CENTRAL UNIVERSITY OF PUNJAB, BATHINDA

M.Sc. Program in Physics

Session - 2021-23

DEPARTMENT OF PHYSICS

SCHOOL OF BASIC SCIENCES

Graduate attributes:

Students graduating from the program will serve humanity by applying their knowledge and skills that are developed by studying physics to serve in the education, research, and industry. Students will generate capabilities of higher order thinking in physics to interface with mathematics, chemistry, and computational sciences.

SEMESTER-I

Course Code	Course Title	Course Type	Contact Hours			Credit Hours
			L	T	P	
PHY.506	Mathematical Physics	Compulsory Foundation	3	0	0	3
PHY.507	Numerical Methods	Compulsory Foundation	3	0	0	3
PHY.508	Classical Mechanics	Core	3	0	0	3
PHY.509	Quantum Mechanics	Core	3	0	0	3
PHY.510	Electronics	Core	3	0	0	3
PHY.511	Numerical Methods Laboratory	Skill Based	0	0	4	2
PHY.512	Electronics Laboratory	Skill Based	0	0	4	2
PHY.513	Modern Physics Laboratory	Skill Based	0	0	4	2
XXX	Choose from IDC courses offered by other Departments	IDC	2	0	0	2
IDC course offered for other departments						
PHY.514	Physics in Everyday Life	IDC	2	0	0	2
					Total Credits	**23**

SEMESTER-II

Course Code	Course Title	Course Type	Contact Hours			Credit Hours
			L		P	
PHY.521	Advanced Quantum Mechanics	Core	3	0	0	3
PHY.522	Electromagnetic Theory	Core	3	0	0	3
PHY.523	Solid State Physics	Core	3	0	0	3
PHY.524	Digital Electronics	Core	3	0	0	3
PHY.525	Solid State Physics Laboratory	Skill Based	0	0	4	2
XXX.XXX	Value Added Course	VAC	2	0	0	2
Discipline Elective Courses (select two)						

PHY.527	Functional Materials and Devices	DE	3	0	0	3
PHY.528	Computational Solid State Physics	DE	3	0	0	3
PHY.529	Nanostructured Materials	DE	3	0	0	3
PHY.530	Nonlinear and Quantum Optics	DE	3	0	0	3
PHY.526	Measurement Science	VAC	2	0	0	2
					Total Credits	**22**

SEMESTER-III

Course Code	Course Title	Course Type	Contact Hours			Credit Hours
			L	T	P	
PHY.551	Statistical Mechanics	Core	3	0	0	3
PHY.552	Nuclear and Particle Physics	Core	3	0	0	3
PHY.553	Atomic and Molecular Physics	Core	3	0	0	3
PHY.554	Nuclear Physics Laboratory	Skill Based	0	0	4	2
PHY.555	Advanced Solid State Physics	DE	3	0	0	3
PHY.556	Materials Characterization	DE	3	0	0	3
PHY.557	Nuclear Techniques	DE	3	0	0	3
PHY.558	Advanced Classical Mechanics	DEC	2	0	0	2
PHY.559	Entrepreneurship	Compulsory Foundation	1	0	0	1
PHY.600	Research Proposal	Skill Based	0	0	8	4
					Total Credits	**21**

SEMESTER-IV

Course Code	Course Title	Course Type	Contact Hours			Cr
			L	T	P	
PHY.600	Dissertation	Skill Based	0	0	40	20
Total Credits						**20**
Total Credits for M.Sc. Physics Program						**86**

L: Lectures; T: Tutorial; P: Practical

MOOCs may be taken upto 40% of the total credits (excluding dissertation credits). MOOC may be taken in lieu of any course but content of that course should match a minimum 70%. Mapping will be done by the department and students will be informed accordingly.

