VIT

Vellore Institute of Technology

(Deemed to be University under section 3 of UGC Act, 1956)

SCHOOL OF ADVANCED SCIENCES
DEPARTMENT OF PHYSICS

M.Sc Physics
(MSP)

Curriculum & Syllabi
(2025-2026 Admitted Students)

VIT
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

VISION STATEMENT OF VELLORE INSTITUTE OF TECHNOLOGY

Transforming life through excellence in education and research.

MISSION STATEMENT OF VELLORE INSTITUTE OF TECHNOLOGY

- **World class Education**: Excellence in education, grounded in ethics and critical thinking, for improvement of life.
- **Cutting edge Research**: An innovation ecosystem to extend knowledge and solve critical problems.
- **Impactful People**: Happy, accountable, caring and effective workforce and students.
- **Rewarding Co-creations**: Active collaboration with national & international industries & universities for productivity and economic development.
- **Service to Society**: Service to the region and world through knowledge and compassion.

VISION STATEMENT OF SCHOOL OF ADVANCED SCIENCES

To be an internationally renowned science school in research and innovation by imparting futuristic education relevant to the society.

MISSION STATEMENT OF SCHOOL OF ADVANCED SCIENCES

- To nurture students from India and abroad by providing quality education and training to become scientists, technologists, entrepreneurs and global leaders with ethical values for a sustainable future.

- To enrich knowledge through innovative research in niche areas.

- To ignite passion for science and provide solutions for national and global challenges.

M.Sc. Physics

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

1. Graduates will be practitioners and leaders in their chosen field.
2. Graduates will function in their profession with social awareness and responsibility.
3. Graduates will interact with their peers in other disciplines in their work place and society and contribute to the economic growth of the country.
4. Graduates will be successful in pursuing higher studies in their chosen field.
5. Graduates will pursue career paths in teaching or research.

M.Sc. Physics

PROGRAMME OUTCOMES (POs)

PO	Element of the Descriptor		NHEQF level descriptor (The graduate should ..)
PO_01	Complex problem solving	:	Demonstrate the capability to different kinds of problems in familiar and non-familiar contexts and apply the learning in real-life situations.
PO_02	Critical Thinking and Creativity	:	Demonstrate the capability to apply analytic thought to a body of knowledge, analyse and synthesise data from a variety of sources and draw valid conclusions and support them with evidence and examples.
PO_03	Digital Communication and Technological skills	:	Demonstrate the skills that enable them to convey ideas, thoughts and arguments using language and ICT that is respectful and sensitive to gender and other minority groups, and the use of appropriate software for analysis of data.
PO_04	Research related skills	:	Demonstrate the ability to problematize, synthesise and articulate issues, design research proposals and the capacity to develop appropriate methodology and tools for data collection, and follow ethical principles and practices in all aspects of research and development and avoid unethical practices.
PO_05	Learning 'how-to-learn' skills	:	Demonstrate the ability to acquire new knowledge and skills that are necessary for pursuing learning activities throughout life, through self-paced and self-directed learning aimed at personal development and demands of the workplace.
PO_06	Ethics and Value inculcation	:	Demonstrate the acquisition of knowledge and attitude that are required to embrace and practice constitutional, humanistic, ethical and moral values in life including universal human values of truth, righteous conduct, peace, love, non-violance, scientific temper.
PO_07	Environmental awareness and action	:	Demonstrate and acquisition and ability to apply the knowledge, skills, attitude, and values required to recognize environmental and sustainable issues, participate in actions to promote sustainable development, and mitigating the effects of changing environment that is required for sustainable development and living.

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PROGRAMME SPECIFIC OUTCOMES (PSOs)

On completion of M.Sc. Physics programme, graduates will be able to

- PSO1: Hone the basic concepts of core areas of Physics especially in mathematical Physics, electromagnetism, classical mechanics, statistical mechanics and quantum mechanics for unraveling the diverse phenomena observed in nature.
- PSO2: Perform the general Physics and research oriented experiments with appropriate analysis for proper interpretation of results; to undertake individual project and present the research findings.
- PSO3: Independently carry out research / investigation to solve practical problems and write / present a substantial technical report/document

Master of Science in Physics
School of Advanced Sciences

Programme Credit Structure	Credits
Discipline Core Courses	28
Skill Enhancement Courses	05
Discipline Elective Courses	21
Open Elective Courses	06
Project/ Internship	21
Total Graded Credit Requirement	81

Discipline Core Courses — 28

		L	T	P	C
PPHY501L	Mathematical Physics	3	1	0	4
PPHY502L	Electronics	3	0	0	3
PPHY503L	Classical Mechanics	3	1	0	4
PPHY504L	Electromagnetic Theory	3	1	0	4
PPHY505L	Quantum Mechanics	3	0	0	3
PPHY506L	Solid State Physics	3	0	0	3
PPHY507L	Statistical Physics	3	0	0	3
PPHY508P	General Physics Lab-I	0	0	4	2
PPHY509P	General Physics Lab-II	0	0	4	2

Skill Enhancement Courses — 05

PENG503P	Technical Report Writing	0	0	4	2
PSTS501P	Qualitative Skills Practice	0	0	3	1.5
PSTS502P	Quantitative Skills Practice	0	0	3	1.5

Discipline Elective Courses — 21

PPHY601L	Advanced Quantum Mechanics	3	0	0	3
PPHY602L	Advanced Mathematical Physics	3	0	0	3
PPHY603L	Nuclear and Particle Physics	3	0	0	3
PPHY604L	Atomic and Molecular Physics	3	0	0	3
PPHY605L	Lasers and Nonlinear Optics	3	0	0	3
PPHY606L	Optoelectronics	3	0	0	3
PPHY607L	Plasma Physics	3	0	0	3
PPHY608L	Biophysics	3	0	0	3
PPHY609L	Advanced magnetism and magnetic materials	3	0	0	3
PPHY610L	Semiconductor Device Physics	3	0	0	3
PPHY611L	General Theory of Relativity	3	0	0	3
PPHY612L	Advanced Statistical Mechanics	3	0	0	3
PPHY613L	Numerical Methods in Physics	3	0	0	3
PPHY614L	Instrumentation Techniques	3	0	0	3
PPHY615L	Nanophysics	3	0	0	3
PPHY616L	Microwave Physics and Device Technology	3	0	0	3
PPHY617L	Materials Science	3	0	0	3
PPHY618L	Thin Film Technology	3	0	0	3
PPHY619L	Photonics	3	0	0	3
PPHY620L	Advanced Solid State Physics	3	0	0	3
PPHY621L	Astrophysics	3	0	0	3

Open Elective Courses — 06

Engineering Disciplines | Social Sciences

Project and Internship — 21

PPHY696J	Study Oriented Project	02
PPHY697J	Research Project	02
PPHY698J	Internship I/ Dissertation I	05
PPHY699J	Internship II/ Dissertation II	12

CREDIT STRUCTURE

Category-wise Credit distribution

Category	Credits
Discipline Core	**28**
Skill Enhancement Courses	**05**
Discipline Elective Courses	**21**
Open Elective Courses	**06**
Project/ Internship	**20**
Total credits	**81**

DETAILED CURRICULUM

Discipline Core Courses

S. No.	Course Code	Course Title	L	T	P	C
1.	PPHY501L	Mathematical Physics	3	1	0	4
2.	PPHY502L	Electronics	3	0	0	3
3.	PPHY503L	Classical Mechanics	3	1	0	4
4.	PPHY504L	Electromagnetic Theory	3	1	0	4
5.	PPHY505L	Quantum Mechanics	3	0	0	3
6.	PPHY506L	Solid State Physics	3	0	0	3
7.	PPHY507L	Statistical Physics	3	0	0	3
8.	PPHY508P	General Physics Lab-I	0	0	4	2
9.	PPHY509P	General Physics Lab-II	0	0	4	2

DETAILED CURRICULUM

Skill Enhancement Courses

S. No.	Course Code	Course Title	L	T	P	C
1.	PENG503P	Technical Report Writing	0	0	4	2
2.	PSTS501P	Qualitative Skills Practice	0	0	3	1.5
3.	PSTS502P	Quantitative Skills Practice	0	0	3	1.5

DETAILED CURRICULUM

Discipline Elective Courses

S. No.	Course Code	Course Title	L	T	P	C
1.	PPHY601L	Advanced Quantum Mechanics	3	0	0	3
2.	PPHY602L	Advanced Mathematical Physics	3	0	0	3
3.	PPHY603L	Nuclear and Particle Physics	3	0	0	3
4.	PPHY604L	Atomic and Molecular Physics	3	0	0	3
5.	PPHY605L	Lasers and Nonlinear Optics	3	0	0	3
6.	PPHY606L	Optoelectronics	3	0	0	3
7.	PPHY607L	Plasma Physics	3	0	0	3
8.	PPHY608L	Biophysics	3	0	0	3
9.	PPHY609L	Advanced magnetism and magnetic materials	3	0	0	3
10.	PPHY610L	Semiconductor Device Physics	3	0	0	3
11.	PPHY611L	General Theory of Relativity	3	0	0	3
12.	PPHY612L	Advanced Statistical Mechanics	3	0	0	3
13.	PPHY613L	Numerical Methods in Physics	3	0	0	3
14.	PPHY614L	Instrumentation Techniques	3	0	0	3
15.	PPHY615L	Nanophysics	3	0	0	3
16.	PPHY616L	Microwave Physics and Device Technology	3	0	0	3
17.	PPHY617L	Materials Science	3	0	0	3
18.	PPHY618L	Thin Film Technology	3	0	0	3
19.	PPHY619L	Photonics	3	0	0	3
20.	PPHY620L	Advanced Solid-State Physics	3	0	0	3
21.	PPHY621L	Astrophysics	3	0	0	3

DETAILED CURRICULUM

Open Elective Courses

S. No.	Course Code	Course Title	L	T	P	C
1.		Engineering Disciplines | Social Sciences				

DETAILED CURRICULUM

Project and Internship

S. No.	Course Code	Course Title	L	T	P	C
1.	PPHY696J	Study Oriented Project				02
2.	PPHY697J	Research Project				02
3.	PPHY698J	Internship I/ Dissertation I				05
4.	PPHY699J	Internship II/ Dissertation II				12

Discipline Core

Course code	Mathematical Physics	L	T	P	J	C
PPHY501L		3	1	0	0	4
Pre-requisite	None	Syllabus version				
		01.00				

Course Objectives:

1. Grasp the basic mathematical concepts used in physics.
2. Correlate mathematical foundations with advanced topics such as Classical and Quantum Mechanics, Field Theory and Relativity.
3. Handle research projects/job assignments in institutes in India/abroad.

Course Outcome: Students will be able to

1. To construct a physical theory using matrix methods and vector operators.
2. To apply non-trivial techniques for solving Ordinary Differential Equations.
3. To apply series solution method to solve second-order differential equation with variable coefficients.
4. To explain the origin of special functions such as Legendre, Bessel, Hermite, and Gamma functions.
5. To learn basic concepts of complex analysis and contour integrals in relevant problems in Physics.

Module:1	Linear Vector Space and Matrix	9 hours

Linear Vector Space, Linear independence, Dimension of Vector Space, Basis vectors, Matrix representation of vectors (bra and ket notation), Inner product, Orthonormal basis, Gram-Schmidt orthogonalization procedure, Linear vector operators and their matrix representation. Special matrices, Similarity transformation, Eigenvalue problem, Diagonalization of a matrix, Eigenvectors of commutating matrices, Cayley-Hamilton theorem, Function of Matrix.

Module:2	Vector Calculus	5 hours

Differentiation of Vectors, Space curves, Vector Operators, Line, surface and volume integrals in Cartesian, Cylindrical and Spherical Polar coordinate system, Laplacian operator in spherical and cylindrical coordinate system, Green's, Divergence and Stokes Theorem (Numerical Problems).

Module:3	Fourier Series	6 hours

Dirichlet Conditions, Fourier Coefficients, Symmetry Considerations, Complex Fourier Series, Parseval's Theorem.

Module:4	Ordinary Differential Equation	5 hours

Exact Equations, Integrating factors, Isobaric Equations, Bernoulli's Equation, Methods for Higher order ODEs, Legendre and Euler's linear Equations, variation of parameters, Green's Function method

Module:5	Series Solution	4 hours

Series solution of linear ODEs (about ordinary and singular points), Frobenius Method, Method of Wronskian, Polynomial Solutions.

Module:6	Special Functions	7 hours

Legendre and Associated Legendre Functions, Spherical harmonics, Bessel and Spherical Bessel Functions, Laguerre and Hermite Functions, Gamma Functions

Module:7	Complex Variables	7 hours

Functions, Differentiation, Cauchy-Riemann conditions, Analytic and harmonic functions, Contour integrals, Cauchy-Goursat theorem, Cauchy integral formula, Series: Taylor Series, Laurent's theorem, Singularities, Residue theorem, applications of residue theorem.			
Module:8	**Contemporary issues**		**2 hours**
Total Lecture hours:			**45 hours**
Tutorial GATE, CSIR problems related to the subject will be solved in the tutorial sessions. Assignment problems/ problem sets will be discussed during the tutorial sessions			**15 hours**

Text Book(s)

1. G. B. Arfken, H. J. Weber and F. E. Harris, Mathematical Methods for Physicists, 2012, Seventh Edition, Elsevier Academic Press, UK and USA.
2. M. L. Boas, Mathematical Methods in Physical Sciences, 2006, 3rd Edition, John Wiley & Sons, USA.

Reference Books

1. A.W. Joshi, Matrices and Tensors in Physics, Paperback, 2017, 4th Edition, New Age International Publisher, India.
2. J. W. Brown and R. V. Churchill, Complex Variables and Applications, 2009, Eighth Edition, McGraw- Hill, USA.
3. Michael Tinkham, Group Theory and Quantum Mechanics, 2003, Dover Publications, New York, USA.
4. Daniel A. Fleisch, A Student's Guide to Vectors and Tensors, 2011, Cambridge University Press.
5. V. Balakrishnan, Mathematial Physics with Applications, Problems & Solutions, 2018, Ane Books Pvt. Ltd.

Mode of Evaluation: CAT / Assignment / Quiz / FAT / Seminar

Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date	14.03.2024

Course code	Electronics	L	T	P	J	C
PPHY502L		3	0	0	0	3
Pre-requisite	None	**Syllabus version**				
		01.00				

Course Objectives:

1. To impart the knowledge of Circuit Analysis
2. To understand the construction and working function of semiconductor devices
3. To apply their knowledge to build new devices

Course Outcome: Students will be able to

1. To analyze the circuit and appreciate the basic physics behind the advanced devices
2. To apply the knowledge of transistors to predict the characteristics of op-amps
3. To construct the filters and oscillators with the knowledge of op-amps
4. To construct composite digital devices for various applications
5. To understand the design and working of Microprocessors

Module:1	Circuit Theorems and PN junction	7 hours

Kirchhoff's laws for current and voltage – Thevenin's and Norton's theorems, superposition and reciprocity theorems with examples Carrier statistics in p-n junction diodes – barrier potential – Application of P-N junctions – Diode as clipper, clamper and switch- reverse recovery time of diode - Zener diode, tunnel diode, Schottky barrier diode varactor diode-photodiode - solar cell photodiodes and transistors - light emitting diode

Module:2	Field Effect Transistor	6 hours

Construction and operation of N-channel FET – Characteristic parameters of JFET- Comparison of JFET and BJT – Application of JFET – FET as voltage variable resistor – MOSFET – Construction and characteristics – Depletion mode and Enhancement mode.

