

**CENTRAL UNIVERSITY OF PUNJAB, BATHINDA**



**M.SC. PHYSICS**

**Batch-2023**

**DEPARTMENT OF PHYSICS**

**SCHOOL OF BASIC SCIENCES**

**Graduate attributes**

Students graduating from the program will gain enhanced basic and advanced knowledge related to various subjects of physics. They will possess skills to work in education, research, and industry. They will be able to apply the knowledge of physics in various areas of physics, mathematics, chemistry, and computational sciences.

**SEMESTER-I**

<b>Sr. No</b>	<b>Course Code</b>	<b>Course Title</b>	<b>Course Type</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>Cr</b>
1	PHY.506	Mathematical Physics	CF	3	0	0	3
2	PHY.507	Numerical Methods	CF	3	0	0	3
3	PHY.508	Classical Mechanics	C	3	0	0	3
4	PHY.509	Quantum Mechanics	C	3	0	0	3
5	PHY.510	Electronics	C	3	0	0	3
6	PHY.511	Numerical Methods Laboratory	SB	0	0	4	2
7	PHY.512	Electronics Laboratory	SB	0	0	4	2
8	PHY.513	Modern Physics Laboratory	SB	0	0	4	2
9	XXX.XXX	Tutorials		0	2	0	0
		<b>Total Credits</b>					<b>21</b>

**SEMESTER-II**

<b>Sr. No</b>	<b>Course Code</b>	<b>Course Title</b>	<b>Course Type</b>	<b>L</b>	<b>T</b>	<b>P</b>	<b>Cr</b>
1	PHY.521	Advanced Quantum Mechanics	C	3	0	0	3
2	PHY.522	Electromagnetic Theory	C	3	0	0	3
3	PHY.523	Solid State Physics	C	3	0	0	3
4	PHY.524	Digital Electronics	C	3	0	0	3
5	PHY.525	Solid State Physics Laboratory	SB	0	0	4	2
6	XXX.XXX	Interdisciplinary Course	IDC	2	0	0	2
Discipline Elective Course (Select one)							
7	PHY.527	Functional Materials	DE	3	0	0	3
	PHY.528	Computational Solid State Physics	DE	3	0	0	3
	PHY. 531	Energy Storage Materials	DE	3	0	0	3
Discipline Elective Course (Select one)							
8	PHY.529	Nanostructured Materials	DE	3	0	0	3

	PHY.530	Nonlinear and Quantum Optics	DE	3	0	0	3
	PHY. 532	Physics at Low Temperatures	DE	3	0	0	3
	PHY.533	Computational Soft Matter	DE	3	0	0	3
9	XXX.XXX	Tutorials		0	2	0	0
		<b>Total Credits</b>					<b>22</b>
IDC course for other departments							
	PHY.514	Physics in Everyday Life	IDC	2	0	0	2
	XXX.XXX	Accelerator Physics*	SB	3	0	0	3

\*For students who want to exit after 1 year of their MSc Physics course, they shall be awarded the Post-Graduate Diploma in Physics. Student will have to opt any one additional course/MOOC course/Project work of 4 credits in addition to the regular/normal syllabus of 1<sup>st</sup> and 2<sup>nd</sup> semester. Any one of the following courses can be chosen:

Minor Project (4 Credits); PHY.554 Nuclear Physics Laboratory; PHY.556 Imaging and Crystallography; PHY.557 Nuclear Techniques; PHY.558 Non-Imaging Techniques; Accelerator Physics\* (available online on Swayam portal)

### SEMESTER-III

Sr. No	Course Code	Course Title	Course Type	L	T	P	Cr
1	PHY.551	Statistical Mechanics	C	3	0	0	3
2	PHY.552	Nuclear and Particle Physics	C	3	0	0	3
3	PHY.553	Atomic and Molecular Physics	C	3	0	0	3
4	PHY.554	Nuclear Physics Laboratory	SB	0	0	4	2
5	XXX.XXX	Value Added Course	VAC	2	0	0	2
Discipline Elective Course (Select one)							
6	PHY.555	Advanced Solid State Physics	DE	3	0	0	3
	PHY.556	Imaging and Crystallography	DE	3	0	0	3
	PHY.557	Nuclear Techniques	DE	3	0	0	3
	PHY.558	Non-Imaging Techniques	DE	3	0	0	3

7	PHY.559	Entrepreneurship	CF	2	0	0	2
8	PHY.600	Dissertation Part I	SB	0	0	8	4
9	XXX.XXX	Tutorials		0	2	0	0
		<b>Total Credits</b>					<b>22</b>
VAC course for other departments							
	PHY.526	Measurement Science	VAC	2	0	0	2

#### SEMESTER-IV

Sr . No	Course Code	Course Title	Course Type	L	T	P	Cr
1	PHY.601	Dissertation Part II	SB	0	0	40	20
<b>Total Credits</b>							<b>20</b>
<b>Total Credits for M.Sc. Physics Program: 85</b>							

**L:** Lecture; **T:** Tutorial; **P:** Practical; **Cr:** Credits; **CF:** Compulsory Foundation, **C:** Core, **P:** Practical, **DE:** Discipline Elective, **IDC:** Interdisciplinary Elective, **SB:** Skill-based, **VAC:** Value Added Courses, **DEC:** Discipline Enrichment Course.

#### Evaluation Criteria for Theory Courses (C, DE, CF, VAC, IDC)

**Formative Evaluation:** Internal assessment shall be 25 marks using any two or more of the given methods: tests, open book examination, assignments, term paper, etc. The Mid-semester test shall be descriptive type of 25 marks including short answer and essay type. The number of questions and distribution of marks shall be decided by the teachers.

**Summative Evaluation:** The End semester examination (50 marks) with 70% descriptive type and 30% objective type shall be conducted at the end of the semester. The objective type shall include one-word/sentence answers, fill-in the blanks, MCQs', and matching. The descriptive type shall include short answer and essay type questions. The number of questions and distribution of marks shall be decided by the teachers. **Questions for exams and tests shall be designed to assess course learning outcomes along with focus on knowledge, understanding, application, analysis, synthesis, and evaluation.**

The evaluation for IDC, VAC and entrepreneurship, innovation and skill development courses shall include MST (50 marks) and ESE (50 marks). The pattern of examination for both MST and ESE shall be same as ESE described above for other courses.

Evaluation of dissertation proposal in the third semester shall include 50% weightage by supervisor and 50% by HoD and senior-most faculty of the department. The evaluation of dissertation in the fourth semester shall include 50% weightage for continuous evaluation by the supervisor for regularity in work, mid-term evaluation, report of dissertation, presentation, and final viva-voce; 50% weightage based on average assessment scores by an external expert, HoD and senior-most faculty of the department. Distribution of marks is based on report of dissertation (30%), presentation (10%), and final viva-voce (10%). The external expert may attend final viva-voce through offline or online mode.

<b>Core, Discipline Elective, and Compulsory Foundation Courses</b>			<b>IDC, VAC, and Entrepreneurship, Innovation and Skill Development Courses</b>	
	Marks	Evaluation	Marks	Evaluation
Internal Assessment	25	Various methods	-	-
Mid-semester test (MST)	25	Descriptive	50	Descriptive (70%) Objective (30%)
End-semester exam (ESE)	50	Descriptive (70%) Objective (30%)	50	Descriptive (70%) Objective (30%)

### **Evaluation Criteria for Dissertation**

<b>Dissertation Proposal (Third Semester)</b>			<b>Dissertation (Fourth Semester)</b>		
	Marks	Evaluation		Marks	Evaluation
Supervisor	50	Dissertation proposal and presentation	Supervisor	50	Continuous assessment (regularity in work, mid-term evaluation) dissertation report, presentation, final viva-voce
HoD and senior-most faculty of the department	50	Dissertation proposal and presentation	External expert, HoD and senior-most faculty of the department	50	Dissertation report (30), presentation (10), final viva-voce (10)

Marks for internship shall be given by the supervisor, HoD and senior-most faculty of the department.

### **Some Guidelines for Internal Assessment**

1. The components/pattern of internal assessment/evaluation should be made clear to students during the semester.
2. The results of the internal assessment must be shown to the students.
3. The question papers and answers of internal assessment should be discussed in the class.
4. The internal assessment shall be transparent and student-friendly and free from personal bias or influence.

**\*A maximum of up to 4 students may be given a broad topic to perform combined research. Subtopics may be distributed to each student to work on.**

**M.Sc. PHYSICS****SEMESTER-I**

L	T	P	Cr
3	0	0	3

**Course Title: Mathematical Physics****Course Code: PHY.506****Total Hours: 45****Learning Outcomes:**

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

CLO1: Develop understanding of the complex functions and complex algebra,

CLO2: Apply of complex algebra to evaluate definite integrals and solve summation of infinite series, integrals involving branch point singularity.

CLO3: Develop understanding of Fourier series, integral transforms and group theory

CLO4: Develop understanding of vector space and tensor

CLO5: Develop understanding of special functions and partial differential equations

CLO6: Apply integral transform to solve ordinary and partial differential equations

<b>Units/ Hours</b>	<b>Contents</b>	<b>Mapping with Course Learning Outcome</b>
I/11	<b>Complex Analysis:</b> Cauchy theorem, Cauchy integral representation, Taylor and Laurent series, Lowville's theorem. Morera's theorem, Singular Points and their classification. Branch Point and branch Cut. Riemann sheets. Residues and evaluation of integrals, Cauchy residue theorem.	CLO1
	<b>Applications of Residue Theorem:</b> The evaluation of definite integrals and the summation of infinite series. Integrals involving branch point singularity.	CLO2



	<b>Learning Activities:</b> Problem Solving and Application based peer thinking	
II/12	<b>Fourier and Laplace Transforms:</b> Fourier series, Dirichlet condition, General properties of Fourier series, Fourier transforms, Their properties and applications, Laplace transforms, Properties of Laplace transform, Inverse Laplace transform. Solution of ordinary and partial differential equations by transform methods.	CLO3
	<b>Group theory:</b> Group postulates, Lie group and generators, representation, Commutation relations, SU (2), O (3).	CLO3
	<b>Learning Activities:</b> Problem Solving, group discussions, Application based peer thinking	
III/11	<b>Vector Space:</b> Linear vector spaces, subspaces, basis and dimension, Linear independence and orthogonality of vectors, Gram-Schmidt orthogonalization procedure.	CLO4
	<b>Tensors:</b> Tensor analysis, scalars, Covariant and Contravariant tensors. Addition, Subtraction, Outer product, Inner product and Contraction. Symmetric and antisymmetric tensors. Quotient law. Metric tensor. Conjugate tensor. Length and angle between vectors. Associated tensors. Raising and lowering of indices. The Christoffel symbols and their transformation laws. Covariant derivative of tensors	
	<b>Learning Activities:</b> Group discussion and problem solving.	
IV/11	<b>Differential Equations:</b> Solutions of Hermite, Legendre, Bessel and Laguerre Differential equations, basic properties of their polynomials, and associated Legendre polynomials	CLO5
	<b>Partial differential equations:</b> Laplace, wave and heat equation in two and three dimensions, Boundary value problems and Euler equation, Green's function and its applications.	CL06
	<b>Learning Activities:</b> Problem Solving	

**Transaction Mode:** Lecture, case study, blended learning, problem solving, discussion & demonstration, self-study.

### Suggested Readings:

- 1) Arfken G, Weber H and Harris F. (2012). *Mathematical Methods for Physicists*. Massachusetts, USA: Elsevier Academic Press.
- 2) Kreyszig E. (2011). *Advanced Engineering Mathematics*. New Delhi, India: Wiley India Pvt. Ltd.

- 3) Pipes L. A. (1985). *Applied Mathematics for Engineers and Physicist*. Noida, India: McGraw-Hill.
- 4) Zill D. G. (2012). *Advanced Engineering Mathematics*. Massachusetts, USA: Jones & Barlett Learning.
- 5) Chattopadhyay P. K. (2000). *Mathematical Physics*. New Delhi: New Age International (P) Ltd.
- 6) Rajput B.S. (2017). *Mathematical Physics*. Pragati Prakashan.
- 7) McQuarrie Donald A. (2015). *Mathematical methods for scientists and engineers*. New Delhi: Viva books private limited.
- 8) M. L. Boas, *Mathematical Methods in the Physical Sciences*, 3ed (2019), Wiley.

**Course Code: PHY.507**

L	T	P	Cr
3	0	0	3

**Course Title: Numerical Methods**

**Total Hours: 45**

**Learning Outcomes:**

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

CLO1: Familiarize with Linux environment.

CLO2: Develop understanding of C language.

CLO3: Acquire knowledge of computational techniques and errors

CLO4: Develop understanding of matrix algebra.

CLO5: Write C programs to solve linear system of equations using matrix methods

CLO6: Write C programs to find the roots, differential, and integration of a function

CLO7: Write C programs to solve differential equations

Units/ Hours	Contents	Mapping with Course Learning Outcome
I/11	<b>Linux operating system:</b> Introduction to the Linux operating system: fundamental commands, editing files, understanding directories and permissions.	CLO1
	<b>Programming with C and Fortran:</b> Computer Algorithm, Data types, C and Fortran programming syntax for Input/Output, Control statements: if, if-else and nested-if statements. Looping: while, for and do-while loops, Functions: Call by values and by references, Arrays and structures: one dimensional and two-	CLO2

	dimensional arrays, Idea of string and structures. Preprocessors, Pointers in C	
	<b>Learning Activities:</b> Writing programs, group discussions	
II/11	<b>Error analysis:</b> Element of computational techniques: Error analysis, Propagation of errors.	CLO3
	<b>Matrices:</b> Eigenvalues and eigenvectors (Power method and Jacobi's method), Solution of linear system of equations – Gauss elimination method – Pivoting – Gauss Jordan method – Iterative methods of Gauss Jacobi and Gauss Seidel.	CLO4 CLO5
	<b>Learning Activities:</b> Problem solving, Writing programs, group discussions	
III/11	<b>Roots of Nonlinear Equations:</b> Roots of functions, Bracketing and open end methods: Bisection Method, False position method and Newton Raphson method. Interpolation and Least Square Fitting: Linear Interpolation, Lagrange and Newton Interpolation, Linear and non-linear curve fitting <b>Numerical Differentiation and Integration:</b> Differentiation of continuous functions Integration by Trapezoidal and Simpson's rule.	CLO6
	<b>Learning Activities:</b> Problem solving, Writing programs	
IV/12	<b>Numerical Solution of Ordinary Differential Equations:</b> Euler method and Runge-Kutta method, Finite Element Method (Solve Wave and Heat Equations). Random Numbers: Introduction to random numbers, Monte Carlo method for random number generation, Chi square test.	CLO7
	<b>Learning Activities:</b> Learning Activities: Problem solving, Writing programs, group discussions	

**Transaction Mode:** Lecture, case study, blended learning, problem solving, discussion & demonstration, self-study.

**Suggested Readings:**

- 1) Kanetkar Y. (2012). Let Us C. New Delhi, India: BPB Publications.
- 2) Balaguruswamy E. (2009). Numerical Methods. Noida, India: Tata McGraw Hill.
- 3) Sastry S. S. (2012). Introductory Methods of Numerical Analysis. New Delhi: PHI Learning Pvt.Ltd.
- 4) Verma R. C, P. K. Ahluwalia & K. C. Sharma. (1999). Computational Physics. New Age, 1st edition.