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

A. **Continuous Assessment** (Course-wise): [25 Marks]

Two or more of the given methods (Surprise Tests, in-depth interview, unstructured interview, Jigsaw method, Think-Pair Share, Students Teams Achievement Division (STAD), Rubrics, portfolios, case based evaluation, video based evaluation, Kahoot, Padlet, Directed paraphrasing, Approximate analogies, one sentence summary, Pro and con grid, student generated questions, case analysis, simulated problem solving, media assisted evaluation, Application cards, Minute paper, open book techniques, classroom assignments, homework assignments, term paper).

B. **Mid Semester Test**: Based on Subjective Type Test [25 Marks]

C. **End-Term Exam**: Based on Objective Type Tests [50 Marks]: 70% subjective type and 30% objective type.

The objective type will include one word answers, fill-in the blank, sentence completion, true/false, MCQs', and matching, analogies. The subjective type will include a very short answer (1-2 lines), short answer (one paragraph), essay type with restricted response, and essay type with extended response.

Core, Discipline Elective, Compulsory Foundation, Value Added and Interdisciplinary Courses			Discipline Enrichment Course		Entrepreneurship Course	
	Marks	Evaluation	Marks	Evaluation	Marks	Evaluation
Internal Assessment	25	Various	-	-	-	-
Mid-semester test (MST)	25	Subjective	50	Objective	25	Objective
End-semester test (EST)	50	Subjective (70%) Objective (30%)	50	Objective	25	Subjective

SEMESTER-I

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

L	T	P	Cr
3	0	0	3

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

- Understand the vector space, complex functions, symmetry, Group theory, tensors, Fourier and Laplace transformations and special functions.
- Develop a strong background to pursue research in theoretical physics.

Course Contents

Unit-I **11 hours**
Complex Analysis: Cauchy theorem,Cauchy integral representation, Taylor and Laurent series, Liouville'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 and its applications to the evaluation of definite integrals and the summation of infinite series. Integrals involving branch point singularity.

Unit-II **12 hours**
Fourier and Laplace Transforms: Fourier series, Dirichlet condition, General properties of Fourier series, Fourier transforms, Their properties and applications, Laplace transforms, Properties of Laplace transform, Inverse Laplace transform. Solution of ordinary and partial differential equations by transform methods·
Group theory: Group postulates, Lie group and generators, representation, Commutation relations, SU(2), O(3).

Unit-III **11 hours**
Vector Space: Linear vector spaces, subspaces, basis and dimension, Linear independence and orthogonality of vectors, Gram-Schmidt orthogonalisation procedure.
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.

Unit-IV **11 hours**

Differential Equations: Solutions of Hermite, Legendre, Bessel and Laugerre Differential equations, basic properties of their polynomials, and associated Legendre polynomials.

Partial differential equations (Laplace, wave and heat equation in two and three dimensions), Boundary value problems and Euler equation. Green's functions for ordinary and partial differential equations of mathematical physics.

Transaction Mode: Lecture, demonstration, tutorial, problem solving.

Suggested Readings:

1. Arfken G, Weber H and Harris F. (2012). *Mathematical Methods for Physicists*. Massachusetts, USA: Elsevier Academic Press.
2. Kreyszig E. (2011). *Advanced Engineering Mathematics.* New Delhi, India: Wiley India Pvt. Ltd.
3. Pipes L. A. (1985). *Applied Mathematics for Engineers and Physicist.*Noida,India: McGraw-Hill.
4. Zill D. G. (2012). *Advanced Engineering Mathematics*. Massachusetts, USA: Jones &Barlett Learning.
5. Chattopadhyay P. K. (2000). *Mathematical Physics.*New Delhi: New Age International (P) Ltd.
6. Rajput B.S. (2017).Mathematical Physics. Pragati Prakashan.
7. Mcquarrie Donald A.(2015). *Mathematical methods for scientists and engineers.* New Delhi: Viva books private limited.

L	T	P	Cr
3	0	0	3

Course Code: PHY.507
Course Title: Numerical Methods
Total Hours: 45

Learning Outcomes: The students will learn to:

- Work in Linux environment.
- Write programs in C language.
- Write programs to find roots of equation, interpolation, curve fitting, numerical differentiation, numerical integration, solution of ordinary differential equations and random numbers.

