CENTRAL UNIVERSITY OF PUNJAB, BATHINDA

M.SC. PHYSICS

Batch-2024

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

Sr. No	Course Code	Course Title	Course Type	L	T	P	Cr
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	PHY.XXX	Individualized Education Plan/ Tutorial		0	2	0	0
		Total Credits					**21**

SEMESTER-II

Sr. No	Course Code	Course Title	Course Type	L	T	P	Cr
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 / MOOC	IDC/ MOOC	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

	PHY.534	Meta–materials	DE	3	0	0	3
Discipline Elective Course (Select one)							
8	PHY.529	Nanostructured Materials	DE	3	0	0	3
	PHY.530	Nonlinear 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
	PHY.535	Laser and Spectroscopy	DE	3	0	0	3
9	PHY.XXX	Individualized Education Plan/ Tutorial		0	2	0	0
		Total Credits					**22**
IDC course for other departments							
	PHY.514	Physics in Everyday Life	IDC	2	0	0	2

Multiple entry and exit: 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 1st and 2nd 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/ MOOC	VAC/ MOOC	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	Non-Imaging Techniques	DE	3	0	0	3
	PHY.558	Nuclear 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
		Total Credits					**22**
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
Total Credits							**20**
Total Credits for M.Sc. Physics Program: 85							

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.

Core, Discipline Elective, and Compulsory Foundation Courses			**IDC, VAC, and Entrepreneurship, Innovation and Skill Development Courses**	
	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

Dissertation Proposal (Third Semester)			**Dissertation (Fourth Semester)**		
	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-	50	Dissertation report (30), presentation (10), final viva-voce (10)

			most faculty of the departmen t		

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.**

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

Units/Hours	Contents	Mapping with Course Learning Outcome
I/11	Complex Analysis: 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
	Applications of Residue Theorem: The evaluation of definite integrals and the summation of infinite series. Integrals involving branch point singularity.	CLO2
	Learning Activities: Problem Solving and Application based peer thinking	
II/12	Fourier and Laplace Transforms: Fourier series, Dirichlet condition, Fourier transforms, Laplace transforms, Solution of ordinary and partial differential equations by transform methods.	CLO3

	Group theory: Group postulates, Lie group and generators, representation, Commutation relations, SU (2), O (3).	CLO3
	Learning Activities: Problem Solving, group discussions, Application based peer thinking	
III/11	Vector Space: Linear vector spaces, subspaces, basis and dimension, Linear independence and orthogonality of vectors, Gram-Schmidt orthogonalization procedure.	CLO4
	Tensors: 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	
	Learning Activities: Group discussion and problem solving.	
IV/11	Differential Equations: Hermite, Legendre, Bessel and Laguerre Differential equations and their properties.	CLO5
	Partial differential equations: Laplace, wave and heat equation, Euler equation, Green's function.	CL06
	Learning Activities: Problem Solving	

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

Suggested Readings:

Arfken G, Weber H and Harris F. (2012). Mathematical Methods for Physicists. Massachusetts, USA: Elsevier Academic Press.

Kreyszig E. (2011). Advanced Engineering Mathematics. New Delhi, India: Wiley India Pvt. Ltd.

Pipes L. A. (1985). Applied Mathematics for Engineers and Physicist. Noida, India: McGraw-Hill.

Zill D. G. (2012). Advanced Engineering Mathematics. Massachusetts, USA: Jones & Barlett Learning.

Chattopadhyay P. K. (2000). Mathematical Physics. New Delhi: New Age International (P) Ltd.

Rajput B.S. (2017). Mathematical Physics. Pragati Prakashan.

McQuarrie Donald A. (2015). Mathematical methods for scientists and engineers. New Delhi: Viva books private limited.

M. L. Boas, Mathematical Methods in the Physical Sciences, 3ed (2019), Wiley.

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	**Linux operating system:** Introduction to the Linux operating system: fundamental commands, editing files, understanding directories and permissions.	CLO1
	Programming with C: Computer Algorithm, Data types, C programming syntax, Control statements: if, if-else and nested-if statements. Switch statement, looping: while, for and do-while loops, Functions: Call by values and by references, Arrays and structures: one dimensional and two-dimensional arrays, Idea of string and structures. Preprocessors, Pointers in C	CLO2
	Learning Activities: Writing programs, group discussions	
II/11	**Error analysis:** Element of computational techniques: Error analysis, Propagation of errors.	CLO3
	Matrices: 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 CL05

	Learning Activities: Problem solving, Writing programs, group discussions	
III/11	**Roots of Nonlinear Equations:** Newton Raphson method. **Numerical Differentiation and Integration:** Differentiation of continuous functions Integration by Trapezoidal and Simpson 1/3 rule.	CLO6
	Learning Activities: Problem solving, Writing programs	
IV/12	**Numerical Solution of Ordinary Differential Equations:** Euler's method, Modified Euler's method, Runge-Kutta 2^{nd} and 4^{th} order method.	CLO7
	Learning Activities: 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	**Lagrangian Formalism:** 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
	Hamiltonian Formalism: Variational principle and problems, Principle of least action, Hamilton's principle, Hamilton's Theorems, Hamilton's equation of motion, Lagrange and Hamilton equations of 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.	CLO2
	Learning Activities: Problem Solving	
II/11	**Theory of Small Oscillations:** 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.	CLO3

	Dynamical systems, Phase space Dynamics and Stability Analysis: 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.	CLO4
	Learning Activities: Group discussions, Application-based peer thinking, and Problem Solving.	
III/11	**Central Force Problem:** 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.	CLO5
	Learning Activities: Group discussion and problem-solving.	
IV/11	**Canonical Transformations:** 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.	CLO6
	Poisson Brackets: 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.	CLO7
	Learning Activities: Group discussion and problem-solving.	