Module:3	Operational Amplifier	6 hours

Block diagram of Operational amplifier IC 741, Characteristics and parameters of Op-Amp, Non-Linear applications of Op-Amp- comparator, Schmitt Trigger, UTP and LTP adjustments – Voltage to current and current to voltage conversions.

Module:4	Linear Integrated Circuits	4 hours

First order Butterworth Low Pass filter, High Pass Filter, Band Pass Filter, Band Reject and Notch Filter Solving simultaneous and differential equations.

Module:5	Oscillators	7 hours

Oscillator principle- oscillator types - frequency stability, RC oscillators – phase shift oscillator - Wein bridge oscillator - LC tunable oscillators- limitations – Timer IC 555: Block diagram, sine wave and triangular wave generator – Monostable multivibrator – Astable multivibrator, Voltage controlled Oscillator (VCO), Phase locked Loop (PLL)

Module:6	BCD codes, Digital Circuits and Combinational Logic	7 hours

Review of Binary Coded Decimal codes, boolean functions, Min-terms and Max- terms, Karnaugh Maping, Tri-state logic, Positive and Negative logic. De Morgan's law. Arithmetil logic circuits: Half adder and full adder, Subtractors, Comparators – Code conversion – Universal gates – Exclusive OR functions – Binnary parallel adder – BCD adder – Decoder – Demultiplexers – Encoders – Multiplexers.

Module:7	**Sequential Logic**	**6 hours**
Flip flops- RS flip flops – Edge triggered RS, JK, JK master-slave flip-flop, T and D flip-flop. Types of registers – serial in serial out – Serial in parallel out – Parallel in serial out – Parallel in parallel out – Ring counters – Asynchronous counter – Synchronous counter – Changing the counter modules – A/D and D/A conversion.		
Module:8	**Contemporary issues**	**2 hours**
Total Lecture hours:		**45 hours**

Text Book(s)

1. R. L. Boylsted and L. Nashelsky, Electronic Device and Circuits, 2015, 11th edition, Pearson Education India, New Delhi
2. Albert Malvino, David J Bates, Electronics Principles, 2017,7th edition, Tata McGraw-Hill, New Delhi
3. Barry B. Brey, The Intel Microprocessors, 2012, 8th edition, Pearson Education India, New Delhi

Reference Books

1. J. Milman and C.C. Halkias, Electronic Devices and Circuits, 2015, 4th edition, McGraw-Hill, New Delhi.
2. R P Jain, Modern Digital Electronics, 2009, 4th edition, Tata McGraw- Hill, New Delhi.
3. Ramkant A.Gayakward, Op-amps and Linear Integrated Circuits, 2015, 4th edition, Prentice Hall of India, New Delhi.
4. M. Morris Mano, Digital Logic and Computer Design, 2016, 4th edition, Prentice Hall of India Private Limited, New Delhi.
5. S.M. Sze, Kwok K. Ng, Physics of Semiconductor Devices, 2007, 2nd Edition, John Wiley & Sons, Hoboken.

Mode of Evaluation: CAT / Assignment / Quiz / FAT / Seminar

Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date	14.03.2024

Course Code	Course title	L	T	P	C
PPHY503L	Classical Mechanics	3	1	0	4
Pre-requisite	None	Syllabus version			
		01.00			

Course Objectives:

1. To learn the Lagrangian and Hamiltonian formalisms of simple classical systems
2. To learn the methods of solving central force problems and rigid body dynamics
3. To understand the basics of special relativity

Course Outcome: Students will be able to

At the end of this course, students will be able to
1. To apply Lagrangian formalism for solving simple classical dynamics problems
2. To apply Lagrangian formalism for solving Kepler's problem
3. To understand rigid body dynamics and small oscillations using Lagrangian approach
4. To apply Hamiltonian formalism for solving simple classical dynamics problems
5. To explain the foundations of relativistic physics

Module:1	Lagrangian Formalism	6 hours

Generalized coordinates -principle of virtual work - D'Alembert's principle - Lagrangian formulation and simple applications - Variational principle and Lagrange equation

Module:2	Hamilton's principle	6 hours

Hamilton's principle - Lagrange equation from Hamilton's principle; Symmetry and conservation laws: conservation of linear momentum, energy and angular momentum.

Module:3	Central Force Problem	7 hours

Reduction of two body problem in central force - Equations of motion - effective potential energy - nature of orbits - Virial theorem - Kepler's problem; Scattering in a central force field - centre of mass and laboratory frame.

Module:4	Rigid Body System - Oscillating System	7 hours

Elements of rigid-body dynamics – Euler angles – symmetric top and applications-- Small oscillations – normal mode analysis – normal modes of a linear tri-atomic molecule – forced oscillations.

Module:5	Hamiltonian Formulation I	5 hours

Legendre transformation – Hamiltonian equations of motion – cyclic coordinates – phase space and Liouville's theorem; Symmetries and conservation laws in Hamiltonian picture.

Module:6	Hamiltonian Formulation II	5 hours

Canonical transformations- Poisson brackets- Hamilton-Jacobi theory - action-angle variables. Time dependent perturbation – examples of time dependent perturbation.

Module:7	Special Theory of Relativity	7 hours

Inertial frames – principle and postulate of relativity – Lorentz transformations - Matrix in Minkowski space-time – Lorentz transformation in real four-dimensional space-time - four-vector notation – energy-momentum –four-vector for a particle - Covariant four-dimensional formulation.

Module:8	Contemporary issues:	2 hours

	Total Lecture hours:	45 hours
Tutorial	Tutorial topics	15 hours

	GATE, CSIR problems related to the subject will be solved in the tutorial sessions. Assignment problems/ problem sets will be discussed during the tutorial sessions		
Text Book(s)			
1.	H. Goldstein, C. Poole and J. Safko, Classical Mechanics, 2011, 3rd edition, Pearson Education, New Delhi.		
2.	W. Greiner, Classical Mechanics: Systems of particles and Hamiltonian Dynamics, 2010, 2nd edition, Springer, New Delhi.		
Reference Books			
1.	Landau and Lifshitz, Mechanics, 1976, 2nd Edition, Pergamon Press, New York.		
2.	David Morin, Introduction to Classical Mechanics - With Problems and Solutions, 2007, Cambridge University Press, New York		
3.	R Resnick, Introduction to Special Relativity, 2021, 1st Edition, Wiley, New Delhi		
4.	Classical Mechanics by N. C. Rana and P. S. Joag, 2017, 1st edition, McGraw Hill Education, New Delhi.		
Mode of Evaluation: CAT, Assignment, Quiz and FAT			
Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date	14.03.2024

Course code	Course Title	L	T	P	C
PPHY504L	Electromagnetic Theory	3	1	0	4
Pre-requisite	None	Syllabus version			
		01.00			

Course Objectives

1. To understand how materials are affected by electric and magnetic fields.
2. To understand the relation between the fields under time varying situations and also the Maxwell equations.
3. To understand principles of propagation of uniform plane waves.

Course Outcome

At the end of this course, students will be able to
1. Solve boundary value problem in the presence of electrostatic field.
2. Apply laws of magnetism to calculate magnetic field in materials.
3. Explain the intrinsic nature of electric and magnetic field by applying laws of electrodynamics.
4. Analyze the electromagnetic wave propagation using Maxwell's equations.
5. Calculate radiation emission from a moving charge under the influence of static electric and magnetic field.

Module 1	Electrostatics	7 hours
Electric field–electric potential–Laplace and Poisson equation– separation of variables: Cartesian, spherical and Polar coordinate systems–Boundary condition and uniqueness theorems-Method of images-field of an electric dipole –multipole expansions		
Module 2	**Electrostatic fields in Matter**	**5 hours**
Gauss's law in dielectrics-Applications of Gauss Law–linear dielectrics-bound charge – polarization-energy density–boundary value problems		
Module 3	**Magnetostatics and Magnetic fields in matter**	**10 hours**
Lorentz force–Biot Savart law–Magnetic vector potential–Magnetization–Ampere's law in magnetized material-Faraday's law–Magnetic induction-Magnetic field due to solenoid and toroid–energy density–free and bound current-boundary condition		
Module 4	**Electrodynamics**	**6 hours**
Maxwell's equations in dielectric–boundary conditions–scalar and vector potentials–Gauge invariance–Lorentz transformation- Electromagnetic energy – Poynting's theorem- Maxwell's stress tensor- Continuity equation		
Module 5	**Electromagnetic waves**	**5 hours**
Electromagnetic wave equation in free space, dielectric and conductors –Polarization-Reflection-Refraction-Dispersion-Fresnel's Law-Coherence-Diffraction		
Module 6	**Wave Guides**	**5 hours**
Reflection from a conducting plane-rectangular wave guide-TE TM and TEM modes - Cylindrical waveguide		
Module 7	**Radiation**	**5 hours`**
Dynamics of charged particles in static and uniform electromagnetic fields; Retarded potentials, Lienard-Wiechert Potentials, Radiation from moving charges, Dipole radiation		
Module:8	**Contemporary issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Tutorial	Tutorial topics			15 hours
GATE, CSIR problems related to the course will be solved in the tutorial sessions. Assignment problems/ problem sets will be discussed during the tutorial sessions				
Text Book(s)				
1.	D. J. Griffith, Introduction to Electrodynamics, 2020, 4th edition, Cambridge University Press, New Delhi			
2.	J.R. Reitz., F.J. Milford and R. W. Christy, Foundations of Electromagnetic Theory 2010, 4th edition, Pearson Education, San Francisco			
3.	Field and Wave Electromagnetics, David K Cheng, 2014 2nd edition, Pearson Education, New Delhi			
Reference Books				
1.	J.D. Jackson, Classical Electrodynamics, 2011, 3rd edition, Wiley-India, Delhi.			
2.	W. Greiner, Classical Electrodynamics, 2010, 3rd edition, Springer, New York.			
3	B. Ghosh, Foundations of Electricity and Magnetism, 2020, 5th Edition, Books & Allied pvt. Ltd, Chennai			
Mode of Evaluation: CAT, Assignment, Quiz and FAT				
Recommended by Board of Studies		20-01-2024		
Approved by Academic Council		No. 73	Date	14.03.2024

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Course Code	Course Title	L	T	P	C
PPHY505L	Quantum Mechanics	3	0	0	3
Pre-requisite	None	Syllabus version			
		01.00			

Course Objectives

1. To introduce the foundations of quantum mechanics
2. To Apply principles of quantum mechanics to calculate observables
3. To understand time-dependent and time-independent Schrödinger equation for simple potentials

Course Outcomes

At the end of the course, the students will be able

1. To interpret the basic formalism of quantum mechanics
2. To explain fundamental quantum mechanical processes in nature
3. To understand the approximate methods for solving time-dependent and time-independent problems
4. To calculate the angular momenta of the particles
5. To explain the quantum formalism for Hydrogen atom and the concept of parity

Module:1	General formalism	7 hours

Description of a particle using wave packets - Physical interpretation of wave function - Postulates of Quantum Mechanics – Schrödinger's wave equation-Normalization-Expectation values and Ehrenfest's theorem- Uncertainty principles

Module:2	Operator formalism	6 hours

Linear Operators-Hermitian operators and their properties – Commutation relations - Dirac representations - Bra and Ket vectors - Hilbert space – Schrödinger, Heisenberg and Dirac pictures.

Module:3	Stationary states	7 hours

Time independent Schrodinger equation - particle in square well - bound states - normalized states. Quantum Confinement Problems (1D, extension to 3D), Potential step and rectangular potential barrier - Reflection and Transmission coefficients - tunnelling of particles-Tunnelling through a barrier-Applications in Scanning tunnelling Microscopy

Module:4	Harmonic oscillator	5 hours

Linear Harmonic oscillator- Schrodinger equation and energy eigenvalues - Energy eigenfunctions. Harmonic oscillator using ladder operator method.

Module:5	Angular momentum	7 hours

Angular momentum operators, eigenvalue equation for L^2 and L_z - Commutation Relation, Separation of variables. Addition of angular momenta- Clebsch-Gordon Coefficients: selection rules – recursion relations-computation of Clebsch-Gordon coefficients

Module:6	Hydrogen atom in 3-dimensions	6 hours

The hydrogen atom - solution of the radial equation – energy levels- Stationary state wave functions - bound states. Spherical Harmonics (Solution to Legendre differential equation may be assumed). Shapes of the probability densities for ground & first excited states.

Module:7	Parity	5 hours

Concept of parity. Identical particles. Symmetric & Antisymmetric Wave Functions. Pauli's Exclusion Principle. Hund's Rule.

Module:8	Contemporary Issues	2 hours

	Total Lecture hours:		**45 hours**
Text Book(s)			
	1. D. J. Griffiths, Introduction to Quantum Mechanics, 2018, 3rd Edition, Cambridge University Press, Delhi 2. Eugen Merzbacher, Quantum Mechanics, 2011, 3rd Edition, Wiley Publication 3. P. M. Mathews and K. Venkatesan: A text book of Quantum Mechanics, 2nd Edition, 2017, McGraw Hill Education, New Delhi.		
Reference Books			
	1. L.D. Landau and E.M. Lifshitz, Quantum Mechanics (Non-relativistic Theory), 2011, 3rd Edition, Elsevier, Amsterdam. 2. R. Shankar, Principles of Quantum Mechanics, 2014, 2nd Edition, Springer, New Delhi. 3. Richard L. Liboff, Introductory Quantum Mechanics, 2003, 4th Edition, Pearson, New Delhi 4. J. J. Sakurai, Modern Quantum Mechanics, 3rd Edition, 2020, Cambridge University Press, New Delhi 5. Nouredine Zettili, Quantum Mechanics Concepts and Applications, 2nd Edition, Wiley, New Delhi 6. S.L. Kakani and H.M. Chandalia, Quantum Mechanics, Theory and Problems, 2007, 1st Edition, Sultan Chand & Sons, New Delhi		
Mode of Evaluation: CAT, Assignment, Quiz, FAT			
Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date:	14.03.2024

Course Code	Course title	L	T	P	C
PPHY506L	Solid State Physics	3	0	0	3
Pre-requisite	None	Syllabus version			
		01.00			

Course Objectives

1. To provide an introduction to some basic concepts in solid state physics.
2. To understand bonding, crystal structure, lattice vibrations, electron interactions, Fermi surface, and models of electron dynamics in solids.