Course Contents

Unit-I **11 hours**

Linux operating system: Introduction to the Linux operating system: fundamental commands, editing files, understanding directories and permissions.

Programming with C: Computer Algorithm, Data types, C programming syntax for Input/Output, Control statements: if, if-else and nested-if statements. Looping: while, for and do-while loops, Functions: Call by values and by references, Arrays and structures: one dimensional and two-dimensional arrays, Pointers, Idea of string and structures. Preprocessors.

Unit-II **11 hours**

Error analysis: Element of computational techniques: Error analysis, Propagation of errors.

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.

Unit-III **11 hours**

Roots of Nonlinear Equations: Roots of functions, Bracketing and open end methods: Bisection Method, False position method and Newton Raphson method.

Interpolation and Least Square Fitting: Linear Interpolation, Lagrange and Newton Interpolation, Linear and non-linear curve fitting

Numerical Differentiation and Integration: Differentiation of continuous functions Integration by Trapezoidal and Simpson's rule.

Unit-IV **12 hours**

Numerical Solution of Ordinary Differential Equations: Euler method and Runge-Kutta method, Finite Element Method (Solve Wave and Heat Equations).

Random Numbers: Introduction to random numbers, Monte Carlo method for random number generation, Chi square test.

Transaction Mode:

Lecture, demonstration, PPT

Suggested Readings:

1. KanetkarY.(2012). *Let Us C.* New Delhi, India: BPB Publications.
2. BalaguruswamyE.(2009). *Numerical Methods.* Noida, India: Tata McGraw Hill.
3. Sastry S. S.(2012). *Introductory Methods of Numerical Analysis*. NewDelhi: 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.

Course Code: PHY.508

Course Title: Classical Mechanics

L	T	P	Cr
3	0	0	3

Total Hours: 45

Learning Outcomes: The learners will be able to

· Explain tools of classical Mechanics such as Newton's laws, Lagrangian mechanics and Hamiltonian formalism.

· Apply the formulations of classical Mechanics to small oscillations and the central force problem.

· Develop theory of Canonical Transformations and Poisson Brackets.

Course Contents

Unit-I **12 hours**

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.

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.

Unit-II **11 hours**

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.

Dynamical systems, Phase space Dynamics and Stability Analysis: Simple harmonic oscillator, Damped harmonic oscillator, Phase portrait of 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.

Unit-III **11 hours**

Canonical Transformations: Canonical transformation (CT) with examples and related problems, Generating functions and Maxwell type relations, Solution of harmonic oscillator using CT, Conditions for CT and related problems.

Poisson Brackets: Poisson brackets and its 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.

Unit-IV **11 hours**

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 centre-of-mass frames.

Transaction Mode:

Lecture delivery using White Board and 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 State: 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.

Course Code: PHY.509
Course Title: Quantum Mechanics
Total Hours: 45

L	T	P	Cr
3	0	0	3

Learning Outcomes: Learning Outcomes:
At the end of course students will able to:
- Explain mathematical formulation of quantum mechanics.
- Apply Schrodinger's equation to solve eigen value problems such as box potential, harmonic oscillator, hydrogen atom and quantum mechanical tunneling.
- Formulate C G coefficients using angular momentum algebra.
- Explain the importance of perturbation theory.
- Explain Stark effect, Paschen Back effect, Anomalous Zeeman effect, fine structure of hydrogen atom, Fermi Golden rule and selection rules for absorption and emission of light.

Course Contents

Unit-I **12 hours**
Foundation of Quantum Mechanics: Limitations of Classical Mechanics, Dirac notation, Basic postulates of quantum mechanics, Expectation values, Commutation relations, Ehrenfest theorem.
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.

Unit-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, 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.

Unit-III **11 hours**

Time-independent 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

The Variational Method: Theory and its applications to ground state of harmonic oscillator and hydrogen atom.

Unit-IV **11 hours**

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.