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. Aruldhas (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: Apply quantum mechanics for a two-electron system.

Units/Hours	Contents	Mapping with Course Learning Outcome
I 12 Hours	**Foundation of Quantum Mechanics:** Limitations of Classical Mechanics, Dirac notation, Basic postulates of quantum mechanics, Expectation values, Commutation relations, Ehrenfest theorem.	CLO1
	Schrödinger Wave Equation and Applications: 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
	Learning Activities: Brain-storming and Problem Solving	

II 11 Hours	**Angular Momentum:** 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
	Spin angular momentum: 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
	Learning Activities: Group discussion and Problem Solving	
III 11 Hours	**Time-independent Perturbation Theory**: General formulation and validity of perturbation theory, 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
	Learning Activities: Problem solving	
IV 11 Hours	**The Variational Method:** Theory and its applications to ground state of harmonic oscillator and hydrogen atom.	CLO5
	Identical Particles: Spin-Statistics connection, Pauli's exclusion principle, Slater determinant, Two-electrons system: Parahelium and orthohelium	CLO6
	Learning Activities: Group discussion and problem solving	

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
3	0	0	03

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 Course Learning Outcome**
I/12	**Semiconductors:** Theory of semiconductors, Semiconductor devices, diode, homo and heterojunction devices.	CLO1
	Transistor Amplifiers: Transistor, Device structure and characteristics, Amplifiers, Frequency dependence and applications, Impedance matching, small signal amplifiers, h parameter (dc and ac analysis), r parameter (dc and ac analysis), Conversion formulae for the h-parameters of the different transistor configurations, CE amplifier with bypassed/ un-	CLO2

	bypassed emitter resistor, Emitter follower, Cascaded amplifiers, Transistor biasing, Self-bias and thermal stability.	
	Learning Activities: Application based peer thinking, Problem Solving	
II/10	**Field Effect Transistor:** 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
	Learning Activities: Group discussions, Application based peer thinking, and Problem Solving.	
III/12	**Basics of Feed backing:** The gain of an amplifier with feedback, General characteristics of negative feedback/instrumentation amplifiers, Stability of feedback amplifiers, Barkhaussen criteria, Grain and phase margins, Compensation, filtering, Noise reduction.	CLO4
	Feedback: Sinusoidal oscillators: RC oscillators: Phase shift and the Wien's bridge oscillators, LC oscillators, Frequency stability and the crystal oscillators.	CLO5
	Learning Activities: Group discussion and problem solving.	
IV/11	**Operational Amplifier and Their Applications:** 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
	Learning Activities: 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. To find the value of y for given value of x using Newton's interpolation method. Perform numerical integration on 1-D function using Trapezoid rule. Perform numerical integration on 1-D function using Simpson rules. To find the solution of differential equation using Runge-Kutta method. To find the solution of differential equation using Euler's method. Choose a set of 10 values and find the least squared fitted curve. To find eigenvalues and eigenvectors of a Matrix. To find solutions of linear equations using Gauss elimination method.	CLO1 CLO2 CLO3

	Any five from the following: Study the motion of spherical body falling in viscous medium using Euler method. To study the path of projectile with and without air drag using Feynman-Newton method. Study the motion of an artificial satellite around a planet. Study the motion of one-dimensional harmonic oscillator without and with damping effects. To obtain the energy eigenvalues of a quantum oscillator using Runge-Kutta method. Study the motion of charged particles in uniform electric field, uniform magnetic field and combined uniform EM field. To study the phenomenon of nuclear radioactive decay. To study the EM oscillation in a LCR circuit using Runge-Kutta method. To find the solution of 1D heat flow equation using Finite Element Method.	CLO4
	Learning Activities: Writing programs, group discussion	

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. (1st edition,1999). Computational Physics. New Age.
5. Tao Pang. (2nd 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 and learn use of Arduino.
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
	Use of Arduino and practice of various circuits using same	
	Realization of universal logic gates.	CL05
	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.	CL06
	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
	Learning Activities: Experimentation, Group discussion	
II 15Hours	Bandgap of a semiconductor by Four Probe method. Wavelength measurement of laser using a diffraction grating.	CLO2
	Learning Activities: Experimentation, Group discussion	
III 15Hours	Michelson interferometer. Dual nature of electron experiment. Millikan oil-drop experiment	CLO3
	Learning Activities: Experimentation, Group discussion	
IV 15Hours	Stefan's law. Zeeman effect experiment. Fabry-Perot Interferometer. Raman Spectroscopy	CLO4
	Learning Activities: 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.
3. Massachusetts, USA: Thomson Brooks/Cole.
4. Krane K.S. (2012). Modern Physics. New Delhi, India: Wiley India(P)Ltd.
5. 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: Explain Fermi Golden rule and selection rules for absorption and emission of light.
CLO2: Outline WKB method and bound states of potentials well, CLO:3 Explain scattering theory for various kind of potential problems, CLO:4 Explain the importance relativistic quantum mechanics.

