi empirical mass formula, stability of nucleus, shell model, spin orbit potential, valance nucleons, Nilsson Model, Collective Model, Rotational and Vibration States.

Nuclear reactions, conservation laws, energetic, compound nuclear reactions, direct reaction, resonant reaction, nuclear fission, energy in fission, controlled fission reactions, fission reactors.

Module III

Nuclear decays: barrier penetration and alpha decay, beta decay, simple theory of beta decay, Kurie plot, parity violation in beta decay, gamma decay, multipole moments and selection rules.
Detection of nuclear radiation: Interaction of radiation with matters, gas-filled counters scintillation detectors, semiconductor detectors, energy and timing measurement.

Module IV

Meson Physics, properties of pi-mesons, decay modes, meson resonance, strange meson and baryons, CP violation in K decay.
Particle interaction and families, symmetries and conservation laws, quark model, coloured quarks and gluons, reactions and decays in the quark model, c, b and t quarks, quark dynamics.

Text Books:

1. Introductory Nuclear Physics (3rd Edition), Kenneth S. Krane, Wiley (1987).
2. The particle hunters (2nd Revised Edition), Yuval Ne'eman & Yoram Kirsh, Cambridge University Press (1996).

Reference Books:

1. Introduction to Nuclear Physics (1st Edition), Harald A. Enge, Addison Wesley (1996).
2. Concepts of Nuclear Physics, B. L. Cohen, McGraw-Hill Inc., US (1971).
3. Nuclear Physics: Theory and Experiment, R. R. Roy and B.P. Nigam, Newagepublishers (1996).
4. Theoretical Nuclear Physics, J. M. Blatt and V. F. Weisskopf, Springer-Verlag New York (1979).
5. An Introduction to Nuclear Physics (2nd Edition), S. B. Patel, New Age International (2011)
6. Introduction to Elementary Particles (2nd Revised Edition), David Griffiths, Wiley VCH (2008).

24-318-0302: Solid State Physics

Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The course aims to make the learner understand the physics of solids, which form the basic foundation for the study of other fields inside and outside the condensed matter physics. The course provides a clear picture about the development of the subject and how the knowledge about the solids and their properties used to change our society.

Course Outcomes

CO	CO Statement	CL
CO1	Understand the semiclassical and quantum mechanical models for explaining various electronic, thermal properties of solids (Module 1)	Understand, Evaluate
CO2	Develop ideas on crystal structure, reciprocal space and diffraction techniques (Module 2)	Understand, Evaluate
CO3	Summarize band theory of solids and the developments of semiconductor physics (Module 3)	Understand, Evaluate
CO4	Explore magnetic properties of solids, mean-field theories and basics of superconductivity (Module 4)	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2	0	0
CO2	3	1	2	0	0
CO3	3	1	2	0	0
CO4	3	1	2	0	0

Module I

Solids Without Considering Microscopic Structure: The Early Days of Solid State , Specific Heat of Solids - Einstein's Calculation-Debye's Calculation-Periodic (Born-von Karman) Boundary Conditions - Debye's Calculation Following Planck - Debye's "Interpolation" - Shortcomings of the Debye Theory - Electrons in Metals: Drude Theory - Electrons in an Electric Field - Electrons in Electric and Magnetic Fields - Thermal Transport - Sommerfeld (Free Electron) Theory - Basic Fermi-Dirac Statistics - Electronic Heat Capacity - Magnetic Spin Susceptibility (Pauli Paramagnetism) - Shortcomings of the Free Electron Model.

Module II

Vibrations of a One-Dimensional Mono-atomic Chain - Phonons-Crystal Momentum , Vibrations of a One-Dimensional Diatomic Chain - The Reciprocal Lattice in Three Dimensions - General Brillouin Zone Construction - Electronic and Vibrational Waves in Crystals in Three Dimensions - Wave Scattering by Crystals - Equivalence of Laue and Bragg conditions - Scattering Amplitudes - Systematic

Absences - Geometric Interpretation of Selection Rules - Methods of Scattering Experiments - Powder Diffraction - Scattering in Liquids and Amorphous Solids.

Module III

Electrons in Solids - Electrons in a Periodic Potential - Kronig-Penny Model- Bloch's Theorem- Nearly Free Electron Model - Tight Binding Model - Energy Bands in One Dimension - Energy Bands in Two and Three Dimensions - Introduction to Electrons Filling Bands - Multiple Bands - Band-Structure Picture of Metals and Insulators - Optical Properties of Insulators and Semiconductors - Direct and Indirect Transitions - Optical Properties of Metals - Optical Effects of Impurities - Electrons and Holes - Doping - Impurity States - Statistical Mechanics of Semiconductors -Band Structure Engineering - Designing Band Gaps - Non-Homogeneous Band Gaps.

Module IV

Magnetism and Mean Field Theories - Hund's Rules - Coupling of Electrons in Atoms to an External Field - Free Spin (Curie or Langevin) Paramagnetism - Larmor Diamagnetism - (Spontaneous) Magnetic Order - Ferromagnets - Antiferromagnets - Ferrimagnets - Macroscopic Effects in Ferromagnets: Domains - Domain Wall Structure and the Bloch/ Neel Wall - Hysteresis in Ferromagnets.
Superconductors - Type-I and Type-II superconductors - Meissner effect - BCS theory (qualitative) - High temperature superconductors - applications - Josephson effect.

Text Books:

1. Solid state physics, Ashcroft, Neil W. and Mermin, N., Brooks/Cole (1976).
2. The Oxford solid state basics, Simon, Steven, Oxford University Press (2004).
3. Introduction to Solid State Physics (8th Edition), Charles Kittel, Wiley (2004).

Reference Books:

1. Solid State Physics, Dekker, A. J., Macmillan (2000).
2. Solid State Physics: Structure and Properties of Materials, M.A. Wahab, 2005, Narosa Publishers.
3. Elementary solid state physics principles and applications, M Ali Omar, 2013, Pearson Education Inc.
4. Elements of x-ray diffraction (3rd edition), Cullity, B. D. and Stock, Stuart H., Prentice Hall (2001).

Elective Courses

06: 2D Materials

Course Code: 06
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective

To introduce the field of 2D materials, different classes and their properties.

Course Outcomes

CO	CO Statement	CL
CO1	To familiarise with low dimensional structures and their properties.	Understand
CO2	To learn about 2D material families (Graphene, 2D transition metal chalcogenides/carbides)	Understand
CO3	To familiarise with properties and applications of 2D materials	Understand
CO4	To introduce 2D topological materials	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	0	1	2	0
CO2	1	0	1	2	0
CO3	1	0	1	2	0
CO4	1	0	1	2	0

Module I

Schrodinger equation for an electron in a crystal- Concept of quasiparticles: electron, hole and exciton, Low dimensional structures: quantum wells, quantum wires and quantum dots. Graphene-Carbon and its allotropes-Dispersion Relation of Graphene - Dirac Points and Dirac Cones - Opening Gaps in Graphene - Electronic Properties of Graphene. Relationship between Dispersions of the 1-D and 2-D Systems, Metal contacts to graphene- Chemical bonding of metal with graphene-electrochemical equalization- orbital hybridization-characteristics of metal contact to graphene- applications of Graphene.

Module II

Introduction to 2D transition metal dichalcogenides (TMDC). Atomic and electronics Structure: Structure of individual triple layers – Bulk structure of polymorphs–Van der Waals Interlayers bonding-Electronic Structures. Raman and electronic spectra of TMDCs. Synthesis of Transition Metal Dichalcogenides – Top down Method:- Mechanical Exfoliation –Liquid Exfoliation-Electrochemical Exfoliation – Bottom up Method:-Chemical Vapour (CVD) – Pulsed Laser Deposition (PLD). Properties: Mechanical Properties-Thermal conductivity –Thermoelectric properties- optical properties-applications of TMDC.

Module III

Introduction to 2D transition metal carbides and nitrides, The M n+1 AX n phases- precursors for MXenes, Top down MXene synthesis (selective etching), Bottom up synthesis of 2D transition metal carbides and nitrides, Effect of synthesis methods on the structure and defects of two dimensional MXenes, MXene surface chemistry, Techniques of MXene delamination into single flakes, MXene films, coatings and bulk processing, Predicted electronic, magnetic, mechanical and optical properties of MXenes- applications of MXenes.

Module IV Two dimensional topological materials, Dirac/Weyl equation, topological insulators, Weyl semimetals, topological superconductors, electron transport in two dimensional topological materials, Weyl fermions in condensed matter systems, Fermi arcs, intrinsic anomalous Hall effect, magnetic breakdown and Klein tunnelling effect, Landau level collapse effect - applications of 2D topological materials.

Text Books :

1. Munarriz Arrieta, Modelling of Plasmonic and Graphene Nanodevices, Springer 2014.
2. S.V. Gaponenko, Optical properties of Semiconductor Nano crystals, Cambridge university press 1998.
3. Vasilios Georgakilas, Functinalization of Graphene, Wiley - VCH Verlag GmbH & Co. KGaA, 2014.
4. Two-DimensionalTransition-Metal Dichalcogenides, Alxander V Kolobov, Junji Tomenaga , https://www.springer.com/series/856.
5. Y. P. Venkata Subbaiah, K. J. Saji, and A. Tiwari, 'Atomically Thin MOS2: A Versatile Non-graphene 2D Material ,' Adv. Funct. Mater., vol. 26, no. 13, pp. 2046–2069, 2016, doi: 10.1002/adfm.201504202.
6. Advanced 2D materials , Editors : Ashutosh Tiwari,Mikeal Syvajarvi DOI:10.1002/9781119242635.
7. 2D Metal Carbides and Nitrides (MXenes), Structure, Properties and Applications, Editors: Anasori, Babak, Gogotsi, Yury (Eds.)
8. Transport in two-dimensional topological materials: recent developments in experiment and theory (Dimitrie Culcer et al 2020 2D Mater. 7 022007).
9. Weyl semi-metals : a short review Sumathi Rao Harish-Chandra Research Institute, Chhatnag Road, Jhusi, Allahabad 211 019, India.
10. Quasiparticle interference on type-I and type-II Weyl semimetal surfaces: a review Hao Zheng & M. Zahid Hasan.

07: Advanced Magnetism and Magnetic Materials

Course Code: 07
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

1. A postgraduate level course in Advanced Magnetism and Magnetic Materials will help in student having a thorough understanding of magnetism in condensed matter.

2. This course will equip the student with required prerequisites to proceed with a Ph.D. program in condensed matter physics or with a scientific position in magnetic materials industry.

Course Outcomes

This course is a postgraduate level course in magnetic materials. The level of treatment presumes familiarity with differential calculus as well as introductory atomic physics, statistical mechanics, and quantum mechanics of solids.

CO	CO Statement	CL
CO1	Articulate knowledge of ferromagnetism, ferrimagnetism and antiferromagnetism in materials.	Understand
CO2	Demonstrate a working understanding of permanent magnets, magnetic data storage, and magnetic refrigeration	Understand
CO3	Explain different types of interactions in a magnetic solid and ordered magnetic structures	Understand
CO4	Understand the origins of magnetic anisotropy and correlate the technical magnetic properties with the underlying microstructure of the material	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	2	0	1
CO2	3	1	2	0	1
CO3	3	1	2	0	1
CO4	3	1	2	0	1

Module I

Interactions in ferromagnetic materials: Weiss molecular field theory - Origin of the Weiss molecular field - Collective-electron theory of ferromagnetism – spontaneously split bands-Ferromagnetic domains - Observing domains - The formation of domains – Domain walls – width of domain walls- Magnetization and hysteresis of multidomain ferromagnets and single domain ferromagnets-The Stoner-Wohlfarth Model-Magnetic nanoparticles and superparamagnetism-Field cooled (FC) and zero field cooled (ZFC) magnetisation measurements in superparamagnetic systems.

Module II

Antiferromagnetism: Neutron diffraction - Weiss theory of antiferromagnetism - Cause of negative molecular field – Indirect exchange in ionic solids: superexchange interactions, Indirect exchange in metals-The RKKY interaction- The effect of a strong magnetic field-spin-flip and spin-flop process-Applications-Exchange bias effects in ferromagnet/antiferromagnet bilayer systems. Ferrimagnetism: Weiss theory of ferrimagnetism – compensation temperature-Ferrites-cubic ferrites-Normal and inverse spinel-examples.

Module III

Magnetic anisotropies-Magnetocrystalline anisotropy-Origin of magnetocrystalline anisotropy- symmetry of magnetocrystalline anisotropy-shape anisotropy-demagnetising fields-Induced magnetic anisotropy-magnetic annealing-Roll anisotropy-Magnetostriction-effect of magnetostriction on anisotropy.

Module IV

Industrial applications of magnetic materials-Soft magnetic materials-amorphous and nanocrystalline soft magnets-permanent magnets-Rare-earth-transition metal alloy based permanent magnets- Alternatives for rare earth permanent magnets-coercivity mechanism in permanent magnets-Magneto caloric effect and magneto caloric materials-Magnetic multilayers-Magneto resistance-giant magneto resistance-spin valves-High density magnetic data storage

Text Books:

1. Magnetic Materials Fundamentals and Applications - Nicola A. Spaldin, Cambridge University Press, 2003 [Module 1,2 and 3].
2. Magnetism in Condensed Matter-Stephan Blundell-Oxford University Press, 2001 [Module 1,2, and 3].
3. Physics of Magnetism and Magnetic Materials - K.H.J Buschow and F.R De Boer, Kluver Academic Publishers, London, 2003 [Module 4]
4. Nanoscale Magnetic Materials and Applications - Editors: J.Ping Lu, Eric Fullerton, Oliver Gutfleish, David J. Sellmyer, Springer, 2009 [Module 4]

Reference Books:

1. Introduction to Magnetic Materials - B.D. Cullity and C.D. Graham. Addison-Wesley, 1972.
2. Introduction to Magnetism and Magnetic Materials - D. Jiles. Chapman & Hall, 1996.