- 5) Tao Pang. (2nd edition, 2006). an Introduction to Computational Physics. Cambridge University Press.
- 6) Richard Petersen. (2008). Linux: The Complete Reference. New Delhi, India: McGraw Hill Education Private Limited.
- 7) J. N. Reddy (2nd edition, 1993), An Introduction to Finite Element Method, McGraw Hill Inc.
- 8) V. Rajaraman (2006), Computer Programming in Fortran 90 and 95, PHI Pvt. Ltd, New Delhi.

L	T	P	Credit
3	0	0	3

**Course Code: PHY.508**

**Course Title: Classical Mechanics**

**Total Hours: 45**

**Course Learning Outcomes:**

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

CL01: Understand alternatives to Newtonian mechanics e.g. Lagrangian mechanics.

CLO2: Apply Hamiltonian formalism to solve mechanical problems.

CL03: Apply above formalisms to solve problems involving small oscillations.

CLO4: Understand dynamical systems, phase space dynamics, and linear stability.

CL05: Apply the formulations of classical mechanics to the central force problem.

CLO6: Develop formulation of canonical transformations.

CL07: Explain Poisson brackets formulation to solve various types of problems.

Units /Hours	Contents	Mapping with Course Learning Outcome
I/12	<b>Lagrangian Formalism:</b> Newton's laws, Classification of constraints, D' Alembert's principle and its applications, Generalized coordinates, Lagrange's equation for conservative, non-conservative and dissipative systems and problems, Lagrangian for a charged particle moving in an electromagnetic field, Cyclic-coordinates, Symmetry, Conservations laws (Invariance and Noether's theorem), Gauge Transformations.	CLO1
	<b>Hamiltonian Formalism:</b> Variational principle and problems, Principle of least action, Hamilton's principle, Hamilton's Theorems, Hamilton's equation of motion, Lagrange and Hamilton equations of	CLO2

	<p>motion from Hamilton's principle, Hamilton's principle to non-conservative and non-holonomic systems, Hamiltonian Formulation, Problems based on Hamiltonian Formulation, Relativistic Lagrangian and Hamiltonian.</p> <p><b>Learning Activities:</b> Problem Solving</p>	
II/11	<p><b>Theory of Small Oscillations:</b> Periodic motion, Types of equilibria, General formulation of the problem, Lagrange's equations of motion for small oscillations, Normal modes, Applications to linear triatomic molecule, Solution of Double and Triple coupled pendulum, N-Coupled oscillators.</p>	CLO3
	<p><b>Dynamical systems, Phase space Dynamics and Stability Analysis:</b> Simple harmonic oscillator, Damped harmonic oscillator, Phase portrait of the pendulum, Classification of equilibrium points: Two-dimensional case, Damped cubic anharmonic oscillator, Undamped and damped pendulum equation, van der Pol oscillator, and Lotka-Volterra equations.</p>	CLO4
	<p><b>Learning Activities:</b> Group discussions, Application-based peer thinking, and Problem Solving.</p>	
III/11	<p><b>Central Force Problem:</b> Central force motions, Reduction to the equivalent one-body problem, Differential equation for the orbit, Classification of orbits, Stability of orbits and condition for closed orbits (Bertrand's theorem without proof), Stability of circular orbits, Kepler's equation, Virial theorem, Kepler's laws and their derivations, Two-body collisions, Rutherford scattering cross-section, Scattering in laboratory and center-of-mass frames.</p>	CLO5
	<p><b>Learning Activities:</b> Group discussion and problem-solving.</p>	
IV/11	<p><b>Canonical Transformations:</b> Canonical transformation (CT) with examples and related problems, Generating functions and Maxwell type relations, Solution of a harmonic oscillator using CT, Conditions for CT and related problems.</p>	CLO6
	<p><b>Poisson Brackets:</b> Poisson brackets and their properties, Jacobi identity, Canonical equations in terms of Poisson bracket, Integral invariants of Poincare, Infinitesimal canonical transformation and generators of symmetry, Relation between infinitesimal transformation and Poisson bracket, Problems based on Poisson bracket, Invariance of Poisson bracket, Liouville's Theorem.</p>	CLO7
	<p><b>Learning Activities:</b> Group discussion and problem-solving.</p>	

**Transaction Mode:** Lecture delivery using white board, explanations through computer programs on PPT, problem solving through assignments.

**Suggested Readings:**

1. Thornton S.T. and Marion J.B. (2013). Classical Dynamics of Particles and Systems. Boston/Massachusetts, United States: Cengage Learning.

2. Safko J, Goldstein H and Poole C. P. (2011). Classical Mechanics. New Delhi, India: Pearson.
3. Walter G.(2010). Systems of Particles and Hamiltonian Dynamics. New York, USA: Springer.
4. Joag P.S and Rana N.C. (2017). Classical Mechanics. McGraw Hill Education, India
5. Aruldas (2008), Classical Mechanics. Prentice-Hall India Learning Private Limited, India
6. Upadhyaya J. C. (2019), Classical Mechanics, Himalaya Publishing House, India.
7. Takwale R., Puranik P (2017), Introduction to Classical Mechanics, McGraw Hill Education, India.
8. Lakshmanan M. (2003), Nonlinear Dynamics: Integrability, Chaos and Patterns, Springer.

L	T	P	Credit
3	0	0	3

**Course Name: Quantum Mechanics**

**Course Code: PHY.509**

**Course type: Core Course**

**Total Hours: 45**

**Course Learning Outcomes:**

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

CLO1: Explain mathematical formulation of quantum mechanics,

CLO2: Apply Schrodinger's equation to solve Eigen value problems such as box potential, harmonic oscillator, hydrogen atom and quantum mechanical tunneling,

CLO3: Formulate C G coefficients using angular momentum algebra,

CLO4: Apply the perturbation theory to explain Stark effect, Paschen Back effect, Anomalous Zeeman effect and fine structure of hydrogen atom

CLO5: Apply variational method to describe ground state of harmonic oscillator and hydrogen atom.

CLO6: Explain Fermi Golden rule and selection rules for absorption and emission of light.

Units/Hours	Contents	Mapping with Course Learning Outcome

I 12 Hours	<b>Foundation of Quantum Mechanics:</b> Limitations of Classical Mechanics, Dirac notation, Basic postulates of quantum mechanics, Expectation values, Commutation relations, Ehrenfest theorem.	CLO1
	<b>Schrödinger Wave Equation and Applications:</b> Schrödinger wave equation (time dependent and time independent), Solution of Harmonic oscillator using matrix mechanics: matrix representation and Eigen values of various operators, Anisotropic and isotropic harmonic oscillator, The box potential, Solution of Schrodinger equation for hydrogen atom.	CLO2
	<b>Learning Activities:</b> Brain-storming and Problem Solving	
II 11 Hours	<b>Angular Momentum:</b> eigenvalues and Eigen vectors of orbital angular momentum, Spherical harmonics, Angular momentum algebra and commutation relations, Matrix representation of angular momentum, Stern-Gerlach experiment,	CLO3
	<b>Spin angular momentum:</b> Pauli matrices and their properties. Addition of two angular momenta, Transformation between bases: Clebsch-Gordan Coefficients, Eigenvalues of $J^2$ and $J_z$ , Coupling of orbital and spin angular momenta.	CLO3
	<b>Learning Activities:</b> Group discussion and Problem Solving	
III 11 Hours	<b>Time-independent Perturbation Theory:</b> Non-degenerate (1st and 2nd order) and degenerate case, Application of perturbation theory: Stark effect, Paschen-Bach Effect and Zeeman effect in hydrogen atom	CLO4
	<b>The Variational Method:</b> Theory and its applications to ground state of harmonic oscillator and hydrogen atom.	CLO5
	<b>Learning Activities:</b> Problem solving	
IV 11 Hours	<b>Time-dependent Perturbation Theory:</b> Time development of states and transition probability, Adiabatic and sudden approximations, Fermi golden rule and its application to radiative transition in atoms, Spontaneous emission: Einstein's A and B coefficients, Selection rules for emission and absorption of light, Optical pumping and population inversion, rate equation, Modes of resonators and coherent length.	CLO6

	<b>Learning Activities:</b> Group discussion and problem solving	
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**Transaction Mode:** Lecture, problem solving, group discussion, self-study.

**Suggested Readings:**

1. Zettili N. (2009). *Quantum Mechanics-Concepts and Applications*. Sussex, U.K: John Wiley & Sons Ltd.
2. Merzbacher E. (2011). *Quantum Mechanics*. New Delhi, India: Wiley India Pvt. Ltd.
3. Schiff L.I. (2010). *Quantum Mechanics*. Noida, India: McGraw-Hill Education.
4. Venkatesan K and Mathews, P. M. (2010). *A Textbook of Quantum Mechanics*. Noida, India: Tata McGraw - Hill Education.
5. Sakurai J. J. (2009). *Modern Quantum Mechanics*. India: Pearson Education.
6. Griffiths D. J. (2015). *Introduction to Quantum Mechanics*, India: Pearson Education.
7. Mahan G. D. (2009). *Quantum Mechanics in a Nutshell*. Princeton University Press.

L	T	P	Credit
0	0	0	03
3	0	0	

**Course Name: Electronics**

**Course Code: PHY.510**

**Course type: Core Course**

**Total Hours: 45**

**Course Learning Outcomes:**

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

CLO1: Explain the working of different semiconductor devices.

CLO2: Construct schematic of different electronic circuitry and able to understand the BJT.

CLO3: Understand the functioning of unipolar transistor devices.

CLO4: Know the need and utilization of feed backing in any electronic circuitry.

CLO5: Built an idea that how to stabilize any electronic circuit operation and local oscillator.

CLO6: Inspect working of operational amplifier and different type of ICs.

Units/ Hours	Contents	Mapping with
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		<b>Course Learning Outcome</b>
I/12	<b>Semiconductors:</b> Theory of semiconductors, Semiconductor devices, diode, homo and heterojunction devices.	CLO1
	<b>Transistor Amplifiers:</b> Transistor, Device structure and characteristics, Amplifiers, Frequency dependence and applications, Impedance matching, H and R parameters and their use in small signal amplifiers, Conversion formulae for the h-parameters of the different transistor configurations, Analysis of a transistor CE amplifier at low frequencies using h-parameters, CE amplifier with unbypassed emitter resistor, Emitter follower at low frequencies, Emitter-coupled differential amplifier and its characteristics, Cascaded amplifiers, Transistor biasing, Self-bias and thermal stability, filtering, Noise reduction, Low frequency power amplifiers, High frequency devices.	CLO2
	<b>Learning Activities:</b> Application based peer thinking, Problem Solving	
II/10	<b>Field Effect Transistor:</b> Field effect transistor and its small signal model, CS and CD amplifiers at low frequencies, Biasing the FET, CS and CD amplifiers at high frequencies.	CLO3
	<b>Learning Activities:</b> Group discussions, Application based peer thinking, and Problem Solving.	
III/12	<b>Basics of Feed backing:</b> The gain of an amplifier with feedback, General characteristics of negative feedback/instrumentation amplifiers, Stability of feedback amplifiers, Barkhausen criteria, Grain and phase margins, Compensation.	CLO4
	<b>Feedback:</b> Sinusoidal oscillators: RC oscillators: Phase shift and the Wien's bridge oscillators, LC oscillators, Frequency stability and the crystal oscillators, locking detector, Box Car integrator and modulation techniques.	CLO5
	<b>Learning Activities:</b> Group discussion and problem solving.	
IV/11	<b>Operational Amplifier and Their Applications:</b> Characteristics of an ideal operational amplifier, Amplification, Applications of operational amplifiers: Inverting and non-inverting amplifiers, Summing circuits, Integration and differentiation, Waveform generators signal conditioning and recovery.	CLO6
	<b>Learning Activities:</b> Brain storming and problem solving.	

**Transaction Mode:** Lecture, case study, blended learning, problem solving, discussion & demonstration, self-study.

**Suggested Readings:**

- 1) Millman J, Halkias C and Parikh C. (2009). Integrated Electronics: Analog and Digital Circuits and Systems. Noida, India: Tata McGraw - Hill Education.
- 2) Boylestad R.L and L. Nashelsky. (2009). Electronic Devices and Circuit Theory. New Delhi, India: Pearson.
- 3) Theraja B.L. (2010). Basic Electronics: Solid State. New Delhi, India: S. Chand & Company Ltd.
- 4) Chattopadhyay D. and Rakshit P. C. (2008). Electronics: Fundamentals and Applications. New Delhi, India: New Age International.