Units/Hours	Contents	Mapping with Course Learning Outcome
I 12Hours	**Time-dependent Perturbation Theory:** 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.	CLO1
	Learning Activities: Group discussion and Problem Solving.	
II 11Hours	**WKB Method and its Applications:** 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.	CLO2
	Learning Activities: Brain- storming and Problem Solving	
III 11Hours	**Scattering Theory:** 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.	CLO3
	Learning Activities: Group discussion and Problem Solving.	
IV 11Hours	**Relativistic Quantum Mechanics:** Klein-Gordon equation, Dirac relativistic equation, Gamma Matrices, Significance of negative energy, Spin-orbit interaction, Relativistic correction, Fine structure of hydrogen atom.	CLO4

	Learning Activities: Problem solving	

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.

L	T	P	Credit
03	00	00	03

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

Units /Hours	Contents	Mapping with Course Learning Outcome
I/11	**Electrostatics:** 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	**Magnetostatics:** Biot-Savart law, Ampere's theorem and its applications, Lorentz Force, Magnetic scalar and Vector potential. **Magnetic Fields and Boundary Condition:** 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,	CLO2
II/11	**Maxwell Equations:** 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/12	**Plane Electromagnetic Waves and wave equations:** 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. **Radiation from Moving Point Charges and Dipoles:** 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 PitaevskiiL. P. (1984). *Electrodynamics of Continuous Media.* New York, USA: Elsevier.
6. Matthew N. O. Sadiku (2015). Principles of Electromagnetics, Oxford University Press

L	T	P	Credit
3	0	0	03

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: Analyse crystal structure, reciprocal lattice and distinguish different X-ray diffraction techniques.
CLO2: Explain the Free Electron and band theory of solids and their applications.
CLO3: Outline the theory of lattice vibrations and its applications to heat capacity, thermal expansion, and thermal conductivity.
CLO4: Outline band theory of solids, types, and mechanism for the formation of bands.
CLO5: Explain properties, theories, and applications of superconductivity.

Units /Hours	Contents	Mapping with Course Learning Outcome
I/12	**Crystal structure and its determination:** Bravais lattices, lattice with a basis, simple crystal structures, close packing, X-ray diffraction, reciprocal lattice, Bragg and von Laue formulation, Ewald sphere, Miller indices, Laue equations, Brillouin zones, Laue method, rotating crystal method, powder method, structure factor, atomic form factor.	CLO1
	Learning Activities: Problem Solving	

II/11	**Free Electron Theory:** Free electron theory, Drude model, Wiedemann and Franz law, Seebeck effect, Sommerfeld Theory of free electrons, Periodic boundary condition, Fermi-Dirac distribution, Density of states, Fermi energy, Electronic contribution to specific heat of solids, Boltzmann transport equation (Response and relaxation phenomena): Thermal Conductivity in Metals, Hall Effect.	CLO2
	Lattice Dynamics: Vibrations of linear monatomic and diatomic lattices, acoustical and optical modes, long wavelength limit and speed of sound, optical properties of ionic crystal in the infrared region, normal modes and phonons, contribution of lattice vibrations to the specific heat of a solid, Planck's distribution law, models of Debye and Einstein,	CLO3
	Learning Activities: Peer learning, and Problem Solving.	
III/11	**Band Theory of Solids:** Nearly free electron model, 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, 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.	CLO4
	Learning Activities: Group discussion and problem-solving.	
	Superconductivity: 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, Superfluity, High TC superconductors: Basic ideas and applications.	CLO5
	Learning Activities: 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. M, Ali Omar (2017), Elementary Solid State Physics, Pearson.
7. Michael P. Marder (2010), Condensed Matter Physics, John Wiley and sons.
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.

Unit s/Ho urs	**Contents**	**Mapping With Course Learning Outcome**
	Basics of Logic Gates: Logic gates and the realization using diodes and transistors.	CLO1

I/12	**Basics of reduction of logic expressions:** 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 (2, 3, 4, 5, and 6 variable) and their applications.	CLO2
	Learning Activities: Application based peer thinking, Problem Solving	
II/11	**Combinational Circuits:** 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
	Learning Activities: 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
	Sequential Circuit-Counters and Register: 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
	Learning Activities: Group discussion and problem solving.	
IV/10	**Programmable logic and Data Converters:** 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
	Learning Activities: 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	Cr
0	0	4	2

Course Code: PHY.525
Course Tile: 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
CL05: Develop insight and hands on skill into magnetic and non-magnetic physical systems