08: Advanced Mathematical Physics

Course Code: 08
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective

To equip the students to use some of the advance topics of mathematical physics.

Course Outcome

CO	CO Statement	CL
CO1	Acquire an in-depth knowledge about ordinary and partial differential equations and various methods of finding their solutions	Understand, Apply, Analyse
CO2	Understand the concepts, terminology and principles of analysing groups	Understand, Apply, Analyse
CO3	Learn the terminology, concepts and principles of analysing tensors. Learn tensor algebra	Understand, Apply, Analyse
CO4	Learn Christoffel symbols and Reimann curvature tensor which are crucial to understand general relativity	Understand, Apply
CO5	Understand basics of stochastic differential equations	Understand, Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	2	1	1	0
CO2	2	2	1	1	0
CO3	2	2	1	1	0
CO4	2	2	1	1	0

Module I

Review of solving first and second order ordinary differential equations. Review of solving first order partial differential equations. Sturm - Liouville theory: eigenvector expansions; Hilbert spaces; self-adjoint operators; eigenfunction expansions; existence of eigenvalues and completeness of eigenfunctions; spectral theory. Classification of second order PDE s hyperbolic, parabolic and elliptic equations. Green function methods for PDEs, Laplace transform and Fourier transform solutions.

Module II

Contravariant and covariant tensors - transformation rules - direct product, con-traction, quotient rule. Metric tensor - lowering and raising of indices - covariant derivatives -Christoffel symbols. Riemann curvature tensor.

Module III

Weiner process and white noise, Stochastic integrals, Ito calculus, stochastic differential equations, The Fokker-Plank equation, Brownian motion, numerical simulations.

Module IV

Definition of a group- Cyclic groups -Group multiplication table - Isomorphic groups - Group of permutations and Cayley's theorem - Subgroups and cosets - Conjugate classes and invariant subgroups - Group representations - symmetry group D2 and D3 - One-dimensional unitary group U(1) Orthogonal groups SO(2) and SO(3) - SU(n) groups.

Text Books :

1. Mathematical Methods for Physicists Paperback (7th Edition), Arfken, Elsevier (2012).
2. Mathematical methods for physics and engineering, K. F. Riley, M. P. Hobson and S. J. Bence, Cambridge Universality Press (2006).
3. Jon Mathews and Robert Walker,Mathematical Methods of Physics, Benjamin/Cummings Publishing Co. ISBN 0805370021.

Reference Books :

1. Mathematical Methods for Physicists: A Concise Introduction, Tai L. Chow, Cambridge University Press (2001).

09: Advanced Raman Spectroscopy

Course Code: 09
Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15
Prerequisites: None

Course Objectives

Raman spectroscopy is one of the important spectroscopic techniques which has wide variety of applications different fields of science and technology. The objective of this course is to understand the advanced applications of Raman spectroscopy including structure determination of micro and nano materials. This course also aims to give insjghts in to different Raman process which has applications in industry, material science, medicine and forensic science etc.

Course Outcomes

After completion of this course, the students will have good fundamental understanding, instrumental aspects, and analysis of materials using Raman spectroscopy.

CO	CO Statement	CL
CO1	Fundamental understanding of Raman spectroscopy	Understand
CO2	Working principle of Raman instrumentation	Understand
CO3	Advanced applications of Raman spectroscopy	Understand, Apply
CO4	Characterisation of materials using Raman spectroscopy	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	1	3	3	0
CO2	2	2	3	3	0
CO3	1	1	3	3	0
CO4	0	1	3	3	0

Module I

Raman effect, classical theory of Raman effect, quantum mechanical treatment of Raman effect, Hyper Raman effect, Classical treatment of Hyper Raman effect, Experimental techniques for hyper Raman effect, Photoacoustic Raman scattering, Surface-Enhanced Raman Spectroscopy (SERS), Principle of SERS, Enhanceemnt mechanism, Electromagnetic enhancement mechanism, Chemical enhancement, Surface selection rules, SERS substrates, metal films, metallic nanoparticles, Applications-biomolecules, fundamentals of SERS based detection of virus, in medicine, forensic science, pharmaceuticals.

Module II

Raman spectrometer, Major Components, Excitation Sources - Lasers, Sample Illumination, Wavelength Selectors, Detection, FT Raman, Detection, Photon Counting, photodiode array, CCD, Instrument Calibration, Sampling Techniques, Fluorescence Problems, Raman Difference Spectroscopy, Miniature Raman Spectrometers, FT Raman spectrometer, Single crystal Raman spectra, Raman Microscopy, Fibre optical Raman spectrometer, Resonance Raman Spectroscopy.

Module III

Special techniques, High pressure Raman spectroscopy, Temperature and pressure induced phase transitions and its sample handling techniques and instrumentation. Raman microscopy, applications, Raman spectroeelctrochemistry- Applications, proton conduction in solids-Raman studies, time resolved Raman Spectroscopy- applications, matrix isolation Raman spectroscopy- applications, 2D correlation Raman Spectroscopy- applications, Raman Imaging, Spectromerty- applications, Industrial Applications, Environmental applications.

Module IV

Stimulated Raman scattering, inverse Raman scattering, CARS (Coherent antistokes Raman scattering), Analysis of Raman data, Compounds having inorganic functional groups, molecular symmetry, fundamental modes of vibration, Molecules of type XY 2 , XY 3 , XY 4 , Sulphates, Phosphates, Carbonates, Iodates, Tungstates, Bromates etc. Analysis of Raman spectra of carbon rich compounds, carbon nano tubes, graphite, graphine G, D and 2D bands, Analysis of oxide nano structures, Analysis of Organic compounds, hydrogen bonds.

Text Books:

1. Molecular Structure and Spectroscopy, G.Aruldhas, PHI Learning Private Limited New Delhi.
2. Introductory Raman spectroscopy Second Edition, J R Ferraro, K.Nakamoto, C.W.Brown, Academic press, Elsevier.

Suggested Reading:

1. Resonance Raman Spectroscopy; Roman S. Czernuszewicz & Marzena B. Zaczek; Encyclopedia of Inorganic and Bioinorganic Chemistry, Online©2011 John Wiley & Sons, Ltd. DOI: 10.1002/9781119951438.eibc0303

10: Advanced Solid State Physics

Course Code: 10
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

To make the students learn modern developments in the field of condensed matter physics particularly to those who wish to do research in this area.

Course Outcomes

CO	CO Statement	CL
CO1	To understand the different perspectives of the carrier absorption and its transport properties	Understand
CO2	To familiarize with the theoretical tools like density of states etc	Understand
CO3	To familiarize with the modern ideas like, quantum well and the associated properties	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	0	1	2	0
CO2	1	0	1	2	0
CO3	1	0	1	2	0

Module I

Optical absorption: Free carrier absorption - optical transition between bands - direct and indirect - excitons - photoconductivity - general concepts - model of an ideal photoconductor - traps - space charge effects - crystal counters - experimental techniques - Transit time. Luminescence in crystal - excitation and emission - decay mechanism - Thallium activated alkali halides - model of luminescence in sulphide phosphors - electroluminescence.

Module II

Density of states - classification of solid into metals, semimetals, semiconductors and insulators - Calculation of number of carries in intrinsic semiconductor - Fermi level - carrier concentration in impurity semiconductors -electronic degeneracy in semiconductors. Equation of motion of electrons in a band - Effective mass and concept of holes - Boltzmann Transport equation. contact potential - metal-semiconductor contact - Schottky boundary layer - injecting contacts - surface states.

Module III

Quantum wells and low dimensional systems: Electron confinement in -infinitely deep square well and square well of finite depth - confinement in two and one dimensional well - ideas of quantum well structures, quantum dots and quantum wires - methods of preparation of nanomaterials: top down and bottom up approaches: wet chemical, self assembled vapour, phase condensation.

Module IV

Growth of single crystals - general ideas. Thin film preparation techniques - thermal and electron gun evaporation - dc and rf sputtering - amorphous solids : preparation techniques - applications. Classification of liquid crystals - applications of liquid crystals - ceramic processing techniques - electrical and mechanical properties - composite materials.

Text Books:

1. Introduction to Solid State Physics, 8th Ed., C. Kittel, Wiley, (2005)

2. Solid State Physics, A. J. Dekker, Macmillan (2000)

3. Electronic Properties of Crystalline Solids, R. H. Bube, Academic Press Inc (1974)

Reference Books:

1. Lectures on Solid State Physics, G. Busch and H. Schade, Pergamon Press (1976)

2. Theoretical Solid State Physics, A. Haug, Pergamon Press (1972)

3. Solid State Physics, N. W. Ashcroft, N. D. Mermin Holt, Rinehart and Winston, New York, 1976

11: Applied Vibrational Spectroscopy

Course Code: 11
Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The course is designed so as to enable a student to understand the fundamentals and applications of vibrational spectroscopic techniques –Raman and infrared spectroscopic techniques. It also aims to familiarize the student about spectroscopic instruments and sample handling techniques.

Course Outcome

CO	CO Statement	CL
CO1	know the techniques to measure Raman and IR spectra of the sample organic and inorganic compounds	Understand, Apply
CO2	get knowledge about the analysis of Raman and Infrared data of the samples	Understand, Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	1	2	2	0
CO2	2	1	2	2	0

Module I

Infrared spectroscopy- Fundamentals of Infrared spectroscopy- Infrared spectra preliminary- Infrared selection rules-Vibrations of polyatomic molecules-Normal vibrations of CO_2 and H_2O molecules-Dipole moment change in CO_2 molecule-Nomenclature of Internal modes- Fermi resonance-Hydrogen bonding-Normal modes of vibration in crystal-Solid state effects-Interpretation of vibrational spectra-group frequencies- Applications-Identification of molecular Constituents-Elucidation of molecular structure-Biological applications-Isotope effect.

Module II

Fundamentals of Raman spectroscopy-Classical and quantum theory-Molecular types-Planar molecules-pyramidal molecules-tetrahedral molecules-octahedral molecules-Rule of mutual exclusion principle-Internal modes of vibration-Polarization of Raman scattered light-Single crystal Raman spectra-Structure determination using Raman and IR spectroscopy- Raman investigations of phase transitions-Proton conduction in solids Raman study-Industrial applications-Resonance Raman scattering-Surface enhanced Raman scattering-Chemical enhancement –Electromagnetic enhancement-Substrates for SERS measurement.

Module III

Raman instrumentation-General idea on laser sources for Raman measurements-Components of Raman spectrometer-Modern spectrometers-Fibre coupled Raman spectrometer-FT Raman spectrometer-Raman microscopy- Raman sample handling techniques- High pressure Raman measurement system-Temperature dependent Raman measurement system- Raman measurement system with electric field

IR instrumentation-IR sources-Components of IR spectrometer -FTIR spectroscopy-Interferometer arrangement- IR sample handling techniques.

Module IV

Analysis of Raman spectra and IR spectra-basic idea of factor group analysis-general idea on softwares for the computation of vibrational spectra- Vibrational spectral anaylysis of Inorganic compouds containing water- Sulphate- phosphate -bromate- carbonate- complexes of sulfate, carbonate, and related ligands-Organic compounds - Carbon nanotubes- graphite- Oxide nanomaterials- Identification of hydrogen bonded ssytem- Analysis of historical monuments-Forensic samples-cyano and nitrile complexes.

Text Books:

1. Molecular Structure and Spectroscopy, G.Aruldhas, PHI Learning Private Limited New Delhi.
2. Infrared and Raman Spectra of Inorganic and Coordination Compounds: Part A: Theory and Applications in Inorganic Chemistry, Sixth Edition; K.Nakamoto; 2009 John Wiley & Sons, Inc.
3. Infrared and Raman Spectra of Inorganic and Coordination Compounds: Part B Applications in Coordination, Organometallic, and Bioinorganic Chemistry, Sixth Edition; K.Nakamoto; 2009 John Wiley & Sons, Inc.

12: Astrophysics

Course Code: 12
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective

To study in detail the elements of Astrophysics, with an aim to develop the taste of research in the field.

Course Outcome

CO	CO Statement	CL
CO1	Acquire a thorough understanding of the basic concepts like magnitudes, color, H-R diagram etc.	Understand
CO2	Understand the theory of hydrostatic equilibrium in stars	Understand
CO3	Get a clear idea about the energy production in stars	Understand
CO4	Get a clear knowledge about the evolution of the main sequence stars	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	0	3	0	2
CO2	2	2	2	0	1
CO3	2	2	2	0	1
CO4	2	1	2	0	1

Module I

Magnitudes: Apparent and Absolute stellar magnitudes, distance modulus, Bolometric and radiometric magnitudes, Color - index, Color temperature, effective temperature, Brightness temperature,luminosities of stars. Equatorial, ecliptic and galactic system of coordinates. Apparent and Mean solar time and their relations. Classification of stars, H-D classification, Hertzsprung-Russel (H-R) diagram.