L	T	P	Cr
0	0	4	2

**Course Code: PHY.511**

**Course Title: Numerical Methods Laboratory**

**Total Hours: 60**

**Learning Outcomes:**

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

CLO1: Write C and Fortran programs to solve linear system of equations using matrix methods

CLO2: Write C and Fortran programs to find the roots, differential, and integration of a function

CLO3: Write C and Fortran programs to solve differential equations

CLO4: Write programs to solve various Physics problems

Units/ Hours	Contents	Mapping with Course Learning Outcome
III/90	To find the root of nonlinear equation using Bisection method. To study the numerical convergence and error analysis of non-linear equation using Newton Raphson method.	CLO1 CLO2 CLO3

	<p>To find the value of <math>y</math> for given value of <math>x</math> using Newton's interpolation method.</p> <p>Perform numerical integration on 1-D function using Trapezoid rule.</p> <p>Perform numerical integration on 1-D function using Simpson rules.</p> <p>To find the solution of differential equation using Runge-Kutta method.</p> <p>To find the solution of differential equation using Euler's method.</p> <p>Choose a set of 10 values and find the least squared fitted curve.</p> <p>To find eigenvalues and eigenvectors of a Matrix.</p> <p>To find solutions of linear equations using Gauss elimination method.</p>	
	<p><b>Any five from the following:</b></p> <p>Study the motion of spherical body falling in viscous medium using Euler method.</p> <p>To study the path of projectile with and without air drag using Feynman-Newton method.</p> <p>Study the motion of an artificial satellite around a planet.</p> <p>Study the motion of one-dimensional harmonic oscillator without and with damping effects.</p> <p>To obtain the energy eigenvalues of a quantum oscillator using Runge-Kutta method.</p> <p>Study the motion of charged particles in uniform electric field, uniform magnetic field and combined uniform EM field.</p> <p>To study the phenomenon of nuclear radioactive decay.</p> <p>To study the EM oscillation in a LCR circuit using Runge-Kutta method.</p> <p>To find the solution of 1D heat flow equation using Finite Element Method.</p>	CLO4
	<p><b>Learning Activities:</b> Writing programs, group discussion</p>	

**Transaction Mode:** Writing programs, group discussion

**Suggested Readings:**

1. Kanetkar Y. (2012). *Let Us C*. New Delhi, India: BPB Publications.
2. Balaguruswamy. (2009). *Numerical Methods*. Noida, India: Tata McGraw Hill.
3. Sastry S. S. (2012). *Introductory Methods of Numerical Analysis*, New Delhi: PHI Learning Pvt.Ltd.

4. Verma R. C, Ahluwalia P. K. & Sharma K.C. (1<sup>st</sup> edition,1999). Computational Physics. New Age.
5. Tao Pang. (2<sup>nd</sup> edition, 2006). an Introduction to Computational Physics. Cambridge University Press.

L	T	P	Credit
0	0	4	2

**Course Name: Electronics Laboratory**

**Course Code: PHY.512**

**Course type: Core Course**

**Total Hours: 60**

**Course Learning Outcomes:**

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

CLO1: Learn that how can an ac signal could be converted in dc signal and how to do Shaping of the signals.

CLO2: Validate the learning in theory classes of transistors.

CLO3: Validate the learning in theory classes about Unipolar transistors, local oscillators and Stabilization of electronic circuitry.

CLO4: Validates the learning of Op-Amp in theory classes.

CLO5: Validate the learning of basics and usefulness of logic gates that study in theory class.

CLO6: Validate the learning of data storage and their use in different application what learnt in theory classes.

Units /Hours	Contents	Mapping with Course Learning Outcome
III/90	Power supplies: Bridge rectifier switch capacitive input filters.	CLO1
	Power supplies: Shunt Voltage regulator using Zener diode.	
	Clipping and Clamping along with CRO.	
	Common Emitter Amplifier with and without feedback.	CLO2
	Determination of h-parameters in the CE configuration using the measured input and output characteristics of a BJT.	

	Common Source and Common Drain Amplifiers using JFET.	
	RC Oscillators: Phase shift oscillator using RC ladder network as the phase shifting network.	CLO3
	Wien's Bridge Oscillator.	
	Colpitts Oscillators.	
	Hartley Oscillators.	
	Emitter Coupled Differential Amplifier using BJT's.	
	Multivibrators–Bistable, Monostable and Free Running multivibrators	

Op-Amp characteristics: $V_{io}$ , $I_b$ , $V_{ol}$ , CMRR, Slew Rate. Applications of Op-amps: inverting Amplifier, Unity Gain Buffer, and Summing Amplifier.	CLO4
Realization of universal logic gates.	CLO5
Implementation of the given Boolean function using logic gates in both SOP and POS form.	
Perform the logic state tables of RS and JK flip-flops using NAND & NOR gates.	
Perform the logics gate tables of T and D flip-flops using NAND& NOR gates.	
Perform the Verification of logic state tables of master slave flip flop using NAND & NOR gates.	CLO6
Triggering mechanism of flip flop.	
Perform the Realization of Half adder and full adder.	
Perform the Half subtractor and full subtractor.	
Decoders and code converters.	
Up/Down Counters.	
Shift Resistor.	

**Transaction Mode:** Demonstration, experimentation.

**Suggested Readings:**

- 1) Millman J, Halkias C and Parikh C. (2009). Integrated Electronics: Analog and Digital Circuits and Systems. Noida, India: Tata McGraw-Hill Education.
- 2) Boyle stad R. L & Nashelsky L. (2009). Electronic Devices and Circuit Theory. New Delhi: Pearson.
- 3) Theraja B. L. (2010). Basic Electronics: Solid State. New Delhi: S. Chand & Company Ltd.
- 4) Chattopadhyay D and Rakshit P. C. (2008). Electronics: Fundamentals and Applications. New Delhi, India: New Age International.
- 5) Saha G, Malvino A.P and Leach D.P. (2011). Digital Principles and Applications. Noida, India: Tata McGraw-Hill Education.

- 6) Malvino P and Brown J.A. (2011). Digital Computer Electronics Noida, India: Tata McGraw-Hill Education.
- 7) Hawkins Cand Segura J. (2010). Introduction to Modern Digital Electronics. New York, USA: SciTech Publishing

L	T	P	Credit
0	0	4	2

**Course Name: Modern Physics Laboratory**

**Course Code: PHY.513**

**Course type: Laboratory**

**Total Hours: 45**

**Course Learning Outcomes:**

Course Learning Outcomes:

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

CLO1: Measure Planck's constant and ionization potential of Ar using photoelectric effect and Frank Hertz experiment, respectively.

CLO2: Measure bandgap of semiconductor using four-probe and wavelength of laser using diffraction grating method.

CLO3: Analyze the dual nature of electrons and the working of the Michelson interferometer.

CLO4: Analyze the theoretical concepts of Stefan's law and Zeeman effect through experimentations and the working of the Fabry-Perot Interferometer

Units/Hours	Contents	Mapping with Course Learning Outcome
I 15Hours	Ionization potential by Franck Hertz experiment. Photoelectric effect.	CLO1
	<b>Learning Activities:</b> Experimentation, Group discussion	

II 15Hours	Bandgap of a semiconductor by Four Probe method. Wavelength measurement of laser using a diffraction grating.	CLO2
	<b>Learning Activities:</b> Experimentation, Group discussion	
III 15Hours	Michelson interferometer. Dual nature of electron experiment. Millikan oil-drop experiment	CLO3
	<b>Learning Activities:</b> Experimentation, Group discussion	
IV 15Hours	Stefan's law. Zeeman effect experiment. Fabry-Perot Interferometer.	CLO4
	<b>Learning Activities:</b> Experimentation, Group discussion	

**Transaction Mode:** Demonstration, experimentation, group learning.

**Suggested Readings:**

1. Serway R.A, Moses C.J& Moyer C.A. (2012). Modern physics. Massachusetts, USA: Brooks Cole.
2. Thornton S. T. (2012).A. Rex Modern Physics for Scientists and Engineers. Massachusetts, USA: Thomson Brooks/Cole.
3. Krane K.S. (2012). Modern Physics. New Delhi, India: Wiley India(P)Ltd.
4. Beiser A. (2007). Concepts of Modern Physics. Noida, India. Tata McGraw – Hill Education.



## SEMESTER-II

L	T	P	Credit
3	0	0	3

**Course Name: Advanced Quantum Mechanics**

**Course Code: PHY.521**

**Course type: Core Course**

**Total Hours: 45**

**Course Learning Outcomes:**

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

CLO1: Outline WKB method and bound states of potentials well, CLO:2 Explain scattering theory for various kind of potential problems, CLO:3 Explain the importance relativistic quantum mechanics,

CLO:4 Apply quantum mechanical concepts in many electron atoms.

Units/Hours	Contents	Mapping with Course Learning Outcome
I 11Hours	<p><b>WKB Method and its Applications:</b> General formulation of WKB method, validity of WKB approximation, Bound states of potential wells with zero, one and two rigid walls, Application of WKB method to barrier penetration and cold emission of electrons from metals.</p>	CLO1
	<p><b>Learning Activities:</b> Brain- storming and Problem Solving</p>	

<p style="text-align: center;">II 11Hours</p>	<p><b>Scattering Theory:</b> Quantum Scattering theory, Scattering cross-section and scattering amplitude, Born scattering formula, Central force problem, Partial wave analysis, Phase shifts, Optical theorem, Low energy's-wave and p-wave scatterings, Bound states and resonances, Born approximation and its validity, Scattering for different kinds of potentials.</p>	<p style="text-align: center;">CLO2</p>
	<p><b>Learning Activities:</b> Group discussion and Problem Solving.</p>	
<p style="text-align: center;">III 11Hours</p>	<p><b>Relativistic Quantum Mechanics:</b> Klein-Gordon equation, Dirac relativistic equation, Gamma Matrices, Significance of negative energy, Spin-orbit interaction, Relativistic correction, Fine structure of hydrogen atom.</p>	<p style="text-align: center;">CLO3</p>
	<p><b>Learning Activities:</b> Problem solving</p>	
<p style="text-align: center;">IV 12Hours</p>	<p><b>Many Electron Atoms:</b> Spin-Statistics connection, Pauli's exclusion principle, Slater determinant, Exchange energy: Parahelium and orthohelium, Independent particle model, Hartree-Fock equations, Born-Oppenheimer approximation, Elementary idea of density functional theory.</p>	<p style="text-align: center;">CLO4</p>
	<p><b>Learning Activities:</b> Group discussion and problem solving</p>	

**Transaction Mode:** Lecture, problem solving, group discussion, self-study.

**Suggested Readings:**

1. Venkatesan K, Mathews P.M. (2010). *A Text book of Quantum Mechanics*. Noida, India: Tata McGraw-Hill Education.
2. Sakurai J. J. (2006). *Advanced Quantum Mechanics*. New Delhi, India: Pearson.
3. Sakurai J.J, Napolitano J. (2014). *Modern Quantum Mechanics*. , New Delhi, India: Pearson.
4. Zettili N. (2009). *Quantum Mechanics: Concepts and Applications*. Sussex, U.K: John Wiley & Sons Ltd.

5. Griffiths D. J. (Second Edition,2015). Introduction to Quantum Mechanics. India: Pearson Education.
6. Mahan G.D. (2009). Quantum Mechanics in a Nutshell. Princeton University Press.
7. Khanna M.P. (1999). Quantum Mechanics. New Delhi: Har Anand Pub.
8. Foot C. J. (2005). Atomic Physics. Oxford, U.K: Oxford University Press.
9. Banwell C. N and Mc Cash E.M. (1983). Fundamentals of Molecular Spectroscopy. Tata, McGraw-Hill Publishing Company Limited.

<b>L</b>	<b>T</b>	<b>P</b>	<b>Credit</b>
0	0	0	03
3	0	0	

**Course Code: PHY.522**

**Course Title: Electromagnetic Theory**

**Total Hours: 45**

**Course Learning Outcomes:**

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

CLO1: Theory and calculation of electrical parameters

CLO2: Estimation of Electric and magnetic fields of the electrical system

CLO3: Application of theories in the technology development

CLO4: Skill to modify existing formula for the modern technology

<b>Units /Hours</b>	<b>Contents</b>	<b>Mapping with Course Learning Outcome</b>

I/11	<b>Electrostatics:</b> Review of Gauss's law and its applications, Work and energy in electrostatics, Electrostatic potential energy, Electric Fields and Boundary Condition, Poisson and Laplace equations, Uniqueness theorem I & II, Method of Images, Solution of Laplace's equation, Multipole expansion, Boundary condition with dielectrics.	CLO1
II/11	<b>Magnetostatics:</b> Biot-Savart law, Ampere's theorem and its applications, Lorentz Force, Magnetic scalar and Vector potential.	CLO2
	<b>Magnetic Fields and Boundary Condition:</b> Magnetic dipole and Magnetization, Field of a magnetized object, Magnetic susceptibility and permeability, Dia, para and Ferro-magnetic materials, Boundary condition on B and H,	
II/11	<b>Maxwell Equations:</b> Faraday's Law, Maxwell's equations in free space and linear isotropic media. Time Varying Fields and Conservation Laws: Scalar and vector potentials, Gauge invariance, Lorentz gauge and Coulomb gauge, Poynting theorem and conservations of energy and momentum for a system of charged particles	CLO3
IV/1 2	<b>Plane Electromagnetic Waves and wave equations:</b> EM wave in free space, Dispersion characteristics of dielectrics, Waves in a conducting and dissipative media, Skin effect, Transmission lines and wave guides, TE mode, TM mode, Cut off frequency, Retarded potentials. <b>Radiation from Moving Point Charges and Dipoles:</b> Lienard-Wiechert potentials, Radiation from a moving point charge and oscillating electric and magnetic dipoles.	CLO4

**Transaction Mode:** Lecture, Demonstration, Power point Presentations.

**Suggested Readings:**

1. Heald M.A and Marion J.B. (2012). *Classical Electromagnetic Radiation* New York, USA: Dover Publications.
2. Griffiths D.J. (2012). *Introduction to Electrodynamics*. New Delhi: Prentice Hall of India Pvt.Ltd.
3. Zangwill A. (2012). *Modern Electrodynamics*. Cambridge, U.K: Cambridge University Press.

4. Jackson J.D. (2004). *Classical Electrodynamics*. New Delhi, India: Wiley India (P) Ltd.
5. Lifshitz E.M, Landau L.D and Pitaevskii L. P. (1984). *Electrodynamics of Continuous Media*. New York, USA: Elsevier.
6. Matthew N. O. Sadiku (2015). *Principles of Electromagnetics*, Oxford University Press

<b>L</b>	<b>T</b>	<b>P</b>	<b>Credit</b>
0	0	0	03
3	0	0	

**Course Code: PHY.523**

**Course Title: Solid State Physics**

**Total Hours: 45**

**Course Learning Outcomes:**

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

CLO1: Explain a clear and logical presentation of the basic and advanced concepts and principles of solid-state physics such as crystal structure of many materials and XRD of different crystal structures.

CLO2: Outline the theory of lattice vibrations and its applications to heat capacity, thermal expansion, and thermal conductivity.

CLO3: Explain the Free Electron and band theory of solids and their applications.

CLO4: Outline band theory of solids, types, and mechanism for the formation of bands.

CLO5: Explain the different types of Defects, Dislocations, and various phenomena.

CLO6: Explain properties, theories, and applications of superconductivity.