Course Contents

Units/Hours	**Contents**	**Mapping with Course Learning Outcome**
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
	Learning Activities: 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
	Learning Activities: Experimentation, Group discussion	
III 15 Hours	Study of thermal expansion of solids. Study of thermal conductivity of solids. Study of specific heat of solids. Determination of critical temperature of high-temperature superconductor and Meissner effect for a high Tc superconductor.	CLO3
	Learning Activities: 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 NiSO4, FeSO4, and CoSO4 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 (TC = Curie temperature	CLO5
	Learning Activities: 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 Tile: 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	**Physics in Earth's Atmosphere:** 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
	Learning Activities: Knowledge and understanding of earth's atmosphere	
II/7	**Physics in Human Body:** 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

	Learning Activities: Understanding of the Physics principles involved in human body	
III/8	**Physics in Sports:** The sweet spot, Dynamics of rotating objects, Running, Jumping and pole vaulting, Motion of a spinning ball, Continuity and Bernoulli equations, Bending it like Beckham, Magnus force, Turbulence and drag	CLO3
	Learning Activities: Knowledge and understanding the Physics principles in Sports activities	
IV/7	**Physics in Technology:** 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
	Learning Activities: 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 distributers.

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

Units /Hours	Contents	Mapping with Course Learning Outcome
I/15	**Advanced Ceramic and Smart Materials:** Ceramic Materials: Classification, Preparation and Properties, Composites, and Smart Materials: Ferroelectric, Dielectrics, Piezoelectric, Thermoelectric, Luminescence, Phase Change Material, Shape Memory Alloys	CLO1
	Learning Activities: Knowledge of growing field of Advanced & Smart Materials	
II/15	**Magnetic and Multiferroics Materials:** 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
	Learning Activities: Application based Critical thinking in Modern Materials	
III/15	**Polymers and Composites:** 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
	Learning Activities: 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	Cr
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 many-body Hamiltonian and 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.

Units/Hours	Contents	Mapping with Course Learning Outcome
I 12Hours	**Many-body Hamiltonian:** Born-Oppenheimer approximation, Independent particle model, Hartree-Fock equations, Electron density in Density Functional Theory, Hohenberg-Kohn theorems, Kohn-Sham formulation, Exchange-correlation functional: local density approximation and generalized gradient approximations.	CLO1
	Learning Activities: Brain-storming	
II 11Hours	**Practical Implementation of Density Functional Theory (DFT)**: 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
	Learning Activities: Group discussion	
III 11Hours	**Treatment of Solids:** 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
	Learning Activities: Brain-storming	
IV 11Hours	**Electronic Structure with DFT**: Free electron theory, Band structure, Density of states. Projected Density of States (Mulliken Methods), Interpretation of Kohn-Sham eigenvalues in relation with ionization potential.	CLO4

	Learning Activities: Group discussion and problem solving	

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

Suggested Readings:

1. Gunn Lee June. (2011). *Computational Materials Science: An Introduction.* CRC Press.
2. Kaxiras Efthimious. (2007). Atomic and Electronic Structure of Solids. Cambridge University Press.
3. M Martin Richard. (2008). Electronic Structure: Basic Theory and Practical Methods. Cambridge University Press.
4. S. Sholl David and A. Steckel Janice. (2009). Density Functional Theory: A Practical Introduction. John Wiley and Sons.
5. Feliciano Giustino. (2009). Materials Modelling Using Density Functional Theory: Properties and Predictions. Wiley.
6. Rajendra Prasad. (2013). Electronic Structure of Materials, Taylor and Francis.
7. M. Dreizler Reiner, K.U. Gross Eberhard. Density Functional Theory, An Approach to the Quantum Many-Body Problem. Springer.

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	**Basic Physics:** 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 **Structure and Bonding in Nanomaterials**: 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	CLO1
	Learning Activities: Application based peer thinking	
II/15	**Nanomaterial Synthesis:** 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 synthesis, mechanism and examples of self-assembly,	CLO2

	nanolithography	
	Learning Activities: Group discussions and Application based peer thinking	
III/15	**Special class of Nanomaterials:** Carbon nano-materials, porous silicon, aerogels, zeolites, template based porosity, magnetic nanoparticles, meta-materials, bio-inspired materials	CLO3
	Learning Activities: 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 (03rd edition).
3. Poole Charles P. Jr., Owens Frank J., (2018) Introduction to Nanotechnology, Wiley Interscience, USA (02nd edition).
4. Vollath Dieter, (2013). Nano-materials: An introduction to synthesis, properties, and applications, Wiley-VCH (02nd edition).
5. Kilmov Victor I, (2023). Semiconductor and metal nano-crystals, Marcel Dekker (05th edition).
6. Alegaonkar Ashwini P., Alegaonkar Prashant S., (2023) Nano-carbons: preparation, assessments and applications, CRC Press: Taylor and Francis (01st edition).
7. Nandi Upendranath, Jana Debnarayana, (2014) Nano-materials: Theory problems and solution, Techno-world (01st edition).
8. Sharma S K, (2019) Nanohybrids in Environmental & Biomedical Applications, CRCPress: Taylor and Francis

L	T	P	Cr
3	0	0	3

Course Code : PHY.530
Course Title : Nonlinear 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