Course Outcomes

At the end of the course, the students will be able
1. Comprehend the models of electron dynamics in metals using classical and semiclassical approaches.
2. Learn basic concepts of bonding in solids, crystal structure, and lattice arrangements.
3. Recall lattice dynamics, electron and lattice interactions.
4. Explain basic electron mobility in a crystal structure.
5. Describe magnetism and superconductivity in solids.

Module:1	Bonding in Solids: Internal Structure of Solids	5 hours

Forces of attraction & repulsion and potentials, van der Waals forces, ionic bond, covalent bond, metallic bond, The hydrogen bond, Comparison between bonds of various kinds, Classification of solids based on the nature of bonds, Cohesive energy.

Module:2	Crystalline Solids: Periodic Structure	7 hours

Some Basic Concepts of Crystal Structure: Basis and Lattice, Symmetry Operations, Symmetry Elements, & Point/Space Groups, Bragg Diffraction, Reciprocal Lattice Vectors and Laue Diffraction, Kinematic Theory of Scattering, Brillouin Zone, Structure Factor and Atomic Form Factor, Imperfections in Crystalline Order: Point Defects, Dislocations and Planner Defects.

Module:3	Lattice Dynamics	8 hours

Classical Theory of Harmonic Crystal, Harmonic Approximation, Specific Heat of A Classical Crystal: Dulong and Petit Law, Normal Modes of a 1-D Monatomic and Diatomic Lattice. Quantum Theory of Harmonic Crystal, Normal Modes and Phonons, High-Temperature Specific Heat, Low-Temperature Specific Heat, Intermediate Temperature Specific Heat: Models of Debye and Einstein, Density of Normal Modes.

Module:4	Drude Model of Metals – Kinetic Theory of Classical Electron Gas	5 hours

DC Electrical Conductivity, Hall Effect and Magnetoresistance, AC Electrical Conductivity, Thermal Conductivity, Thermoelectric Effect, Limitation of Drude Model.

Module:5	Sommerfeld Theory of Metals – Treating the Electrons as a Fermi Gas	5 hours

Fermi Statistics and Fermi Surface, Electronic Heat Capacity – The Linear T-dependence, Consequences to the Transport Properties of Metals, Inadequacy of the Free Electron Model.

Module:6	Electrons In A Periodic Potential	7 hours

Bloch's Theorem: Statement and Proof; Crystal Momentum, Energy Bands, Mean Velocity, Fermi Surface; Density of States and van Hove Singularity; Kronig-Penney model; Electrons in a Weak Periodic Potential – A Simple Example: Tight Binding Model; Fermi Surface in Reduced Zone Scheme; Metal, Semiconductor, and Insulator: Qualitative Description using Band Structure; Failures of Band-Structure Picture of Metals and Insulators.

Module:7	Magnetism and Superconductivity	6 hours

Bohr magneton, Magnetization, Susceptibility, and Hysteresis, Magnetization and Susceptibility, Diamagnetism, Paramagnetism, Curie-Weiss Law, Ferromagnetism, Superconductivity: discovery and phenomena (Experimental survey). Zero resistance and Meissner effect, Transition temperature, Specific Heat, Type-I, Type-

II superconductors.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	C. Kittel, Introduction to Solid State Physics, 2012, 8th Edition, John Wiley , New Delhi.
2.	W. Ashcroft, N. David Mermin, Dan Wei, 2016, 3rd Edition, Solid State Physics-Neil, Cengage Learning, New Delhi.
3.	M. A. Wahab, Solid State Physics, 2015, 3rd Edition, Narosa Publishing House, New Delhi

Reference Books

1.	A. J. Dekker, Solid State Physics, 2008, 1st Edition, Prentice Hall of India, New Delhi
2.	S.O. Pillai, Solid State Physics, 2022, 10th Edition, New Age International Private Limited, New Delhi
3.	Steven H. Simon, The Oxford Solid State Basics, 2013, 1st Edition, Oxford University Press, New Delhi.

Mode of Evaluation: CAT, Assignment, Quiz and FAT			
Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date	14.03.2024

Course code	Course title		L	T	P	C
PPHY507L	Statistical Mechanics		3	0	0	3
Pre-requisite	None	Syllabus version				
		01.00				

Course Objectives

1. To understand the concepts of Statistical Mechanics
2. To apply Statistical Mechanics tools to evaluate theromodynamic parameetrs for classical and quantum systems

Course Outcome

At the end of the course students will be able to

1. Analyze the concepts of microstate and macrostate of a model system
2. Apply the concept of partition function to obtain macroscopic properties of thermodynamic systems
3. Apply Bose-Einstein statistics to quantum mechanical systems.
4. Explain the formation of white dwarf star through Fermi – Dirac statistics
5. Apply Fermi – Dirac statistics to understand the electrical conductivity of metals

Module:1	Review of Thermodynamics and Introduction to Statistical Mechanics	7 hours
Thermodynamic potentials- Internal energy, Enthalpy, Helmholtz free energy, Gibbs free energy, Chemical potential, Maxwell's thermodynamic relations, Entropy and probability, Γ-space, Microstates and Macrostates, Density distribution function, Maxwell-Boltzmann statistics, Ensembles, Ergodic hypothesis, Postulate of equal a-priori probability, Equivalence of ensemble average and time average, Boltzmann's postulate of entropy, Liouville's theorem, ,		

Module:2	Microcanonical Ensemble	6 hours
Density distribution function for microcanonical ensemble, Volume occupied by microcanical ensemble in Γ-space, Generalized equipartition theorem, Classical ideal gas in microcanonical ensemble – Equation of state, Expression for entropy, Gibbs paradox, Correct Boltzmann counting, Sackur-Tetrode equation		

Module:3	Canonical and Grand Canonical Ensemble	8 hours
System in contact with a heat reservoir, Density distribution function for canonical ensemble, Canonical partition function, Expression for entropy and Helmholtz free energy, Energy flucttutations in canonical ensemble, System in contact with a particle reservoir, Density distribution function for grand canonical ensemble, Grand partition function and grand potential, Fluctuations in number of particles, Chemical potential of ideal gas and equation of state		

Module:4	Few Applications of Classical Statistical Mechanics	4 hours
System of classical harmonic oscillators, Diatomic molecules – Rigid rotations, Vibrations, Heat capacity – Dulong and Petit's law		

Module:5	Quantum Statistical Mechanics	8 hours
Density matrix, Quantum Liouville theorem, Density matrices for microcanonica, canonical and grand canonical ensembles, Quantum treatment for ideal gases – Ideal Bose gas and Ideal Fermi gas, Bosons and Fermions in microcanonical ensembles, Bose-Einstein and Fermi-Dirac distribution		

Module:6	Bose – Einstein Statistics and its Applications	5 hours
Bosons in grand canonical ensemble, Equation of state, Bose – Einstein condensation, Black body radiation – Planck's radiation law, Einstein and Debye theory of heat capacity		

Module:7	Fermi – Dirac Statistics and its Applications	5 hours
Fermions in grand canonical ensemble, Equation of state, Degenerate Fermi gas, White dwarf star – Chandrasekhar limit, Free electrons in metals		

Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)			
1.	Kerson Huang, Statistical Mechanics – An Indian Adaptation, 2021, 2nd Edition, Wiley, New Delhi		
Reference Books			
1.	R. K. Patharia and Paul D. Beale, Statistical mechanics, 2021, 4th Edition, Academic Press, London		
2.	F Reif, Fundamentals of Statistical and Thermal Physics, 2010 4th Edition, Waveland Press, Long Grove.		
Mode of Evaluation: CAT, Assignment, Quiz and FAT			
Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date	14.03.2024

Course code	**Course Title**		**L**	**T**	**P**	**C**
PPHY508P	**General Physics Lab-I**		**0**	**0**	**4**	**2**
Pre-requisite	None	**Syllabus version**				
		01.00				

Course Objectives

1. To apply the theoretical knowledge gained in theory to practical experiment by collecting, analyzing, and interpreting the experimental data.

Course Outcomes

At the end of the course, the students will be able

1. Verify some fundamental concepts of physics through simple experiments using laboratory instruments
2. Acquire skill to handle laboratory instruments
3. Learn techniques to design and develop the instruments for advanced studies

Indicative Experiments

1	To find the radius of curvature of a Plano-convex lens using sodium lamp source and mercury lamp source by Newton's Ring Experiment
2	To determine the average particle size of Lycopodium powder (nano/micron) using Laser beam diffraction
3	To determine the elastic constants of a transparent medium by obtaining elliptical fringes using Cornus interference Method.
4	To measure the Refractive index of air and a given glass slide using a Michelson interferometer
5	To study the non-linear optical properties of electro-optic crystal using pockel's cell.
6	To determine the Hall coefficient and carrier concentration of a given semiconductor/metal at room/varying temperature.
7	To find the bandgap of a semiconductor using the four-probe method
8	To understand atomic systems with discrete energy levels by the Frank-Hertz Experiment.
9	To study the Heisenberg Uncertainty Principle Using Single Slit diffraction pattern.
10	To determine the material's and Planck's constant using a Light Emitting Diode (LED).
11	To determine the inter-planer spacing between carbon atoms in graphite through electron diffraction.
12	To determine the Fermi energy and Fermi temperature of a given Metal using Fermi-Energy Experiment
13	To determine the Young's modulus of the material of the given bar by subjecting it to uniform bending
14	To record the intensity vs. voltage characteristics and verify inverse square law using the Geiger-Muller (GM) Counter.
15	To learn the growth of thin film using physical vapor deposition (DC sputtering) system
16	To find the Amplitude and Frequency of a signal using an Oscilloscope and study the amplitude and frequency modulation circuits using it
17	Design the Half wave rectifier and full wave rectifier using PN junction diode
18	Design a single-stage BJT amplifier
19	Design the Zener diode as a voltage regulator and study its I-V characteristics
20	Design of FET as an amplifier
21	Design and study the characteristics of UJT and UJT as a relaxation oscillator
22	Designing Active High, Low, Bandpass and Notch Filters using Op-amp

	Total Laboratory hours:	**60 hours**	
Mode of Evaluation: Continuous Viva-voce, Lab performance, FAT			
Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date	14.03.2024

Course code	Course Title	L	T	P	C
PPHY509P	General Physics Lab-II	0	0	4	2
Pre-requisite	None	Syllabus version			
		01.00			

Course Objectives

1. To apply the theoretical knowledge gained in theory to practical experiment by collecting, analyzing, and interpreting the experimental data.

Course Outcomes

At the end of the course, the students will be able

1. Verify some fundamental concepts of physics through simple experiments using laboratory instruments
2. Acquire skill to handle laboratory instruments
3. Learn techniques to design and develop the instruments for advanced studies

Indicative Experiments

1	To study the B-H curve and to find out the values of coercivity, retentivity, and saturation magnetization of a given material
2	To measure the Lande's g-factor in a free radical using Electron Spin Resonance Spectrometer
3	To Study the Magnetic field dependence and calculate the magnetoresistance of a given Semiconductor
4	To study the temperature-dependent dielectric properties of a given ferroelectric material to determine the Curie temperature
5	To measure the Lande's g-factor in a free radical using Nuclear Magnetic Resonance (NMR) Simulation
6	To study the Magneto-optical Kerr Effect (MOKE) of a given material.
7	To determine the electronic charge of an electron by Millikan's Oil drop experiment
8	To measure the magnetic susceptibility of a given material by Guoy's Method
9	To determine the wavelength of the laser light and the refractive index of a transparent medium by using Mach Zehnder Interferometer
10	To calculate the ratio of e/m using Zeeman Effect
11	To Study the I-V characteristics and calculate the fill factor of Solar Cell.
12	Design optoelectronics/photonics devices using finite element analysis (FEA) method
13	Determination of band gap of a semiconductor sample using UV-VIS spectroscopy
14	Analysis of FTIR spectrum - Determination of vibration levels in a compound
15	Calculate the average crystallite size of nanomaterials by analyzing the given XRD spectrum
16	To study the thermoelectric properties of a given sample by measuring Seebeck coefficient
17	To measure the thickness of the thin film using Ellispometry
18	Study of SCR characteristics
19	Designing an Astable and Monostable Multivibrator using an IC555 timer
20	Study the output characteristics of MOSFET
21	Study of LCR resonant circuit
22	RC circuit as a filtering and phase-shifting network

	Total Laboratory hours:	**60 hours**	
Mode of Evaluation: Continuous Viva-voce, Lab performance, FAT			
Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date	14.03.2024

Discipline Elective

Course Code	Course Title	L	T	P	C
PPHY601L	**Advanced Quantum Mechanics**	**3**	**0**	**0**	**3**
Pre-requisite	None	**Syllabus version**			
		01.00			

Course Objectives

1. To compute wavefunctions and energy eigenvalues via degenerate and non-degenerate perturbation theory, both time-dependent and time-independent.
2. To calculate scattering cross section for particles scattering on potentials/other particles in a variety of situations, including low energy, high energy and for identical particles
3. To introduce relativistic quantum mechanics.

Course Outcomes

At the end of the course, the students will be able 1.
1. To apply path integrals to explain quantum dynamics principles.
2. To Solve energy eigenvalues via degenerate and non-degenerate perturbation theory
3. To explain the basics of scattering theory
4. To apply approximation methods to solve scattering problem
5. To interpret the principles of relativistic quantum mechanics

Module:1	**Path integrals**	**5 hours**

Path integrals in quantum mechanics, Double slit experiment using path integrals, Propagator, Schrödinger Equation from Path Integral. Free Particle and Normalization.

Module:2	**Approximation Methods I**	**8 hours**

Time-Independent Perturbation Theory in Non-Degenerate Case - Anharmonic Oscillator: First order Correction- ground state of Helium- Degenerate Case - Stark Effect in Hydrogen atom – Spin-orbit interaction - Variational Method – Born-Oppenheimer approximation - WKB Approximation

Module:3	**Approximation Methods II**	**6 hours**

Time Dependent Perturbation Theory-First and Second Order Transitions-Transition to Continuum of States-Fermi Golden Rule-Constant and Harmonic Perturbation- exchange interaction - A Charged Particle in an Electromagnetic Field.

Module:4	**Basics of Scattering Theory**	**7 hours**

Theory of scattering- Scattering cross section- Theory of scattering -Scattering Experiment-Differential and total cross-section-Scattering amplitude-Method of partial waves

Module:5	**Scattering Problems**	**5 hours**

Scattering by a square well potential - Scattering by attractive square well potential- Scattering Amplitude- Born approximation Breit Wigner formula--Rutherford scattering-validity of Born approximation.