<b>Units /Hours</b>	<b>Contents</b>	<b>Mapping with Course Learning Outcome</b>

I/12	<p><b>Crystal Structure and its determination:</b> Bravais lattices, Crystal structures, Reciprocal lattices, Ewald sphere, X-ray diffraction, Lattice parameter determination, Atomic scattering factor, crystal structure factors for various structures, Intensity of diffraction maxima, Indexing of peaks for cubic structure, Electron, and neutron diffraction.</p>	CLO1
	<p><b>Learning Activities:</b> Problem Solving</p>	
II/11	<p><b>Lattice Dynamics:</b> Elastic properties of solids, Vibrations of linear monatomic and diatomic lattices, Acoustical and optical modes, Long wavelength limits, Optical properties of ionic crystal in the infrared region, Normal modes and phonons, Inelastic scattering of a neutron by a phonon, Lattice heat capacity, Models of Debye and Einstein, Comparison with electronic heat capacity, Thermal expansion, Thermal conductivity and Thermal Resistance of solids.</p>	CLO2
	<p><b>Free Electron Theory:</b> Free electron theory, Density of states, Drude model and Sommerfeld theory of electrical and thermal conductivity, Boltzmann transport equation (Response and relaxation phenomena): Sommerfeld Theory of Electrical Conductivity, Thermal Conductivity in Metals, Hall Effect and quantum Hall effect (Integral and Fractional), Thermoelectric power (Seebeck, Peltier, and Thomson effect).</p>	CLO3
	<p><b>Learning Activities:</b> Group discussions, Application-based peer thinking, and Problem Solving.</p>	
III/11	<p><b>Band Theory of Solids:</b> Electrons motion in periodic potentials, Bloch theorem and Bloch functions, Kronig Penny model, Interpretation of momentum, velocity, and mass of electrons derived from the Kronig – Penney model of the motion of electrons in periodic crystals, Band theory for nearly free electron, Band gap, Number of states in a band, Nearly free electron approximation, Tight binding approximation, Effective mass of an electron in a band, Classification of metal, Semiconductor (Direct and Indirect) and insulator, the Band structure of semiconductor materials.</p>	CLO4
	<p><b>Learning Activities:</b> Group discussion and problem-solving.</p>	
IV/1 1	<p><b>Defects and Dislocations:</b> Point defects (Concentration of Frenkel and Schottky), Line defects (slip, plastic deformation, edge and screw dislocation, Burger's vector, mechanism of dislocation motion), Frank-Reid mechanism of dislocation multiplication,</p>	CLO5

	Strength of alloy, Role of dislocation in crystal growth, Surface defects: Grain boundaries and stacking faults, volume defects.	
	<b>Superconductivity:</b> Meissner effect, Type-I, and type-II superconductors; Heat capacity, energy gap, and isotope effect, BCS theory, London equation, Flux quantization, Coherence, AC and DC Josephson effect, Superfluidity, High TC superconductors: Basic ideas and applications.	CLO6
	<b>Learning Activities:</b> Group discussions, Application-based peer thinking, and Problem Solving.	

**Transaction Mode:**

Lecture delivery using White Board and PPT, Problem Solving through Assignments.

**Suggested Readings:**

1. Ziman J.M. (2018). *Principles of the Theory of Solids*. Cambridge University Press, India.
2. Kittel C. (2019). *Introduction to Solid State Physics*. New Delhi, India: Wiley India (P) Ltd.
3. Singh R.J. (2011). *Solid State Physics*. New Delhi, India: Pearson.
4. Dekker A.J. (2012). *Solid State Physics*. London, U.K: Macmillan.
5. Ashcroft N. W and Mermin N. D. (2003). *Solid State Physics*. Cengage, India.
6. Pillai S.O. (2020), *Solid State Physics*, New Age International Private Limited, India.
7. Wahab M.A. (2015), *Solid State Physics*, Narosa Publishing House Pvt. Ltd. - New Delhi, India.
8. Wahab M.A. (2011), Numerical Problems in *Solid State Physics*, Alpha Science International Ltd, India.
9. Wahab M.A. (2021), Numerical Problems in Crystallography, Springer Nature, Singapore Pte. Ltd., Singapore.

L	T	P	Credit
3	0	0	3

**Course Name: Digital Electronics**

**Course Code: PHY.524**

**Course type: Core Course**

**Total Hours: 45**

**Course Learning Outcomes:**

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

CLO1: Realize the logic operation using hardware's.

CLO2: Understand that how to reduce the quantity of hardware's and boost up the electronic Circuit operation.

CLO3: Realize how could perform the basic mathematic operation using electronic circuitry.

CLO4: Know that how to store two-bit information's.

CLO5: Know that how to store more than two-bit information's and could be utilize in Different sequential circuit applications.

CLO6: Built an idea that how to program our information and could be able to convert in one form to other.

<b>Unit s/Ho urs</b>	<b>Contents</b>	<b>Mapping With Course Learning Outcome</b>
I/12	<b>Basics of Logic Gates:</b> Logic gates and the realization using diodes and transistors.	CLO1
	<b>Basics of reduction of logic expressions:</b> Boolean algebra, Boolean equation of logic circuits, de-Morgan theorem, Method of realization a circuit for given truth table, Sum of product (SOP) and product of sum (POS) representation, Karnaugh map and their applications.	CLO2
	<b>Learning Activities:</b> Application based peer thinking, Problem Solving	
II/11	<b>Combinational Circuits:</b> Design procedure, Adders-subtractors, Carry look ahead adder, BCD adder, Magnitude comparator, Multiplexer/DE multiplexer, Encoder/decoder, parity checker, Code converters, Implementation of combinational logic.	CLO3
	<b>Learning Activities:</b> Group discussions, Application based peer thinking, and Problem Solving.	



III/12	Sequential Circuit – Flip Flop: SR, JK, D and T flipflop, Master slave flipflops, Triggering mechanism of flipflop, Realization of one flip flop using other flipflops.	12
	<b>Sequential Circuit-Counters and Register:</b> Asynchronous/ripple counters, Synchronous counters, Shift counters, Shift registers, Universal shift register, MSI and LSI based design, MSI and LSI implementation on sequential circuit.	CLO5
	<b>Learning Activities:</b> Group discussion and problem solving.	
IV/10	<b>Programmable logic and Data Converters:</b> Programmable logic device (PLD), Programmable logic array (PLA), Implementation of ROM and PLA, Analog to Digital (A/D) data converters, Digital to analog(D/A) data converters, logic families, microprocessors.	CLO6
	<b>Learning Activities:</b> Brain storming and problem solving.	

**Transaction Mode:** Lecture, case study, blended learning, problem solving, discussion & demonstration, self-study.

**Suggested Readings:**

- 1) SahaG, MalvinoA. Pand Leach D.P. (2011). Digital Principles and Applications. Noida, India: Tata McGraw-Hill Education.
- 2) Malvino Pand Brown J.A. (2011). Digital Computer Electronics. Noida, India: Tata McGraw-Hill Education.
- 3) Hawkins Cand Segura J. (2010). Introduction to Modern Digital Electronics. New York, USA: SciTech Publishing.

L	T	P	C r
0	0	4	2

**Course Code: PHY.525**

**Course Title: Solid State Physics Laboratory**

**Total Hours: 60**

**Learning Outcomes:** The learners will be able to

CLO1: Develop understanding about crystal structure of solids,

CLO2: Develop knowledge in transport fundamentals of materials,

CLO3: Learn thermal properties of specific compounds

CLO4: Develop understanding about complex physical systems through experimenting structure property correlation

CLO5: Develop insight and hands on skill into magnetic and non-magnetic physical systems

**Course Contents**

<b>Units/Hours</b>	<b>Contents</b>	<b>Mapping with Course Learning Outcome</b>
I 15 Hours	Study of the X-ray diffraction pattern of NaCl and KCl. To determine magneto-resistance of a bismuth crystal as a function of the magnetic field.	CLO1
	<b>Learning Activities:</b> Experimentation, Group discussion	
II 15 Hours	Determination of carrier concentration and their sign-in semiconductor at room temperature by Hall Effect. Determination of dielectric constant of PZT material with Temperature variation and thus determining Curie temperature Electrons spin resonance Determination of dielectric constant of solids	CLO2
	<b>Learning Activities:</b> Experimentation, Group discussion	
III 15 Hours	Study of thermal expansion of solids. Study of thermal conductivity of solids. Study of specific heat of solids.	CLO3

	Determination of critical temperature of high-temperature superconductor and Meissner effect for a high T <sub>c</sub> superconductor.	
	<b>Learning Activities:</b> Experimentation, Group discussion	
IV 15 Hours	Study of the dispersion relation and cut-off frequency for the mono-atomic lattice. Study of the dispersion relation for the di-atomic lattice – ‘acoustical mode’ and ‘optical mode’ and energy gap	CLO4
	To determine the magnetic susceptibility of NiSO <sub>4</sub> , FeSO <sub>4</sub> , and CoSO <sub>4</sub> by Gouy's method. To determine magneto-resistance of a bismuth crystal as a function of the magnetic field. Magnetic parameters of a magnetic material by hysteresis loop tracer. Determination of ferromagnetic to paramagnetic phase transition temperature (T <sub>C</sub> = Curie temperature	CLO5
	<b>Learning Activities:</b> Experimentation, Group discussion	

**Transaction Mode:**

Experimentation and Viva-voce.

**Suggested Readings:**

1. Ziman J.M. (2018). *Principles of the Theory of Solids*. Cambridge University Press, India.
2. Kittel C. (2019). *Introduction to Solid State Physics*. New Delhi, India: Wiley India (P) Ltd.
3. Singh R.J. (2011). *Solid State Physics*. New Delhi, India: Pearson.
4. Dekker A.J. (2012). *Solid State Physics*. London, U.K: Macmillan.
5. Ashcroft N. W and Mermin N. D. (2003). *Solid State Physics*. Cengage, India.
6. Pillai S.O. (2020), *Solid State Physics*, New Age International Private Limited, India.
7. Wahab M.A. (2015), *Solid State Physics*, Narosa Publishing House Pvt. Ltd. - New Delhi, India.
8. Wahab M.A. (2011), Numerical Problems in *Solid State Physics*, Alpha Science International Ltd, India.

9. Wahab M.A. (2021), Numerical Problems in Crystallography, Springer Nature, Singapore Pte. Ltd., Singapore.

L	T	P	Cr
2	0	0	2

**Course Code: PHY.514**

**Course Title: Physics in Everyday Life**

**Total Hours: 30**

**Course Learning Outcomes:**

CLO1: To understand the Physics principles in earth's atmosphere

CLO2: To apply the Physics principles in human body

CLO3: To apply the Physics principles in Sports activities

CLO4: To apply the Physics principles to technology

Units/ Hours	Contents	Mapping with Course Learning Outcome
I/8	<b>Physics in Earth's Atmosphere:</b> Sun, Earth's atmosphere as an ideal gas; Pressure, temperature and density, Pascal's Law and Archimedes' Principle, Coriolis acceleration and weather systems, Rayleigh scattering, the red sunset, Reflection, refraction and dispersion of light, Total internal reflection, Rainbow.	CLO1
	<b>Learning Activities:</b> Knowledge and understanding of earth's atmosphere	
II/7	<b>Physics in Human Body:</b> The eyes as an optical instrument, Vision defects, Rayleigh criterion and resolving power, Sound waves and hearing, Sound intensity, Decibel scale, Energy budget and temperature control	CLO2
	<b>Learning Activities:</b> Understanding of the Physics principles involved in human body	
III/8	<b>Physics in Sports:</b> The sweet spot, Dynamics of rotating objects, Running, Jumping and pole vaulting, Motion of a spinning ball,	CLO3

	Continuity and Bernoulli equations, Bending it like Beckham, Magnus force, Turbulence and drag	
	<b>Learning Activities:</b> Knowledge and understanding the Physics principles in Sports activities	
IV/7	<b>Physics in Technology:</b> Microwave ovens, Lorentz force, Global Positioning System, CCDs, Lasers, Displays, Optical recording, CD, DVD Player, Tape records, Electric motors, Hybrid car, Telescope, Microscope, Projector etc.	CLO4
	<b>Learning Activities:</b> Understanding of the Physics principles in various technological equipment's	

**Transaction Mode:** Lecture, demonstration, PPT.

**Suggested Readings:**

1. Louis A. Bloomfield. (2013). How Things Work THE PHYSICS OF EVERYDAY LIFE: Wiley.
2. Sears and Zemansky. (2007). University Physics. Boston, USA: Addison Wesley.
3. Nelkon M and Parker P. (2012). *Advanced Level Physics*. London, U.K: Heinemann International.
4. Lal B and Subramanian. (2013). Electricity and Magnetism. Agra, India: Ratan Prakashan Mandir.
5. Hecht E. (2001). *Optics*. Boston, USA: Addison Wesley.
6. Verma H. C. (2011). *Concepts of Physics*. New Delhi, India: Bharati Bhawan publishers and distributors.

L	T	P	Cr
3	0	0	3

**Course Code: PHY.527**

**Course Title: Functional Materials**

**Total Hours: 45**

**Course Learning Outcomes:**

CLO1: Assess the growing field of materials research

CLO2: Importance of magnetic materials for memory applications

CLO3: Understanding innovative/smart modern materials

<b>Units /Hours</b>	<b>Contents</b>	<b>Mapping with Course Learning Outcome</b>
I/15	<b>Advanced Ceramic and Smart Materials:</b> Ceramic Materials: Classification, Preparation and Properties, Composites, and Smart Materials: Ferroelectric, Dielectrics, Piezoelectric, Thermoelectric, Luminescence, Phase Change Material, Shape Memory Alloys	CLO1
	<b>Learning Activities:</b> Knowledge of growing field of Advanced & Smart Materials	
II/15	<b>Magnetic and Multiferroics Materials:</b> Fundamentals of magnetic materials, Types of magnetic order, Spin Glasses behavior, dc and ac magnetometry, Exchange bias in magnetic nanostructures, Interpretation of various magnetic measurements, Important properties in relation to nanomagnetic granular materials, Colossal/Giant magnetoresistance (CMR/GMR), Magnetic materials for recording, La and Bi-based Perovskite, Multiferroics	CLO2
	<b>Learning Activities:</b> Application based Critical thinking in Modern Materials	
III/15	<b>Polymers and Composites:</b> Basic Concepts on Polymers, Polymers (Insulating, electronic and functionalized), Polymer Configuration (Tacticity), Polymer Conformation (Trans, Staggered, Gauche, Eclipsed), Polymer processing: Hot molding, Melt spinning etc. Composites: Varieties, Role of Matrix Materials, Polymer composites and nanocomposites (PNCs), PNCs for Li-ion battery, Super capacitor, fuel cell, LED's and solar cell	CLO3
	<b>Learning Activities:</b> Knowledge on Engineering of Polymers and composite materials	

**Transaction Mode:** Lecture, problem solving, discussion & demonstration, self-study.

**Suggested Readings:**

1. Schwartz Mel. (2009). *Smart Materials*. Boca Raton: CRC Press.
2. Granqvist C. G. (1995). *Handbook of Inorganic Electrochromic Materials*, Elsevier Science.
3. Scrosati Bruno, Abraham K. M, Walter Van Schalkwijk, and Jusef Hassoun. (2013). *Lithium Batteries: Advanced Technologies and Applications*. John Wiley & Sons, Inc.
4. Ogale S.B, Venkatesan T.V, Blamire M. (2013). *Functional Metal Oxides*. Germany: Wiley-VCH Verlag GmbH.
5. Banerjee S. and Tyagi A. K. (2011). *Functional Materials: Preparation, Processing and Applications*. USA: Elsevier, Insights, Massachusetts.
6. Chung D. D. L. (2003). *Composite Materials: Functional Materials for Modern Technologies*. New York, USA: Springer.
7. Chung Deborah D. L. (2010). *Functional Materials: Electrical, Dielectric, Electromagnetic, Optical and Magnetic Applications*. Singapore: World Scientific Publishing Company.
8. Cullity B.D and graham C. D. (2009). *Introduction to Magnetic Materials*. New Jersey: Willey.
9. Kao K. C. (2004). *Dielectric Phenomena in Solids*. London, U. K: Elsevier, Academic Press.
10. Kasap S. O. (2001). *Principles of Electronic Materials and Devices*. McGraw Hill Publications.
11. B E Conway Brian E Conway Conway.(1999). *Electrochemical Super capacitors: Scientific Fundamentals and Technological Applications*. Springer.