Units/ Hours	Contents	Mapping with CLO
I/12	**Basics of linear optics:** Maxwell's EM wave formulation, plane wave solution, monochromatic, non-monochromatic waves, **D, P,** n, directions of **D** and **E** in isotropic medium, Poynting vector, energy flow, intensity of an EM wave	CLO1
	Non-linear effects: 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	
	Learning Activities: Problem Solving, Group discussion	
II/11	**Second order nonlinear effects:** 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	CLO2
	Phase matching and frequency generation rules: Type 1 and Type 2 phase matching, symmetry in nonlinear susceptibility, Kleinman`s symmetry, Neumann`s principle, centro-symmetric system, matrix formulation of harmonics generation in postssiam dihydrogen phosphate crystal	
	Three wave mixing: three wave interaction, equation for pump, signal, and idler wave, non-co-linear phase	CLO3

	matching, Manley-Rowe relation for three wave mixing, paramagnetic down conversion, optical parametric amplification, optical parametric oscillator, resonant oscillator	
	Learning Activities: Application based peer thinking, and Problem Solving	
III/11	**Third and higher order effects**: optical Kerr effect, self focusing, symmetry in 3rd 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	CLO4
	Advanced optical systems: Raman scattering, stimulated Raman scattering, Raman amplification, linear pulse propagation, optical soliton	
	Learning Activities: Group discussion and problem solving.	

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.

L	T	P	Cr
3	0	0	3

Course Tile: 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.

Units /Hours	**Contents**	**Mapping with CLO**
I/13	**Basic Principle:** Basic Principle of Batteries (Primary, Secondary- Ni Cd, Li-Ion, Na-Ion), Super capacitors (pseudo, EDLC, Hybrid), Supercapattery, Supercabattery, Hydroelectric Cells (HECs).	CLO1
	Learning Activities: Application based peer thinking	
II/18	**Materials and Methodology:** Electrode materials (Transition Metal oxides (TMOs), carbon nanostructured (Graphene, Graphitic Carbon Nitride, CNTs, Activated Carbon, Carbon Nanofibers), Conducting Polymer (CPs) (Polyaniline (PANI), Polypyrrole (ppy)), nanocomposite etc.),	CLO2

	Electrolytes (liquid polymer electrolyte, gel polymer electrolyte and solid polymer electrolyte). **Material Synthesis Techniques:** Electrochemical method, Spin coating, Dip coating, Spray pyrolysis, Doctoral blade technique, Hydrothermal, Solvothermal, Solid-state reaction method, Co-precipitation method, Sol-gel synthesis. Fabrication: Li-Ion Cell, Supercapacitors, Hydroelectric Cells (HECs)	CL03
	Learning Activities: Group discussions and Application based peer thinking.	
III/14	**Specific Characterization Techniques:** X-ray photoelectron spectroscopy (XPS), Brunauer-Emmett-Teller (BET) Technique, Electrochemical impedance spectroscopy (EIS), Bode Plot, Dielectric Spectroscopy, Nyquist plot, Cyclic Voltametry, Galvanometric charge discharge (GCD), Ragone Plot.	CLO4
	Learning Activities: Brainstorming and Application based peer thinking.	

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 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

Unit/Hours	Contents	Mapping
I/12	**Production of Low Temperature:** History of low temperature, Liquefaction of cryogens, 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	**Measurements at Low temperature:** Magnetic susceptibility measurements, Superconducting Quantum Interference Device (SQUID) magnetometer,	CLO2

	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.	
III/10	**Phenomena in Bulk Materials at Low Temperature:** 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	**Low Dimension Systems at Low Temperatures:** 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 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.	CLO4

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. Heinzel, 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: get familiar with soft condensed matter and computational tools required to simulate 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	**Introduction to Theory of Soft Materials:** Introduction to basic theory of soft matter systems e.g. *colloids, polymers, liquid crystals, granular materials, biological matter;* 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	**Molecular, Brownian, and Colloidal Dynamics:** Time integration of equations of motion: Verlet, leap frog, and Gear's algorithm; calculation of forces and torques: neighbor lists, interaction potentials, handling of long-range forces; initial and boundary conditions; noise, random numbers, and their properties; Brownian dynamics: Langevin and other stochastic differential equations, simulation of random walks, Wiener and Ornstein-Uhlenbeck type processes, computation of mean squared displacement, mean squared velocity, and autocorrelation functions; basic applications to simulations of *colloids, polymers, and granular matter.*	CLO2
III/11	**Statistical Calculations:** Sampling from ensembles, thermodynamic averages; calculation of fluctuations, time and space correlation functions, and structural quantities;	CLO3

	calculation of stresses, pressure, temperature, and energies; errors and accuracy checks.	
IV/12	**Continuum Simulation Methods:** 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 *liquid crystal* simulations.	CLO4

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

Suggested Readings:

Theoretical:

1. Mewis, J. and Wagner, N.J. (2012). *Colloidal Suspension Rheology.* Cambridge University Press.

2. Doi, M. and Edwards S.F., (1998). *Theory of Polymer Dynamics.* Clarendon Press Oxford.

3. De Gennes, P.G. and Prost J., (2003). *The Physics of Liquid Crystals*, Clarendon Press Oxford.

3. Gardiner, C.W. (2004). *Handbook of Stochastic methods for physics, chemistry, and natural sciences.* Springer.

4. Van Kampen, N.G. (2007). *Stochastic processes in physics and chemistry.* Elsevier.

Computational:

1. Allen M.P. and Tildesley D.J. (2017). *Computer Simulation of Liquids.* Clarendon 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.