Module II

Fundamental Equations: Equation of mass distribution. Equation of hydrostatic equilibrium. Equation of energy transport by radiative and convective processes. Equation of thermal equilibrium. Equation of state. Stellar opacity. Stellar energy sources.

Module III

Stellar Models : The overall problem and boundary conditions. Russell Voigt theorem. Dimensional discussions of mass luminosity law. Polytropic configurations. Homology transformations.

Module IV

Stellar Evolution: Jean's criterion for gravitational contraction and its difficulties. Pre-main sequence contraction under radiative and convective equilibrium. Evolution in the main sequence. Growth of isothermal core and subsequent development. Ages of galactic and globular clusters.

Text Books :

1. Textbook of astronomy an astrophysics with elements of cosmology, V.B.Bhatia, Narosa publishing house, 2001.
2. Astrophysics - Stars and Galaxies, K. D. Abhyankar, University Press, 2001.

Reference Books :

1. M.Schwarzschild:Stellar Evolution
2. S.Chandrasekhar:Stellar Structure
3. Theoritical Astrophysics (Vols.I,II,III) - T. Padmanabhan (CUP)
4. Menzel,Bhatnagar and Sen:Stellar Interiors.
5. Black Holes, White Dwarfs and Neutron Stars - S.L.Shapiro and S.A.Teukolsky (John Wiley, 1983)
6. Cox and Guili:Principles of Stellar Interiors - Vol.I and II.
7. R.Bowers and T. Deeming:Astrophysics (John and Barlett.Boston)

13: Biophysics

Course Code: 13
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The objective of this course is to introduce the interdisciplinary subject biophysics. This course also aims to give insights to the students on applications of physics in biosystems.

Course Outcomes

CO	CO Statement	CL
CO1	Fundamental understanding of biophysics	Understand, Analyse
CO2	Fundamental understanding of allied areas of biophysics	Understand
CO3	Fundamental areas of crystal structure determination of proteins	Understand
CO4	To get an insight on Protein folding	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	3	2	0
CO2	3	3	2	2	0
CO3	1	3	3	3	0
CO4	2	2	3	3	0

Module I

Fundamental building blocks of biological systems-Molecules essential for life- Water-proteins- lipids-carbohydrates-cholestrol-Nucleic acid-living state interactions-forces and molecular bonds-electric and thermal interactions-polarisations and induced dipoles-Casimir interactions- (Qualitative treatment) heat transfer in biomaterials-heat transfer mechanisms-heat equation-heat transfer through a living cell-Joule heating tissue (Qualitative treatment).

Module II

Living state thermodynamics-thermodynamic equilibrium-First and second law of thermodynamics-measures of entropy-free expansion of gas-physics of many particle systems- Boltzmann factor in biology-DNA stretching- Brownian motion-Ficks laws of diffusion-Ficks law for growing bacterial cultures(Qualitative treatment)-Sedimentation of cell cultures.

Module III

Nerve impulses-Neurotransmitters and synapses-Passive and active transports in dendrites- Mechanical properties of biomaterials (Qualitative treatment)-Youngs, shear modulus and Poisson ratio-electrical stresses in bilological membranes-Mechanical effects of microgravity during space flight, fundamentals of biomagnetic field sources- fundamentals Passive electrical properties of living cells.

Module IV

Light absorption in biomolecules-Bioimpedence-Time harmonic current flow- Dielctric spectroscopy-Deybe relaxation model-Cole equation-Fundamentals of protein folding, basic techniques for protein folding, protein crystallization, Vapor diffusion- Sitting drop method- Hanging drop method- Basics of structure determination of proteins with X-ray crystallography- sample handling techniques.

Text Books:

1. Introductory biophysics perspectives on the living state J.Claycomb, J.Quoc P.Tran, Jones & Bartlet Publishers.
2. Biophysics; N. Arumugam, V. Kumaresan, Saras publication; SBN : 9789384826673.
3. Biological Physics; Philip Nelson; W. H. Freeman & Company ; 2013.
4. Protein Folding; Charis Ghelis; Academic Press;1982.
5. Preparation and Analysis of Protein Crystals; McPherson, A. 1982, John Wiley & Sons.
6. Terese M. Bergfor's, Protein Crystallization Techniques, Strategies and Tips, International University Line, 1999.

14: Complex Networks

Course Code: 14
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15
Prerequisites: None

Course Objectives

This course aims to introduce to the students the emerging area of complex networks. The course is a very relevant one in this era of complex systems and gives the students a flavor of interdisciplinary approaches to problem solving.

Course Outcomes

CO	CO Statement	CL
CO1	Demonstrate an understanding of the terminology, concepts and principles involved in the study of complex networks	Understand
CO2	Identify problems that can be treated using the tools of complex networks	Understand, Analyse
CO3	Calculate various properties of a complex network related to its local structure	Apply
CO4	Calculate various properties of a complex network related to its global structure	Apply
CO5	Demonstrate an understanding of various models of complex networks and their properties and applications	Understand, Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	1	2	0
CO2	3	2	1	2	0
CO3	3	3	1	2	0
CO4	3	3	1	2	0
CO5	3	2	1	2	0

Module I

Introduction,Examples of networks, Mathematics of networks: Networks and their representation, The adjacency matrix, Networks: Weighted, Directed, Bipartite and Planar, Trees, Hypergraphs. Degree, Path, Components. Independent paths, connectivity, cut sets, The graph Laplacian, random walks.

Module II

Measures and Metrics: Degree centrality, Eigenvector centrality, Katz centrality, Page-rank, Hubs and authorities, Closeness centrality, Betweenness, Signed edges and structural balance, Similarity, Homophily and assortative mixing.

Module III

Large scale structure of networks: Components, Shortest paths and the small world effect, Degree distributions, Power-laws and scale free networks, Clustering coefficients.

Module IV

Network models, Erdos-Renyi random graph: Definition and properties. The configuration model: Definition and properties, Models of network formation.

Text Books:

1. Networks: An Introduction, M.E.J. Newman, Oxford University Press (2010).

Reference Books:

1. Network science, Albert Barabasi, Cambridge University Press (2016).

15: Computational Physics

Course Code: 15
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective

To introduce students to numerical methods and computational techniques for solving problems in various areas of Physics and Mathematics using Computers. This will prepare them for PhD level research or a career in the Industry, where scientific computing is widely used.

Main Prerequisite

Bachelor level understanding of Physics and Mathematics.

Course Outcome

CO	CO Statement	CL
CO1	Develop skills in solving problems in various areas of Physics using appropriate numerical methods and simulation techniques, on a Computer	Understan, Apply, Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	3	1	2	0

Module I

Introduction and Objectives of Computational Physics, Basic Programming techniques and data visualization. Machine representation, Numerical precision and stability, Errors. Review of Numerical Methods: Root finding, Numerical Differentiation, Numerical Integration, Interpolation Methods, Matrices and Linear Algebraic Equations, Ordinary Differential Equations. Data Fitting, Fourier Transforms, Optimization methods.

Module II

Simple harmonic motion, damped and driven oscillator. Nonlinear Dynamics and Chaos: Nonlinear oscillations, Phase Diagrams for Nonlinear systems. Chaos: Discrete and Continuous systems. Few-Body Problems.

Module III

Motion of classical electrons in crossed electric and magnetic fields. Partial differential equations: Laplace's equation, Poisson's equation, diffusion equation. Numerical solution of Schroedinger equation.

Module IV

Molecular dynamics: Theory, Integration methods, Measurement of static and dynamic properties. Langevin dynamics simulations for Brownian motion. The Monte Carlo method: Probability distribution functions, random number generation, Monte Carlo integration, importance sampling, Random walks and the Metropolis Algorithm, Application to model systems.

Text Books :

1. An Introduction to Computer Simulation Methods: Applications to Physical Systems - Gould, Tobochnik & Christian, 3rd Edition, Addison Wesley (2006).
2. Basic Concepts in Computational Physics - Stickler and Schachinger, Springer (2013).
3. Computational Physics: Problem Solving with Computers - Landau and Paez, 2nd Edition, John Wiley & Sons (2007).
4. Computational Physics - Nicholas J Giordano and Hisao Nakanishi, 2nd Edition, Pearson-Prentice Hall (2006).
5. Computational Physics - P. Scherer, Springer (2010).

Reference Books :

1. An Introduction to Numerical Analysis - K.E. Atkinson, 2nd Edition, John Wiley & Sons (1989).
2. An Introduction to Computational Physics - Tao Pang, 2nd Edition, Cambridge University Press (2006).

16: Crystal Growth

Course Code: 16
Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The objective of this course to provide information on the important aspects of crystals growth. This course also aims to give insights to the students on growing techniques crystals with different methods.

Course Outcomes

CO	CO Statement	CL
CO1	Acquire good fundamental understanding on crystal growth	Understand, Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	1	2	0

Module I

Supersaturation and supercooling – nucleation concept – Kinds of nucleation - Homogeneous nucleation - Equilibrium stability and metastable state -Classical theory of nucleation - Gibbs-Thomson equation –Kinetic theory of nucleation - Statistical theory of nucleation - Free energy of formation of nucleus considering translation, vibration and rotation energies, Theories of crystal growth - Surface energy theory - Diffusion theory - Adsorption layer theory -Volmer theory -Bravais theory - Kossel theory.

Module II

Melt Growth Techniques -Crystal Pulling-Bridgman Method-Skull Melting Methods-Zone Melting-Verneuil Process -Kyropolous method - Czochralski method-Zone melting method - Growth of crystal from flux - Slow cooling method - Temperature difference method – High pressure method - Solvent evaporation method - Top seeded solution growth - Growth of crystals from vapour phase - Physical vapour deposition - Chemical vapour transport.

Module III

Solution Growth Techniques -General Aspects-Low-Temperature Methods-High- Temperature Methods-Growth of crystals from solutions - solvents and solutions - solubility - preparation of a solution -saturation and supersaturation - Measurement of supersaturation - Expression for supersaturation -Low temperature solution growth - Crystal growth by hydrothermal method– Crystal growth by solvo-hydrothermal method- Slow cooling method - Mason-jar method - Evaporation method -Temperature gradient method - Crystal growth in gels - Experimental methods -Chemical reaction method - Reduction method method - Growth of biologically important crystals.

Module IV

Crystallization of hydroxy apatite - Protein crystallization techniques - Hanging Drops-Sitting Drops-Sandwich Drops-Reverse Vapor Diffusion- pH Gradient Vapour Diffusion-Practical Tips for Vapuor Diffusion –Dialysis-Batch Techniques –Micro batch –Protein Samples- Precipitants- Buffers and pH

–Temperature-Crystallization Strategies-A Flexible Sparse Matrix Screen-An Alternative to Sparse-Matrix Screens-Reverse Screen- Imperial College Grid Screen- Seeding-Macro seeding-bio-crystallization, protein crystallization and characterization of biological crystals.

Text Books:

1. J.C. Brice, Crystal growth processes, John Wiley and sons, New York, 1986.
2. P.Santhana Raghavan and P.Ramasamy, Crystal Growth Processes and Methods, KRU Publications, Kumbakonam (2000).
3. A. Laudise, The Growth of single crystals. Prentice Hall, 1970.
4. B.Pamplin, Crystal Growth. Volume 16, Pergamon Press.1973.
5. F.F. Abraham, Homogenous nucleation theory, Advances in Theoretical Chemistry, Academic Press, New York, 1974.
6. R.F. Strickland, Kinetics and Mechanism of Crystallization, Academic Press, New York, 1968.
7. Sujata V. Bhat, Biomaterials, Narosa Publising House, New Delhi,2002
8. A.Ducruix and R.Giege, Crystallization of Nucleic Acids and Proteins A Practical Approach, Oxford University Press, England, 1992
9. Terese M. Bergfor's, Protein Crystallization Techniques, Strategies and Tips, International University Line, 1999.

17: Elementary Astronomy

Course Code: 17
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective

This course enable the students learn the salient advancements in the field of Astronomy.

Course Outcome

CO	CO Statement	CL
CO1	Get knowledge about the celestial sphere and its various properties and uses.	Understand
CO2	Get good knowledge regarding the theories of solar system, planets - their formation and properties	Understand
CO3	Get a reasonable knowledge about the formation of stars, and objects like white dwarf, black hole etc.	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	0	1	2	0
CO2	1	0	1	2	0
CO3	1	0	1	2	0

Module I

Celestial Sphere and Time : Constellations. The celestial sphere. Equatorial, ecliptic system of co-ordinates. Seasons, Sidereal, Apparent and Mean solar time. Calendar. Julian date. Stellar Distances and Magnitudes : Distance scale in astronomy. Determination of distances to planets and stars. Magnitude scale. Atmospheric extinction. Absolute magnitudes and distance modulus. Colour index.

Module II

Theories of formation of the Solar System, The Sun: Photosphere, chromosphere and corona of the Sun. Sun spots and magnetic fields on the sun. Solar activity, solar wind.
Planets and their Satellites : Surface features, atmospheres and magnetic fields of Earth, Moon and Planets. Satellites and rings of planets. Asteroids, Meteors, Meteorites and Comets.

Module III

Stars : Basics of Star formation & Evolution. The HR diagram. Pre-main sequence contraction, main sequence stage and formation of super dense objects - White dwarfs, Neutron stars & Pulsars. Black holes.