Transaction Mode:

Lecture, demonstration, tutorial, problem solving.

Suggested Readings:

1. ZettiliN.(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	Cr
3	0	0	3

Course Code: PHY.510
Course Title: Electronics
Total Hours: 45

Learning Outcomes: On completion of the course, students would be able to

- Explain Semiconductor devices

- Construct Electronic Circuitry
- Inspect different application and working of Transistors, Operational Amplifier and different ICs.

Course Contents

Unit-I **12 hours**

Transistor Amplifiers: Theory of semiconductors, Semiconductor devices: diode, homo and hectojunction devices, Transistor, Device structure and characteristics, Amplifiers, Frequency dependence and applications, Impedance matching, H and R parameters and their use in small signal amplifiers, Conversion formulae for the h-parameters of the different transistor configurations, Analysis of a transistor CE amplifier at low frequencies using h-parameters, CE amplifier with unbypassed emitter resistor, Emitter follower at low frequencies, Emitter-coupled differential amplifier and its characteristics, Cascaded amplifiers, Transistor biasing, Self-bias and thermal stability, filtering, Noise reduction, Low frequency power amplifiers, High frequency devices.

Unit-II **10 hours**

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.

Unit-III **12 hours**

Feedback: 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, Sinusoidal oscillators: RC oscillators: Phase shift and the Wien's bridge oscillators, LC oscillators, Frequency stability and the crystal oscillators, lockindetector , Box Car integrator and modulation techniques.

Unit-IV **11 hours**

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.

Transaction Mode:

Lecture, demonstration, problem solving, PPT.

Suggested Readings:

1. Millman J, Halkias C and Parikh C.(2011). *Integrated Electronics: Analog and Digital Circuits and Systems*. Noida, India: Tata McGraw - Hill Education.

2. Boylestad R.L and L. Nashelsky.(2013). *Electronic Devices and Circuit Theory.* New Delhi, India: Pearson.
3. TherajaB.L.(2019). *Basic Electronics: Solid State.*New Delhi, India: S. Chand & Company Ltd.
4. Chattopadhyay D.and Rakshit P. C.(2016). *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: The students will learn:
- Use of computers for solving physics based problems.
- Usage of C language to solve a mathematical problem and various physics problems.

Course Contents
Students have to perform at least five experiments from Part-A and five experiments from Part-B.

Part-A

1. To find the root of nonlinear equation using Bisection method.
2. To study the numerical convergence and error analysis of non-linear equation using Newton Raphson method.
3. To find the value of y for given value of x using Newton's interpolation method.
4. Perform numerical integration on 1-D function using Trapezoid rule.
5. Perform numerical integration on 1-D function using Simpson rules.
6. To find the solution of differential equation using Runge-Kutta method.
7. To find the solution of differential equation using Euler's method.
8. Choose a set of 10 values and find the least squared fitted curve.
9. To find eigenvalues and eigenvectors of a Matrix.
10. To find solutions of linear equations using Gauss elimination method.

Part-B

1. Study the motion of spherical body falling in viscous medium using Euler method.
2. To study the path of projectile with and without air drag using Fynmen-Newton method.
3. Study the motion of an artificial satellite around a planet.

4. Study the motion of one dimensional harmonic oscillator without and with damping effects.
5. To obtain the energy eigenvalues of a quantum oscillator using Runge-Kutta method.
6. Study the motion of charged particles in uniform electric field, uniform magnetic field and combined uniform EM field.
7. To study the phenomenon of nuclear radioactive decay.
8. To study the EM oscillation in a LCR circuit using Runge-Kutta method.
9. To find the solution of 1D heat flow equation using Finite Element Method.

Transaction Mode:
Demonstration, experimentation.

Suggested Readings:

1. KanetkarY.(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	Cr
0	0	4	2

Course Code: PHY.512
Course Title: Electronics Laboratory
Total Hours: 60

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

- Examine complete circuit analysis
- Examine practically working of Diode/Transistors discussed in the theory classes.
- Explain practically logic gate, flip-flop, counter, resister and different digital operations through different ICs.
- Test precise measurements and sensitive equipment.