L	T	P	Cr
3	0	0	3

Course Code : **PHY.534**
Course Title : **Meta–materials**
Total Hours : **45**

Course Learning Outcomes (CLO)

On completion of this course, students will be able to:
CLO1: Develop artificially architected materials,
CLO2: Validate electromagnetic and optics approach for meta-materials,
CLO3: Model sound systems analogue of electromagnetic meta-systems,
CLO4: Develop understanding about sonic systems
CLO5: Realization of sonic systems for environmental noise suppression

Units/ Hours	Contents	Mapping with CLO
I/12	**Metamaterial–Fundamentals:** Meta-materials concept; effective medium theories: Maxwell–Garnett theory, Bruggeman theory, anisotropic mixtures: multilayers and wire media; Negative-permittivity and negative-permeability meta-materials; Double-Negative Materials	CLO1
	Metamaterial–Applications: 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	
	Learning Activities: Problem Solving, Group discussion	
II/11	**Metasurfaces:** Introduction to metasurfaces; frequency selective surfaces; guided mode resonances (GMR); examples of metasurfaces and GMR based devices; perfect control over transmission and reflection using metasurfaces	CLO2
	Transformation Optics: Introduction to Transformation optics; transformation principle; invisibility cloaks; carpet cloaking; transformation optics and metamaterials, introduction to alternative materials	

	Acoustic–Fundamentals: Acoustic fundamentals, sound propagation in fluids, advanced concept in acoustics, sound signal analysis, noise control	CLO3
	Learning Activities: Application based peer thinking, and Problem Solving	
III/11	**Acoustic materials**: Enclosures, barriers, absorber, porous sound absorber, Helmholtz resonator,	CLO4
	Advanced systems: Perforated panel absorber, micro-absorber, limitations on conventional acoustic materials	
	Learning Activities: Application based peer thinking and problem solving.	
IV/11	**Acoustic metamaterials:** membrane type acoustic metamaterials, introduction to sonic crystals	CLO5
	Sonic crystals: Array, caging, material selection	
	Learning Activities: Brain storming and problem solving.	

Transaction Mode:
Lectures, PPT.

Suggested Readings

1. W. Cai and V. Shalaev, Optical Metamaterials: Fundamentals and Applications, 1^{st} Ed., Springer 2010.
2. B. E. A. Saleh and M. C. Teich, Fundamentals of Photonics, 2^{nd} Ed. John Wiley, 2007.
3. L. E. Kinsler, A. R. Fery, A. B. Coppens, J. V. Sanders, Fundamentals of Acoustics, 4^{th} Ed. John Wiley and Sons, 2000.
4. R. V. Craster, S. Guenneau, Acoustic Metamaterials: Negative Refraction, Imaging, Lensing and Cloaking, Springer Series in Materials Science.

L	T	P	Cr
3	0	0	3

Course Code: PHY.535
Course Title: Laser and Spectroscopy
Total Hours: 45
Course Learning Outcomes:
CLO1: Understanding Lasers and its working.
CLO2: Laser fundamentals, Detectors and Spectroscopic Techniques.
CLO3: Spectroscopy in multidisciplinary research and their application.

Units /Hours	Contents	Mapping with Course Learning Outcome
I/15	Types of Lasers: Nd-YAG, Argon-Ion, Excimer, Semiconductor Lasers, Dye, Tunable Lasers, Topological Lasers and Light Sources.	CLO1
	Learning Activities: Knowledge of Laser and their working.	
II/15	Laser fundamentals and techniques: Principles of Laser, Rate equations, Width and Profile of Spectral lines, Power and Wavelength Tuning range, Lasing action, Temporal Coherence and Polarization. Charge Coupled Detector (CCD), Thermal and Direct Photo Detectors, Grating Spectrographs.	CLO2
	Learning Activities: Knowledge of Laser fundamentals, Detectors and Spectroscopic Techniques.	
III/15	Spectroscopy: **Laser Induced Breakdown Spectroscopy (LIBS)**, Coherent anti-Stokes Raman spectroscopy (CARS), Time Resolved Spectroscopy, Magnetic Particle Imaging (MPI) and Magnetic Resonance Spectroscopy (MRS), Laser Induced Fluorescence (LIF), Photoacoustic and Optogalvanic Spectroscopy, Two/three Photon Spectroscopy, Applications of Lasers.	CLO3
	Learning Activities: Knowledge of advanced spectroscopy used in multidisciplinary research and their application.	

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

Suggested Readings:

1. Molecular Quantum Mechanics, P Atkins & R. Friedman (Oxford Univ. Press, 2005).
2. Molecular Physics, W. Demtroder (Wiley-VCH, 2005).
3. Laser Spectroscopy, W. Demtroder (3rd Ed., Springer, 2003).
4. Modern Spectroscopy, J. M. Hollas (4th Ed., John Wiley, 2004).
5. Spectrophysics: principles and applications, Thorne, Anne P (Berlin ; New York : Springer, 1999).
6. Lasers and Non-Linear Optics by B.B. Laud.