Module IV

The Milky Way Galaxy & Galaxies beyond : Structure of the Milky Way Galaxy Galactic and globular clusters. Inter Stellar Matter, Position of our Sun and its motion around the galactic centre. Rotation of the Galaxy and its mass.

Extragalactic Systems : Hubble's classification of galaxies and clusters of galaxies. Galaxy interactions, Elements of Astrobiology.
Introduction to Cosmology : The expanding universe. Big Bang and Steady State models of the universe. Dark matter.

Text books:

1. H. Karttunen, P Kroger, H Oja, M Poutanen & K. J. Donner editors. Fundamental Astronomy, 5^{th} Edition, Springer-Verlag (2007).

2. Baidyanath Basu: Introduction to Astrophysics, PHI, 2nd ed. (2013)

References :

1. W.M.Smart: Foundations of Astronomy, Longmans (1965)

2. Frank H. Shu: The Physical Universe-An Introduction to Astronomy, Univ Science Books (1981)

3. K D Abhyankar: Astrophysics of the Solar System, Universities Press (1999)

4. Horneck and Rettberg: Complete Course in Astrobiology, Wiley (2009)

5. Introduction to cosmology, J V Narlikar, Cambridge University Press; 3 edition (2002)

18: Fundamentals of Photovoltaics

Course Code: 18
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The objective of the course is to develop in-depth understanding of the physics of solar cells and various photovoltaic technologies (PV) and their applications to harness solar energy to electricity. The course will cover the basic semiconductor physics. The course will give an insight in the fabrication of the solar cells in laboratory and industrial scale, module fabrication and power generation using PV in off grid and grid connected systems.

Course Outcomes

CO	CO Statement	CL
CO1	Explain the working principle of solar cells	Understand
CO2	Understand PV based electricity generation	Understand
CO3	Differentiate the manufacturing and performance differences between different c- Si wafer technologies and between c-Si and thin film PV technologies	Understand, Analyse
CO4	Identify the critical losses and loss mechanisms in c-Si solar cells	Understand, Analyse
CO5	Calculate the power and energy produced by a solar module	Apply
CO6	Explain the differences and design aspects of off-grid and on-grid PV systems.	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	0	1	2	0
CO2	1	0	1	2	0
CO3	1	0	1	2	0
CO4	1	0	1	2	0
CO5	1	0	1	2	0
CO6	1	0	1	2	0

Module I

Basic Semiconductor Physics: Fundamental Properties of Semiconductors - Crystalline structure - Band model - Doping - Carrier concentration in equilibrium - Light absorption -Generation and recombination of electron and hole pairs: Band gap to band gap processes - Shockley-Read-Hall recombination - Auger recombination - Carrier transport - Minority carrier diffusion - Semiconductor junctions: p-n homojunctions - ideal diode equation - p-n heterojunctions - Metal-semiconductor junctions.

Module II

Solar Cell fundamentals: p-n junction under illumination - Solar Cell Parameters - Spectral response - the equivalent circuit - parasitic resistance effects -temperature effect - p-i-n solar cells - Losses and Efficiency Limits: The thermodynamic limit - the Schokley-Quiesser limit - other losses - design rules for solar cells - tandem solar cells First Generation technology: Crystalline Silicon Solar Cells - Physics of c-Si Solar cells - Sand to silicon - Silicon to wafer - wafer manufacturing - Design and manufacturing of Al-BSF solar cell - Passivation concepts

Module III

High efficiency concepts in c-Si Solar cells: PERL and PERC cells - interdigitated back contacts - TOPCon - Heterojunction solar cells Second generation technology: Thin film solar cells - merits and demerits -Transparent conducting oxides - the III-V PV technology - thin film Si technology - Chalcogenide solar cells - Organic photovoltaics - Hybrid organic-inorganic solar cells Third generation concepts: Multi junction solar cells - Spectral conversion - Multi- exciton generation - Intermediate band solar cells - Hot carrier solar cells.

Module IV

Module manufacturing: Interconnection of cells - series and parallel connections- silicon module production - PV systems: Standalone systems – grid connected systems - hybrid systems - micro grids - smart grids - specific applications- Solar cell and module measurement techniques.

Text Books:

1. K. Mertens, Photovoltaics: Fundamentals, Technology and Practice, John Wiley & Sons Ltd (2014)
2. A. Smets, K. Jager, O. Isabella, R. V. Swaaij, M. Zeman, Solar Energy: The physics and engineering of photovoltaic conversion, technologies and systems, UIT Cambridge Ltd. (2016).
3. D. A. Neamen and D. Biswas, Semiconductor Physics and Devices

Reference Books:

1. Handbook of Photovoltaic Science and Engineering 2nd Ed. , A. Luque, S. Hegedus (editors), John Wiley & Sons Ltd (2011)
2. S.R. Wenham, M. Green, M.E. Watt, R. Corkish, A. Sproul, Applied Photovoltaics, 2nd Edition (2009)
3. Chetan Singh Solanki, Solar Photovoltaics: Fundamentals, Technologies and applications, 3rd Edition, PHI Learning Pvt. Ltd. (2019).
4. Jenny Nelson, The Physics of Solar Cells, Imperial College Press (2003).
5. Peter Wurfel, Physics of solar cells: from principles to advanced concepts, 2nd Edition, Wiley-VCH (2009).
6. SM Sze and Kwok K Ng, Physics of semiconductor devices, third edition, John Wiley & Sons (2007)
7. R.F. Pierret, Semiconductor Device Fundamentals

19: Gravitation and Cosmology

Course Code: 19
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

Provide a basic introduction to the general theory of relativity and its applications in astrophysics. Specific objectives are as follows.

- Introduce tensor algebra and Einstein's general theory of relativity.
- Apply the general theory of relativity to various astrophysical systems.
- Introduce the modern theory of cosmology as an application of general theory of relativity.

Course Outcomes

CO	CO Statement	CL
CO1	Learn tensor algebra and using it they will understand the general theory of relativity.	Understand
CO2	Apply general theory of relativity to various astrophysical systems like planetary motion, black holes and gravitational waves	Understand
CO3	Understand models of expanding Universe in connection with the general theory of relativity	Understand
CO4	Familiarize with concepts of exotic components of matter in the Universe like dark matter and dark energy	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	2	1	2	0
CO2	1	2	1	2	0
CO3	1	2	1	2	0
CO4	1	1	1	2	0

Module I

Tensor Analysis: Tensors ; Contravariant and covariant tensors; direct product; contraction; inner product; quotient rule; tensor densities, dual tensors. Metric tensor, Parallel transport; Christoffel symbol; Covariant derivative; Riemannian geometry, Riemann curvature tensor; Ricci tensor; Equation of geodesics.

Module II GTR: Drawback's of Newtonian theory of gravity, Mach's principle, Principle of equivalence; consequences of principle of equivalence (bending of light, redshift, time dilation); Gravity as curvature of space-time; Einstein equation; reduction to Newtonian form.

Module III

Astrophysical Applications of Einstein's equation: Schwarzschild solution: derivation, Schwarzschild singularity, gravitational redshift, particle orbits - precession of the perihelion of planet Mercury, light ray orbits - the deflection and time delay of light. Linearized gravitational waves.

Module IV

Cosmology: Cosmological Principle, Hubble's law, FRW model of the universe:- FRW metric, cosmological redshift, open, closed and flat universes, matter dominated and radiation dominated universes, Particle horizon and event horizon, primordial nucleosynthesis, CMBR, Flaws of the FRW model. Jean's mass in the expanding universe, evolution of the Jean's mass. Dark matter, recent acceleration of the universe, Dark energy. (only introductory ideas.)

Text Books:

1. Gravitaion and Cosmology, S. Weinberg, ,John Wiley & Sons (1972)
2. A First Course in General Relativity, Schutz, Bernard. New York, NY: Cambridge University Press, 1985. ISBN: 9780521277037.
3. Introduction to cosmology, J. V. Narlikar, Cambridge University Press, 3rd edition (2002)

Reference Books:

1. Gravity, J. B. Hartle, Pearson Education.(2003).
2. Gravitation, Charles W. Misner, Kip S. Thorne, and John Archibald Wheeler,(1973).
3. Gravitation - Foundations and Frontiers , T. Padmnabhan, cambridge University Press, New York (2010)

20: Laser and Nonlinear Optics

Course Code: 20
Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The course aims at developing creative skills among students by understanding the principles of high-power lasers and applications. Topics include revising the basic principles of lasers, laser cavities, properties of Gaussian beams and imaging. The latter part of the course focuses on high power pulsed lasers from Q-switched nanosecond lasers to femto-second lasers and amplifiers.

Course Outcomes

CO	CO Statement	CL
CO1	Analyse the propagation of Gaussian beams	Understand, Analyse
CO2	Apply the principles of phase contrast imaging	Apply
CO3	Illustrate pulse shortening mechanisms and chirped pulse amplification	Understand, Apply
CO4	Elaborate high power laser interaction with material	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	1	2	1	0
CO2	3	1	2	1	0
CO3	3	0	2	0	1
CO4	2	2	3	0	2

Module I

Review of Radiation Laws (Stefan Boltzmann, Wien Displacement, Planks) and basics of lasers (Population Inversion - Stimulated emission - Einstein Coefficients) - Laser , Ruby Laser.

Module II

Optical Resonant Cavities , Longitudinal and Transverse modes , Properties of Gaussian laser beams , Spatial frequencies , Abbels theory of image formation , Spatial Filtering phase contrast Imaging.

Module III

Pulsed high power lasers , Q switching , Methods of producing Q switching , Mode locking , Methods of producing mode locking , Pulse shortening by self phase modulation, Group velocity dispersion, gratings or prisms , femto-second lasers , basic ideas of chirped pulse amplification and regenerative amplifiers.

Module IV

Nonlinear Optics , Nonlinear Wave equation , Optical rectification , Harmonic Generation , Phase matching , Third Harmonic generation , Parametric oscillator , B integral - self focusing , Two photon absorption.

Text Books:

1. Hecht, E and A R Ganesan, Optics 4th Ed., Pearson (2019).
2. Silfvast, W T, Laser Fundamentals 2nd Ed., Cambridge University Press (2008)
3. Boyd, R. W - Nonlinear Optics, Second Edition, Academic Press (2003).

References

1. Ajoy Ghatak, Optics 5th Ed., McGraw Hill.
2. Bahaa E . A. Saleh and Malvin Carl Teich , Fundamentals of Photonics 2nd Ed., Wiley (1991)
3. Laud, B.B. - Lasers and Nonlinear Optics, New Age International (P) Limited (1991)

21: Light Sources and Detectors

Course Code: 21
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

This course aims to introduce students to the basic characteristics and working principle of various light sources and detectors in the UV-VIS-IR regimes.

Course Outcomes

CO	CO Statement	CL
CO1	Explain the difference between natural and artificial sources of light.	Understand
CO2	Explain the basic characteristics and working principle of various photon sources and detectors in ultraviolet-visible-infrared regions of the electromagnetic spectrum.	Understand
CO3	Demonstrate the safety procedures to be taken while setting up experiments with advanced optical sources and detectors.	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1
CO2	3	1	3	3	1
CO3	3	1	3	3	1

Module I

Natural and Artificial Sources of Light, Characteristics of Light Sources, UV-VIS- IR Light Sources, Type of Optical Sources- Incandescent Lamp, Discharge Lamps-Low Pressure, High Pressure, and High Intensity Discharge Lamps, Semiconductor Diode-Light Emitting Diode (LED), Supercontinuum Sources.

Module II

Laser Fundamentals, Gas Lasers, Solid State Lasers, Semiconductor Laser Diodes, Safety Standards and Hazard Classifications, Laser Applications.

Module III

Detector Characteristics Quantum Efficiency, Response Time, Spectral Response. Types of Photoeffects-Photovoltaic Effect, Photoemissive Effect, and Photoconductive effect. Optical Detectors - UV, VIS, NIR, & IR Ranges.

Module IV

Types of Photon Detectors: Photodiodes, Photomultiplier Tube (PMT), Photodiode Array (PDA), Light Dependent Resistor (LDR), Charge-Coupled Device (CCD), Time Gated Detectors-Intensified Charged Coupled Device (ICCD).

Text Books:

1. Introduction to Solid-State Lighting - Zukauskas, Shur, Gaska, Wiley (2002)
2. Laser Fundamentals, 2nd Ed., William T Silfvast, Cambridge University Press (2008).
3. E. L. Dereniak, and D. G. Crowe, Optical Radiation Detectors, (Wiley Series in Pure and Applied Optics), Wiley, New York (1984).

References

1. Kingston, Robert H., Detection of Optical and Infrared Radiation, (Springer Series in Optical Sciences, Vol.10), Springer Verlag, New York (1978).
2. Chandra Roychoudhuri (Editor), Fundamentals of Photonics, SPIE (2008)
3. Bahaa E. A. Saleh Malvin Carl Teich, Fundamentals of Photonics, John Wiley & Sons, Inc. (1991)

22: Measurements and Optical Instrumentation

Course Code: 22
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The course is designed so as to enable a student to understand different types of errors and noise occurred in Physical measurement system. It also aims to familiarize the student about optical detectors and spectroscopic instruments.