Course Contents
The students have to perform the following experiments.
1. Power supplies: Bridge rectifiers with capacitive input filters.
2. Power supplies: Shunt Voltage regulator using Zener diode.
3. Clipping and Clamping along with CRO.

4. Common Emitter Amplifier with and without feedback.
5. Determination of h-parameters in the CE configuration using the measured input and output characteristics of a BJT.
6. Common Source and Common Drain Amplifiers using JFET.
7. RC Oscillators: Phase shift oscillator using RC ladder network as the phase shifting network.
8. Wien's Bridge Oscillator.
9. Colpitts Oscillators.
10. Hartley Oscillators.
11. Emitter Coupled Differential Amplifier using BJT's.
12. Multivibrators – Bistable, Monostable and Free Running multivibrators
13. Op-Amp characteristics: Vio, Ib, Vol, CMRR, Slew Rate. Applications of Op-amps: inverting Amplifier, Unity Gain Buffer, Summing Amplifier.
14. 555 IC timers. Free Running and Monostable Multivibrators, Sawtooth wave generator.
15. Realization of universal logic gates.
16. Implementation of the given Boolean function using logic gates in both SOP and POS form.
17. Perform the logic state tables of RS and JK flip-flops using NAND & NOR gates.
18. Perform the logic state tables of T and D flip-flops using NAND &NOR gates.
19. Perform the Verification of logic state tables of master slave flip flop using NAND & NOR gates.
20. Triggering mechanism of flip flop.
21. Perform the Realization of Half adder and full adder.
22. Perform the Half substractor and full substractor.
23. Decoders and code converters.
24. Up/Down Counters.
25. Shift Resistor.

Transaction Mode:
Demonstration, experimentation.

Suggested Readings:
1. Millman J, Halkias C and Parikh C.(2011). *Integrated Electronics : Analog and Digital Circuits and Systems.* Noida, India: Tata McGraw-Hill Education.
2. BoylestadR.L&Nashelsky L.(2013).*Electronic Devices and Circuit Theory*. New Delhi: Pearson.
3. Theraja B. L.(2019). *Basic Electronics: Solid State.* New Delhi: S. Chand & Company Ltd.
4. Chattopadhyay Dand Rakshit P. C.*(2016).Electronics: Fundamentals and Applications.* New Delhi, India: New Age International.
5. Saha G, Malvino A.P and Leach D.P.(2014). *Digital Principles and Applications.* Noida, India: Tata McGraw - Hill Education.

6. Malvino P and Brown J.A.(2017). *Digital Computer Electronics* Noida, India*:* Tata McGraw - Hill Education.
7. Hawkins C and Segura J.(2010). *Introduction to Modern Digital Electronics.* New York, USA: Scitech Publishing.

L	T	P	Cr
0	0	4	2

Course Code: PHY.513
Course Tile: Modern Physics Laboratory
Total Hours: 60

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

- Analyze various theoretical aspects of modern physics in various experiments in modern Physics.
- Measure planks constant using photoelectric effect experiment.

Measure ionization potential of Ar, band gap of semiconductor, wavelength of laser etc.

Course Contents

Student has to perform following experiments.

1. Ionization potential by Franck Hertz experiment.
2. Photo electric effect.
3. Band gap of a semiconductor by Four Probe method.
4. Wavelength measurement of laser using diffraction grating.
5. Michelson interferometer.
6. Fabry-Perot Interferometer.
7. Dual nature of electron experiment.
8. Millikan's oil drop experiment.
9. Stefan's law.
10. Zeeman effect experiment.

Transaction Mode:

Demonstration, experimentation, group learning.

Suggested Readings:

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

L	T	P	Cr
2	0	0	2

Course Code: PHY.514
Course Tile: Physics in Everyday Life
Total Hours: 30
Learning Outcomes: Students will learn

- The important role of physics in the everyday life of human beings.
- The Physics principles in earth's atmosphere, human body, sports, and technology.
- To apply the physics principles in another discipline as a way to deepen the learning experience.