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
I/12	**Basics of Thermodynamics:** Laws of thermodynamics and their consequences, Thermodynamic potentials and Maxwell relations.	CLO1
	Statistical Basis of Thermodynamics: 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
	Learning Activities: Problem Solving	
II/11	**Elements of Ensemble Theory:** 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
	Grand Canonical Ensemble: 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
	Learning Activities: Group discussions, Application based peer thinking, and Problem Solving.	
III/11	**Elements of Quantum Statistics:** Quantum statistics of various ensembles: the density matrix, Ideal gas in various ensembles, statistics of occupation number, Thermodynamics of black body radiations.	CLO5
	Phase Transitions: 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

	Learning Activities: Group discussion and problem solving.	
IV/11	**Ideal Bose and Fermi Gas:** 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
	Thermodynamic Fluctuations: Diffusion equation, Random walk and Brownian motion, Introduction to non-equilibrium processes.	
	Learning Activities: 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) Sadovskii 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.

L	T	P	Cr
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

Unit /hours	Contents	Mapping with Course Learning Outcome
I/11	**Introduction to Nuclear Properties:** Review of Nuclear size and shape, charge distribution, empirical formula of radius, Magnetic Moment, Electric Quadrupole, Mass and binding energy, semi-empirical mass formula.	**CL01**
II/11	**Two Nucleon Problems:** 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.	**CL02**
III/12	**Nuclear Model:** 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.	**CL03**
	Nuclear Decay: 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.	
IV/12	**Elementary Particle Physics:** 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.	**CL-04**

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

L	T	P	Cr
3	0	0	3

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: Distinguish between the different origins of the fine structure and calculate the expressions for the fine structure.

CL02: Analyze the fine structure of multi-electron atoms.

CL03: Analyze molecular structure.

CL04: Analyze realistic molecular spectra of standard as well as fairly complex molecular systems.

Unit/ Hours	Contents	Mapping with Course Learning Outcome
I/12	**Fine structure of single electron atom:** Bohr's and Sommerfeld's models of the hydrogen atom, Schrodinger equation and wavefunctions of the hydrogen atom, orbital and spin angular momentum, orbital and spin magnetic moments, spin-orbit interaction, isotope effect, fine structure due to spin-orbit interaction, fine structure due to relativistic mass correction term, Darwin term, Lamb shift, Fine structure considering all relativistic effects.	**CL 01**
II/11	**Multi-electron Atoms:** Helium atom; ground state, excited state, exchange integral, direct integral, spin eigenstates; singlet and triplet states, symmetric and antisymmetric wavefunctions, energy levels of the Helium atom, term symbols, alkali atoms, the	**CL 02**

	quantum defect, equivalent and non-equivalent atoms, L-S and J-J coupling, normal and anomalous Zeeman effect.	
III/11	**Molecular Structure:** Molecular potential, Separation of electronic and nuclear wave functions, Born-Oppenheimer approximation, Molecular orbital and electronic configuration of diatomic molecules: H_2, and NO, LCAO approach, States for hydrogen molecular ion, Coulomb, Exchange and overlap integral, Shapes of molecular orbital, Sigma and pi bond.	**CL03**
IV/11	**Molecular Spectra:** Electronic, Vibrational and rotational spectrum of diatomic molecules, Frank-Condon principle, Raman transitions and Raman spectra, Normal vibrations of CO_2 and H_2O molecules	**CL04**

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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. B. H. Bransden and C. J. Joachain, Physics of Atoms and Molecules, Longman Scientific and Technical , United Kingdom, 1990.
4. J.M. Hollas, Basic Atomic and Molecular Spectroscopy (Royal Soc. of Chemistry, London,2002.
5. G. Herzberg, Atomic Spectra and Atomic Structure (Dover Publications, New York, USA) 2010.
6. Introduction to Atomic Spectra, H. E. White, (McGraw Hill International Ed.)
7. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, (Tata, McGraw Hill Publishing Company Limited).

L	T	P	Cr
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.

Units/ Hours	Contents	Mapping with Course Learning Outcome
III/90	1) Study of the characteristics of a GM tube and determination of its operating voltage, plateau length / slope etc. 2) Verification of inverse square law for gamma rays. 3) Study of nuclear counting statistics. 4) Estimation of efficiency of the G.M. detector for beta and gamma sources. 5) To study beta particle range and maximum energy (Feather Analysis). 6) Backscattering of beta particles. 7) Production and attenuation of bremsstrahlung. 8) Measurement of short half-life	CLO1, CLO2, CL03, CL04

	9) Demonstration of nucleonic level gauge principle using G.M counting system and detector. 10) Beam interruption detection system to check packs for content level, or counting of individual items. 11) Scintillation detector: energy calibration, resolution and determination of gamma ray energy. 12) Alpha spectroscopy using surface barrier detectors. 13) Study of energy resolution characteristics of a scintillation spectrometer as a function of applied high voltage and to determine the best operating voltage 14) Measurement of resolution for a given scintillation detector using Cs-137 source. 15) Finding the resolution of detector in terms of energy of Co-60 system. 16) Energy calibration of gamma ray spectrometer (Study of linearity). 17) Spectrum analysis of Cs-137 and Co-60 and to explain some of the features of Compton edge and backscatter peak. 18) Unknown energy of a radioactive isotope. 19) Variation of energy resolution with gamma energy. 20) Activity of a gamma source (Relative and absolute methods). 21) Measurement of half value thickness and evaluation of mass absorption coefficient. 22) Back scattering of gamma Rays.	
	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. T soulfanidis 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	Cr
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	**Units of Measurement:** Fundamental units, Derived units, Systems of units, Conversion of units, Accuracy, precision, and errors in measurements, Dimensional analysis, and its applications	CLO1
	Learning Activities: Knowledge and understanding of the different unit and measurement systems	
II/15	**Measurement and Measurement Characteristics:** History and measurement of length, mass, time, temperature, pressure, and current. History, basics, and methods for standardization of length, mass, time	CLO2
	Learning Activities: 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.