L	T	P	Credit
3	0	0	3

**Course Name: Computational Solid State Physics**

**Course Code: PHY.528**

**Course type: Core Course**

**Total Hours: 45**

**Course Learning Outcomes:**

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

CLO1: Explains the nuts and bolts of density functional theory.

CLO2: Apply the laws of quantum physics for practical implementation of density functional theory.

CLO3: Apply the concepts of solid state physics for practical implementation of density functional theory.

CLO4: Explain the details of density functional theory for electronic structure problems.

<b>Units/Hours</b>	<b>Contents</b>	<b>Mapping with Course Learning Outcome</b>
I 12Hours	<b>Density Functional Theory (DFT):</b> Electron density in DFT, Hohenberg-Kohn theorems, Kohn-Sham formulation, Exchange-correlation functional: local density approximation and generalized gradient approximations.	CLO1
	<b>Learning Activities:</b> Brain-storming	
II 11Hours	<b>Practical Implementation of Density Functional Theory (DFT):</b> Pseudopotentials: Ultrasoft, Norm-conserving, PAW, Basis sets: Slater type, Gaussian, Plane waves. Self-consistent field (SCF) methods. Understanding why LDA works, Strengths and weaknesses of DFT.	CLO2
	<b>Learning Activities:</b> Group discussion	
III 11Hours	<b>Treatment of Solids:</b> Irreducible Brillouin zone, k-point sampling, Periodic boundary conditions and slab model; Some practical topics: energy cutoff and smearing; Electronic and Ionic minimization, Crystal structure prediction, Phase transformations, Surface relaxation, Surface reconstruction.	CLO3
	<b>Learning Activities:</b> Brain-storming	
IV 11Hours	Electronic Structure with DFT: Free electron theory, Band structure, Density of states. Projected Density of States (Mulliken Methods), Interpretation	CLO4



	of Kohn-Sham eigenvalues, In relation with ionization potential.	
	<b>Learning Activities:</b> Group discussion and problem solving	
<p><b>Transaction Mode:</b> Lecture, problem solving, group discussion, self-study.</p> <p><b>Suggested Readings:</b></p> <ol style="list-style-type: none"> <li>1. Gunn Lee June. (2011). <i>Computational Materials Science: An Introduction</i>. CRC Press.</li> <li>2. Kaxiras Efthimios. (2007). <i>Atomic and Electronic Structure of Solids</i>. Cambridge University Press.</li> <li>3. M Martin Richard. (2008). <i>Electronic Structure: Basic Theory and Practical Methods</i>. Cambridge University Press.</li> <li>4. S. Sholl David and A. Steckel Janice. (2009). <i>Density Functional Theory: A Practical Introduction</i>. John Wiley and Sons.</li> <li>5. Feliciano Giustino. (2009). <i>Materials Modelling Using Density Functional Theory: Properties and Predictions</i>. Wiley.</li> <li>6. Rajendra Prasad. (2013). <i>Electronic Structure of Materials</i>, Taylor and Francis.</li> <li>7. M. Dreizler Reiner, K.U. Gross Eberhard. <i>Density Functional Theory, An Approach to the Quantum Many-Body Problem</i>. Springer.</li> </ol>		

L	T	P	Credit
3	0	0	3

**Course Title: Energy Storage Materials**

**Paper Code: PHY. 531**

**Course type: Discipline Elective Course**

**Total Lectures: 45**

**Course Learning Outcomes:**

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

CLO1: Know the basic principle and working of smart energy devices like: batteries and super capacitors.

CLO2: Explain different materials use in development of Batteries (Li-Ion and Sodium Ion) and Super capacitors.

CLO3: Get concept of synthesis of smart and functional materials in order to develop the efficient secondary batteries and super capacitors.

CLO4: know the set of characterization techniques which are essential to confirm the ability of materials for such energetic applications.

<b>Units /Hours</b>	<b>Contents</b>	<b>Mapping With Course Learning Outcome</b>
I/11	<b>Basic Principle:</b> Basic Principle of Batteries (Primary, Secondary- Ni Cd, Li-Ion, Na-Ion), Super capacitors (pseudo, EDLC, Hybrid), Supercapattery, Supercabattery, Hydroelectric Cells (HECs).	CLO1
	<b>Learning Activities:</b> Application based peer thinking	
II/12	<b>Energy Storage Materials:</b> Nanomaterials, transition Metal oxides (TMOs), carbon nanostructured (Graphene, Graphitic Carbon Nitride, CNTs, Activated Carbon, Carbon Nanofibers), Conducting Polymer (CPs) (Polyaniline (PANI), Polypyrrole (ppy)), nanocomposite- carbon-Metal oxides, Carbon-Carbon, MOs-CPs, Two-Dimensional (2D) Electrode Materials, Ferrite based HECs, Metal-oxide based HECs, LiCoO <sub>2</sub> (layered), LiMn <sub>2</sub> O <sub>4</sub> (spinel), LiFePO <sub>4</sub> (olivine), Polyoxyanion Cathode materials, liquid polymer electrolyte, gel polymer electrolyte and solid polymer electrolyte.	CLO2
	<b>Learning Activities:</b> Group discussions and Application based peer thinking.	

III/10	<b>Material Synthesis Techniques:</b> Electrochemical method, Spin coating, Dip coating, Spray pyrolysis, Doctoral blade technique, Hydrothermal, Chemical bath deposition, Solid-state reaction method, Co-precipitation method, Sol-gel synthesis, Fabrication: Li-Ion Cell, Supercapacitors, Hydroelectric Cells (HECs)	CLO3
	<b>Learning Activities:</b> Group discussion	
IV/12	<b>Material Characterization Techniques:</b> X-ray diffraction (XRD), FESEM, HR-TEM, Brunauer-Emmett-Teller (BET), Electrochemical impedance spectroscopy (EIS), Bode Plot, X-ray photoelectron spectroscopy (XPS), Dielectric Spectroscopy, Keithley source meter, Nyquist plot, Polarization curve, Fill Factor, Transport Number: Ion and cation, Cyclic Voltametry, Galvanometric charge discharge (GCD), Ragone Plot.	CLO4
	<b>Learning Activities:</b> Brainstorming	

**Transaction Mode:** Lecture, case study, blended learning, problem solving, discussion & demonstration, self-study, PPT.

**Suggested Readings:**

- 1.Kulkarni, S. K. (2015) Nanotechnology: Principles and Practices: Springer.
- 2.Gaur A, Sharma A. L., Arya A. (2021) Energy Storage and Conversion Devices: Supercapacitors, Batteries, and Hydroelectric Cell CRC Press, Taylor and Francis.
- 3.Dasgupta N., Ranjan S., Lichtfouse E. (2020) Environmental Nanotechnology Volume 4, Springer.
- 4.Murty B.S., Shankar P., Baldev Raj, Rath B B, James Murday. (2013) Textbook of Nanoscience and Nanotechnology: Springer
5. Lu, M., Beguin F., Elzbieta F. (2013) Super capacitors: Materials, Systems, and Applications, Wiley-VCH Verlag GmbH & Co.

L	T	P	Cr
3	0	0	3

**Course Name** : **Nanostructured Materials**  
**Course Code** : **PHY.529**  
**Course type** : **Discipline Elective Course**  
**Total Hours** : **45**

### Course Learning Outcomes (CLO)

CLO1: Develop peer thinking about basic physics and structure and bonding in nanomaterials.

CLO2: Learn that how could be different variety of advanced nanomaterials

CLO3: Develop insight about new class of nano-materials and their innovative applications

Units/ Hours	Content	CLO
I/15	<p><b>Basic Physics:</b> Introduction to Low-dimensional materials, Historical development, and their classification, Fundamental: Size and scale, Atoms, Molecules, Clusters and Supramolecular; Electron confinement: Particle in a box, Density of states, Particle in coulombic potential, Tunneling of particle through potential barrier</p> <p><b>Structure and Bonding in Nanomaterials:</b> Chemical bonds (types and strength), Intermolecular forces, Molecular and crystalline structure, Hierarchical Structures, Bulk to Surface transition, Surface reconstruction, Self-assembly and thermodynamics, Size dependent physio-chemical properties</p>	CLO1
	<b>Learning Activities:</b> Application based peer thinking	
II/15	<p><b>Nanomaterial Synthesis:</b> Top-down and bottom up approach in synthesis of nanomaterials, mechanical (ball milling, melt mixing) methods, synthesis techniques based on evaporation, sputter deposition, chemical/physical vapor deposition, electric arc deposition, ion beam techniques, molecular beam epitaxy; Colloidal approach, properties of colloids, nucleation and growth model, metal and semiconductor nano-particles by chemical route, Langmuir-Blodgett method, micro-emulsion, Sol-Gel, hydro-thermal, microwave synthesis, Bio-inspired</p>	CLO2

	synthesis, mechanism and examples of self-assembly, nanolithography	
	<b>Learning Activities:</b> Group discussions and Application based peer thinking	
III/15	<b>Special class of Nanomaterials:</b> Carbon nano-materials, porous silicon, aerogels, zeolites, template based porosity, magnetic nanoparticles, meta-materials, bio-inspired materials	CLO3
	<b>Learning Activities:</b> Review of current applications, Brainstorming, video demo	

**Transaction Mode:** Lecture, case study, blended learning, problem solving, discussion & demonstration, self-study, PPT.

### Suggested Readings

1. Frank J. Owens and Charles P. Poole (2008), The Physics and Chemistry of Nano Solids by Jr, Wiley-Interscience.
2. Kulkarni Sulbha K., (2015) Nanotechnology: Principles and Practices, Springer, UK (03<sup>rd</sup> edition).
3. Poole Charles P. Jr., Owens Frank J., (2018) Introduction to Nanotechnology, Wiley Interscience, USA (02<sup>nd</sup> edition).
4. Vollath Dieter, (2013). Nano-materials: An introduction to synthesis, properties, and applications, Wiley-VCH (02<sup>nd</sup> edition).
5. Kilmov Victor I, (2023). Semiconductor and metal nano-crystals, Marcel Dekker (05<sup>th</sup> edition).
6. Alegaonkar Ashwini P., Alegaonkar Prashant S., (2023) Nano-carbons: preparation, assessments and applications, CRC Press: Taylor and Francis (01<sup>st</sup> edition).
7. Nandi Upendranath, Jana Debnarayana, (2014) Nano-materials: Theory problems and solution, Techno-world (01<sup>st</sup> edition).
8. Sharma S K, (2019) Nanohybrids in Environmental & Biomedical Applications, CRC Press: Taylor and Francis

	<b>T</b>	<b>P</b>	<b>Cr</b>
3	0	0	3

**Course Code** : **PHY.530**  
**Course Title** : **Nonlinear and Quantum Optics**  
**Total Hours** : **45**  
**Course Learning Outcomes (CLO) :**

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

CLO1: Develop understanding about wave formulation of light,

CLO2: Validate non-linear approach for traditional notion of electromagnetic waves (EM),

CLO3: Develop understanding about higher order polarization effects,

CLO4: Apply models to lasing systems under specific conditions,

CLO5: Model ultrafast quantum systems,

CLO6: Evaluate optical systems under specific conditions (like stimulated emission),

CLO7: Realization of optical systems based on quantum phenomena

<b>Units/ Hours</b>	<b>Contents</b>	<b>Mappin g with CLO</b>
I/12	<b>Basics of linear optics:</b> Maxwell's EM wave formulation, plane wave solution, monochromatic, non-monochromatic waves, <b>D</b> , <b>P</b> , $n$ , directions of <b>D</b> and <b>E</b> in isotropic medium, Poynting vector, energy flow, intensity of an EM wave	CLO1
	<b>Non-linear effects:</b> Anisotropic media, susceptibility tensor, its properties, wave propagation in anisotropic media, ordinary and extraordinary ray, index surfaces and ellipsoid, linear response and polarization, dielectric susceptibility	CLO2
	<b>Learning Activities:</b> Problem Solving, Group discussion	
II/11	<b>Second order nonlinear effects:</b> Classical origin of non-linearity, Miller law, optical rectification, linear electro-optic effect, sum and difference frequency generation, nonlinear Maxwell equations, second harmonic generation, phase matching, gain bandwidth, Manley-Rowe relation, birefringence phase-matching	CLO3
	<b>Phase matching and frequency generation rules:</b> Type 1 and Type 2 phase matching, symmetry in nonlinear	CLO4