Course Outcomes

CO	CO Statement	CL
CO1	Know the techniques to reduce errors in measurements and reduction of noises in experimental data	Understand, Apply
CO2	Get knowledge about different types of optical detectors and the design concept of optical spectrometer	Understand, Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	2	1	2	0
CO2	1	2	1	2	0

Module I

Measurement, The Result of a Measurement, Sources of Uncertainty and Experimental Error, Systematic Error, Random Error, Definition of the Uncertainty, The Analysis of Repeated Measurements, The Mathematical Description of Data Distribution Functions, Derivation and properties of the Data Distribution Functions, Propagation of Error, Analysis of Data, Instrumentation and system design, experiment design, Multi-parameter Experiments.

Module II

Transducers, Transducer Characteristics, selection of an Instrumentation Transducer, The Transducer as an Electrical Element, Modeling External Circuit Components, Signal to noise considerations, Fluctuations and Noise in Measurement Systems, Noise in the Frequency Domain, Sources of Noise, Signal to Noise, a signal to Noise and Experimental Design, Frequency and Bandwidth Considerations, Boxcar integration.

Module III

Optical Measurements and the Electromagnetic Spectrum, Detectors, Thermal detectors, Photoconductive, piezoelectric and photo emissive detectors, photodiodes, Avalanche Photodiode phototransistors, applications, optical couplers, materials used to fabricate LEDs and lasers design of LED for optical communication, response times of LEDs, LED drive circuitry.

Module IV

Interferometry: Interference effect, radiometry, types of interference phenomenon and its application, Michelson's interferometer and its application refractometer, Rayleigh's interferometers, Spectroscopic instrumentation, Visible and Infrared Spectroscopy, Spectrometer Design, Refraction and Diffraction, Lenses and Refractive Optics, Dispersive Elements, spectrographs and monochromators, spectrophotometers, calorimeters Spectrometer Design.

Text Books:

1. Measurement, Instrumentation and experiment design in Physics and Engineering Michael Sayer and Abhai Mansingh prentice-Hall India.
2. J.Wilson & J F B Hawkes, Opto Electronics: An Introduction, Prentice Hall of India, (2011), 3rd ed.
3. Rajpal, S.Sirohi , Wave Optics and its Application, (2001), 1st ed.
4. A Yariv , Optical Electronics/C.B.S. Collage Publishing, New York, (1985).
5. Pollock ,Fundamentals of OPTOELECTRONICS, (1994).

23: Modern Optics

Course Code: 23
Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The first part of the course (Modules 1 & 2) aims to expose learners to the concepts of polarization, coherence, interference, and diffraction and to apply these for the design of optical devices. Topics include polarization of light, coherence, and interference, Fraunhofer (far-filed) and Fresnel (near-field) diffraction, holography, and light modulators. The latter part of the course aims to develop creative skills among students by understanding the principles of high-power lasers and applications. Topics include revising the basic principles of lasers, laser cavities, properties of Gaussian beams and imaging. The course focuses also on high power pulsed lasers from Q-switched nanosecond lasers through to femto-second lasers and amplifiers.

Course Outcomes

CO	CO Statement	CL
CO1	Illustrate and apply principles of optical systems	Understand, Apply
CO2	Apply concepts for the design of high and anti-reflection coatings, interference filters etc.	Apply
CO3	Employ the theory of interference and diffraction for the development of devices like zone plates, holographic recording and re-construction.	Apply
CO4	Illustrate pulse shortening mechanisms and pulse amplification in modern lasers.	Analyse
CO5	Explain linear to nonlinear transformation in laser material interactions	Understand
CO6	Embrace lifelong learning and scientific research.	Apply, Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	2	2	1	1
CO2	3	1	2	0	1
CO3	3	1	2	0	1
CO4	3	0	3	0	1
CO5	3	1	2	0	1
CO6	0	0	1	0	2

Module I

Polarisation: Nature of polarized light – linear, partial, elliptical and circular polarizations- Polarizers and Retarders - Jones Vectors of linearly, elliptically and circularly polarized light - Jones matrices for optical components. Induced optical effects – electro-optic modulators – Pockels effect - longitudinal and transverse electro optic modulators - Kerr effect - Magneto-optic effect, acousto-optic effect – Raman Nath and Bragg-type modulators.

Module II

Coherence: Spatial and temporal coherence-Visibility-Mutual coherence function - Degree of coherence – Temporal and spatial coherence. Interference: General considerations - Condition for interference - Wave front splitting- and Amplitude splitting interferometers – Fringes of equal inclination – Fringes of equal thickness – Michelson, Mach Zehnder and Sagnac interferometers - Fabry Perot interferometer – Fabry-perot spectroscopy - Applications of single and multilayer films - Anti-reflection coatings – Multilayer periodic systems - Interference filters.

Module III

Diffraction: Kirchhoff's theorem - Fresnel-Kirchhoff Formula – Babinets principle – Fraunhofer and Fresnel diffraction - Fraunhofer diffraction patterns for single, double slits, rectangular aperture, and circular aperture – Optical resolution – Diffraction gratings - Fresnel diffraction pattern – Fresnel Zones – Fourier analysis of Franhaufer diffraction - Zone plate – Applications of the Fourier transform to diffraction – Apodization and spatial filtering - Holography - Recording and reconstruction of wave fronts.

Module IV

Nonlinear Optics - Polarization response of materials to light – Nonlinear Wave equation – Optical rectification – second Harmonic Generation – Phase matching – Sum and difference Frequency generation – Third harmonic generation – Intensity dependent refractive index - self focusing - B integral – Optical Parametric oscillator –Two photon absorption.

Text Books:

1. G. R. Fowles, Introduction to modern optics 2nd Ed., Dover Publications (1975).
2. E Hecht and A R Ganesan, Optics 4th Ed., Pearson (2008).
3. Fibre optics and Optoelectronics, R.P. Khare, Oxford University Press, (2004).
4. W T Silfvast, Laser Fundamentals 2nd Ed., Cambridge University Press
5. Boyd, R. W - Nonlinear Optics, Second Edition, Academic Press, 2003.

Reference Books:

1. M. Born and E. Wolf, Principles of Optics 7 th Edition, Cambridge University Physics (2013).
2. Bahaa E . A. Saleh and Malvin Carl Teich , Fundamentals of Photonics 2 nd Ed., Wiley.
3. Optoelectronics: An Introduction, J. Wilson and J.F.B. Hawkes, PHI, (2000).

24: Molecular Physics and Laser Spectroscopy

Course Code: 24
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective

To impart the modern ideas and applications of Molecular Physics and spectroscopy.

Course Outcome

CO	CO Statement	CL
CO1	Have basic knowledge of the chemical bonding in molecules and also adequate knowledge in Valence theory	Understand
CO2	Posses the knowledge about the structure properties of polytropic molecules including water molecule.	Understand
CO3	Know the spectra of different molecules, which will enable to identify the molecule through a spectroscopic study	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1
CO2	3	1	3	3	1
CO3	3	1	3	3	1

Module I

Theory of chemical bonding in diatomic molecules Born-Oppenhemier approximation – Molecular orbital theory LCAO approximation. – H_2 molecule – Valence-Bond theory – H_2 molecule – Heitler and London treatment of H_2 molecule.
LCAO-MO treatment of general diatomic molecule – Valence-Bond treatment of diatomic molecules – Electronic states and Term symbols – Hund's coupling cases.

Module II

M.O. theory of simple polyatomics and application to water molecule, Huckel M.O. theory and its application to ethylene, allyl and butadiene systems.
Microwave spectroscopy – Rotational spectrum of non-rigid diatomic molecules – Stark effect in rotational spectra. Nuclear Quadrupole hyperfine interaction due to single nuclear spin. Zeeman effect in rotational spectra. Description of microwave spectrometer.

Module III

Electronic spectra of diatomic molecules – Rotational Structure of electronic bands – PQR branches – Bandhead formation and shading – Combination relations for evaluation of rotational constants.
Laser systems – three and four level schemes – solution of rate equations for three level systems – System description of semiconductor diode lasers – Ti-saphire lasers and Tunable Dye Lasers.

Module IV

Description of diode laser spectrometer – examples of diode laser spectra of diatomic molecules. Dunham representation of re-vibrational transitions. (basic ideas only)
CW dye laser spectrometers - basic ideas of intermodulated fluorescence spectroscopy – Microwave frequency - optical double resonance spectroscopy and infrared optical double resonance spectroscopy

Text Books:

1. R.K. Prasad, Quantum Chemistry, NEW AGE; Fourth edition (2010)
2. W. Gordy and E.L. Cook, Microwave Spectroscopy, John Wiley & Sons (1984)
3. G. Herzbera, Spectra of Diatomic Molecules, Van Nostrand Reinhold Company (1979)

Reference Books:

1. Qrazio Svelto, Principles of Lasers
2. Eizi Hirota, High Resolution Spectroscopy of Transient Molecules
3. A. Mooradian.T., Jaeger and P. Stockseth, Tunable Lasers and Applications
4. A.B. Budgor, L. Esterowitz and L.G. Deshazer, Tunable Solid State Lasers-II

25: Nondestructive Measurement Techniques and Applications

Course Code: 25
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

Obtain knowledge about fundamental principles different types of non-destructive testing and characterization methods used to determine the structure and composition of materials for practical applications.

Course Outcomes

CO	CO Statement	CL
CO1	Fundamental of Non-destructive measurement techniques	Understand
CO2	Instrumental application of Non-destructive measurement techniques	Apply
CO3	Application of Non-destructive measurement techniques	Apply
CO4	Industrial applications of Non-destructive measurement techniques	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	2	3	0
CO2	2	3	3	3	0
CO2	2	3	3	3	0
CO2	1	3	3	3	1

Module I

Magnetism-Basic Definitions- Principle of MPT - Magnetizing Techniques -Magnitization using a magnet - Magnetization using an electromagnet - Contact current flow method. Eddy Current - Principles - Instrumentation for ECT -Techniques - High sensitivity techniques - Inspection of heat exchanger tubings by single frequency EC system - Multifrequency ECT - High frequency ECT - Pulsed ECT - 3D or phased array ECT - Inspection of ferromagnetic materials - Sensitivity - Applications - Limitations - Standards.

Module II

Radiography - Basic principle - Electromagnetic Radiation Sources -X-ray source - Production of X-rays - High energy X-ray source - Gamma ray sources - Properties of X- and gamma rays - Radiation Attenuation in the specimen - Effect of Radiation in film - Film ionization -Inherent unsharpness-Radiographic Imaging - Geometric factors - Radiographic film - Intensifying screens -Film density - Radiographic sensitivity - Penetrameter - Determining radiographic exposure -Inspection Techniques -Single wall single image technique - Double wall penetration technique .
Microwave methods-introduction, microwave radiation, microwave instrumentation, microwave measurements. Raman spectroscopy for NDT applications. Raman spectroscopy as nondestructive tool. Instrumentation.

Module III

Ultrasonic Testing - Basic properties of Sound Beam - Sound waves - Velocity of ultrasonic waves - Acoustic pressure - Behaviour of ultrasonic waves - Ultrasonic Transducers - Characteristics of ultrasonic beam - Attenuation - Inspection methods - Normal incident pulse- echo inspection - Normal incident through transmission testing - Angle beam pulse-echo testing - Criteria for probe selection - Flaw sensitivity - Beam divergence - Penetration and resolution - Techniques for Normal beam inspection - Fatigue cracks -Inclusions, slag, porosity, and large grain structure - Thickness measurement-corrosion detection - Intergranular cracks-hydrogen attack-Techniques for Angle beam inspection- Flow characterization techniques - Ultrasonic flaw detection equipment - Modes of display - A-scan - B-scan - C-scan - Immersion testing - Applications of ultrasonic testing -Advantages - Limitations – Standards.

Module IV

Visual Examination Basic Principle - The Eye - Defects which can be detected by unaided visual inspection-Optical Aids Used for Visual Inspection-Microscope Borescope - Endoscope - Flexible fibre-optic Borescope (Flexiscope) - Telescope –The concept of Holographic imaging – The inline hologram- The off axis hologram-Fourier hologram- Nondestructive applicationof holography- Holographic interferometry-Real time holographic interferometry-Double-Exposure holographic interferometry-Sandwitch holograms- Holographic interferometry in an industrial environment- Holographic strain analysis.

Reference Books :

1. Electrical and Magnetic Methods of Non -Destructive Testing, Jack Blitz,Champan & Hall,2-6 Boundary Row,London SE1 8HN.
2. Practical Nondestructive Testing, Baldev Raj, T. Jayakumar, M. Thavasimuthu,Narosa Publishing House New Delhi
3. Optical Electronics, Ajoy Ghatak and K.Thygarajan,Cambridge University Press India Pvt.Ltd.
4. Molecular Structure and Spectroscopy, G.Aruldhas, PHI Learning Private Limited New Delhi.
5. P.Hariharan, Optical Holography-Principles techniques and applications. Cmbridge Studies in Modern Optics.

26: Non-equilibrium Statistical Physics

Course Code: 26
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

1. To introduce the important concepts in non-equilibrium physics.
2. To learn about natural systems and exact models that exhibit such processes.

Course Outcome

CO	CO Statement	CL
CO1	Get a grasp on various theoretical methods useful in understanding non-equilibrium phenomena	Understand
CO2	Solve problems in stochastic processes and to predict the distributions of random variables.	Apply
CO3	Differentiate non-equilibrium systems from equilibrium systems wherever applicable.	Analyse
CO4	Apply large deviation theory in physical systems.	Apply
CO5	Understand the technical terminology, and to follow the scientific literature of past and recent advances in the field.	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	3	2	2	1
CO2	3	2	3	3	1
CO3	3	2	3	3	1
CO4	3	1	3	3	1
CO5	3	1	3	3	1

Module I

Introduction to stochastic processes: basics of probability theory, Random numbers, Probability distributions, Moments, cumulants, generating functions Central limit theorem, Levy stable distributions.