Units/ Hours	Contents	Mapping with Course Learning Outcome
I/11	**Fermi Surfaces:** 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.	CLO1

	Learning Activities: Problem Solving	
II/11	**Magnetic Properties of Solids:** 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 T3/2 law, brief discussion of Kondo effect.	CLO2
	Learning Activities: Group discussions, Application based peer thinking, and Problem Solving.	
III/12	**Optical Processes, Exciton, Color Centre's and Luminescence:** 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 luminescence, mechanism and applications in dosimetry and dating.	CLO3
	Learning Activities: Group discussion and problem solving.	
	Dielectrics and Ferroelectrics: 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. **Learning Activities**: Group discussions, Application based peer thinking, and Problem Solving.	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	**Microscopy:** 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
	Learning Activities: Knowledge of microscopic analysis of nanomaterials	
II/15	**X-ray Crystallography and Diffraction:** 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
	Learning Activities: Knowledge of crystal structure of nanomaterials	
III/15	**Surface analysis:** 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
	Learning Activities: 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

5. S. K. Sharma et al. (2018) Handbook of Materials Characterization: Springer International Publishing AG

L	T	P	Credit
3	0	0	3

Course Code: PHY:557
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 Learning Outcome
I/15	**Spectroscopy:** IR Spectroscopy, FTIR, UV-Visible spectroscopy, Raman Spectroscopy, Auger Spectroscopy **Complex Impedance Spectroscopy:** Nyquist Plot, Bode Plot, Electrical conductivity, ac conductivity and Jonscher Power law **Complex Dielectric Spectroscopy:** Cole-Cole Plot, Cole-Davidson plot, Debye Plot, loss tangent, sigma representation, relaxation time, Modulus spectroscopy.	CLO1
	Learning Activities: 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.	
II/15	**Thermal and Mechanical Analysis:** Melting temperature (Tm), Glass transition temperature (Tg), Degradation and Crystallization temperature (Td and Tc), Thermogravimetric analysis (TGA), Differential Scanning calorimetry (DSC), Universal tensile machine, Dynamic mechanical analysis (DMA) Dynamic Thermal Analysis (DTA).	CLO2
	Learning Activities: To understand the different aspect of nanomaterials in terms of thermal and mechanical effect over it. Getting exposure with some real time data.	
III/15	**Transport Number Analysis:** Transference Number (Electron, ion, cation transport measurement) Analysis, IV characteristics, Activation Energy Estimation (VTF and Arrhenius), Transport Parameters analysis.	CLO3

	Learning Activities: Understanding of Transport phenomena occurring in nanomaterials. Getting exposure with some real time data.	

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*: 3rd 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.

L	T	P	Credit
3	0	0	3

Course Code: PHY.558
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	**Accelerators:** 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)	**CL01**
II/11	**Detectors:** 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), Gel(Li) and HPGe detectors.	**CL02**
	Interaction of radiation with matter: 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.	
III/11	**Reactors and artificial radioisotopes**: 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.	**CL03**
IV/11	**Analysis Nuclear reaction**: Elemental analysis by neutron activation analysis, proton induced X-ray emission, Rutherford backscattering, Resonance nuclear reaction, Elastic RDA, ion scattering and Neutron Depth Profile.	**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	Cr
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.

Unit/ Hours	Contents	Mapping with CLO
I/8	**Introduction to Entrepreneur and Entrepreneurship:** Characteristics of an entrepreneur and entrepreneurship; entrepreneurial traits, skills; innovation and entrepreneurship; types of entrepreneurial ventures; enterprise in Indian context. **Learning activities:** *Concept built with real examples.*	CLO1
II/7	**Ventures and Start-Ups:** 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. **Learning activities:** *Project report preparation as a group activity.*	CLO2 & CLO3
III/8	**Road map from Laboratory to the Market:** 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. **Learning activities:** *Mind map for laboratory to market transition.*	CLO3
IV/7	**Innovation and Value Creation:** 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. **Learning activities:** *Case studies and discussion sessions with successful science-based entrepreneurs.*	CLO4

Suggested Readings:

L	T	P	Cr
0	0	8	4

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.

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.
- Explainthenutsandboltsofthetheoreticalconceptsoftheproblem(experimentalortheoretical)tobecarriedout.
- 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.

Dissertation Proposal (Third Semester)		
	Marks	**Evaluation**
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.

Dissertation (Fourth Semester)		
	Marks	**Evaluation**
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.