Module:6	**Relativistic Quantum Mechanics I**	**7 hours**

Relativistic quantum mechanics and elements of second quantization Klein-Gordan equation for a free particle - Dirac equation - Dirac matrices. – spin and magnetic moment of electron – Plane wave solution – **Dirac equation - Conserved current - -Free particle solution - Interpretation of n**egative energy states

Module:7	**Relativistic Quantum Mechanics II**	**5 hours**

Transition from particle to field theory. Second quantization of Schrodinger, Klein, Dirac and Electromagnetic equations (qualitative). Creation and annihilation operators - commutation and anti-commutation relation and their physical implications

Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1. D. J. Griffiths, Introduction to Quantum Mechanics, 2014, 2nd Edition, Pearson Education, New Delhi
2. Eugen Merzbacher, Quantum Mechanics, 2011, 3rd Edition, Wiley, New Delhi
3. P. M. Mathews and K. Venkatesan: A text book of Quantum Mechanics, 2017, 2nd Edition, McGraw Hill Education, New Delhi.
4. J. J. Sakurai, Modern Quantum Mechanics, 3rd Edition, 2020, Cambridge University Press, New Delhi

Reference Books

1. L.D. Landau and E.M. Lifshitz, Quantum Mechanics (Non-relativistic Theory), 2011, 3rd Edition, Elsevier, Amsterdam.
2. Richard L. Liboff, Introductory Quantum Mechanics, 2003, 4th Edition, Pearson, New Delhi
3. A. Zee, Quantum Field Theory in a Nutshell, 2010, 2nd Edition, Princeton University Press, New Jersey
4. Steven Weinberg, The Quantum Theory of Fields, Foundations Volume1, 2005, Cambridge University Press, New Delhi.
5. Hans Paar, An Introduction to Advanced Quantum Physics, 2010, 1st Edition, Wiley, New Delhi
6. Franz Schwabl, Advanced Quantum Mechanics, 2008, 4th Edition, Springer-Verlag Berlin

Mode of Evaluation: CAT, Assignment, Quiz, FAT			
Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date	14.03.2024

Course code	Course title	L	T	P	C
PPHY602L	**Advanced Mathematical Physics**	**3**	**1**	**0**	**4**
Pre-requisite	None	**Syllabus version**			
		01.00			

Course Objectives

1. Use advanced mathematical concepts to formulate research problems in physics.
2. Start a PhD/research career in Theoretical and Computational Physics.
3. Qualify for research positions in institutions of eminence (IISc, TIFR)

Course Outcome

At the end of the course, the students will be able

1. Explain the underlying concept in Tensors and their applications in physics.
2. Analyze physical principles using integral transforms.
3. Evaluate solutions of partial differential equations
4. Apply laws of operator algebra on advanced quantum mechanical systems.
5. Understand basic, preliminary concepts related to group of elements and their applications.

Module: 1	**Curvilinear Coordinates**	**6 hours**

Orthogonal and Non-orthogonal Coordinates, tangent and normal spaces, Scale Factors, Contravariant and Covariant Vectors, calculation of arc length and volume element, Gradient, Divergence, Curl and Laplacian, Examples: Cylindrical, Spherical, Parabolic Cylindrical, Elliptic Cylindrical Coordinates.

Module: 2	**Tensors and Riemannian Geometry**	**7 hours**

Tensors in index notation, inner and outer products, Kronecker and Levi Civita tensors, tensor rank, symmetric and asymmetric, covariant and contravariant, tensor transformation and contraction, metric tensors and their determinants, Applications, Covariant differentiation and parrallel transport, affine connection, geodesics and their deviations.

Module: 3	**Integral Transforms**	**6 hours**

Fourier Transforms: Uncertainty principle, Dirac delta function, Laplace Transform, Bromwich integral; Transform of derivative and integral of a function; Solution of differential equations using integral transforms.

Module: 4	**Partial Differential Equation**	**6 hours**

General form and Particular Solutions, Method of separation of variables for wave equations in Cartesian and curvilinear coordinates, applications in electrostatics, Laplace and Poisson equations, Inhomogeneous Problems.

Module: 5	**Calculus of Variations**	**5 hours**

Euler-Lagrange Equation, Special Cases, Constrained variation, Variational Principles.

Module: 6	**Operator Formalism**	**7 hours**

Commutators, Uncertainty Principle, Angular Momentum, Creation and Annihilation Operators, Numerical Examples

Module: 7	**Group Theory**	**6 hours**

Groups, cyclic groups, subgroups, cosets, permutation group, multiplication table, conjugate element and class structure, factor groups and invariant subgroups, isomorphism and homomorphism.

Module: 8	**Contemporary Issues**	**2 hours**

	Total Lecture hours:	**45 hours**

Text Book(s)

1. G. B. Arfken, H. J. Weber and F. E. Harris, Mathematical Methods for Physicists, 2012, 7th Edition, Elsevier Academic Press, Cambridge, Massachusetts.
2. M. L. Boas, Mathematical Methods in Physical Sciences, 2006, 3rd Edition, Wiley, New Delhi

Reference Books

1. A.W. Joshi, Matrices and Tensors in Physics, Paperback, 2017, 4th Edition, New Age International Publisher, New Delhi
2. J. W. Brown and R. V. Churchill, Complex Variables and Applications, 2009, Eighth Edition, McGraw-Hill, New York.
3. Michael Tinkham, Group Theory and Quantum Mechanics, 2003, Dover Publications, New York.
4. Daniel A. Fleisch, A Student's Guide to Vectors and Tensors, 2011, Cambridge University Press, Cambridge
5. V. Balakrishnan, Mathematical Physics with Applications, Problems & Solutions, 2018, Ane Books Pvt. Ltd, New Delhi

Mode of Evaluation: CAT, Assignment, Quiz, FAT

Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date	14.03.2024

Course Code	Course Title	L	T	P	C
PPHY603L	**Nuclear and Particle Physics**	**3**	**0**	**0**	**3**
Pre-requisite	None	**Syllabus version**			
		01.00			

Course Objectives:

1. To know the basic properties of nucleus and visualize the characteristics
2. To Understand the fundamentals of shell model and the necessity of nuclear models
3. To know the standard particle model and nuclear synthesis of elements in stars

Expected Course Outcome:

At the end of the course, the students will be able

1. Describe the general construction and properties of nuclei by using the standard nuclear models.
2. Apply the different nuclear model to calculate the radioactivity decay process.
3. Analyze the abundance of H, He, C, O, N and Fe in interstellar.
4. Calculate quantum numbers of elementary particles by using standard models.
5. Describe the scientific principles and applications of particle detectors.

Module:1	Basic Nuclear Properties	6 hours

Nuclear size, shape, density, nuclear masses, segre chart, classification of nuclei, separation energy, binding energy, spin, parity of nuclear states, electric moments, magnetic dipole moment, quadrupole moment.

Module:2	Nuclear Forces	6 hours

Nuclear stability, nature of nuclear force, meson theory of nuclear force, reaction cross-sections, Q-value equation.

Module:3	Nuclear Models	7 hours

Single particle shell model – Evidences that led to shell model, its validity and limitations, Parabolic and square well, Collective modes of motion, vibrational and rotational modes, collective spectra of nuclei, and back-bending.

Module:4	Nuclear Radiations	6 hours

Radioactivity- Gamow' theory, nuclear reaction in stars, continuous beta ray spectrum, Pauli's Neutrino hypothesis, detection of neutrino, Nuclear isomerism.

Module:5	Nucleosynthesis in Interstellar	6 hours

Helium burning, nuclear synthesis of elements in stars, Hydrogen chain, carbon chain, emission and escape of neutrinos from the core of stars, Chandrasekhar limit, evolution of neutron rich matter and supernova explosion.

Module:6	Introduction to Particle Physics	6 hours

Fundamental interactions, classification of elementary particles, Quantum numbers of different particles, Conservation laws, Production of pions and their mass determination, Quark Gluon model.

Module:7	Detectors and Accelerators	6 hours

Interaction of charged particles and electromagnetic radiation with matter. Basic principles of particle detectors, Geiger-Muller counter, scintillation detectors.
Particle accelerators LINAC, cyclotron, synchrotron.

Module:8	**Selected Topics in Nuclear and Particle Physics**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	S. B. Patel, Nuclear Physics, An Introduction, 2021, 3rd Edition, New Age International Pvt. Ltd, New Delhi
2.	Kennath S Krane, Introductory Nuclear Physics, 2008, 1st edition, Wiley, New Delhi.
3.	David Griffiths, Introduction to particle physics, 2008, 2nd Edition, Willey VCH, New Delhi
4.	B.R. Martin and G. Shaw, Particle Physics, 2017, 4th Edition, Wiley, New Delhi.
Reference Books	
1.	Harwit, M. Astrophysical Concepts, 2006,4th Edition, Springer, New York.
2.	Irving Kaplan, Nuclear Physics, 2002, 2nd Edition, Narosa Publications, New Delhi.
3.	W. R. Leo, Techniques for Nuclear and particle Physics Experiments, 2009, 2nd Edition, Springer, New Delhi
4.	Hans Ohanian, Gravitation and space time, 2013, 3rd Edition, Cambridge University Press, New Delhi
5.	Donald A Perkins, Particle Astro Physics (Oxford Master Series in Physics), 2008, 2ndedition, OUP Oxford. Oxford

Mode of Evaluation: CAT, Assignment, Quiz and FAT			
Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date	14.03.2024

Course code	Course Title	L	T	P	C
PPHY604L	**Atomic and Molecular Physics**	**3**	**0**	**0**	**3**
Pre-requisite	None	**Syllabus version**			
		01.00			

Course Objectives

1. To get acquainted with the atomic and molecular systems and their interaction.
2. To get insight regarding several coupling mechanisms involving angular momentum and spin in electronic and molecular spectroscopy.
3. To gain knowledge about the structure of atoms and molecules relevant to spectroscopic analysis.
4. To study the mechanism behind spectroscopic techniques for analysing atomic and molecular spectra.

Course Outcome

At the end of the course, the students will be able

1. Explain the fine/hyperfine spectral structure using single and multi-electron atomic models
2. Explain the influence of magnetic and electric fields on atomic as well as molecular interactions.
3. Understand rotational, vibrational, and electronic spectroscopy and their application to elucidate the structure of atoms and molecules.
4. Apply the principle of Raman spectroscopy to determine the structure of molecules, and in various science disciplines.
5. Describe the working principles and application of nuclear magnetic resonance spectroscopic techniques.

Module:1	**One electron atom:**	**6 hours**

Quantum states – Atomic orbitals – Vector atom model of a one-electron atom – Space quantization – Larmor's theorem – Pauli Exclusion Principle – Spectra of alkali elements – Spin-orbit coupling – Quantum defect and screening parameter – Fine structure in alkali spectra.

Module:2	**Many electron atom:**	**6 hours**

Equivalent and non-equivalent electrons – Vector model for two valance electrons atom – Central field approximation for many-electron system (He atom as an example) – Interaction energy in LS coupling – Interaction energy in j-j Coupling – spectroscopic terms - Lande interval rule – Spectra of alkaline earth elements – Selection rules – Intensity of spectral lines.

Module:3	**Fine and hyperfine structure**	**6 hours**

Effect of external magnetic field – Hyperfine splitting of spectral lines – Zeeman effect – Landé g-factor – Paschen Back effect – Effect of external electric field – Stark effect for single and many-electron systems – Width of spectral lines – classical and quantum mechanical treatment.

Module:4	**Rotational spectroscopy**	**6 hours**

Diatomic – linear symmetric top, asymmetric top, and spherical top molecules- Molecular rotation spectra – rigid and non-rigid rotator, the intensity of spectral lines - Effect of isotopic substitution on spectra - Microwave spectrometer.

Module:5	**Infrared spectroscopy**	**7 hours**

Molecular vibration: Harmonic and anharmonic oscillators approximation – Morse potential energy curves - Vibrational spectra of diatomic vibrating rotator- transition probability – P, Q, R branches- Breakdown of Born- Oppenheimer approximation – Vibrational spectra of polyatomic molecules- Fourier transform infrared spectroscopy instrumentation.

Module:6	**Raman Spectroscopy**	**6 hours**
Raman effect–Classical and Quantum theory- Pure rotational and vibrational Raman spectra – Vibrational rotational Raman spectrum of diatomic molecules – instrumentation and application of Raman and IR spectroscopy. Electronic transition: Franck-Condon principle – rotational fine structure of electronic transition – Fortrat diagram.		
Module:7	**Spin resonance spectroscopy**	**6 hours**
Nuclear Magnetic Resonance (NMR): Quantum theory- coupling constant – chemical shift. Electron spin resonance (ESR): g-factor- resonance condition – hyperfine structure. Experimental techniques of NMR and ESR. Mossbauer's spectroscopy.		
Module:8	**Atomic and molecular spectroscopy instrumentation**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1. Harvey Elliott White, Introduction to Atomic Spectra, 1934, McGraw Hill Book Company, Inc., USA.
2. B.H. Bransden and C.J. Joachain, Physics of Atoms and Molecules, 2003, 2nd Edition, Prentice Hall, New Delhi.
3. Svanberg Sune, Basic Atomic and Molecular Spectroscopy, Basic Aspects and Practical Applications, 2012, 4th edition, Springer, New Delhi.
4. Colin N. Banwell and Elaine M. McCash, Fundamentals of Molecular Spectroscopy, 2004, 4th Edition, McGraw Hill Education, New Delhi

Reference Books

1. G. Aruldhas, Molecular structure and spectroscopy, 2008 2nd Edition, PHI learning Pvt. Ltd., India, New Delhi
2. M. Demtröder, Molecular Physics, 2008, 1st Edition, Wiley-VCH, Germany.
3. J. Micheal Hollas, Basic atomic and molecular spectroscopy, 2002, 1st Edition, Royal Society of Chemistry, London
4. Gerhard Herzberg, Molecular Spectra and Molecular Structure, 1950, 2nd Edition, D. Van Nostrand Company, Inc. Princeton, New Jersey

Mode of Evaluation: CAT, Assignment, Quiz and FAT			
Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date	14.03.2024

Course code	Course Title	L	T	P	C
PPHY605L	**Lasers and Nonlinear Optics**	**3**	**0**	**0**	**3**
Pre-requisite	None	**Syllabus version**			
		01.00			

Course Objectives

1. To expose the students to the physics of lasers.
2. To get familiarised with the operation of a few typical laser systems.
3. To introduce the basics of nonlinear optics.
4. To understand the various nonlinear effects and their applications.

Course Outcome

At the end of the course the student will be able to
1. Analyse the interaction of radiation with matter.
2. Construct the rate equations for two, three and four level systems for building a workable laser.
3. Understand the working of various laser systems.
4. Apply various second order nonlinear effects for applications in photonics.
5. Analyse various third order nonlinear effects in nonlinear optical media.

Module	Title	Hours
Module:1	**Fundamentals of Lasers**	**6 hours**

Interaction of light and matter– Einstein's theory –two, three and four level pumping schemes– building lasers–threshold condition- characteristics of laser light-line shape function-line broadening mechanisms.

Module	Title	Hours
Module:2	**Laser Rate Equations**	**5 hours**

Laser rate equations – two, three and four level systems- condition for population inversion.

Module	Title	Hours
Module:3	**Optical Resonators and Modes**	**7 hours**

Need for resonators–types of resonators– Fabry-Perot resonator– resonator modes– longitudinal modes– quality factor – cavity finesse –transverse modes.