Course Contents

Unit-I **8 hours**
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.

Unit-II **7 hours**
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.

Unit-III **8 hours**
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.

Unit-IV **7 hours**
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.

Transaction Mode: Lecture, demonstration, PPT.

Suggested Readings:
1. Louis A. Bloomfield. (2013).How Things Work THE PHYSICS OF EVERYDAY LIFE: Wiley.
2. Sears andZemansky.(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 Subramaniam.(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.

SEMESTER II

L	T	P	Cr
3	0	0	3

Course Code: PHY.521
Course Title: Advanced Quantum Mechanics
Total Hours: 45

Learning Outcomes: At the completion of course students will be able to:
- Outline WKB method and bound states of potentials well.
- Explain scattering theory for various kind of potential problems.
- Explain the importance relativistic quantum mechanics.
- Apply quantum mechanical concepts in many electron atoms.

Course Contents

Unit-I **11 hours**
WKB Method and its Applications: Generalformulation 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.

Unit-II **11 hours**
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.

Unit-III **11 hours**
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.

Unit-IV **12 hours**
Many Electron Atoms: Spin-Statistics connection, Pauli's exclusion principle, Slater determinant, Exchange energy: Parahelium and orthohelium,

Independent particle model, Hartree-Fock equations, Born-Oppenheimer approximation, Elementary idea of density functional theory.

Transaction Mode:
Lecture, tutorial, problem solving.

Suggested Readings:

1. Venkatesan K, Mathews P.M.(2010). *A Textbook 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. ZettiliN.(2009). *Quantum Mechanics: Concepts and Applications* . Sussex, U.K: John Wiley & Sons Ltd.
5. Griffiths D. J.(Second Edition,2015). *Introduction to Quantum Mechanics*. India: Pearson Education.
6. Mahan G. D.(2009).Quantum Mechanics in a Nutshell. Princeton University Press.
7. Khanna M.P.(1999).Quantum Mechanics. New Delhi: Har Anand Pub.
8. Foot C.J.(2005). Atomic Physics. Oxford, U. K: Oxford University Press.
9. Banwell C.N and McCash E. M.(1983). Fundamentals of Molecular Spectroscopy. Tata, McGraw Hill Publishing Company Limited.

L	T	P	Cr
3	0	0	3

Course Code: PHY.522
Course Title: Electromagnetic Theory
Total Hours: 45

Learning Outcomes:
- Students will able to explain various concepts of electrostatics and magnetostatics.
- Students will solve the boundary value problems and will estimate required field.
- Students will discuss the propagation of electromagnetic waves in dielectrics, insulator and metals.
- Students will find its importance in the design of accelerator, TEM, SEM etc.

Course Contents

Unit-I **12 hours**

Electrostatics: Gauss's law and its applications, Work and energy in electrostatics, Electrostatic potential energy, Poisson and Laplace equations, Uniqueness theorem I & II, Multipole expansion, Dielectrics and conductors, Boundary condition with dielectrics.

Unit-II **11 hours**

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,

Unit-III **11 hours**

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.

Unit-IV **12 hours**

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.

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 88 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	Cr
3	0	0	3

Course Code: PHY.523
Course Title: Solid State Physics
Total Hours: 45
Learning Outcomes: The learners will be able to

· Develop a clear and logical presentation of the basic and advanced concepts and principles of solid state physics such as crystal structure of many materials, XRD of different crystal structures.

· Outline theory of lattice vibrations and its applications to heat capacity, thermal expansion, thermal conductivity, Free Electron and band theory of solids.

· Outline the different types of Defects, Dislocations and various phenomenon and application of superconductivity.