	<p>susceptibility, Kleinman`s symmetry, Neumann`s principle, centro-symmetric system, matrix formulation of harmonics generation in postssiam dihydrogen phosphate crystal</p> <p><b>Three wave mixing:</b> three wave interaction, equation for pump, signal, and idler wave, non-co-linear phase matching, Manley-Rowe relation for three wave mixing, paramagnetic down conversion, optical parametric amplification, optical parametric oscillator, resonant oscillator</p> <p><b>Learning Activities:</b> Application based peer thinking, and Problem Solving</p>	CLO5
III/11	<p><b>Third and higher order effects:</b> optical Kerr effect, self focusing, symmetry in 3<sup>rd</sup> order susceptibility, self-phase modulation, frequency shift, third harmonic generation (3HG), energy conservation, cross phase modulation (XPM), nonlinear absorption, four wave mixing, parametric amplification under four wave mixing, optical phase conjugation</p> <p><b>Advanced optical systems:</b> Raman scattering, stimulated Raman scattering, Raman amplification, linear pulse propagation, optical soliton</p> <p><b>Learning Activities:</b> Group discussion and problem solving.</p>	CLO6
IV/11	<p><b>Ultrafast optics:</b> Introduction to ultrashort pulses, ultrashort pulse generation through mode-locking, nonlinear Schrödinger equation, super continuum generation. review of quantum mechanics basics, quantization of electromagnetic fields, number states, coherent states and squeezed states of light and their properties.</p> <p><b>Quantum optics:</b> beam splitters and interferometers, spontaneous parametric down conversion, concept of quantum entanglement, application of optical parametric processes to generate squeezed states of light and entangled states, applications of quantum optics.</p> <p><b>Learning Activities:</b> Brain storming and problem solving.</p>	CLO7

**Transaction Mode:** Lecture, case study, blended learning, problem solving, discussion & demonstration, self-study, PPT

### Suggested Readings

1. A. Yariv and P. Yeh, Optical waves in crystals: propagation and control of laser radiation, Wiley, New York, 2002.
2. G P Agrwal Peter E. Powers, Fundamentals of Nonlinear Optics, CRC Press, 2011.
3. A. Yariv, Quantum Electronics, John Wiley, 1989.Y. R. Shen, The Principles of Non-linear Optics, John Wiley & Sons, 2003
4. R. W. Boyd, Nonlinear Optics, Academic Press, 2008.
5. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, 2nd ed. John Wiley, 2007.
6. A. M. Weiner, Ultrafast Optics, Wiley Books, 2008
7. Gerry, Christopher; Knight, Peter, Introduction to Quantum Optics. Cambridge University Press, 2004.
8. L. Mandel, E. Wolf, Optical Coherence and Quantum Optics (Cambridge 1995).
9. D. F. Walls and G. J. Milburn, Quantum Optics (Springer 1994).
10. H. M. Moya-Cessa and F. Soto-Eguibar, Introduction to Quantum Optics (Rinton Press 2011).

<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
3	0	0	3

**Course Code: PHY.532**

**Course Title: Physics at Low Temperatures**

**Total Hours: 45**

**Course Learning Outcomes:** At the end of the course, students would be able to

CLO1: Relate to the significance of low temperature physics and explain the methods of production of low temperature.

CLO2: Distinguish between different measurements methods used at low temperature.

CLO3: Analyze the different phenomena in solids at low temperature.

CLO4: Explain the various phenomena in low dimensional systems at low temperature

**Course Contents**



<b>Unit/Hours</b>	<b>Contents</b>	<b>Mapping</b>
I/12	<b>Production of Low Temperature:</b> History of low temperature, Liquefaction of cryogenes, Liquid nitrogen, Liquid helium, Cryostats, Vacuum systems, Basics of Cryostat design, Closed cycle refrigerators, Wet systems versus dry systems, Double walled glass Dewars, Metal Dewars, Transfer Siphons, Minimum temperature obtainable using liquid helium-4, Lower temperatures using liquid helium-3, Low temperature thermometry, Electromagnet versus superconducting magnets.	CLO1
II/12	<b>Measurements at Low temperature:</b> Magnetic susceptibility measurements, Superconducting Quantum Interference Device (SQUID) magnetometer, Vibrating Sample Magnetometer (VSM), Heat capacity measurements, Four probe resistivity measurements, Magneto resistivity measurements, Hall effect measurements, Specific heat of insulators and metals, Thermal conductivity, Electrical resistivity, Residual Resistivity Ratio (RRR), Thermopower.	CLO2
III/10	<b>Phenomena in Bulk Materials at Low Temperature:</b> Large magnetoresistance, GMR, CMR and XMR, topological insulators, Shubnikov-de Haas oscillations in magnetoresistance, other applications of low temperature, Thermoelectric cooling, Weak Localization, Kondo effect.	CLO3
IV/11	<b>Low Dimension Systems at Low Temperatures:</b> Quantum-hall effect, two-dimension electron gas, GaAs-Al GaAs systems, electrostatic confinement for tunnel point contacts, electron beam lithography, other two-dimensional materials, e.g., Transition metal dichalcogenides (TMDCs), Single electron tunneling, Coulomb Island, Energy levels in coulomb	CLO4

	dots, Metallic versus semiconducting Nano-islands, Quantum dots, Coulomb blockade and coulomb staircase, Single electron transistor, Mesoscopic rings, Aharonov-Bohm effect, Josephson junction, SQUID devices.	
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**Transaction Mode:**

Lecture, demonstration, tutorials, power point presentations.

**Suggested Readings:**

1. Pobell, Frank (2007), Matter and Methods at Low Temperature (Third edition), Springer.
2. Ventura, Guglielmo and Risegari, Lara (2008), The Art of Cryogenics (First edition), Elsevier,
3. White, Guy Kendall (1968), Experimental Techniques in Low-temperature Physics (Second edition), Clarendon Press
4. Enss, Christian and Hunklinger, Siegfried (2005), Low-Temperature Physics, Springer.
5. McClintock, P.V.E, Meredith, D. J. and J. K. Wigmore (1992), Low Temperature Physics: An Introduction for Scientists and Engineers (First edition), Springer-Science.
6. Balestra, Francis (Editor) and Ghibaudo, Gerard (Editor) (2001), Device and Circuit Cryogenic Operation for Low Temperature Electronics (First Edition), Springer-Science
7. Kent, Anthony (1993), Experimental Low-Temperature Physics, MacMillan.
8. Rosenberg, H. M (1963)., Low Temperature Solid State Physics, Oxford University Press/Clarendon Press.
9. Gutierrez-D. E.A., Jamal Deen, M, Claeys, Cor. L. (2001), Low Temperature Electronics: Physics, Devices, Circuits, and Applications, Academic press.
10. Heinzl, Thomas (2007), Mesoscopic Electronics in Solid State Nanostructures, (Second Edition), Wilev-VCH.
11. Ferry, David. K., Good nick, Stephen M., Bird, Jonathan (2009), Transport in Nanostructures, (Second edition), Cambridge University Press.

12. Ihn, Thomas (2010), Semiconductor Nanostructures, Oxford University Press.

L	T	P	Credit
3	0	0	3

**Course Code: PHY.533**

**Course Title: Computational Soft Matter**

**Total Hours: 45**

**Course Learning Outcomes:**

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

CL01: understand what is soft condensed matter, its distinguishing features, and computational tools required to study the soft materials.

CL02: use tools of particle based simulations to study soft materials such as polymers and colloids.

CL03: calculate statistical quantities from the simulation data.

CL04: use tools of continuum based simulations to study systems such as liquid crystals.

Units/ Hours	Contents	Mapping with Course Learning Outcome
I/10	<b>Soft Materials:</b> Introduction to soft matter systems like <i>polymers, colloids, liquid crystals, granular materials, biological matter</i> ; what makes these materials “soft” and distinguish them from hard condensed matter; notes on computer hardware, programming languages, computer precision, errors, and reduced units.	CLO1
II/12	<b>Molecular Dynamics:</b> Equations of motion for molecular systems; time integration: Verlet algorithm, Gear algorithm; calculation of forces and torques: neighbor lists, interaction potentials, handling of long-range forces; initial and boundary conditions; random numbers; error and accuracy checks; Brownian dynamics; application to simulations of <i>colloids, polymers, and granular matter</i> .	CLO2
III/11	<b>Statistical Calculations:</b> Sampling from ensembles, thermodynamic averages; calculation of fluctuations, time and space correlation functions, and structural quantities; calculation	CLO3

	of stresses, pressure, temperature, and energies.	
IV/12	<b>Continuum Simulation Methods:</b> Conservation laws for in terms of partial differential equations; finite difference and finite volume discretization schemes, calculation of fluxes, solution of system of linear equations, solution of Poisson equation, multigrid method; application to <i>liquid crystal</i> simulations.	CLO4

**Transaction Mode:** Lectures, computer code demonstrations, implementation of computer programs.

**Suggested Readings:**

1. Allen M.P. and Tildesley D.J. (2017). Computer Simulation of Liquids. Crarendon Press, Oxford.
2. Poeschel T., Schwager T. (2010). Computational Granular Dynamics, Models and Algorithms, Springer.
3. Anderson, J.D. (2017). Computational Fluid Dynamics: Basics with Applications, McGraw Hill.
4. Tryggvason G., Scardovelli R., Zaleski S. (2011). Direct Numerical Simulations of Gas-Liquid Multiphase Flows, Cambridge University Press.

### SEMESTER-III

L	T	P	Credit
3	0	0	3

**Course Name: Statistical Mechanics**

**Course Code: PHY.551**

**Course type: Core Course**

**Total Hours: 45**

**Course Learning Outcomes:**

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

CLO1: Develop understanding about thermodynamics potentials,

CLO2: Validate statistical approach for classical thermodynamic systems,

CLO3: Apply ensemble models to typical thermodynamic systems,

CLO4: Apply grand models for chemical systems under constraints,

CLO5: Model advanced quantum systems,

CLO6: Evaluate systems with sudden statistical changes apply,

CLO7: Evaluate realistic systems.

Units/ Hours	Contents	Mapping with Course Learning Outcome
1/12	<b>Basics of Thermodynamics:</b> Laws of thermodynamics and their consequences, Thermodynamic potentials and Maxwell relations.	CLO1
	<b>Statistical Basis of Thermodynamics:</b> Micro- and macro-states, Postulate of equal a priori probability, Contact between statistics and thermodynamics, Classical ideal gas, Entropy of mixing, Gibbs' paradox and its solution.	CLO2
	<b>Learning Activities:</b> Problem Solving	

II/11	<b>Elements of Ensemble Theory:</b> Phase space and Liouville's theorem, Microcanonical ensemble theory and its application to classical ideal gas and simple harmonic oscillator, System in contact with a heat reservoir, Thermodynamics of canonical ensemble, Partition function, Classical ideal gas in canonical ensemble, Energy fluctuation.	CLO3
	<b>Grand Canonical Ensemble:</b> System in contact with a particle reservoir, Chemical potential, Grand canonical partition function, Classical ideal gas in grand canonical ensemble theory, Density and energy fluctuations.	CLO4
	<b>Learning Activities:</b> Group discussions, Application based peer thinking, and Problem Solving.	
III/11	<b>Elements of Quantum Statistics:</b> Quantum statistics of various ensembles: the density matrix, Ideal gas in various ensembles, statistics of occupation number, Thermodynamics of black body radiations.	CLO5
	<b>Phase Transitions:</b> Thermodynamic phase diagrams, Super-fluidity in liquid He II, First and second order phase transitions, Dynamic model of phase transition, Ising and Heisenberg model.	CLO6
	<b>Learning Activities:</b> Group discussion and problem solving.	
IV/11	<b>Ideal Bose and Fermi Gas:</b> Thermodynamical behavior of ideal Bose gas, Bose-Einstein condensation, Gas of photons and phonons. Thermodynamical behavior of ideal Fermi gas, Heat capacity of ideal Fermi gas at finite temperature, Pauli paramagnetism, Landau diamagnetism, Ferromagnetism.	CLO7
	<b>Thermodynamic Fluctuations:</b> Diffusion equation, Random walk and Brownian motion, Introduction to non-equilibrium processes.	
	<b>Learning Activities:</b> Brain storming and problem solving.	

**Transaction Mode:** Lecture, case study, blended learning, problem solving, discussion & demonstration, self-study.

**Suggested Readings:**

- 1) Pathria R.K and Beale Paul D. (2020). Statistical Mechanics. USA: Elsevier.
- 2) Huang K. (2017). Statistical Mechanics. New Delhi, India: Wiley India Pvt. Ltd.
- 3) Swendsen R.H. (2018). An Introduction to Statistical Mechanics and Thermodynamics, Oxford University Press, UK.
- 4) Sadvskii M.V. (2017). Statistical Physics. Berlin/Boston, USA: Walter de Gruyter GmbH and Co.
- 5) Laud B.B. (2018). Fundamentals of Statistical Mechanics, New Delhi, New Age International.
- 6) Rief F. (2019) Fundamentals of Statistical and Thermal Physics. Waveland Press incorporation, NY, USA.
- 7) Landau L. D. Lifshitz E. M. (2020), Statistical Physics: Part 1, Ed. 05, Elsevier.

<b>L</b>	<b>T</b>	<b>P</b>	<b>C</b>
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3	0	0	3

**Course Code: PHY.552**

**Course Title: Nuclear and Particle Physics**

**Total Hours: 45**

**Learning Outcomes:**

Nuclear and Particle Physics:

CL01: Develop understanding about nuclear properties, various models related to existence of nucleus and nuclear force.

CL02: Develop insight into nuclear potential, Scattering and its characteristics

CL03: Understanding about basics of nuclear force to implement it to understand designing of nuclear structure

CL04: Develop understanding about fundamental elementary particles

<b>Unit /hours</b>	<b>Contents</b>	<b>Mapping with Course Learning Outcome</b>

<b>I/11</b>	<b>Introduction to Nuclear Properties:</b> Review of Nuclear size and shape, charge distribution, empirical formula of radius, Magnetic Moment, Electric Quadrupole, Mass and binding energy, semi-empirical mass formula.	<b>CL01</b>
<b>II/11</b>	<b>Two Nucleon Problems:</b> Nature of nuclear forces, Deuteron problem, Spin, Parity, Magnetic moment and electric quadrupole moment of deuteron, scattering cross-section, n-p scattering, phase shifts and Scattering length.	<b>CL02</b>
<b>III/12</b>	<b>Nuclear Model:</b> Liquid drop model, Evidence of shell structure, Shell model, Single particle shell model, its validity and limitations, Collective model, Vibrational and Rotational spectra, Exchange force model.	<b>CL03</b>
	<b>Nuclear Decay:</b> Different kinds of particle emission from nuclei, Alpha, Beta and Gamma decay and their selection rules. Fermi's theory of allowed beta decay, Selection rules for Fermi and Gamow-Teller transitions. Double beta decay.	
<b>IV/12</b>	<b>Elementary Particle Physics:</b> Elementary Particles and antiparticles, Quarks model, baryons, mesons and leptons, Classification of fundamental forces, Parity non-conservation in weak interaction, CPT invariance. Baryon and Lepton numbers, Strangeness, charm and other additive quantum numbers, Gell Mann Nishijima formula.	<b>CL-04</b>

**Transaction Mode:**

Lecture, tutorial, problem solving.