Module	Title	Hours
Module:4	**Laser Systems and Applications**	**7 hours**

Nd: YAG laser – dye laser – He: Ne laser – CO_2 laser– excimer laser-Applications in Engineering and Medicine.

Module	Title	Hours
Module:5	**Origin of Nonlinearity**	**6 hours**

Polarization response of materials to light – linear and nonlinear polarizations – nonlinear susceptibilities – nonlinear refractive index.

Module	Title	Hours
Module:6	**Second order Nonlinear Phenomena**	**6 hours**

Second order susceptibility – second harmonic generation (SHG) – Physics of SHG – first experimental demonstration of SHG- sum frequency generation – difference frequency generation – phase matching.

Module	Title	Hours
Module:7	**Third order Nonlinear Phenomena**	**6 hours**

Third harmonic generation – Four-wave mixing – degenerate four-wave mixing – optical phase conjugation by four wave mixing – optical limiting.

Module	Title	Hours
Module:8	**Contemporary issues**	**2 hours**

	Total Lecture hours:		**45 hours**	
Text Book(s)				
1.	K. Thyagarajan and Ajoy Ghatak, Lasers: Fundamentals and Applications, 2019, 2nd Edition Macmillan Publishers India Ltd., New Delhi			
2.	P. E. Powers, Fundamentals of Nonlinear Optics, 2019, 2nd Edition, CRC Press, Taylor & Francis Group, Abingdon			
Reference Books				
1.	Richard S.Quimby, Photonics and Lasers, 2006, Wiley, New Delhi			
2.	Orazio Svelto, Principles of Lasers, 2010, 5th Edition, Springer, New Delhi			
3.	Jeff Hecht, Understanding Lasers, 2008, 3rd Edition, Wiley, New Delhi			
4	William T. Silfvast, Laser Fundamentals, 2009, 2nd Edition, Cambridge University Press, New Delhi			
5	R. W. Boyd, Nonlinear Optics, 2020, 4th Edition, Academic Press, Elsevier, Netherlands			
6	Y. R. Shen, Principles of Nonlinear Optics, 2002, Wiley, New Delhi			
Mode of Evaluation: CAT, Assignment, Quiz and FAT				
Recommended by Board of Studies		20-01-2024		
Approved by Academic Council		No. 73	Date	14.03.2024

Course code	Course Title	L	T	P	C
PPHY606L	**Fiber optics and Optoelectronics**	**3**	**0**	**0**	**3**
Pre-requisite	None	**Syllabus version**			
		01.00			

Course Objectives:

1. To expose the working principles of various light sources as well as detectors.
2. To learn about various modulators.
3. To understand the underlying principle behind confining light in optical fibers and various linear effects.
4. To know about various ways of coping with linear and nonlinear effects in fibers.

Course Outcome

At the end of the course the student will be able to

1. Outline the working principles of various optical sources and detectors for optical fiber communication system.
2. Apply the ideas of modulation in both communication and non-communication applications.
3. Analyze the conditions for light propagation in optical fibers and the mitigations of linear effects.
4. Choose appropriate sources, detectors, modulators and optical fibers for various optical networks.
5. Apply the linear and nonlinear optical effects for realizing soliton based optical fiber communication system.

Module:1	**Light Sources**	**7 hours**

Semiconductor – basics - direct and indirect bandgap semiconductors – light emitting diode (LED)- internal, extraction and external quantum efficiency – LED characteristics – types of LEDs – Laser diode.

Module:2	**Detectors**	**6 hours**

Photodiode – quantum efficiency – responsivity – long-wavelength cut-off – p-i-n photodiode – avalanche photodiode (APD) – heterojunction photodiodes – separate absorption and multiplication (SAM) APD – phototransistor-CCD

Module:3	**Modulators**	**7 hours**

Introduction – Pockels effect - optical polarization – birefringence – retardation plates – electro-optic modulator (EOM) – longitudinal and transverse EOMs- acousto-optic modulator (AOM) – Raman - Nath modulator – Bragg modulator.

Module:4	**Light Propagation in Optical Fibers**	**6 hours**

Optical fibers – basic structure – light propagation in a step index fiber – conditions – linear effects – attenuation – dispersion – inter and intra – fiber modes – V-parameter – mode field diameter.

Module:5	**Mitigations to Linear Effects**	**6 hours**

Mitigations to attenuation – repeaters – optical amplifier – semiconductor optical amplifier – Erbium doped fiber amplifier – fiber Raman amplifier – mitigations to dispersion – dispersion shifted fiber – non- zero dispersion shifted fiber – dispersion flattened fiber – dispersion compensating fiber.

Module:6	**Optical Network**	**5 hours**

System architecture: point to point links – distribution networks – local area networks- Link power budget –rise time budget.

Module:7	**Mitigations to Nonlinear Effects: Soliton**	**6 hours**

Nonlinear effects in optical fibers – Kerr effect – self-phase modulation – modelling pulse propagation in optical fibers – nonlinear Schrödinger equation – soliton based optical fiber communication system.					
Module:8		**Contemporary issues**		**2 hours**	
		Total Lecture hours:		**45 hours**	
Text Book(s):					
1.	G. P. Agrawal, Nonlinear Fiber Optics, 2019, 6th Edition, Academic Press, New Delhi				
2.	Ajoy Ghatak and K. Thyagarajan, Introduction to Fiber Optics, 2017, Cambridge University Press, New Delhi				
Reference Books					
1.	S. O. Kasap, Optoelectronics and Photonics-Principles and Practices, 2013, Prentice-Hall, Inc., New Jersey.				
2.	Djafar K. Mynbaev and Lowell L. Scheiner, Fiber-optic communications technology, 2011, Addison Wesley Longman (Singapore) Pte Ltd, Indian reprint.				
3.	L. F. Mollenauer and J. P. Gordon, Solitons in Optical Fibers: Fundamentals and Applications, 2006, Academic Press.				
Mode of Evaluation: CAT, Assignment, Quiz and FAT					
Recommended by Board of Studies		20-01-2024			
Approved by Academic Council		No. 73	Date	14.03.2024	

Course code	Course Title	L	T	P	C
PPHY607L	Plasma Physics	3	0	0	3
Prerequisite	None	Syllabus version			
		01.00			

Course Objectives

1. To understand the basic physical models in plasma physics
2. To apply the fluid model to analyze waves in plasmas
3. To apply standard models to analyze the applications of plasma.

Course Outcome

At the end of the course student will be able to

1. Analyse charged-particle dynamics due a constant force in an inhomogeneous magnetic field
2. Evaluate various theoretical models to study plasma-dynamics
3. Evaluate the effect of magnetic field on the plasma dynamics and plasma modes
4. Apply the fluid model to derive the dispersion relations of waves in plasma
5. Explain the construction of various plasma sources and its applications

Module:1	Introduction to Plasma	7 hours

Fourth state of matter, collective behaviour, charge neutrality, Debye shielding and Debye length, Plasma sheath, Plasma frequency, plasma parameters and criteria for plasma state, Collisions in plasmas, Ionization and Saha equation

Module:2	Single particle dynamics	6 hours

Charge particle dynamics in constant electric and magnetic, Drift velocities in presence of magnetic field, Magnetic mirror

Module:3	Plasma Theory	8 hours

Elementary kinetic theory of plasmas, Boltzmann and Vlasov equation, Fluid theory of plasma, single & multi-fluid approximations, generalized Ohm’s law, MHD equations. Concepts of diffusion, mobility and electrical conductivity, Ambipolar diffusion, Effect of magnetic field on mobility, diffusion of plasma in presence of magnetic field.

Module:4	Waves in plasma without magnetic field	5 hours

Langmuir wave-Dispersion relation in stationary, moving, and collisional plasma, ion waves, electromagnetic wave-underdense and overdense plasma,

Module:5	Wave in plasma with magnetic field	7 hours

Upper and Lower hybrid wave, Alfven wave, electromagnetic waves along and perpendicular to B, Instabilities in plasmas (General description)

Module:6	Plasma production and diagnostics	6 hours

Electrical discharges, Electrical Breakdown in gases, glow discharge, self-sustained discharges, Paschen curve, high frequency electrical discharge in gases, Electrostatic probe (Langmuir probe, Retarding analyzer, emissive probe), Spectroscopic diagnostics for measuring density and temperature.

Module:7	**Application of plasmas**	**4 hours**
Controlled thermonuclear fusion, Concept of Tokamak, plasma-based particle accelerator, industrial applications of plasmas.		
Module:8	**Contemporary Topics:**	**2 hours**
	Total Lecture hours:	**45 hours**
Text Book(s)		
1.	Francis F. Chen, Introduction to Plasma Physics and Controlled Fusion, 2016, 3rd Edition, Springer, New Delhi.	
2.	J.A Bittencourt, Fundamentals of plasma physics, 2004, 3rd Edition, Springer, New Delhi	
Reference Books		
1.	C. S. Liu, V. K Tripathi and Begt Eliasson, High-Power Laser-Plasma Interaction, 2019, Cambridge university press, New Delhi	
2.	K. Nishikawa, Plasma Physics, 2020, 3rd Edition, Springer, Berlin	
3.	Principles of Plasma Discharges and Materials Processing by Michael A. Lieberman, Allan J. Lichtenberg, 2005, 2nd Edition, Wiley, New Delhi	
Mode of Evaluation: CAT, Assignment, Quiz and FAT		

Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date	14.03.2024

Course code	Course Title	L	T	P	C
PPHY608L	**Bio Physics**	3	0	0	3
Pre-requisite	Statistical Physics	**Syllabus version**			
		01.00			

Course Objectives

1. To understand the structure of biomolecules
2. To study the functions and properties of biomolecules

Course Outcome

At the end of the course, the students will be able
1. Analyse the structure and properties of DNA
2. Analyse the structure and properties of RNA
3. Analyse the structure and function of proteins
4. Explain the conversion and storage of energies inside cells
5. Explain the micromolecular structure determination and bioinformatics methods

Module	Title	Hours
Module:1	**Structure and Properties of DNA**	**7 hours**
Composition of DNA, Structure of DNA, Watson and Crick model, Synthesis of DNA, DNA melting, Melting temperature, Effect of GC content on melting, Force extension curve, Persistence Length of DNA		
Module:2	**Structure and Properties of RNA**	**6 hours**
Composition and structure of RNA, Synthesis of RNA, Types of RNA and their role in protein synthesis, Nucleic acid codon wheel, Force-extension curve for RNA hairpin		
Module:3	**Structure of Proteins**	**7 hours**
Four levels of structure of a protein: Amino acids and their properties, Peptide backbone, dihedral angles, Ramachandran Plot, Types of interaction between amino acids, fibrous and globular proteins, Protein folding: Levinthal paradox, Proteins as a random walk, HP model		
Module:4	**Function and properties of proteins**	**6 hours**
Enzymes: Enzymatic reactions, Inhibitors, Molecular motors: Self propulsion, Response to external load, Maximum force exerted my motors, Ion channels: Propagation of nerve impulses		
Module:5	**Cellular energetics**	**7 hours**
Light absorption in photosynthesis, Electron transfer in the photosynthetic reaction, Proton-Motive Force generation, Calvin cycle, Carbohydrates and their classification, Energy storage in carbo hydrates, Cellular respiration (Glycolysis, Krebs cycle and electron transfer)		
Module:6	**Structure determination techniques**	**6 hours**
X-ray diffraction: Electron density, Structure factor expression, reciprocal lattice, diffractometers, area detectors and image plates, Nuclear Magnetic Resonance: Principle, Chemical shift, Relaxation mechanism, NMR spectrometer		
Module:7	**Introduction to Bioinformatics**	**4 hours**
DNA and RNA sequencing, Nucleic acid database, Sequence alignment, Protein Sequencing, Protein Sequence Database, Protein Data Bank		
Module:8	**Contemporary Topics**	**2 hours**
Total Lecture hours:		**45 hours**

Textbook(s)	
1.	Rob Phillips, Jane Kondev, Julie Theriot, Hernan G. Garcia, Physical Biology of the Cell, 2013, 2nd Edition, Garland Science, New York,
2.	David L. Nelson and Michael M. Cox, Lehninger Principles of Biochemistry, 2021, 8th Edition, Macmillan Education, London.
Reference Books	
1.	Rob Phillips and Ron Milo, Cell Biology by the Numbers, 2015, 1st Edition, Garland Science, New York.
2.	P. Narayanan, Essentials of Biophysics, 2023, 3rd Edition, New Age International, New Delhi
3.	William Bialek, Biophysics: Searching for Principles, 2012, 1st Edition, Princeton University Press, Princeton.

Mode of Evaluation: CAT, Assignment, Quiz and FAT			
Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date	14.03.2024

Course code	Course Title	L	T	P	C
PPHY609L	**Advanced Magnetism and Magnetic Materials**	3	0	0	3
Pre-requisite	Quantum Mechanics	**Syllabus version**			
		01.00			

Course Objectives

1. Illustrates the importance of quantum mechanics in understanding magnetic phenomena.
2. Introduces the various experimental techniques to quantify the magnetic parameter.
3. Details the different mechanism responsible for various magnetic applications.

Course Outcome

At the end of the course the students will be able to
1. Understand how non-interacting magnetic moments lead to paramagnetism.
2. Realize the quantum mechanical origin of ferromagnetism.
3. Understand of various techniques to identify magnetic domains
4. Apply the knowledge to connect the crystal structure and magnetic properties.
5. Apply magnetism in actuator, sensor, refrigeration and recording applications.

Module:1	**Isolated magnetic moments**	**6 hours**

Isolated magnetic moments, Energy, Force and Torque of the isolated magnetic moment, Magnetic susceptibility, Curie's law, Brillouin function, Origin of diamagnetism and paramagnetism (Classical & Quantum), Van vleck and Pauli paramagnetism, Landau quantization and diamagnetism

Module:2	**Ferromagnetism**	**7 hours**

Weiss molecular field theory, Heisenberg exchange interaction, Heitler-London model, types of exchange interactions, Anti-ferro and ferrimagnetism, Spin flip and flop transitions, Stoner criterion and band magnetism

Module:3	**Magnetic Domains**	**7 hours**

Energies associated with domain structure, Domain walls, Observation methods (Bitter, MFM, MOKE), magnetization dynamics, hysteresis loops- Vibrating sample magnetometer (VSM) – Superconducting quantum interference devices (SQUID), Ferromagnetic resonance (FMR).

Module:4	**Magnetic anisotropy**	**6 hours**

Origin of magnetic anisotropy, spin-orbit coupling, Easy axis, Hard axis, uniaxial and biaxial anisotropies, Magnetization reversal, Temperature dependence and measurement of anisotropy, perpendicular magnetic anisotropy (PMA).

Module:5	**Magnetostriction and Magnetic Shape Memory Effect**	**6 hours**

Magnetostriction Classification, physical origin, effect of stress on magnetostriction and applications, ferro magnetic shape memory alloys, twinning mechanism, magnetic field induced strain (MFIS),magnetic actuators and sensors

Module:6	**Magnetocaloric**	**5 hours**

Theory of magnetocaloric effect (MCE), MCE at first order and second order phase transitions, MCE and electrocaloric effect, adiabatic demagnetization, direct and indirect investigation methods, Green refrigeration and applications.