Module II

Brownian motion, first passage properties, Markov processes, Master equation, Detailed balance condition, Langevin equations and Fokker-plank equation, Solutions to the Fokker plank equation for simple systems

Module III

Correlations, response, Fluctuation dissipation theorem, Linear response theory, Large deviation theory, Fluctuation relations.

Module IV

Non-equilibrium phenomena, Nucleation, Spinodal decomposition, Active and driven systems, Glassy systems, granular matter Exactly solvable systems

Text Books :

1. N G Van Kampen, Stochastic Processes in Physics and Chemistry (North-Holland Personal Library) North Holland; 3rd edition.

2. V Balakrishnan, Elements of Nonequilibrium statistical mechanics, Ane books, Delhi & CRC Press (2008)

3. R. Kubo, M Toda, N. Hashitsume, Statistical Physics II:Non-equilibrium statistical Mechanics, Springer-verlag, Berlin (1985)

4. A Kinetic view of statistical physics: Pavel L. Krapivsky, Sydney Redner, Eli Ben-Naim Cambridge University Press, (2013)

Reference Books :

1. Non-equilibrium Statistical Mechanics, Robert Zwanzig, OUP USA (2001)

2. Non-equilibrium Statistical Physics: Linear Irreversible Processes, Noelle Pottier OUP (Oxford Graduate Texts)

3. The mechanics and statistics of Active matter, Sriram Ramaswamy, Annual Review of Condensed Matter Physics 323-345 (2010).

27: Non-linear Dynamics and Chaos

Course Code: 27
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

To make the students understand the field of non-linear dynamics.

Course Outcomes

CO	CO Statement	CL
CO1	Understanding the basic of non-linearity in physical systems.	Understand
CO2	Understanding the discrete dynamical systems, logistic map and associated things.	Understand
CO3	Familiarise the concepts like Lyapunov exponents and its application in detecting chaos in systems.	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1
CO2	3	1	3	3	1
CO3	3	1	3	3	1

Module I

Linear and nonlinear forces- Working definition of nonlinearity. Linear oscillators- free, damped and forced oscillators- Nonlinear oscillations and resonance.
Dynamical systems as systems of first order ordinary differential equations. Equilibrium points and their classification (two-dimension). Limit cycles, attractors, dissipative and conservative systems.

Module II

Simple bifurcations in dissipative systems. Discrete dynamical systems. Logistic map. Equilibrium points and stability. Periodic orbits. Period-doubling bifurcations. Onset of chaos. Lyapunov exponents. Bifurcation diagram. Strange attractors in Henon map. Quasiperiodic and intermittency route to chaos. Period-doubling bifurcations and chaos in Duffing oscillator and Lorenz equations.

Module III Canonical perturbation theory- problem of small divisors. Statement and discussion of KAM theorem. Surface of section. Henon-Heiles Hamiltonian(numerical results). Area-preserving maps. Poincare-Birkhoff theorem. Homoclinic points.

Module IV

Lyapunov exponents-numerical computation-one-dimensional maps and continuous time systems. Power spectrum. Autocorrelations.
Fractal sets-examples. Fractal dimension-box counting. Correlation dimension. Criteria for chaotic motion.

Text Books:

1. Nonlinear Dynamics, M.Lakshmanan and S.Rajasekar, Springer, (2003)
2. Chaos and Integrability in Nonlinear dynamics, M.Tabor, John Wiley, (1989)

Reference Books:

1. Chaos- an introduction to nonlinear dynamics, J. Alligood, T. Sauer and J.Yorke, Springer, (1997)
2. Chaos and Nonlinear Dynamics, R.C. Hilborn, Oxford University Press, (1994)
3. Deterministic Chaos, H.G.Schuster, Wiley-VCH, 3rd edition (1995)

28: Non-linear Optics

Course Code: 28
Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective

Aquire the modern ideas on Non-linear optics.

Course Outcomes

CO	CO Statement	CL
CO1	Get a thorough knowledge of polarizability and wave propagation in dielectric material.	Understand
CO2	Get a clear knowledge of second harmonic generation, four wave mixing, phase-conjugation, etc.	Understand
CO3	Get good hand on the ideas of resonating oscillators.	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	1	0	1	1
CO2	2	1	0	0	1
CO3	2	1	0	0	1

Module I

Review of the concepts of polarizability and dielectric tensor of a medium. Frequency dependence of the dielectric tensor – wave vector dependence of the dielectric tensor – electromagnetic waves in an isotropic dielectrics.
Nonlinear dielectric response of matter – frequency variation of the nonlinear susceptibilities – wave vector dependence of the nonlinear susceptibilities.

Module II

Second harmonic generation – perturbation theory – phase matching evolution of SHW under phase matching conditions.
Four wave mixing spectroscopy – optical phase conjugation – nonlinear materials.

Module III

Scattering of light – Raman scattering – Quantum theory of Raman scattering – Brillouin scattering. Interaction of atoms with nearly resonant fields – wave function under near resonant conditions. Bloch equations – self induced transparency.

Module IV

Fibre optics – normal modes of optical fibres – nonlinear Schrödinger equations – linear theory.
Basic concepts of solitons and non-linear periodic structures. Effect of fibre loss – effect of wave guide property of a fibre – conditions of generation of a solitons in optical fibres.

Text Books:

1. D.L. Mills, Nonlinear Optics, Springer, 2nd,ed. (1998)

Reference Books:

1. F.Zernike and J.E. Midwinter, Applied Nonlinear Optics
2. G.C. Badwin, Nonlinear Optics
3. A. Hasegawa, Optical Solitons in Fibres

29: Phase Transition and Critical Phenomena

Course Code: 29
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

To understand how to develop the physics of a system with many interacting components in equilibrium.
Understand the physics of phase transitions and related critical phenomena.

Course Outcomes

CO	CO Statement	CL
CO1	Get an in-depth understanding of equilibrium statistical mechanics.	Understand, Apply, Analyse
CO2	Acquire the ability to develop a quantitative theory of a system with many interacting degrees of freedom using exact and approximate methods	Apply, Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1
CO2	3	1	3	3	1

Module I

Review of equilibrium statistical physics, statistical physics of interacting systems: Cluster expansion for a classical gas. Virial expansion of the equation of state. Evaluation of the Virial coefficients. Van-Der-Walls equation of state and the liquid-vapor phase transition.

Module II

Ising models on lattices. Exact solution in $1D$ using transfer matrix, High and low temperature behavior of $2D$ model. Concepts related to phase transitions: Critical behavior, Order parameter, Peierls-Griffiths argument, Critical exponents.

Module III

Computer simulation methods, Metropolis algorithm. Mean field approach. Solution of d-dimensional Ising model. Evaluation of mean-field exponents. Landau theory of phase transition.

Module IV

Percolation phase transition. Exact solution in 1D and Bethe lattice. Cluster structure. Continuum percolation. Finite size scaling and the renormalization group approach (basic ideas).

Text Books :

1. R. K. Pathria, Statistical Mechanics, 2 nd edition, Elsevier (2005).
2. Principles of equilibrium statistical mechanics, D. Chowdhury and D. Stauffer, Wiley (2000).
3. D. Stauffer and A. Aharony, Introduction to percolation theory, Taylor & Francis (2003)

Reference Books :

1. K. Huang, Statistical Mechanics, 2 nd Edition, Wiley India (2008).
2. Landau and Lifshitz, Statistical Physics, Elsevier (2005).
3. Scaling and Renormalization in Statistical Physics, John Cardy, Cambridge University Press (2002).
4. Lectures On Phase Transitions And The Renormalization Group, Nigel Goldenfeld, CRC Press (2018).

30: Physics of Nanomaterials

Course Code: 30
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The course aims to develop an understanding of nanostructured materials and their various synthesis methods and characterization techniques. After completing the course, the students will be able to differentiate between bulk materials and nanomaterials, understand the optical, electrical, mechanical, and magnetic properties specific to nanomaterials. Additionally, the students become familiar with various top-down and bottom-up approaches for the synthesis of nanomaterials, as well as characterization tools for calculating particle size.

Course Outcomes

CO	CO Statement	CL
CO1	Understand the fundamental differences between nanostructured materials and bulk materials, and classification of nanomaterial based on dimension.	Understand
CO2	Classify 0D,1D,2D, and 3D materials and its optical, electrical, mechanical and magnetic properties	Understand, Analyse
CO3	Differentiate between different Bottom-up and Top-down methods used for nanomaterials synthesis with examples from literature.	Analyse
CO4	Assess different characterization tools used for understanding the size and distribution of nanomaterials	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	2	0	3	3	2
CO2	3	0	3	3	2
CO3	2	0	3	3	1
CO4	3	1	3	3	1

Module I

Introduction to nanoscience and technology (brief ideas), concept of electrons, holes, and excitons, low dimensional structures, quantum well, quantum wire and quantum dots, fullerenes, carbon nanotubes, structure of CNT, vibrational, mechanical and optical properties of CNT, applications of carbon nanotube.

Module II

Size effects on the optical, electrical, mechanical and magnetic properties, weak excitonic confinement and strong excitonic confinement, blue shift, Giant magnetoresistance (GMR) and Colossal magnetoresistance (CMR).

Module III

Synthesis of nanostructured materials, Bottom-up and Top-down processes, method of making 1- D and 2-D nanomaterials, high energy ball milling, co-precipitation technique, sol gel synthesis, solvothermal methods-control of grain size chemical vapor deposition (CVD), physical vapor deposition (PVD), Lithography.

Module IV

Characterization of nanomaterials, preliminary ideas about the operation and characterization of nano materials using scanning electron microscope (SEM), transmission electron microscope (TEM), scanning tunneling microscope (STM), atomic force microscope (AFM) and x-ray diffraction (XRD).

Text Books:

1. Michael F. Ashby, Paulo J. Ferreira, Daniel L. Schodek, Nanomaterials, Nanotechnologies and design, an introduction for engineers and architects, Elsevier (2009).
2. K.K Chattopadhyay, and A.N Banerjee, Introduction to nanoscience and nanotechnology, PHI Learning Private Limited, New Delhi.
3. B S Murty, P Shankar, Baldev Raj, B B Rath, and B B Rath, Textbook of Nanoscience and Nanotechnology, springer.
4. S.V. Gaponenko, Optical properties of semiconducting nanocrystals, Cambridge University Press (1997).
5. David B. Williams, and C. Barry Carter, Transmission Electron Microscopy: A textbook for materials science, second edition, Springer.
6. B. D. Cullity, and S. R. Stock, Elements of X-Ray diffraction, Springer, (2001).

Reference Books:

1. A. K. Bandhyopadhyay, Nanomaterials, New Age International Publishers (2007).
2. Bieter K. Schroder, Semiconductor material and device characterization, Wiley - Inter-science publication (1993)
3. A I Gusev and A A Remphal, Nanocrystalline materials, Cambridge International Science Publishing
4. Hari Singh Nalwla, Nanostructured materials and nanotechnology Vol. I, II, III, IV, V, VI, VII,VIII, IX (2002)
5. K L Chopra and Inderjeet Kaur, Thin Film Device Applications, Plennum Press (1983)
6. J H Davis, Physics of low dimensional structures Cambridge (1998).

31: Principles of Biomedical Instruments

Course Code: 31
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The objective of this course is to understand the underlying physics of the medical imaging systems and to give an overview of major modern diagnostic techniques.

Course Outcomes

CO	CO Statement	CL
CO1	Get a good understanding, on biomedical instruments	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1

Module I

Flame photometers, Introduction to Spectro photometers,Beer lambert law,Colorimeters, Blood gas analyzers, Principles and techniques of sterilization–Autoclave, Sterrad. Chromatography – Gas and liquid Chromatographs – Principle and applications. Mass spectroscopy, flow cytometry–Principles and applications. Electrophoresis – Principles and applications.

Module II

X-rays:Principle and production of X-rays, Interaction of X rays with matters, Transfer characteristics of screen, Film and image intensifier systems, Properties of X-ray films and screens, Characteristics of Imaging system by image modulation transfer functions, Radiography:Various components of Radiography systems – Exposure switching and control of exposure time – Types of timer circuits, Filament circuit and KV– mA controls – HT units – X-ray tubes for various medical applications – fixed anode, rotating anode, X-ray tubes for specialized applications – collimators

Module III

Medical ultrasound: Physics of ultrasonic waves, Interactions with body matter, Generation and detection, Single element transducer, Linear and sector scanning Transducer arrays, Different modes of display, Modes of transmission of ultrasound, Colour Doppler, Ultrasonic diagnosis in abdomen, Breast, Heart, Chest, Eye, Kidney, Skull, Pulsatile motion, Pregnant and Non-Pregnant uterus. Ultrasound pulse echo imaging system, Design of scan converters, Design of frame grabbers, 2D scanners.