**Suggested Readings:**

1. Martin B. (2011). *Nuclear & Particle Physics an Introduction*. New Jersey, USA: John Wiley & Sons.
2. Krane K.S. (2008). *Introductory Nuclear Physics*. New Jersey, USA: John Wiley & Sons, Inc.
3. Bertulani C.A. (2007). *Nuclear Physics in a Nutshell*. Princeton, USA: Princeton University Press.
4. Wong S.S.M. (2008). *Introductory Nuclear Physics*. New Jersey, USA: John Wiley & Sons, Inc.



5. Heyde K. (2004). *Basic Ideas and Concepts in Nuclear Physics* an Introductory approach. London, U. K: CRC Press.
6. Povh B, Rith K, Schol C. (2012). *Particles and Nuclei: An Introduction to the Physical Concepts*. New York, USA: Springer.
7. Perkin D.H. (2000). *Introduction to High Energy Physics*. Cambridge, U.K: Cambridge University Press.
8. Hughes I.S. (1991). *Elementary Particles*. Cambridge, U.K: Cambridge University Press.
9. Leo W.R. (2009). *Techniques for Nuclear and Particle Physics Experiments*. New York, USA: Springer.
10. Stefan T. (2010). *Experimental Techniques in Nuclear and Particle Physics*. New York, USA: Springer.
11. Griffiths D. J.(2008). *Introduction to Elementary Particles*. Germany: Wiley-VCH Verlag GmbH

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**Course Code: PHY.553**

**Course Title: Atomic and Molecular Physics**

**Total Hours: 45**

**Learning Outcomes:** At the end of the course, students will be able to:

CL01: Develop knowledge about spectroscopic origins and model involved there in.

CL02: Develop understanding in analyzing standard spectra of typical elements

CL03: Increase understanding about atomic structure of typical elements by analyzing atomic spectra

CL04: Develop skill to analyze realistic molecular spectra of standard as well as fairly complex molecular systems.

<b>Unit/ Hours</b>	<b>Contents</b>	<b>Mapping with Course</b>
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		<b>Learning Outcome</b>
<b>I/12</b>	<b>Electrons Systems:</b> Quantum state of an electron in an atom, Spectrum of hydrogen, helium and alkali atoms, Electron spin, Spin - orbit coupling, Mass correction term, Relativistic correction for energy level of hydrogen atom, Lamb shift, Paschen-Back effect, Stark effect, and isotopic shift, Independent particle model, Central field approximation for many electron atom, Slater determinant, Equivalent and nonequivalent electrons, Energy levels and spectra, Spectroscopic terms.	<b>CL 01</b>
<b>II/11</b>	<b>Atomic Structure and Atomic Spectra:</b> Revision of quantum numbers, Pauli's exclusion principle, electron configuration, Hund's rule etc. origin of spectral lines, selection rules, some features of one-electron, two-electron spectra and X-ray spectra, fine spectra, hyperfine structure, Level scheme for two electron atoms- LS and JJ coupling – multiplet splitting – Lande's 'g' factor, Lande's interval rule, Zeeman effect, Width of spectral lines.	<b>CL 02</b>
<b>III/11</b>	<b>Molecular Structure:</b> Molecular potential, Separation of electronic and nuclear wave functions, Born-Oppenheimer approximation, Molecular orbital and electronic configuration of diatomic molecules: H <sub>2</sub> , and NO, LCAO approach, States for hydrogen molecular ion, Coulomb, Exchange and overlap integral, Shapes of molecular orbital, Sigma and pi bond.	<b>CL03</b>
<b>IV/11</b>	<b>Molecular Spectra:</b> Electronic, Vibrational and rotational spectrum of diatomic molecules, Frank-Condon principle, Raman transitions and Raman spectra, Normal vibrations of CO <sub>2</sub> and H <sub>2</sub> O molecules	<b>CL04</b>

**Transaction Mode:**

Lecture, tutorial, problem solving.

**Recommended books:**

1. C.J. Foot, Atomic Physics (Oxford University Press, Oxford, U. K.) 2005.
2. W. Demtroder, Molecular Physics (Springer, New York, USA) 2008.

3. J.M. Hollas, Basic Atomic and Molecular Spectroscopy (Royal Soc. of Chemistry, London,2002.
4. G. Herzberg, Atomic Spectra and Atomic Structure (Dover Publications, New York, USA) 2010.
5. Introduction to Atomic Spectra, H. E. White, (McGraw Hill International Ed.)
6. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, (Tata, McGraw Hill Publishing Company Limited).

L	T	P	C r
0	0	4	2

**Course Code: PHY.554**

**Course Title: Nuclear Physics Laboratory**

**Total Hours: 60**

**Learning Outcomes:** At the end of the course the students will be able to  
 CL01: Develop understanding in performing experiments related to nuclear physics.

CL02: Develop skill in calibrating number of nuclear detectors and sensors, estimating their sensitivity and performance characteristics.

CL03: Handle and use various radioactive sources

CL04: Develop understanding related to nuclear instrumentation such as Preamplifier, Amplifier, gains of the system for performing measurements

### **Course Contents**

Student has to perform ten experiments out of the following list of experiments.

<b>Units/ Hours</b>	<b>Contents</b>	<b>Mapping with Course Learning Outcome</b>

III/90	<ol style="list-style-type: none"> <li>1) Study of the characteristics of a GM tube and determination of its operating voltage, plateau length / slope etc.</li> <li>2) Verification of inverse square law for gamma rays.</li>   <li>3) Study of nuclear counting statistics.</li> <li>4) Estimation of efficiency of the G.M. detector for beta and gamma sources.</li> <li>5) To study beta particle range and maximum energy (Feather Analysis).</li> <li>6) Backscattering of beta particles.</li> <li>7) Production and attenuation of bremsstrahlung.</li>   <li>8) Measurement of short half-life</li> <li>9) Demonstration of nucleonic level gauge principle using G.M counting system and detector.</li> <li>10) Beam interruption detection system to check packs for content level, or counting of individual items.</li> <li>11) Scintillation detector: energy calibration, resolution and determination of gamma ray energy.</li> <li>12) Alpha spectroscopy using surface barrier detectors.</li> <li>13) Study of energy resolution characteristics of a scintillation spectrometer as a function of applied high voltage and to determine the best operating voltage</li> <li>14) Measurement of resolution for a given scintillation detector using Cs-137 source.</li> <li>15) Finding the resolution of detector in terms of energy of Co-60 system.</li> <li>16) Energy calibration of gamma ray spectrometer (Study of linearity).</li> <li>17) Spectrum analysis of Cs-137 and Co-60 and to explain some of the features of Compton edge and backscatter peak.</li> <li>18) Unknown energy of a radioactive isotope.</li> <li>19) Variation of energy resolution with gamma energy.</li> <li>20) Activity of a gamma source (Relative and absolute methods).</li> <li>21) Measurement of half value thickness and evaluation of mass absorption coefficient.</li> <li>22) Back scattering of gamma Rays.</li> </ol>	CLO1, CLO2, CLO3, CLO4
Learning Activities: Experimentation, Group discussion		

**Transaction Mode:**

Demonstration, experimentation.

**Suggested Readings:**

1. Knoll G. F. (2010). *Radiation Detection and Measurement*. Sussex, U.K: John Wiley & Sons.
2. Leo W. R. (2012). *Techniques for Nuclear and Particle Physics Experiments: a how-to approach*. New York, USA: Springer.
3. Beach K, Harbison S and Martin A. (2012). *An Introduction to Radiation Protection*. London, U.K: CRC Press.
4. Tsoulfanidis N, Landsberger S. (2010). *Measurement and Detection of Radiation*. London, U.K: CRC Press.
5. Nikjoo H, Uehara S, Emfietzoglou D. (2012). *Interaction of Radiation with Matter*. London, U.K: CRC Press.

L	T	P	C
2	0	0	2

**Course Code: PHY.526**

**Course Title: Measurement Science**

**Total Hours: 30**

**Course Learning Outcomes:**

CLO1: To understand the units and measurements

CLO2: To understand and apply the measurement methods and characteristics of fundamental units

**Course Contents**

Units /Hours	Contents	Mapping with Course Learning Outcome
I/15	<b>Units of Measurement:</b> Fundamental units, Derived units, Systems of units, Conversion of units, Accuracy, precision, and	CLO1

	errors in measurements, Dimensional analysis, and its applications	
	<b>Learning Activities:</b> Knowledge and understanding of the different unit and measurement systems	
II/15	<b>Measurement and Measurement Characteristics:</b> History and measurement of length, mass, time, temperature, pressure, and current. History, basics, and methods for standardization of length, mass, time	CLO2
	<b>Learning Activities:</b> Knowledge and understanding of the measurement methods and characteristics of fundamental units	

**Transaction Mode:** Lecture, PPT.

**Suggested Readings:**

1. Physics, NCERT Textbooks, Class 11.
2. Units of Measurement: Past, Present and Future. International System of Units, S. V. Gupta, Springer Series in Materials Science, Volume 122, 2009.

L	T	P	Credit
3	0	0	3

**Course Code: PHY.555**

**Course Title: Advanced Solid State Physics**

**Total Hours: 45**

**Course Learning Outcomes:**

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

CLO1: Explain Fermi surfaces and their construction and the experimental methods used for detection of Fermi surfaces.

CLO2: Explain the theories of magnetism.

CLO3: Explain Plasmon, color centers, excitons, Raman Effect, luminescence and optical properties of solids.

CLO4: Outline the theory of dielectrics and ferroelectrics.

<b>Units/ Hours</b>	<b>Contents</b>	<b>Mapping with Course Learning Outcome</b>
I/11	<p><b>Fermi Surfaces:</b> Zone schemes, Construction of Fermi surfaces, Electron, Hole and open orbits, Harrison's method of constructing Fermi surfaces in two dimensions for monovalent, divalent, and tetravalent metal, Fermi surfaces in metals for SC, BCC, and FCC, Fermi surface of Cu and Al, Experimental methods in Fermi surface studies: De Haas-van Alphen Effect, Anomalous skin effect and cyclotron resonance, Extremal orbits, Magnetic breakdown, Calculation of energy bands: Wigner-seitz Method, Pseudopotential Method.</p>	CLO1
	<p><b>Learning Activities:</b> Problem Solving</p>	
II/11	<p><b>Magnetic Properties of Solids:</b> Classical and quantum theory of diamagnetism and paramagnetism, Pauli paramagnetism, Landau diamagnetism, Cooling by adiabatic demagnetization, Weiss theory of ferromagnetism, Curie-Weiss law, Heisenberg's model and molecular field theory, Domain structure and Bloch wall, Neel model of anti-ferromagnetism and ferrimagnetism, Ferrites, Spin waves (Magnons in ferro and anti-ferromagnets), Bloch T<sub>3/2</sub> law, brief discussion of Kondo effect.</p>	CLO2
	<p><b>Learning Activities:</b> Group discussions, Application based peer thinking, and Problem Solving.</p>	
III/12	<p><b>Optical Processes, Exciton, Color Centre's and Luminescence:</b> Connection between optical and dielectric constants, Optical reflectance, Optical properties of metals, Color centers: Types (Electronic and Hole centers), F' centers, Production and properties, NV center's in diamond and applications in quantum computation and quantum cryptography, Excitons (Frenkel, Mott-Wannier), Excitonic insulators, Experimental studies of excitons in alkali halide, molecular crystals and carbon nanostructures, Free Excitons at High Densities, Raman effect in crystal, Types of luminescent systems: Electroluminescence, Triboluminescence, Mechanism of luminescence, Thermo</p>	CLO3

	luminescence, mechanism and applications in dosimetry and dating.	
	<b>Learning Activities:</b> Group discussion and problem solving.	
	<p><b>Dielectrics and Ferroelectrics:</b> Local field, Clausius-Mossotti relation, Components of polarizability: Electronic, Ionic, Orientational, Measurements of dielectric constant, Pyroelectric and ferroelectric crystals and classification, Electrostatic screening, Plasma oscillations (Plasmons), Transverse optical modes in plasma, Interaction of EM waves with optical modes: Polaritons, LST relation, Electron-electron interaction, Electron-phonon interactions: Polarons.</p> <p><b>Learning Activities:</b> Group discussions, Application based peer thinking, and Problem Solving.</p>	CLO4

#### **Transaction Mode:**

Lecture delivery using White Board and PPT, Problem Solving through Assignments.

#### **Suggested Readings:**

1. Ziman J.M. (2018). *Principles of the Theory of Solids*. Cambridge University Press, India.
2. Kittel C. (2019). *Introduction to Solid State Physics*. New Delhi, India: Wiley India (P) Ltd.
3. Singh R.J. (2011). *Solid State Physics*. New Delhi, India: Pearson.
4. Dekker A.J. (2012). *Solid State Physics*. London, U.K: Macmillan.
5. Ashcroft N.W and Mermin N. D. (2003). *Solid State Physics*. Cengage, India.
6. Pillai S.O. (2020), *Solid State Physics*, New Age International Private Limited, India.
7. Wahab M.A. (2015), *Solid State Physics*, Narosa Publishing House Pvt. Ltd. - New Delhi, India.
8. Wahab M.A. (2011), Numerical Problems in *Solid State Physics*, Alpha Science International Ltd, India.
9. Wahab M.A. (2021), Numerical Problems in Crystallography, Springer Nature, Singapore Pte. Ltd., Singapore.