Module:7	**Spintronics**	**6 hours**

Introduction, magnetic recording principles and applications, spin for novel functionalities, giant magneto resistance (GMR), tunnelling magnetoresistance (TMR), Spin transferred Torque (STT), Racetrack

Memory, spintronics devices		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1. Allan. H. Morrish, The Physical Principles of Magnetism, 2001, Wiley-IEEE Press, New York.
2. Stephen Blundell, Magnetism in Condensed Matter, 2001, Oxford University Press, New York.
3. R. C.O' Handley, Modern Magnetic Materials: Principles and Applications, 2000, Wiley, New York.
4. B. D. Cullity, C.D. Graham, Introduction to Magnetic Materials, 2008, 2nd Edition, Wiley-IEEE Press, New York.

Reference Books

1. J. Stohr and H. C. Siegmann, Magnetism From fundamentals to Nanoscale Dynamics, 2016 Springer, Heidelberg.
2. A M Tishin, Y I Spinchkin, The Magnetocaloric Effect and its Applications, 2013, 1st Edition, CRC Press, Florida.
3. Victorino Franco, Brad Dodril, Magnetic Measurement Techniques for Materials Characterization, 2021 Springer Nature, Switzerland.

Mode of Evaluation: CAT, Assignment, Quiz and FAT			
Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date	14.03.2024

VIT®
Vellore Institute of Technology
(Deemed to be University under section 3 of UGC Act, 1956)

Course code	Course title		L	T	P	C
PPHY611L	General Theory of Relativity		3	0	0	3
Pre-requisite	Mathematical Physics, Classical Mechanics	Syllabus version				
		01.00				

Course Objectives: The primary objective of this course is to teach the students:

1. The basics of Riemannian Geometry in physics of curved spacetime.
2. Tensor Algebra and principles of Gravitation as a geometric property of space-time continuum.
3. Implementation of fundamental principles of relativity to study the astrophysical processes.

Course Outcome

At the end of the course the student will be able to
1. Understand the concept of invariance and principles of equivalence.
2. Formulate principles of gravitational physics in a curved space-time.
3. Analyze the geometry of space time using Einstein's field equations.
4. Understand the structure of a Black Hole and space-time singularity.
5. Apply the principles of general relativity to understand the cosmic evolution.

Module: 1	Physics of curved spacetime	7 hours

Vectors and Tensors, Idea of Invariance: Invariance of space, time and space-time as a continuum, Principle of general covariance and principle of equivalence, Parallel transport and covariant differentiation; Geodesics

Module: 2	Riemannian Geometry	7 hours

Riemann-Christoffel curvature tensor and its properties; Ricci tensor; Ricci scalar, Bianchi identities; Idea of Curvature and Flatness Condition; Geodesic deviation equation; Lie derivatives and Killing vectors.

Module: 3	Einstein's Field Equations	7 hours

Einstein field equations and its derivation; Schwarzschild exterior solution; Birkhoff's theorem; Geodesics in a Schwarzschild geometry

Module: 4	Tests of General Relativity	4 hours

Deflection of light by massive object, gravitational lensing, Perihelion shift of planets

Module: 5	Black Holes	7 hours

Schwarzschild blackhole - event horizon and static limit; Kruskal-Szekeres diagram; Reissner - Nordstrom solutions – A charged blackhole; rotating blackholes: Ergosphere ; Penrose process.

Module: 6	Weak Field Approximation	4 hours

Linearized field equations: Newtonian Gravity, Gravitational Waves, Poisson's equation.

Module: 7	Cosmology	7 hours

Cosmological principle, Robertson- Walker metric, Friedmann equations, Cosmological Redshift, Hubble's law, Cosmological distances, Hubble's constant and deceleration parameter, Critical density and Geometry of universes, Age of the universe, dark matter, dark energy and standard model of Cosmology.

Module: 8	Contemporary Issues	2 hours

	Total Lecture hours:	**45 hours**

Text Book(s)

1. James B. Hartle, GRAVITY: An Introduction to Einstein's General Relativity, 2021 ,Cambridge University Press, New Delhi.
2. Sean M. Carroll, Spacetime and Geometry : An introduction to General Relativity, 2016, Pearson, New Delhi.
3. Ray d'Inverno, Introducing Einstein's Relativity, 1992, Clarendon Press, Oxford.

Reference Books

1. Charles W. Misner, Kip S. Thorne, John Archibald Wheeler, Gravitation, 2017, Princeton University Press, Princeton.
2. Jayant V. Narlikar, An introduction to Relativity, 2012, Cambridge University Press, New Delhi.
3. Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity, 2008 Wiley, New Delhi.
4. Eric Poisson, A Relativist's Toolkit : The Mathematics of Black-Hole Mechanics, 2012, Cambridge University Press, New Delhi
5. R. M. Wald, General Relativity, 1984, University of Chicago Press; Chicago.

Mode of Evaluation: CAT, Assignment, Quiz and FAT

Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date :	14.03.2024

Course code	Course title	L	T	P	C
PPHY612L	**Advanced Statistical Mechanics**	**3**	**0**	**0**	**3**
Pre-requisite	Statistical Physics	**Syllabus version**			
		01.00			

Course Objectives

1. To introduce advanced topics in equilibrium statistical mechanics
2. To give an exposure to basic concepts in non-equilibrium statistical mechanics

Course Outcome

At the end of the course student will be able to
1. Explain the Mean Field Theory
2. Introduce the Renormalization group techniques
3. Discuss the concepts of non-equilibrium statistical mechanics
4. Discuss the principles of motion for fluids
5. Introduce the disordered systems

Module:1	**Phase Transitions and Critical Phenomena**	**7 hours**

Thermodynamics of phase transitions; metastable states, Van der Waals' equation of state, coexistence of phases, Landau theory, critical phenomena at second-order phase transitions, spatial and temporal fluctuations, scaling hypothesis, critical exponents, universality classes.

Module:2	**Mean Field Theory**	**6 hours**

Ising model, mean-field theory, exact solution in one dimension, renormalization in one dimension.

Module:3	**Non equilibrium Statistical Mechanics**	**6 hours**

Systems out of equilibrium, kinetic theory of a gas, approach to equilibrium and H-theorem, Boltzmann equation and its application to transport problems, master equation and irreversibility, simple examples, ergodic theorem.

Module:4	**Stochastic processes**	**6 hours**

Brownian motion, Langevin equation, fluctuation-dissipation theorem, Einstein relation, Fokker-Planck equation.

Module:5	**Correlation Functions**	**6 hours**

Time correlation functions, linear response theory, Kubo formula, Onsager relations.

Module:6	**Hydrodynamics**	**6 hours**

Conserved and broken-symmetry variables; Goldstone theorem; spin dynamics; Navier-Stokes equation and viscous hydrodynamics.

Module:7	**Disordered systems**	**6 hours**

Spin glasses; Sherrington-Kirkpatrick model; topological defects; dislocations; vortex unbinding and Kosterlitz-Thouless transition.

Module:8	**Contemporary issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	P. M. Chaikin and T. C. Lubensky, Principles of Condensed Matter Physics, 1995, 1st edition, Cambridge University Press, Cambridge.

2.	**K. Huang,** *Statistical Mechanics, 2008, 2nd Edition, 2008,* Wiley, New Delhi.
3.	R.K. Patharia, Statistical Mechanics, 2022, *4th Edition,* Elsevier, New Delhi.
Reference Books	
1.	J. M. Yeomans, Statistical Mechanics of Phase Transitions, 1992, Oxford University Press, Oxford.
2.	H E Stanely, Introduction to Phase Transitions and Critical Phenomena, 1977, Oxford University Press, Oxford.

Mode of Evaluation: CAT, Assignment, Quiz and FAT			
Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date	14.03.2024

Course code	Course Title	L	T	P	C
PPHY613L	**Numerical Methods in Physics**	**3**	**1**	**0**	**4**
Pre-requisite	None	**Syllabus version**			
		01.00			

Course Objectives

1. Learn the basics of computer programming and numerical methods
2. Solve physics problems through different numerical techniques
3. Use computer programming for simulation and data analysis

Course Outcome

the end of the course, the students will be able

1. Device a flowchart for numerical analysis
2. Apply interpolation techniques to analyse a discrete set of data.
3. Apply numerical methods to solve partial differential equations
4. Apply numerical techniques to solve integrals
5. Compare simulation techniques used in stochastic systems.

Module:1	**Introduction to Computational Physics**	**7 hours**
Role of computers in physics: Modelling and simulation; Flow charts; Introduction to computer programming: (Number representation and rounding errors) Integer and floating point, Variables, Operators, Functions, Control statements, Arrays and loops, Data I/O structure, Format.		
Module:2	**Root Finding Methods**	**5 hours**
Methods for determination of zeroes of nonlinear algebraic equations, False position, Newton-Raphson method, Secant Method, Muller's method, Horner's method		
Module:3	**Solution to a set of Linear Algebraic Equations**	**7 hours**
Introduction to linear algebraic equations, Gaussian elimination, Gauss-Jordan elimination method, Pivoting, Jacobi's iterative Method, Gauss-Seidel iterative Method		
Module:4	**Interpolation and Curve fitting**	**7 hours**
Introduction to interpolation, Lagrange interpolation, Newton interpolation, Linear and non-linear Curve fitting: Least squares, Polynomial least squares, Cubic splines fitting.		
Module:5	**Numerical Differentiation**	**6 hours**
Euler algorithm, Runge-Kutta method, Finite difference method, Finite difference equations for partial differential equations and their solution		
Module:6	**Numerical Integration**	**5 hours**
Newton – Cotes formula, Simpson's rule, Gauss's quadrature formula, Trapezoidal formula,		
Module:7	**Random Variables and Monte Carlo Methods**	**6 hours**
Random numbers, Random number generators, Importance of sampling, Simulation technique: Monte-Carlo method, Metropolis algorithm		
Module:8	**Contemporary issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

~~1. James F. Epperson, An Introduction to Numerical Methods and Analysis, 2021, 3rd Edition, Wiley,~~

	New Delhi
2.	Rajesh Kumar Gupta, Numerical Methods Fundamentals and Applications, 2019, 1st Edition, Cambridge University Press, New Delhi.
3.	John H. Mathews and Kurtis K Fink, Numerical methods using MATLAB, 1998, 3rd Edition, Pearson, New Delhi
Reference Books	
1.	William H. Press, Saul A. Teukolsky, William Vetterling, and Brian P. Flannery, Numerical Recipes, 2007, 3rd Edition, Cambridge University Press, New Delhi.
2	Kendall E Atkinson, Introduction to Numerical Analysis, 2008, 2nd Edition, Wiley, New Delhi.
3.	Richard L. Burden and J. Douglas Faires, Numerical Analysis, 2010, 9th edition, Cengage Learning, New Delhi.

Mode of Evaluation: CAT, Assignment, Quiz and FAT			
Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date	14.03.2024

Course code	**Course Title**	**L**	**T**	**P**	**C**
PPHY614L	**Instrumentation Techniques**	**3**	**0**	**0**	**3**
Prerequisite	None	**Syllabus version**			
		01.00			

Course Objectives

1. Introduce basic of instrumental techniques to characterise materials for various structural, optical, chemical, electrical and magnetic properties.

Course Outcome

At the end of the course student will be able to

1. Describe the basic principle and functioning of optical and electron.
2. Apply appropriate X-ray-based characterization techniques to study structural analysis.
3. Determine the optical absorption and bandgap of unknown materials using optical spectroscopy
4. Apply thermal analysis techniques to determine the thermal properties of the materials.
5. Determine the electric and magnetic properties of materials using different techniques.

Module:1	**Optical Microscopic Techniques**	**4 hours**
Basic concepts of Diffraction, interference, polarisation of light, Wave particle duality and Quantum mechanical tunnelling. General concepts of microscopy: resolution. Magnification, depth of field, depth of focus, Optical microscope, Grain size estimation		

Module:2	**Electron Microscopic Techniques**	**7 hours**
Scanning Electron Microscope (SEM), Composition analysis by Energy Dispersive X-ray microanalysis (EDS) Transmission Electron Microscope (TEM), Scanning Tunnelling Microscope (STM), Applications of surface morphology		

Module:3	**X-ray based Techniques**	**8 hours**
Introduction to X-ray diffraction: Principle, Production and Characteristics of X-rays. X-ray for characterization of powdered and crystalline materials (Full Width at Half Maximum and line broadening, Crystallite size effect and Scherer formula). Grazing angle incident measurements for thin films (Effect of strain, tensile vs compressive, uniform vs. non-uniform),		

Module:4	**Spectroscopic Techniques**	**7 hours**
Principle of Spectroscopy, instrumentation and applications of UV-Visible Spectroscopy, (Band-gap calculation), FTIR, Raman and Fluorescence spectroscopy. Hands on experience of operation of UV-Vis- and Raman		

Module:5	**Thermo-analytical Techniques**	**7 hours**
Principle, instrumentation and applications of Thermogravimetric Analysis (TGA), Differential Temperature Analysis (DTA) and Differential Scanning Calorimetry (DSC). Factors affecting the TGA/DTA/DSC results and their interpretations. Hand on experience of operation of TG/DSC and data analysis to understand phase transition.		

Module:6	**Instrumentation for Electrical and magnetic Properties**	**6 hours**
Resistance/Resistivity Measurement, 4-probe-method, van der Pauw method, I-V Characteristics measurement by probe station. Hall effect, Vibration sample magnetometer (VSM) and SQUID.		
Module:7	**Imaging Techniques**	**4 hours**
Introduction to X-Ray Reflectivity (XRR), X-ray Fluorescence (XRF), X-ray magnetic circular dichroism (~~XMCD), Near field scanning optical microscope imaging (NSOM), Atomic force microscopy (AFM)~~		

Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Sam Zhang, Li, Lin, Ashok Kumar, Materials Characterization Techniques, 2008 CRC Press, Florida.
2.	Tyagi, A.K., Roy, Mainak, Kulshreshtha, S.K., and Banerjee, S., Advanced Techniques for Materials Characterization, 2009, Volumes 49 – 51, Materials Science Foundations (monograph series), Zurich.
3	Brundle, Evans, and Wilson, Encyclopaedia of materials characterization: surfaces, interfaces, thin films, 1992, Butterworth-Heinemann, Oxford

Reference Books	
1	B. D. Cullity, and R. S. Stock, Elements of X-Ray Diffraction, 2001, 3rd Edition, Pearson, New Delhi.
2	Murphy, B. Douglas, Fundamentals of Light Microscopy and Electronic Imaging, 2012, 2nd Edition, Wiley, New Delhi.
3	W. W. Wendlandt, Thermal Analysis, 1986, Wiley New Delhi
4	J. B. Wachtman, Z. H. Kalman, Characterization of Materials, 1993, Butterworth- Heinemann, Oxford.
5	Goldstein, Newbury, Joy, Lyman, Echlin, Lifshin, Sawyer, Michael, Scanning electron microscopy and x-ray microanalysis, 2003, 3rd Edition, Kluwer Academic/Plenum Publishers. Netherlands.
6	Donald Pavia, Gary M Lampman, George S. Kriz, Introduction to Spectroscopy, 2015, 5th Edition, Cengage India Private Ltd, New Delhi.