Module IV

Magnetic Resonance Imaging:Principles of image formation– MRI instrumentation-magnets Gradient system – RF coils receiver system, Pulse sequence– Image acquisition and reconstruction techniques, Application of MRI, Fundamentals of magnetocardiography and magnetoencephalography

Text Books:

Text Books :

1. Fundamental Physics of radiology,W.J. Meredith & J.B. Massey, Varghese Publishing House, Bombay, 1992.

2. The Physics of Diagnostic Ultrasound, Peter Fish, John Wiley & Sons, England, 1990. 4.

3. Ultrasound Physics & Instrumentation,D.L. Hykes, W.R. Hedrick & D.E. Starchman, Churchill Livingstone, Melbourne, 1985.

Reference Books :

1. Principles of Applied Biomedical Instrumentation,L.A.Geddes & L.E.Baker, Wiley

2. Handbook of Analytical Instruments, Khandpur R S, Tata McGraw Hill,1989
   India Pvt.Ltd, Third Edition, 1989.

3. Radiographic Imaging,D.N. & M.O. Chesney, CBS Publishers, 1990.

4. The Physics of Medical Imaging, S. Webb, IOP Publishing Ltd., 1988.

32: Quantum Field Theory

Course Code: 32
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

To introduce the basic concepts and methods of classical and quantum field theory.

Course Outcomes

CO	CO Statement	CL
CO1	Understand the basics of classical field theory concepts and methods of calculation	Understand
CO2	Understand about the scalar field and Feymann propagator and it's usage	Understand
CO3	Familiarize with the idea of quantization of the filed and allied facts	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1
CO2	3	1	3	3	1
CO3	3	1	3	3	1

Module I

Classical field theory, Euler Lagrange equations, Hamilton formalism, conservation laws. Canonical quantization of neutral and charged scalar filed, symmetry transformations.
(Sect. 2.1-2.2, 2.4, 4.1-4.3 of Ref. 1)

Module II

Scalar fields: The invariant commutation relations, scalar Feynman propagator. Dirac fields-- canonical quantization of Dirac fields-Feynman propagator.
(Sect. 4.4-4.5, 5.1-5.4 of Ref. 1)

Module III

Canonical quantization of Maxwell's field-Maxwell's equations-Lorentz and Coulomb gauges-Lagrangian density.
Canonical quantization in Lorentz and Coulomb gauges-Coulomb interaction and transverse delta functions.
(Sect. 6.1--6.2, 7.1--7.5, 7.7 of Ref. 1)

Module IV

Interacting fields, interaction picture, time evolution operator, scattering matrix, Wick's theorem(no proof), Feynman rules(no rigorous treatment) -Moller and Compton scattering.
(Sect. 8.1-8.7 of Ref. 1)

Spontaneous symmetry breaking, scalar theory, Goldston theorem(no proof), spontaneous breaking of gauge symmetries.
(Sect. 8.1-8.3 of Ref. 2)

Text Books:

1. Field Quantization, Greiner W and Reinhardt J, Springer, (2013)
2. Quantum Field Theory, Ryder L H, Cambridge University Press; 2 edition (1996)

Reference Books:

1. Quantum Field Theory, Itzykson C and Zuber J B, Dover Publications Inc., (2006)
2. Relativistic Quantum Fields I & II, Bjorken J D and Drell S D, McGraw Hills(1965)

33: Quantum Computation and Information

Course Code: 33
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Prerequisites

Knowledge of basic quantum mechanics and Mathematical Physics.

Course Objectives

Course Outcomes

CO	CO Statement	CL
CO1	Get an overview of the emerging field of quantum computation and the techniques involved in that	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1

Module I

Introduction to classical computation. The Turing machine - the circuit model of computation - computational complexity (elementary ideas) - energy and information - reversible computation. Introduction to quantum mechanics - Linear vector space - Tensor products - Postulates of quantum mechanics - the EPR paradox and Bell's theorem. (relevant sections of Chapter 1 and 2 of Benenti et.al.)

Module II

The qubit - single qubit gates - controlled gates - universal quantum gates - Deutsch and Deutsch - Josza algorithms - the quantum Fourier transform - period finding and Schor's algorithm - quantum search - first experimental implementations (relevant sections of Chapter 3 of Benenti et.al.)

Module III

Classical cryptography-quantum no - cloning theorem - quantum cryptography - BB84 and E91 protocols - dense coding - quantum teleportation - experimental implementations. (relevant sections of Chapter 4 of Benenti et.al.)

Module IV

Classical information and Shannon entropy - data compression - density matrix in quantum mechanics - von Neumann etropy - quantum data compression - composite systems - Schmidt decomposition - entanglement concentration (relevant sections of Chapter 5 of Benenti et.al.)

Text Books:

1. G. Benenti, G. Casati and G. Strini, Principles of quantum computation and information (World Scientific)

Reference Books:

1. M. A. Nielson and I. L. Chuang, Quantum computation and quantum information (Cambridge University Press)

34: Quantum Optics

Course Code: 34
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective

To teach the students about the basics and sufficient advanced ideas of Quantum Optics.

Course Outcome

CO	CO Statement	CL
CO1	Acquire sufficient knowledge regarding the radiation-matter interaction	Understand
CO2	Acquire a thorough understanding of the black body radiation and laser theory	Understand
CO3	Get a clear idea about the modern concepts like, Doppler broadening, multimode field quantization, etc.	Understand, Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1
CO2	3	1	3	3	1
CO3	3	1	3	3	1

Module I

Interaction between electromagnetic waves and matter – linear dipole oscillator method – radiative damping – coherence.
Nonlinear dipole oscillator method. Coupled mode equations cubic nonlinearity – nonlinear susceptibilities.

Module II

Atom-field interaction for two level atoms – blackbody radiation – Rabi Flopping.
Introduction to laser theory – the laser self consistency equation – steady state amplitude and frequency – stability analysis – mode pulling.

Module III

Doppler – broadened lasers – Two mode operation and the ring laser – mode locking – single mode semiconductor theory – evaluation of laser gain and index formulas – transverse vibrations and Gaussian beams.
Field quantization - single mode field quantization – multimode field quantization – single mode in thermal equilibrium. Coherent states – coherence of Quantum fields p ( ) representations.

Module IV

Interaction between atoms and quantized fields – Dressed states – Jaynes-Cummings model – collapse and revival.
Squeezed state of light – squeezing the coherent states – two side mode master equation – two mode squeezing – squeezed vacuum.

Text Books:

1. P. Meystre and M. Sargent III, Elements of Quantum Optics (2^{nd} Ed.)

Reference Books:

1. W.H. Louisell, Quantum Statistical Properties of Radiation
2. M. Sargent III, M.O. Scully and W.E. Lamb, Laser Physics

35: Radiation Physics

Course Code: 35
Credits: 4
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

This course provides a comprehensive overview of the physics of radiation, including its sources, interactions with matter, detection methods, and applications across various fields such as medicine, industry, and environmental science. Emphasis is placed on understanding the fundamental principles underlying radiation physics and the practical implications for radiation safety and protection.

Course Outcomes

CO	CO Statement	CL
CO1	Explain the difference between natural and artificial sources of light.	Understand
CO2	Understand the mechanisms of radiation interaction with matter.	Understand
CO3	Describe methods for detecting and measuring radiation.	Understand
CO4	Apply principles of radiation protection and safety.	Apply
CO5	Discuss the applications and implications of radiation in various fields.	Analyse

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	3	3	1	1
CO2	3	3	2	1	1
CO3	3	3	3	3	0
CO4	3	1	3	2	1
CO5	3	3	3	1	1

Module I

Introduction to Radiation Physics, Radioactivity, Types of Radioactive decay, alpha, beta, gamma, x-rays, neutrons, Sources of radiation: natural and artificial, Units of radiation measurement, Atomic and Nuclear Physics Fundamentals, Structure of matter and radiation, Radioactive decay processes, Nuclear reactions and energy.

Module II

Interaction of Radiation with Matter, Mechanisms of energy transfer, Attenuation and absorption, Scattering processes, Radiation Detection and Measurement, Detection principles, Instrumentation: ionization chambers, Geiger-Müller counters, scintillation detectors, semiconductor detectors, Dosimetry and dose measurement techniques.

Module III

Radiation Protection and Safety, Biological effects of radiation, Radiation dose limits and exposure control, Shielding materials and design, Regulatory and safety standards, Applications of Radiation Physics.

Module IV

Medical applications: diagnostic imaging, radiation therapy, Industrial applications: non- destructive testing, material analysis, Environmental and space applications, Agriculture Applications.

Text Books:

1. Introduction to Radiological Physics and Radiation Dosimetry by Frank Herbert Attix, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, 2004.

2. Fundamentals of Ionizing Radiation Dosimetry; by Pedro Andreo, David T. Burns, Alan E. Nahum, Jan Seuntjens, 2017, Wiley-VCH Verlag GmbH, Germany, 2017.

3. Radiation Physics for Medical Physicists; by Ervin B. Podgorsak, Springer Cham, Switzerland, 2016.

4. Radiation Detection and Measurement; by Glenn F. Knoll, Fourth Edition, John Wiley & Sons, Inc. New York, 2010.

36: Science to Data Science: An Introductory Course with Python applications

Course Code: 36
Credits: 4
Academic Level: 300
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The course aims to provide the big picture of data science/analytics with specific applications that enable a science graduate to choose a career involving statistical analysis and modeling of data.

Course Outcomes

CO	CO Statement	CL
CO1	Learn elements of probability theory with commonly used probability distributions.	Understand
CO2	Build foundations of statistical inference and parameter estimation	Understand
CO3	Learn advanced topics of Bayesian inference and Monte Carlo methods.	Apply, Analyse
CO4	Learn techniques and tools for analyzing modeling data (including machine learning).	Understand, apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1
CO2	3	1	3	3	1
CO3	3	1	3	3	1
CO4	3	1	3	3	1

Module I

Elements of probability theory: conditional probability, Bayes theorem. Random variables: continuous and discrete case, probability distribution functions, expectation values. Common probability distributions and applications: binomial, Poisson, Gaussian, power law distributions, etc.; Multivariate Gaussian distributions.

Module II

Statistical inference: General Concepts - population, sample, statistic, estimator, bias, sampling distribution - chi2, Student-t distributions Hypothesis testing: Null and alternate hypothesis, test statistic, significance level, p-value Point estimation - method of moments, maximum likelihood method, least square and Chi-square fitting, Confidence intervals and limits - goodness of fit.

Module III

Bayesian inference and their applications - Bayesian parameter estimation. Stochastic Processes: Continuous and Point Processes - White noise, Poisson Process, Markov Process, etc. Time series analysis - basic concepts, auto, and cross-correlations; Monte Carlo Methods - Uniformly distributed random numbers, the acceptance-rejection method, applications, Markov Chain Monte Carlo methods, Metropolis-Hastings Algorithm.

Module IV

Data visualization with Python.
Regression analysis - least square linear regression, non-linear regression.
Introduction to Machine Learning: Elements of neural networks, deep learning Applications.

Reference Books:

1. Probability and Statistics: The Science of Uncertainty (Second Edition), Michael J. Evans and Jeffrey S. Rosenthal, W. H. Freeman Publishers, 2010.
2. Applied Statistics and Probability for Beginners, , D. C. Montgomery, G. C. Runger, John Wiley & Sons, 2024.
3. Stochastic Processes in Physics and Chemistry (third edition), N. G. Van Kampen, Elsevier Science B, 2007.
4. Machine Learning Specialization https://www.coursera.org/specializations/machine-learning-introduction.

37: Solar Photovoltaic Technology

Course Code: 37
Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The objective of the course is to develop a general understanding of the need for clean energy sources and the potential and application of photovoltaic (PV) technology to generate power. The course will give an insight into the fabrication of solar cells in the laboratory and industrial scale, module fabrication and power generation using PV in off-grid and grid-connected systems.

Course Outcomes

CO	CO Statement	CL
CO1	Explain the working principle of solar cells.	Understand
CO2	Differentiate the fabrication and performance differences between different c-Si wafer technologies and between c-Si and thin film PV technologies.	Understand, Analyse
CO3	Illustrate cells and their interconnection.	Understand
CO4	Calculate the power and energy produced by a solar module.	Apply
CO5	Explain the differences and design aspects of off-grid and on-grid PV systems and futuristic applications of solar energy.	Analyse
CO5	Simulate Si solar cell performance and solar power generation at a place.	Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1
CO2	3	1	3	3	1
CO3	3	1	3	3	1
CO4	3	1	3	3	1
CO5	3	1	3	3	1

Module I

Introduction: Energy scenario - Fossil fuel and Climate change - Renewable Energy sources - Integrating Renewable Energy - Renewable energy scenarios - Economic Analysis of Renewable Energy System - Photovoltaics - history of photovoltaics - status of Photovoltaics - Grid Parity - Challenges - trends in photovoltaic technology - Policy Impacts - PV market growth scenarios - Solar radiation: Solar constant - Solar Spectra - Air Mass - Global radiation - Position of the Sun - Solar Insolation. **Physics of Solar cells:** Fundamental Properties of Semiconductors - Band model - Doping - Semiconductor types - absorption of light - recombination - p-n junction - Solar cells - Solar cell parameters - Spectral response - Upper limits of cell parameters - Thermodynamic limit - the Schokley-Quiesser limit - effect of temperature - effect of parasitic resistances.