L	T	P	Credit
3	0	0	3

**Course Code: PHY.556**

**Course Title: Imaging and Crystallography**

**Total Hours: 45**

**Course Learning Outcomes:**

CLO1: Analyze Microscopy analysis of the nanomaterials

CLO2: Knowledge of the process of crystal structure analysis

CLO3: Interpret Surface Probe analysis/properties of the nanomaterials

Units/ Hours	Contents	Mapping with Course Learning Outcome
I/15	<b>Microscopy:</b> A Brief History of Microscopy; Optical Microscopy versus Electron Microscopy, Electron Beam Specimen Interactions, Scanning Electron Microscope (SEM), Electron Optics: Electron sources, Lenses, Electron detectors, Image formation in SEM, Magnification, Depth of Field/Depth of Focus, Contrast, Chemical Analysis in SEM: Energy-dispersive X-ray spectroscopy (EDS), Transmission Electron Microscopy (TEM), High resolution TEM, Selected area electron diffraction (SAED), Specimen preparation for SEM and TEM analysis	CLO1
	<b>Learning Activities:</b> Knowledge of microscopic analysis of nanomaterials	
II/15	<b>X-ray Crystallography and Diffraction:</b> x-ray properties, X-ray history and generation of x-rays, X-ray detection and uses in characterization, X-ray interactions with materials, Diffraction geometry: Bragg's law, Diffraction Intensity: Scattering from atoms, from the contents of a unit cell; structure factor function, Phase identification from powder data, Structure and refinement, Thin films and single crystal X-ray diffraction, Electron diffraction	CLO2

	<b>Learning Activities:</b> Knowledge of crystal structure of nanomaterials	
III/15	<b>Surface analysis:</b> Introduction to surface science, Electronic and ionic spectroscopies, X-ray photoemission spectroscopy (XPS), scanning probe microscopies: Scanning tunneling microscopy (STM), Atomic force microscopy (AFM), Magnetic Force Microscopy (MFM), Instrumental aspects : scanner, probes, artifacts etc., Rutherford Back Scattering (RBS), Ion Beam (Low energy and high energy) irradiation.	CLO3
	<b>Learning Activities:</b> Probing the surface properties of nanomaterials	

**Transaction Mode:** Lecture, problem solving, discussion & demonstration, self-study.

**Suggested Readings:**

1. Yang Leng, (2013). Materials Characterization: Introduction to Microscopic and Spectroscopic Methods: 2nd Edition, WILEY.
2. Greg Haugstad. (2012). Atomic Force Microscopy: Understanding Basic Modes and Advanced Applications: WILEY
3. C. Julian Chen (1993). Introduction to Scanning Tunneling Microscopy: Oxford University Press.
4. John F. Watts, and John Wolstenholme (2003). An Introduction to Surface Analysis by XPS and AES: WILEY
6. S. K. Sharma et al. (2018) Handbook of Materials Characterization: Springer International Publishing AG

**Course Code: PHY.557**

**Course Title: Nuclear Techniques**

**Total Hours: 45**

**Learning Outcomes:**

CL01: Develop understanding about design of electron and ion accelerators.

CL02: Develop insight in analyzing characteristics of nuclear detector and evaluate their performance

CL03: Develop understanding about energetic radiations affecting matter

CL04: Develop understanding about nuclear reactors their design and applications.

Unit/hours		
I/12	<p><b>Accelerators:</b> Motion of charged particles in electric and magnetic fields, Axial and radial magnetic field distributions in dipole, quadrupole and hexapole arrangement, Equipotential lines in different electrodes arrangement, Particle trajectory in electric and magnetic field, Electron sources, ion sources, Van de Graaf generator, DC linear accelerator, RF linear accelerator, Cyclotron, Microtone, introduction to advance accelerator (LHC)</p>	CL01
II/11	<p><b>Detectors:</b> Relation detectors Gaseous ionization, ionization and transport phenomena in gases, proportional counters, organic and inorganic scintillators, detection efficiency for various types of radiation, photomultiplier gain, semiconductor detectors, surface barrier detector, Si(Li), Ge(Li) and HPGe detectors.</p> <p><b>Interaction of radiation with matter:</b> General description of interaction processes, photoelectric effect, Compton Effect, pair production, interactions of directly ionizing radiation, stopping power, linear energy transfer, range of particles, interaction of indirectly ionizing radiation attenuation coefficient.</p>	CL02
III/11	<p><b>Reactors and artificial radioisotopes:</b> Neutron sources, neutron detectors, measurement of cross-sections for nuclear reaction, thermal and fast reactors, Q values, Fission, Fusion, production of radioisotopes, Reactor operation, thermal neutrons, neutron scattering and applications.</p>	CL03
IV/11	<p><b>Analysis Nuclear reaction:</b> Elemental analysis by neutron activation analysis, proton induced X-ray emission, Rutherford backscattering, Resonance nuclear reaction, Elastic RDA, ion scattering and Neutron Depth Profile.</p>	CL04

**Transaction Mode:**

Lecture, demonstration, PPT.

**Suggested Readings:**

1. Kappor S. S and Ramamurthy V. S.(1986). Nuclear radiation detectors. New Delhi: Wiley Eastern Limited.
2. Sabol J and Weng P. S. (1995). Introduction to radiation protection dosimetry. World Scientific.
3. Len W. R. (1955). Techniques for nuclear and particle physics. Springer.
4. Price W. J. (1964). Nuclear radiation detection New York: Mc Graw -Hill.
5. Siegbahn K. (1965). Alphas, beta and gamma-ray spectroscopy. North Holland, Amsterdam.
6. Singru R. M. (1974). Introduction to experimental nuclear physics. John Wiley and Sons.
7. Kappor S. S and Ramamurthy V. S. (1986). Nuclear radiation detectors. New Delhi: Wiley Eastern Limited.
8. Sabol J and Weng P.S. (1995). Introduction to radiation protection dosimetry. World Scientific.
9. Len W. R. (1955). Techniques for nuclear and particle physics. Springer.
10. Price W. J. (1964). Nuclear radiation detection. New York: McGraw-Hill.
11. Siegbahn K. (1965). Alphas, beta and gamma-ray spectroscopy. Amsterdam: North Holland.
12. Singru R. M. (1974). Introduction to experimental nuclear physics. John Wiley and Sons.

L	T	P	Credit
3	0	0	3

**Course Code: PHY:558**

**Course Title: Non-imaging techniques**

**Total Hours: 45**

**Learning Outcomes:** At the end of the course students would be able to

CLO1: Analyze Spectroscopic technique to interpret the nanomaterials

CLO2: Interpret thermal properties of nanomaterials

CLO3: understand Transport phenomena at nanostructure level

Units /Hours	Contents	Mapping with Course
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		<b>Learning Outcome</b>
I/15	<p><b>Spectroscopy:</b> IR Spectroscopy, FTIR, UV-Visible spectroscopy, Raman Spectroscopy, Auger Spectroscopy</p> <p><b>Complex Impedance Spectroscopy:</b> Nyquist Plot, Bode Plot, Electrical conductivity, ac conductivity and Jonscher Power law</p> <p><b>Complex Dielectric Spectroscopy:</b> Cole-Cole Plot, Cole-Davidson plot, Debye Plot, loss tangent, sigma representation, relaxation time, Modulus spectroscopy.</p>	CLO1
	<p><b>Learning Activities:</b> To learn the efficiency of nanomaterials in broad frequency spectrum in terms of energy, electrical properties and communication fields. Getting exposure with some real time data.</p>	
II/15	<p><b>Thermal and Mechanical Analysis:</b> Melting temperature (T<sub>m</sub>), Glass transition temperature (T<sub>g</sub>), Degradation and Crystallization temperature (T<sub>d</sub> and T<sub>c</sub>), Thermogravimetric analysis (TGA), Differential Scanning calorimetry (DSC), Universal tensile machine, Dynamic mechanical analysis (DMA) Dynamic Thermal Analysis (DTA).</p>	CLO2
	<p><b>Learning Activities:</b> To understand the different aspect of nanomaterials in terms of thermal and mechanical effect over it. Getting exposure with some real time data.</p>	
III/15	<p><b>Transport Number Analysis:</b> Transference Number (Electron, ion, cation transport measurement) Analysis, IV characteristics, Activation Energy Estimation (VTF and Arrhenius), Transport Parameters analysis.</p>	CLO3
	<p><b>Learning Activities:</b> Understanding of Transport phenomena occurring in nanomaterials. Getting exposure with some real time data.</p>	

**Transaction Mode:** Lecture, problem solving, discussion & demonstration, self-study.

**Suggested Readings:**

1. J. R. Macdonald and E Barsoukov (2018). Impedance Spectroscopy: *Theory, Experiment, and Applications*: 3<sup>rd</sup> Edition, WILEY.
2. A Gaur, AL Sharma, A Arya (2021). Energy Storage and Conversion Devices: Supercapacitors, Batteries, and Hydroelectric Cell: 1st Edition, CRC Press, Taylor and Francis.
3. AL Sharma, A Gaur, A Arya (2021). Polymer Electrolytes and their Composites for Energy Storage/Conversion Devices: 1st Edition, CRC Press, Taylor and Francis.
4. A K Jonscher (1995). Dielectric Relaxation in Solids: Chelsea Dielectrics Press Ltd
5. Alain Degiovanni (Author), Yves Jannot (2018). Thermal Properties Measurement of Materials (Materials Science), WILEY.

<b>L</b>	<b>T</b>	<b>P</b>	<b>Cr</b>
2	0	0	2

**Course Title: Entrepreneurship**

**Course Code: PHY.559**

**Total Hours: 30**

**Learning Outcomes:** On the completion of this course, the learners will:

CLO1: Understand the concepts of entrepreneur, entrepreneurship, and its importance.

CLO2: Comprehend the opportunities, challenges and strategies required in entrepreneurship.

CLO3: Develop capabilities of preparing proposals for starting small businesses.

CLO4: Bring innovative ideas and innovative services to the market and develop patents.

<b>Unit/ Hours</b>	<b>Contents</b>	<b>Mappi ng with CLO</b>

I/8	<b>Introduction to Entrepreneur and Entrepreneurship:</b> Characteristics of an entrepreneur and entrepreneurship; entrepreneurial traits, skills; innovation and entrepreneurship; types of entrepreneurial ventures; enterprise in Indian context. <b>Learning activities:</b> <i>Concept built with real examples.</i>	CLO1
II/7	<b>Ventures and Start-Ups:</b> Why, when, and how to start a business; opportunity analysis, environmental analysis, legal requirements, funding, collaborations & partnership, establishing the venture - building a preliminary project report, format for a detailed/final project report. <b>Learning activities:</b> <i>Project report preparation as a group activity.</i>	CLO2 & CLO3
III/8	<b>Road map from Laboratory to the Market:</b> Familiarization with entrepreneurial development programs (MSME, DBT, BIRAC, make in India); technology assessment, development & upgradation; quality control, regulatory compliances and procedures (CDSCO, NBA, GCP, GLA, GMP); developing distribution channels, changing customer needs, patenting & commercialization. <b>Learning activities:</b> <i>Mind map for laboratory to market transition.</i>	CLO3
IV/7	<b>Innovation and Value Creation:</b> Conceptualizing innovations from laboratory research for societal benefit and its impact assessment; partnership between academia, industry, investors and society; develop science-based ideas towards business such as in health & disease, agricultural, environmental and/or industrial sectors. <b>Learning activities:</b> <i>Case studies and discussion sessions with successful science-based entrepreneurs.</i>	CLO4

### Suggested Readings:

1. Arora, R (2008). *Entrepreneurship and Small Business*, Dhanpat Rai & Sons Publications.
2. Chandra, P (2018). *Project Preparation, Appraisal, Implementation*, Tata Mc-Graw Hills.
3. Desai, V (2019). *Management of a Small Scale Industry*, Himalaya Publishing House.
4. Jain, P. C. (2015). *Handbook of New Entrepreneurs*, Oxford University Press.

5. Srivastava, S. B. (2009). *A Practical Guide to Industrial Entrepreneurs*, Sultan Chand & Sons.

**Modes of transaction:**

Lectures and tutorials, group discussions and group activities, brain-storming sessions, PPT, videos, animations, google classroom.

L	T	P	Cr
0	0	8	4

**Course Code: PHY.600**

**Course Title: Dissertation Part I**

Total Hours: 120

**Learning Outcomes:** At the end of Research Proposal, students will be able to:

- Outline the literature on as Specific research problem.
- Construct objectives and motivations of research problem to be carried out.
- Explain the nuts and bolts of the theoretical concepts of the problem (experimental or theoretical) to be carried out.
- Making research proposal for further research.

Students will prepare a research proposal based on literature review and extensive student-mentor interactions involving discussions, meetings and presentations. Each student will submit a research/dissertation proposal of the research work planned for the M.Sc. dissertation with origin of the research problem, literature review, hypothesis, objectives and methodology to carry out the planned research work, expected outcomes and bibliography. Group dissertation may be opted, with a group consisting of a maximum of **four** students. These students may work using a single approach or multidisciplinary approach. Research projects can be taken up in collaboration with industry or in a group from within the discipline or across the discipline.

**Evaluation Criteria:**



The evaluation of the dissertation proposal will carry 50% weightage by supervisor and 50 % by HoD and senior-most faculty of the department.

<b>Dissertation Proposal (Third Semester)</b>		
	<b>Marks</b>	<b>Evaluation</b>
Supervisor	50	Dissertation proposal and presentation
HoD and senior-most faculty of the department	50	Dissertation proposal and presentation

### **Modes of transaction**

Group discussions and presentations; Self-Learning; Experimentation, Report writing.

## SEMESTER IV

L	T	P	Cr
0	0	40	20

**Course Code: PHY.601**

**Course Title: Dissertation Part II**

**Total Hours: 600**

**Learning Outcomes:** At the end of Dissertation students will be able to:

**CLO1:** Demonstrate an in-depth knowledge of scientific research pertaining to the area of study

**CLO2:** Demonstrate experimental/theoretical research capabilities based on rigorous hands-on training

**CLO3:** Critically analyze, interpret and present the data in light of existing scientific knowledge to arrive at specific conclusions

**CLO4:** Develop higher order thinking skills required for pursuing higher studies (Ph.D.)/research-oriented career options in respective fields.

Students will carry out their research work under the supervision of a faculty member. Students will interact with the supervisors through meetings and presentations on a regular basis. After completion of the research work, students will complete the dissertation under the guidance of the supervisor. The dissertation will include literature review, hypothesis, objectives, methodology, results, discussion, and bibliography.

### **Evaluation Criteria:**

The evaluation of dissertation in the fourth semester will be as follows: 50% weightage for continuous evaluation by the supervisor which includes regularity in work, mid-term evaluation, report of dissertation, presentation, and final viva-voce; 50% weightage based on average assessment scores by an external expert, HOD and senior-most faculty of the department. Distribution of marks will be based on the report of dissertation (30%), presentation (10%), and final viva-voce (10%). The final viva-voce will be through offline or online mode.

<b>Dissertation (Fourth Semester)</b>		
	<b>Marks</b>	<b>Evaluation</b>
Supervisor	50	Continuous assessment (regularity in work, mid-term evaluation) dissertation report, presentation, final viva-voce
External expert, HoD and senior-most faculty of the department	50	Dissertation report (30), presentation (10), final viva-voce (10)

**Transaction Mode:**

Power point presentation, report writing, group work, viva-voce.