Mode of Evaluation: CAT, Assignment, Quiz and FAT

Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date	14.03.2024

Course Code	Course Title	L	T	P	C
PPHY615L	**Nanophysics**	**3**	**0**	**0**	**3**
Pre-requisite	None	**Syllabus version**			
		01.00			

Course Objectives

1. To provide students with a comprehensive understanding of nanomaterials.
2. To introduce various synthesis methods of preparing the materials in nanoscale.
3. To teach various characterization techniques of nanomaterials and their applications.

Course Outcomes

At the end of the course, the students will be able.
1. Explain the foundational scientific principles governing the properties of materials on the nanometer scale
2. Explain different types of nanomaterials including carbon and metal-based materials
3. Synthesize nanomaterials from physical, chemical and biomimetic approaches
4. Develop proficiency in employing advanced techniques for characterizing nanomaterials, such as microscopy, spectroscopy, and other analytical tools
5. Comprehend the diverse applications of nanomaterials.

Module:1	**Introduction to Nanoscience**	**6 hours**

Overview of nanotechnology, quantum confinement, nanotechnology in nature. Properties: physical, chemical, electrical, mechanical, magnetic and semiconducting properties of nanomaterials, effects on structure, ionization potential, melting point, and heat capacity, electronic structure at nanoscale,

Module:2	**Nanomaterials**	**5 hours**

Carbon based materials (nanotubes and fullerene), metal-based materials (quantum dots, nanogold, metal oxide), Nanocomposites, nanoporous materials and dendrimers

Module:3	**Nanomaterials Synthesis**	**6 hours**

Solgel, hydrothermal and co-precipitation methods, CVD, PVD, Molecular beam epitaxy, Vapor (solution) liquid-solid growth (VLS or SLS), mechanical milling, Inert gas condensation technique, spray pyrolysis, lithography technique.

Module:4	**Chemical approaches**	**6 hours**

Self-assembly, self-assembled monolayers (SAMs), Langmuir-Blodgett (LB) films, organic block copolymers, emulsion polymerization, template-based synthesis, and confined nucleation and/or growth

Module:5	**Biomimetic approaches**	**6 hours**

Polymer matrix isolation, and surface-templated nucleation and/or crystallization. Electrochemical approaches: anodic oxidation of alumina films, porous silicon, and pulsed electrochemical deposition

Module:6	**Characterization Techniques**	**9 hours**

Particle size determination, UV-vis spectroscopy, (Structural, Morphological and Thermal studies): X-ray diffraction (XRD): (Powder and single crystal diffraction), Thermal analysis (DTA-TGA), Spectroscopic studies (FTIR), Microscopic studies (SEM, TEM and AFM), (Electrical, Magnetic and Optical studies):- Electrical studies (Dielectric studies and Four probe method), Magnetic studies (VSM and SQUID) and Mechanical studies (Nano indentation).

Module:7	**Nanomaterials Applications**	**5 hours**

Energy storage and generation, Molecular Electronics and Nanoelectronics, Nanosensors, Catalysts, Biological Applications, Carbon Nanotube, Nanophotonics, Green nanotechnology.

Module:8	**Contemporary Issues**	**2 hours**

	Total Lecture hours:	**45 hours**

Text Book(s)

1. Mark A. Ratner and Daniel Ratner, Nanotechnology: A Gentle Introduction to the Next Big Idea, 2016, 1st Edition, Prentice Hall, New Jersey.
2. Charles P. Poole and Frank J. Owens, Introduction to Nanotechnology, 2003, John Wiley and Sons, New Delhi.
3. Guozhong Cao, Ying Wang, Nanostructures and Nanomaterials, 2007, 2nd Edison, Imperial College Press, London.
4. Carl. C. Koch, Nanostructured materials, processing, properties and applications, 2007, 2nd Edition, William Andrew Publishing, New York.
5. C. N. R. Rao, P. J. Thomas and U. Kulkarni, Nanomaterials: Synthesis, properties and applications, 2007, Springer Verlag, Germany.
6. Zhen Guo, Li Tan, Fundamentals and Applications of Nanomaterials, 2009, Artech house, London.

Reference Books

1. T. Pradeep, Nano: The Essentials Understanding Nanoscience and Nanotechnology, 2017, McGraw Hill Education, New Delhi.
2. R. Vajtai, Handbook of nanomaterials, 2013, Springer publications, Verlag Berlin, Heidelberg.
3. Dieter Vollath, Nanomaterials: An Introduction to Synthesis, Properties and Applications, 2013, 2nd Edition, Wiley-VCH, New York.
4. B. Bhusha, D. Luo, S. R. Schricker, W. Sigmund, S. Zauscher, Handbook of Nanomaterials Properties, 2014, Springer Verlag, Berlin.

Mode of Evaluation: CAT, Assignment, Quiz, FAT			
Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No.73	Date	14.03.2024

Course code	Course title	L	T	P	C
PPHY616L	**Semiconductor Device Physics**	**3**	**0**	**0**	**3**
Pre-requisite	Solid State Physics	**Syllabus version**			
		01.00			

Course Objectives

1. To understand the concepts related to semiconductors and physics of basic devices
2. To apply these concepts in analyzing device responese under various conditions.

Course Outcome

At the end of the course student will be able to
1. Draw and explain energy band diagrams of variuos types of devices with or without applied bias.
2. Estimate various quantities such as carrier concentration, electric field and potential inside a device.
3. Understand recombination and generation processes and their importance
4. Calculate non-equilibrium densities for different carrier lifetimes.
5. Understand the fundamental operation of a bipolar transistor.

Module:1	**Energy bands and Charge carriers**	**9 hours**

Qualitative description of energy band formation, E-k diagram, Density of states for semiconductiors, Metals, insulators and semiconductors, Equation of motion of electrons in crystal, concept of effective mass, concept of holes, Fermi Dirac statistics, energy band diagrams, Idea of thermal equilibrium, Carrier concentraion under equilibrium, Effective density of states, non-degenerate and degenarate semiconductors, Intrinsic carrier concentration and Intrinsic Fermi level. Extrinsic semiconductors,Dopant energies; Hydrogenic model of shallow dopants, Extrinsic carrier density, Charge neutrality condition, Position of Fermi level, Invariance of Fermi level at equilibrium.

Module:2	**Nonequilibrium excess carriers**	**5 hours**

Recombination and generation processes: mechanisms and classifications. Momentum considerations in Indirect bandgap, generalized rate relationships, steady state relationships, Low level and high level injection, surface recombination-generation, surface recombination velocity, Quasi-Fermi levels.

Module:3	**Carrier Transport**	**5 hours**

Conductivity and mobility, Dependence of mobility on temperature and doping concentration, Drift of charge carriers, drift velocity, velocity saturation, Diffusion of charge carriers, Diffusion current, Einstein relationship, Continuity equation, Minority carrier diffusion equations, Gradients in quasi Fermi levels.

Module:4	**P-N Junction**	**9 hours**

Formation of p-n junction, idealization of doping profile-step junction, qualitative description of current components, energy band diagrams, built-in electric field-derivation, depletion approximation, calculation of relevant electrostatic qunatities and their distribution at space-charge region.
Qualitative description of current flow at junction, energy band diagram under forward and reverse bias, Derivation of ideal current voltage equation-assumptions and formal derivation, Minority carrier distribution under forward and reverse bias, Distribution of majority and minority carrier currents, variation of quasi Fermi level with position under forward bias and reverse bias.

Module:5	**Metal-semicondutor junction**	**5 hours**

Ideal metal-semiconductor (MS) contact-energy band diagrams, electrical nature of ideal MS contact, Rectifying and Ohmic contact, Electrostactics of MS contact, built-in voltage, charge density and electric field, depletion width, Current-voltage characteristics, comparison of Schottky and p-n junction diode.

Module:6	**Bipolar Junction Transistor (BJT)**	**6 hours**

BJT fundamentals, terminologies, device structure, band diagram, basic operational principle, modes of operation, performance parameters, Minority carrier distributions and terminal currents, approximations of terminal currents, Ebers-Moll equations and coupled diode model.

Module:7	**Optoelectronic Devices**	**4 hours**
Photodetectors, p-n junction, pin, solar cells, LED - device structure, working principle, materials, characteristics and figures of merit, physics of tunnel diode, High electron mobility transistor (HEMT).		
Module:8	**Contemporary issues**	**2 hours**
	Total Lecture hours:	**45 hours**
Text Book(s)		
1.	Ben G Streetman, Sanjay Kumar Banerjee, Solid State Electronic Devices, 2016, 7th Edition, Pearson Education, New Delhi.	
Reference Books		
1.	Donald A. Neamen, Semiconductor Physics and Devices Basic Principles, 2017, 4th Edition, McGraw-Hill, New Delhi	
2.	Robert F. Pierret, Semiconductor Device Fundamentals, 1996, Pearson, New Delhi.	
3.	S. M. Sze, Kwok K. Ng, Physics of Semiconductor Devices, 2015, 3rd Edition, Wiley, New Delhi.	
Mode of Evaluation: CAT, Assignment, Quiz and FAT		

Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date	14.03.2024

Course code	Course title		L	T	P	C
PPHY617L	**Materials Science**		**3**	**0**	**0**	**3**
Pre-requisite	Solid State Physics	**Syllabus version**				
		01.00				

Course Objectives

1. To understand and appreciate the fundamentals of the dynamics involved in the formation of various materials.
2. To appreciate the underlying physical properties of materials that differentiate materials from one another.
3. To learn different characterization and processing techniques.

Course Outcome

At the end of the course student will be able to
1. Comprehend the fundamentals of different types of materials.
2. Understand the dynamics involved in the formation of materials.
3. Appreciate and apply various physical properties of materials.
4. Have a working understanding of different characterization and processing techniques.
5. Build upon various concepts in emerging materials

Module:1	**Classification and Structure of Materials**	**6 hours**

Classification of materials: metals, ceramics, polymers, and composites. Nature of bonding in materials: metallic, ionic, covalent, Vander walls and mixed bonding. Fundamentals of crystallography, crystal structure, Bravais lattices, unit cells, primitive cells, crystallographic planes, and Miller indices. Defects in crystalline materials: point defects, dislocations, grain boundaries, planar defects.

Module:2	**Kinetics of materials**	**5 hours**

Fields and Gradients; Fluxes; Continuity Equation, Fundamentals of diffusion: driving forces and fluxes for diffusion, Self-diffusion and inter-diffusion, diffusion equation, phase transformation, Nucleation, and growth: homogeneous and heterogeneous nucleation, diffusional growth, particle coarsening, grain growth.

Module:3	**Electrical and thermal properties of materials**	**6 hours**

Theory of electrical conduction in materials, material classification based on bandgap, semi-conductivity, dielectric materials and polarizability, ferroelectricity, piezoelectricity. Short description of special topics: electrical conduction in ionic materials and in conducting polymers, heat capacity, thermal expansion, thermal conductivity, and thermal stresses

Module:4	**Optical and magnetic properties of materials**	**7 hours**

Light matter interaction in metals, dielectric and semiconductor materials. Optical processes: absorption, transmission, Optical phenomena of luminescence, thermal emission, photoconductivity. Magnetism in materials: para-, dia-, ferro- and ferrimagnetism. Influence of temperature on magnetic properties, Curie Weis Law, magnetic domains, and hysteresis.

Module:5	**Characterization and material properties measurement techniques**	**6 hours**

X-ray diffraction for crystal structure determination: (Bragg's law, Scherrer formula); Photoelectron spectroscopy for elemental and structural analysis: XPS, UPS; Electron Microscopy: SEM, STM, TEM; Optical Spectroscopy: UV-Vis Absorption, Reflection, Transmission, Fluorescence: Emission and Excitation, IR spectroscopy: FTIR and Raman; Magnetic resonance spectroscopy: ESR, NMR

Module:6	**Material processing techniques**	**7 hours**

Solidification and casting of metals, joining processes (welding, brazing, and soldering), polymer and composite processing, sheet metal processing (shearing, bending, deep drawing), powder processing of metals and ceramics, machining processes (turning, drilling, milling, shaping etc.), coating processes, Thin film processing: physical and chemical vapor deposition, sputtering techniques

Module:7	**Advanced Functional Materials**	**6 hours**
Nanomaterials, Quantum material, Multifunctional materials, Quantum effect in controlling optical properties, charge transport, Applications of nanomaterial and quantum materials: energy and environment, medical fields, quantum information.		
Module:8	**Contemporary issues**	**2 hours**
	Total Lecture hours:	**45 hours**
Text Book(s)		
1.	Ben G Streetman, Sanjay Kumar Banerjee, Solid State Electronic Devices, 2016, 7th Edition, Pearson Education, New Delhi.	
Reference Books		
1.	Donald A. Neamen, Semiconductor Physics and Devices Basic Principles, 2017, 4th Edition, McGraw-Hill, New Delhi	
2.	Robert F. Pierret, Semiconductor Device Fundamentals, 1996, Pearson, New Delhi.	
3.	S. M. Sze, Kwok K. Ng, Physics of Semiconductor Devices, 2015, 3rd Edition, Wiley, New Delhi.	

Mode of Evaluation: CAT, Assignment, Quiz and FAT			
Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date	14.03.2024

ourse code	Course Title	L	T	P	C
PPHY618L	**Thin Film Technology**	**3**	**0**	**0**	**3**
Prerequisite	Solid-State Physics	**Syllabus version**			
		01.00			

Course Objectives

1. Introduce basic concept of vacuum science and thin film depositions and characterizations

Course Outcome

At the end of the course student will be able to

1. Explain the physical concepts behind the thin film based on thermodynamics of solids.
2. Recognize different ways to create vacuum through pumping component.
3. Describe the growth mechanism of thin film by different physical and chemical techniques.
4. Explain the various methods for nano-lithography.
5. Learn various techniques to characterise the thin films and their use in technological applications.

Module:1	**Introduction to Thin Films**	**3 hours**

Introduction to thick and thin films, difference between thin and thick films, Crystalline solids, Thermodynamics of Solids, Kinetics, Nucleation and Growth, Thin films, exotic properties of Thin Film, Amorphous, Polycrystalline, Single crystalline thin films

Module:2	**Vacuum Components and Systems**	**9 hours**

Introduction to vacuum, Concept of rough, high and ultrahigh vacuum, Kinetic Theory of Gases, Knudsen number, Gas Transport and Pumping, Vacuum Pumps: Rotary pump, Diffusion pump, Turbo-molecular pump, Ion-pump, Cryogenic pump, Pressure measurement, Direct and Indirect gauges, Pirani gauge, Penning gauge, Leak Detection.