Module II

Solar PV technologies (qualitative)

First generation: Silicon wafer based technology: Design of c-Si solar cell - loss mechanism - high-efficiency approaches - PERL and PERC cells - Interdigitated back contacts - TOPCon - heterojunction solar cells - lab to industry requirements.
S**econd generation: Thin film technologies:** Merits and demerits of thin film technologies - Transparent conducting oxides - GaAs, amorphous-Si, CdTe and CIGS solar cells.
—bf Third generation/emerging PV technologies: Organic PV - organic-inorganic hybrid solar cells -perovskite solar cells- Quantum-dot - Hot-carrier – Up conversion and down conversion- concentrated solar cells- perovskite/Si tandem solar cells - Multijunction Solar Cells, Concentrated Solar Cells.

Module III

Solar cell to modules: Thin film solar modules by monolithic integration- silicon feedstock - production of silicon wafers - Manufacturing process of c-Si solar cells – the interconnection of cells - series and parallel connections - design and structure of PV module - production - measurement of modules - field performance- module reliability.

Module IV

PV systems: Standalone systems - grid-connected systems - hybrid systems - micro grids - smart grids - system components - system design. **Specific purpose PV application:** Agrovoltaics, Lighting, Building integrated Photovoltaics, refrigeration, telecommunications, space, fencing, water purification, navigation, solar cars, etc. **Simulations and hands-on:** introduction to PVSyst software, PC1D, AFORS-HET, Solar Module Installation, Solar Cell Characterization, field performance analysis.

Text Books:

1. S.R. Wenham, M. Green, M.E. Watt, R. Corkish, A. Sproul, Applied Photovoltaics ? 2nd Edition (2009)

2. K. Mertens, Photovoltaics: Fundamentals, Technology and Practice, John Wiley & Sons Ltd (2014)

3. Smets, K. Jager, O. Isabella, R. V. Swaaij, M. Zeman, Solar Energy: The physics and engineering of photovoltaic conversion, technologies and systems, UIT Cambridge Ltd. (2016).

Reference Books:

1. Handbook of Photovoltaic Science and Engineering - 2nd Ed. , A. Luque, S. Hegedus (editors), John Wiley & Sons Ltd (2011)

2. Chetan Singh Solanki, Solar Photovoltaics: Fundamentals, Technologies and applications, 3rd Edition, PHI Learning Pvt. Ltd. (2019).

3. Jenny Nelson, The Physics of Solar Cells, Imperial College Press (2003).

4. Godrfrey Boyle (Eds), Renewable Energy: Power for a sustainable future, Oxford University Pres (2012).

5. S.P. Sukhatme, J.K. Nayak, Solar Energy 4th Edn, McGraw-Hill Education (2017)

6. SM Sze and Kwok K Ng, Physics of semiconductor devices, third edition ,John Wiley & Sons (2007)
7. R.F. Pierret, Semiconductor Device Fundamentals
8. D. A. Neamen and D. Biswas ,Semiconductor Physics and Devices

38: Sophisticate Material Characterization Techniques

Course Code: 38
Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

To train the students on the fundamentals of structural characterization of materials and to understand the usefulness of different characterization techniques.

Course Outcomes

CO	CO Statement	CL
CO1	Get good fundamental understanding, on different types of sophisticated material characterisation techniques.	Understand, Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1

Module I

X-ray diffraction - X-ray methods - Production of X-rays and X-ray Spectroscopy - Instrumental units - Detectors for the measurements of radiation - Semiconductor detectors - Direct X-ray methods - Powder method - rotating crystal method - specimen preparation - -Single crystal diffractometer – Electron diffraction-Neutron diffraction- Reflection high energy electron diffraction (RHEED), XPS-principle-Instrumentation and applications-X-ray topography(XRT)- Rutherford Back Scattering analysis(RBS)- XRF (X-ray fluorescence)- Synchrotron radiation- Applications (Qualitative) – XANES-XAFS.

Module II

Morphological studies Optical microscope, Electron matter interaction- Fundamental principle and instrumentation and applications of Scanning Electron Microscope (SEM)- Transmission Electron Microscope (TEM) - Scanning transmission electron microscopy (STEM)- Atomic Force Microscope- Elemental composition analysis-EDX-EELS- Auger electron spectroscopy (AES)- Optical measurements-UV-visible spectroscopy- Determination of band gap of semiconductors- Atomic emission spectrometry.

Module III

Absorption and Emission spectroscopy - Nature of electromagnetic radiation - Atomic energy level-Raman effect - Raman Spectroscopy- Instrumentation -Infrared spectroscopy - Near IR - Mid IR - Far IR Region - Correlation of infrared spectra with molecular structure - structural Analysis - Radiation sources - Detectors - Thermal Detectors -Spectrophotometers - Fourier Transform Interferometer Quantitative analysis- Sample handling. - Luminescence –Photoluminescence(PL) spectroscopy–Nuclear magnetic Resonance Spectroscopy - Basic principles - Quantitative analysis-Dyanamic Light scattering- Secondary ion mass spectroscopy (SIMS).

Module IV

Thermal analysis - Differential Thermal Analysis - Instrumentation – Differential Scanning calorimetry - Thermogravimetry - Instrumentation - Methodology of Differential Scanning Calorimetry and Thermo Gravimetric Analysis - Conductance method – Electrical conductivity- Measurement of electrical conductance - Measurement of dielectric constant- Hall Mobility – Magnetic measurements-SQUID magnetometer- Fundamentals of cyclic voltammetry CV measurements.

Text Books:

1. B.D. Cullity, Element of X-ray Diffraction, Addison Wesley Publication, 1978.
2. X.F. Zong, Y.Y.Wang, J. Chen, Material and Process characterization for VLSI, World Scientific, New Jersey, 1988.
3. H.H.Willard, D.L.Merrti, Dean and Settle, Instrumental methods of analysis, CBS publishers.1992.
4. Yang Leng, Materials Characterization Introduction to Microscopic and Spectroscopic Methods; Wiley-VCH-Second Edition.
5. P.E. J. Flewitt and R K Wild Physical methods for Materials Characterization, IOP Publishing (2003).
6. P.Duke ; Synchratron radiation, Oxford university press 2000.
7. Molecular Structure and Spectroscopy, G.Aruldhas, PHI Learning Private Limited New Delhi.
8. Zoski, C. G., Ed. Handbook of Electrochemistry; Elsevier: Amsterdam, The Netherlands, 2006.
9. John Clarke , Alex I. Braginski; The SQUID Handbook: Fundamentals and Technology of SQUIDs and SQUID Systems- Wiley-VCH.
10. Banwell and E M McCash, Fundamentals of Molecular Spectroscopy; McGraw-Hill Education (India) Pvt Limited, 2001.

39: Thin Film Physics

Course Code: 39
Credits: 4
Academic Level: 500
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objective

To impart the modern ideas of thin film technologies used in various solid state physics and day today applications.

Course Outcome

CO	CO Statement	CL
CO1	Familiarise with the different thin film deposition methods.	Understand
CO2	Understand the nuclear theories of thin film formation.	Understand
CO3	Familiarise with the measurements techniques of the properties of thin films.	Understand
CO4	Get awareness and knowledge of various application of thin films in semiconductor devices and in day today life.	Understand, Apply

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	1	1	3	3	1
CO2	3	1	3	3	1
CO3	3	1	3	3	1
CO4	3	1	3	3	1

Module I

Vacuum Technology: High vacuum production: Mechanical pumps – Diffusion pumps-Cryogenic pumps – Getter pumps – ion pumps- basics of ultra-high vacuum Measurement of Vacuum: McLeod gauge – Thermal conductivity gauges - Cold cathode and hot cathode ionisation gauges Designing a vacuum system- vacuum leak detection: helium leak detector, residual gas analyzer.

Module II

Thin film growth techniques: Physical Vapour Deposition: Vacuum evaporation - Evaporation theory - Rate of evaporation - Hertz-Kundsen equation - Free evaporation and effusion - Evaporation mechanisms - Directionality of evaporating molecules - vapour sources - wire and metal foils - Electron beam gun- sputtering - Glow discharge sputtering - Bias sputtering - Reactive sputtering - Magnetron sputtering - Ion beam sputtering - PLD- epitaxial films- MBE Chemical Vapour deposition: conventional CVD, Plasma enhance CVD, MOCVD, Atomic layer Deposition Film thickness measurements: Optical methods - basics of multilayer modelling- Ellipsometry -Other techniques: Electrical - Mechanical - Micro-balance - Quarts crystal monitor - X ray reflectivity.

Module III

Nucleation Theories: Condensation process - Theories of Nucleation – Capillarity theory – Atomistic theory – Comparison – stages of film growth – Incorporation of defects during growth.

Optical properties:Reflection and transmission at an interface – Reflection and transmission by a single film – Optical constants - Refractive index measurement techniques – Reflectivity variation with thickness Patterned films: lithography techniques – film etching methods.

Module IV

Electrical Properties: Electrical Properties: Sources of resistivity – sheet resistance – electron mobility- Hall Effect -TCR – Influence of thickness on resistance – Theories of size effect – Theories of conduction in discontinuous films – Electronic conduction in thin insulating films- MIS structure -Dielectric properties – D.C. conduction mechanisms – High and low field conduction – Temperature dependence – space charge limited conduction – A.C. conduction mechanisms Application of thin films: electrodes, transparent conducting oxides, thin film devices: LED, TFT, -Solar cells - optical and decorative coatings - dichroic coatings- biomedical coatings – tribological coatings.

Text Books:

1. Hand Book of Thin Film Technology, Maissel and Glang, McGraw Hill Higher Education (1970)
2. Materials science of thin films deposition and structures, Milton Ohring, Academic press, 2006.
3. Vacuum deposition of thin films, L. Holland, Chapman and Hall.
4. Glow discharge processes, B. Chapman, Wiley, New York.
5. Physics of Non-Metallic Thin Films, Dupy and Kachard, Plenum Press (1976).
6. Scientific Foundations of Vacuum Technology, S. Dushman and J.M. Lafferty, John Wiley & Sons, Inc.; 2nd Ed. (1962).
7. Thin Film Phenomena, K.L. Choppra, McGraw-Hill Inc.,US (1969).

Reference Books:

1. O. S. Heavens, Optical Properties of Thin Films, by, Dover Publications, Newyork 1991
2. Donald L. Smith ‘Thin Film deposition principle and Practice’s, McGraw Hill international Edition, 1995.
3. Various web resources and research papers

40: Ultrashort Pulse Lasers and Applications

Course Code: 40
Credits: 4
Academic Level: 400
Hours per week: L - 4, T - 1, P - 0. Total Hours per semester: L - 60, T - 15

Course Objectives

The course is on intense femto-second lasers and applications with emphasis on the current trends on the subject. Learning will be through lectures, books, journal articles and recent reviews on the subject.

Course Outcomes

CO	CO Statement	CL
CO1	Illustrate process of generation, amplification, and measurement of ultrashort lasers	Understand
CO2	Analyse high power relativistic and non-relativistic laser interaction with gaseous and condensed media.	Apply, Analyse
CO3	Evaluate Research Opportunities and technology of intense field interaction physics.	Analyse
CO4	Develop lifelong learning skills through research	Understand

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2	3	1	1
CO2	2	1	3	1	1
CO3	2	1	3	1	1
CO4	2	0	3	0	2

Module I: Femtosecond Lasers

Femtosecond laser oscillators - Mode locking - Kerr lens mode locking - Group velocity dispersion–Chirped Mirrors - Time bandwidth product - bandwidth limited pulses - Ti: Sapphire laser - chirped pulse amplification - regenerative amplifiers - multipass amplifiers –Ultrafast pulse measurements - intensity autocorrelation - cross correlation - FROG and SPIDER.

Module II: Laser Interaction with gas phase

Laser interaction with low density Gas - Ionization-Multiphoton ionization - Tunnel ionization - Keldysh Approximation - Over the barrier ionization - Laser interaction with Clusters - Generation of rare gas clusters - cluster diagnostics through Rayleigh scattering – Properties of clusters – cluster ionization – Nano plasma model – Expansion of clusters – Coulomb explosion – Hydrodynamic expansion.

Module III: Interaction with condensed media

Basics of a plasma – Plasma density, plasma temperature, Debye length plasma frequency, critical density - Laser interaction with solids above damage threshold - Inverse bremsstrahlung absorption – collisional absorption – resonance absorption (Brunel heating) – vacuum heating - Laser produced plasma – Free-free, free-bound and line radiations in a plasma.

Module IV: Applications of Intense Lasers

Transient absorption spectroscopy - THz radiation - Two photon polymerization and direct laser 3D printing - High harmonic generation (re-collision picture) – Attosecond pulses - X-ray sources from laser-solid and laser-cluster interactions – Water window radiation – Laser Wakefield acceleration (LWFA) of electrons – Inertial Confinement Fusion.

Text Books: Units I & II

1. Claude Rulliere, Femtosecond Laser Pulses – Principles & Experiments 2 nd Ed., Springer (2005).
2. Jean-Claude Diels and Wolfgang Rudolph Ultrashort Laser Pulse Phenomena, Elsevier (2006)

Unit III

1. W L Kruer, The Physics of Laser-plasma Interactions, Addison-Wesley (1988).
2. F F Chen Plasma Physics and Controlled Fusion, 2 nd Ed., Plenum Press (1984)

Unit IV

1. Jean-Claude Diels and Wolfgang Rudolph Ultrashort Laser Pulse Phenomena, Elsevier (2006).
2. Soft x-rays and Extreme Ultraviolet Radiation: Principles and Applications, David Atwood, Cambridge University Press, 1999.