Module:3	**Growth of Thin Films**	**7 hours**

Substrate surface, Role of substrate surface and contamination, Methods of substrate surface preparation Adsorption, Thermodynamic aspects of nucleation, Kinetic processes in Nucleation and Growth, Adatom mobility, Concept of grain and grain boundary, Energetics of growth process, Layer by Layer growth, Stranski-Krastanov Growth, Island growth, Epitaxy–homo, hetero and coherent epitaxial layers, Texture and Microstructure Control in thin films, lattice misfit and imperfections

Module:4	**Physical Vapour Deposition (PVD) Techniques**	**8 hours**

Evaporation, Physics and Chemistry of evaporation, Evaporation hardware, Thermal evaporation and E-beam evaporation, Activated Reactive Evaporation, Sputtering: Physics of Sputtering, RF and DC Magnetron Sputtering, Reactive and Co-sputtering, Principles of glow, Plasma and Arc Discharge, Pulsed Laser Deposition (PLD), Molecular Beam Epitaxy (MBE), Atomic Layer Deposition (ALD).

Module:5	**Chemical Vapour Deposition (CVD) Techniques**	**7 hours**

Chemical Vapour Deposition (CVD), Thermodynamics of CVD, Plasma Enhanced CVD (PECVD), Metal Organic CVD (MOCVD), Sol-Gel, Spin and Dip Coating, Electroplating, Spray Pyrolysis. Film contaminations and steps to avoid contaminations

Module:6	**Introduction to Lithography**	**5 hours**

Concepts of Lithography, Photo resists (Positive, Negative), Masking, Exposure and Development, Material removal by etching: Wet (chemical) and Dry (Plasma, Reactive Ion), Lithography types: photolithography, X-ray lithography, Electron-beam lithography, Nano-imprinting and soft nano-lithography, Dip pen nano-lithography

Module:7	Thin Film Characterization Techniques and Applications	4 hours
Thin film thickness measurement, Atomic Force Microscopy (AFM), Electron Microscopy, X-ray diffraction (XRD), 4-probe method, van der Pauw method, Hall effect, UV-Visible spectroscopy, Vibration Sample Magnetometer (VSM). Thin films in Semiconductor devices, Gas and Chemical Sensors, Healthcare and Automobile Sector.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)			
1.	Hartmut Frey and Hamid R. Khan, Handbook of Thin-Film Technology, 2015, Springer Nature Switzerland AG.		
2.	Milton Ohring, The Materials Science of Thin Films, 2003, Academic Press, Elsevier, San Diego, California, USA.		
Reference Books			
1	K.L. Chopra, Thin Film Phenomena, 1979, McGraw Hill Publications, India.		
2	John L. Vossen, Werner Kern, Thin Film Processes, 1991, Academic Press, New York		
3	Sushil Kumar, D. K. Aswal, Recent Advances in Thin Films, 2020, Springer, Singapore.		
4	Smith D. L., Thin Film Deposition: Principles and Practice, 1995, 1st edition, McGraw Hill, New York		
Mode of Evaluation: CAT, Assignment, Quiz and FAT			
Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date	14.03.2024

Course code	Course Title	L	T	P	J	C
PHY-	Photonics	3	0	0	0	3
Pre-requisite	Quantum Mechanics	Syllabus version				
		V1.0				

Course Objectives

1. To understand the fundamental concepts of photonics and light-matter interactions.
2. To gain knowledge about photonics structures and the ability to solve problems.
3. To investigate the potential applications of photonic technology.

Course Outcome

At the end of the course, the students will be able.

1. Analyze the beam propagation using Fourier optics.
2. Construct the polarization states through matrix formalism.
3. Develop the resonator cavity utilizing cavity optics.
4. Explain the optical properties of crystals under external fields in terms of polarization.
5. Summarize the photonics systems using the concept of near field optics.

Module:1	Beam optics	5 hours
Introduction – Gaussian beams –Transmission through optical components – Hermite-Gaussian beams – Short duration beams –Non diffracting beams.		

Module:2	Fourier optics	7 hours
Plane waves and spatial frequency – Harmonic analysis of signal – Amplitude and phase modulations – Transfer function of free space – Optical Fourier transform – Diffraction and interference Image shaping – basics of holography		

Module:3	Polarization optics	7 hours
Light polarization – Polarization states – Elliptically polarized light – Stokes polarization parameters – Stokes vector – Stokes parameters for polarized and unpolarized light – Jones Vector and Jones Matrix – Matrix formulism of polarizer – retarder – rotator – Poincare sphere – representation of polarization states.		

Module:4	Cavity optics	6 hours
Requirements of resonator-Gain and loss in cavity- Longitudinal modes-Single frequency operation-Resonator stability-Spatial energy distributions: Transverse modes.		

Module:5	Anisotropic media-crystal optics	6 hours
Polarisation in crystals- Susceptibility in anisotropic medium- Wave equation in anisotropic medium- Condition of propagation in Uniaxial crystal- Optical properties of crystals under external fields- Electro optic effect-Elasto optic effect-Magneto optic effect – Acousto-optics effect – Photorefractive effect-Liquid crystals.		

Module:6	Photonics components and microsystems	6 hours
Photonic crystals – one, two and three dimensional – Optical switching systems – Scaling concepts, planar systems, 3D systems – Micro electro-mechanical systems (MEMS)		

Module:7	Basics of Nanophotonics	6 hours
Nanophotonics and its true nature – Breaking through diffraction limit – Optical near fields – Nanophotonic devices using optical near fields – Nanophotonic AND and OR gate – System hierarchy in Nanophotonics – Basics of Nanophotonic fabrication – Near field optical CVD and photolithography – Size dependent resonance to regulate size of the devices – Basics of Nano-biophotonics.		

Module:8	Contemporary Issues	2 hours
	Total Lecture hours:	45 hours

Text Book(s)

1. B. E. A. Saleh, M.C. Teich, Fundamentals of Photonics, 2019, John Wiley & Sons, Inc., New Delhi
2. Mark Csele, Fundamentals of Light Sources and Lasers, 2004, 2nd Edition, Wiley publishers, New York
3. Motoichi Ohtsu, Kiyoshi Kobayashi, Tadashi Kawazoe, Takashi Yatsui and Makoto Naruse, Pinciples of Nanophotonics. 2008, CRC Press-Taylor & Francis Group, New York

Reference Books

1. G. S. Agarwal, Quantum Optics, 2015. Cambridge University Press, New Delhi
2. G. Keiser, Optical Fiber Communications, 2000, 3rd Edition, McGraw-Hill Inc., New Delhi
3. P. Bhattacharya, Semiconductor Optoelectronic Devices, 1995, 1st Edition, Prentice Hall of India, New Delhi
4. G. P. Agarwal, Nonlinear Fiber Optics, 2013, 1st edition, Academic Press, Boston.
5. A. Ghatak and K. Thyagarajan, Introduction to fiber optics, 1998, 1st edition, Cambridge Univ. Press, Cambridge

Mode of Evaluation: CAT, Assignment, Quiz and FAT			
Recommended by the Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date	14.03.2024

Course code	Course title	L	T	P	C
PPHY620L	Advanced Solid State Physics	3	0	0	3
Pre-requisite	Solid State Physics, Quantum Mechanics	Syllabus version			
		01.00			
Course Objectives					

1. To understand the higher level concepts in solid state physics 2. To apply solid-state physics concepts in materials science research		
Course Outcome		
At the end of the course, student will be able to 1. Comprehend the nature of bonds in solid-state matter. 2. Calculate and infer the electronic band structure of simple solid systems. 3. Understand and analyse the optical and dielectric response of solid state materials. 4. Analyse the magnetic response from the experimental data. 5. Explain the basic principles of superconductivity.		
Module:1	**Classification of Solids**	**6 hours**
Bonds and Bands, Ionic, Covalent and Molecular Orbital Theory, Van Der Waal's, H-bonded crystals, Cohesive energy, Madelung Constant.		
Module:2	**Self-Consistent Field Approximation**	**7 hours**
Many body hamiltonian, Born-Oppenheimer approximation, Hartree approximation, Self-consistent field, Hartree-Fock approximation, Slater Determinant, Free electron exchange, Koopman's Theorem.		
Module:3	**Electronic Band Structure of Solids**	**6 hours**
Formation of energy bands, empty lattice energy bands and Fermi Surface, Plane wave, orthogonalized plane wave and pseudopotential method, examples, Tight binding method, Overview of Photoemission Spectroscopy		
Module:4	**Dielectric Properties**	**6 hours**
Introduction, Basic Concepts in Electrodynamics, Complex Refractive Index and Dielectric Constant, Free Electron Drude Theory of Optical Properties, Drude–Lorentz Dipole Oscillator Theory of Optical Properties, Optical Behavior of Glass, Metals, and Semiconductors, Optical Spectroscopy, Kramers-Kronig Relationship		
Module:5	**Semiclassical Model of Electron Dynamics**	**5 hours**
Description of the Semiclassical Model; Basis for Equation of Motion; Concept of Holes, Effective Mass, Direct and Indirect Band Gap; Semiclassical Motion in Uniform Electric and Magnetic Field; Quantization of Electron Orbits in a Magnetic Field, Landau levels; De Haas-van Alphen Effect.		
Module:6	**Atomistic view of magnetism**	**7 hours**
Hysteresis, Stoner-Wohlfarth Model of Hysteresis, Langevin Theory of Paramagnetism, Curie-Weiss Law, Building Blocks of Atomic Magnetism, Spin, Orbital, and Total Angular Momentum, Atomic Orbitals, Spin-orbit Interaction, Ground State of an Ion: Hund's Rules, Quantum Theory of Paramagnetism, Exchange Interaction, Pauli Paramagnetism.		
Module:7	**Superconductivity**	**6 hours**
Superconductivity (revisit), Thermodynamics of superconducting transition, London equation, Coherence length, BCS theory, energy gap, isotope effect, transition temperature, Specific Heat. Type-I, Type-II superconductors, Vortex state, Quantum interference, Josephson effect (DC and AC), superconducting junctions, squid and its applications.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**
Text Book(s)		
1.	Harald Ibach, Hans Lüth, Solid-State Physics. An Introduction to Principles of Materials Science, 2009, 4th edition, Spriner, New Delhi	
2.	Walter A. Harrison, Solid State Theory.1970. McGraw-Hill, New York	

3.	N. Mermin , Neil Ashcroft, Solid State Physics, 2016 , 2nd edition,Cengage Learning Asia, New Delhi
Reference Books	
1.	Robert M White, Quantum Theory of Magnetism, 2006, 1st Editon, Springer, New Delhi
2.	J. B Ketterson and S N Song, Superconductivity, 1999, 1st edition, Cambridge University Press, New Delhi
3.	Stephen Blundell, Magnetism in Condensed Matter, 2001, 1st Edition, Oxford University Press, New York.
4.	Javier E. Hasbun, Trinanjan Datta, Introductory Solid State Physics with MATLAB Applications, 2020,1st Edition, CRC Press, New Delhi

Mode of Evaluation: CAT, Assignment, Quiz and FAT			
Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date	14.03.2024

Course code	Course Title		L	T	P	C
PPHY621L	**Astrophysics**		**3**	**0**	**0**	**3**
Prerequisite	Classical Mechanics, Mathematical Physics	**Syllabus version**				
		01.00				
Course Objectives						

1. Astronomical coordinate systems
2. Properties of the Sun and our solar system
3. Stellar structure and stellar evolution.
4. Properties of various astrophysical phenomena

Course Outcome

At the end of the course student will be able to,

1. Apply spherical trigonometric rules to interconnect the astronomical coordinate systems.
2. Understand the origin and basic properties of the Sun and our solar system.
3. Describe the fundamental astrophysical parameters.
4. Explain the stellar structure and stellar evolution of various types of stellar objects.
5. Describe the galaxies, cluster of galaxies and large-scale structures of the Universe.

Module:1	**Spherical astronomy**	**5 hours**
Celestial sphere – Azimuthal and Equatorial coordinate systems - Measuring distance to stars using parallax, Proper motion of stars - Astronomical units		
Module:2	**Sun and our solar system**	**7 hours**
Sun and solar system (planetary system, asteroids, comets and Oort cloud) - Ecliptic plane - Basics of planetary motion (Kepler's laws) and eclipses - Introductory anatomy of Sun (radiative and convective zones, photosphere, chromosphere, corona, flares and prominences, solar winds) - Introduction of sunspots and solar cycle		
Module:3	**Astrophysical parameters**	**6 hours**
Determination of mass, luminosity, radius, Temperature of a star - Color index - Magnitude Scales (Apparent and absolute magnitude) - Empirical mass-luminosity relation - Distance modulus - Stellar classification (M-K Classification schemes, H-R Diagram), Stellar spectra		
Module:4	**Stellar Structure**	**7 hours**
Stellar formation scenarios - Hydrostatic equilibrium in stars - Polytropic gas spheres, Energy generation in stars (Introduction to P-P and C-N cycles) - Radiative and convective transport of energy - Equations of stellar structure and their solution		
Module:5	**Stellar Evolution**	**6 hours**
Evolution of stars of different masses - Pre and post main sequence evolution – various scenarios for end of a star (novae, supernovae, hypernovae, white dwarfs, neutron stars/ pulsars and black holes)		
Module:6	**Milky way and the Interstellar medium**	**6 hours**
Structure of Milky way - Galactic coordinates - Various components of Milky way and their physical properties - Interstellar medium, Various component of the interstellar medium (gas/molecular clouds, dust, stellar nurseries) and their properties		
Module:7	**Galactic and Extragalactic Astronomy**	**6 hours**
Classification of Galaxies (Elliptical Galaxies, Spiral galaxies) - Active galactic nuclei (AGN), quasars and supermassive black holes (SMBH) - Intergalactic Medium (IGM) - Galaxy clusters/ superclusters and other large scale structures in the universe		

Module:8	Contemporary Topics:	2 hours
	Total Lecture hours:	45 hours

Text Book(s)

1.	Arnab Rai Choudhuri, Astrophysics for Physicists, 2010, Cambridge University Press, New Delhi
2.	B.W. Carroll & D.A. Ostlie , An Introduction to Modern Astrophysics and Cosmology, 2017, Second Edition, Cambridge University Press, New Delhi

Reference Books

1.	Kenneth R. Lang, Essential Astrophysics, 2015,1st Edition, Springer Publication, New Delhi
2.	Martin Harwit , Astrophysical Concepts, 2012 , Springer Publication, New Delhi
3.	T. Padmanabhan , Theoretical Astrophysics: Volume 1, 1st Edition ,Cambridge University Press, Cambridge, 2015.
4.	Frank Shu, The Physical Universe: An Introduction to Astronomy, 1983, University Science Books, New Delhi
5.	Stephan Gregory, Michael Zellik, Introductory Astronomy and Astrophysics, 1997, 1sts Edition, Brooks Publishers, New Delhi

Mode of Evaluation: CAT, Assignment, Quiz and FAT

Recommended by Board of Studies	20-01-2024		
Approved by Academic Council	No. 73	Date	14.03.2024