Course Contents

Unit-I **12 hours**

Crystal Structure and its determination: Bravais lattices, Crystal structures, Reciprocal lattices, Ewald sphere, X-ray diffraction, Lattice parameter determination, Atomic scattering factor, crystal structure factors for various structures, Intensity of diffraction maxima, Indexing of peaks for cubic structure, Electron and neutron diffraction.

Bonding in solids: Ionic bonding and its properties, calculation of Cohesive energy for ionic crystal, Evaluation of Madelung constant for ionic structure, Covalent, Metallic and Van Der Waals bonding and calculation of cohesive energy, Hydrogen bond, Ordered phases of matter: translational and orientational order, kinds of liquid crystalline order, Quasicrystals.

Unit-II **11 hours**

Lattice Dynamics: Elastic properties of solids, Vibrations of linear monatomic and diatomic lattices, Acoustical and optical modes, Long wavelength limits, Optical properties of ionic crystal in the infrared region, Normal modes and phonons, Inelastic scattering of neutron by phonon, Lattice heat capacity, Models of Debye and Einstein, Comparison with electronic heat capacity, Thermal expansion, Thermal conductivity and Thermal Resistance of solids.

Free Electron Theory: Free electron theory, Density of states, Drude model and Sommerfeld theory of electrical and thermal conductivity, Boltzmann transport equation (Response and relaxation phenomena), Hall Effect and quantum Hall effect (Integral and Fractional), Thermoelectric power (Seebeck, Peltier, and Thomson effect).

Unit-III **11 hours**

Band Theory of Solids: 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 motion of electrons in periodic crystals, Band theory for nearly free electron, Band gap, Number of states in a band, Nearly free electron approximation, Tight binding approximation, Effective mass of an electron in a band, Classification of metal, Semiconductor (Direct and Indirect) and insulator, Band structure of semiconductor materials.

Unit-IV **11 hours**

Defects and Dislocations: Point defects (Concentration of Frenkel and Schottky), Line defects (slip, plastic deformation, edge and screw dislocation, Burger's vector, mechanism of dislocation motion), Frank-Reid mechanism of dislocation multiplication, Strength of alloy, Role of dislocation in crystal growth, Surface defects: Grain boundaries and stacking faults, volume defects.

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 T_C superconductors: Basic ideas and applications.

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	Cr
3	0	0	3

Course Code: PHY.524
Course Title: Digital Electronics
Total Hours: 45

Learning Outcomes: On completion of the course, students would be able to

- Construct different circuit operations
- Explain signal processing, their applications and Digital Circuitry: Combinational/Sequential Logic Operation
- Inspect Data Conversion (A/D and D/A)

Course Contents

Unit-I **11 hours**

Basics: Logic gates and their realization using diodes and transistors, Boolean algebra, Boolean equation of logic circuits, de-Morgan theorem, Method of realization a circuit for given truth table, Sum of product (SOP) and product of sum (POS) representation, Karnaugh map and their applications.

Unit-II **12 hours**

Combinational Circuits: Design procedure, Adders-subtractors, Carry look ahead adder, BCD adder, Magnitude comparator, Multiplexer/demultiplexer, Encoder/decoder, parity checker, Code converters, Implementation of combinational logic.

Unit III **11 hours**

Sequential Circuit:SR, JK, D and T flip flop, Master slave flip flops, Triggering mechanism of flip flop, Realization of one flip flop using other flip flops, Asynchronous/ripple counters, Synchronous counters, Shift counters, Shift registers, Universal shift register, MSI and LSI based design, MSI and LSI implementation on sequential circuit.

Unit IV **11 hours**

Logic devices and 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.

Suggested Readings:

1.Saha G, Malvino A.P. and Leach D.P.(2014). *Digital Principles and Applications.* Noida, India: Tata McGraw - Hill Education.
2.Malvino P. and Brown J.A. (2017). *Digital Computer Electronics* Noida, India*:* Tata McGraw - Hill Education.
3.Hawkins C. and Segura J.(2010). *Introduction to Modern Digital Electronics.* New York, USA: Scitech Publishing.
4.Kumar A. A. (2016) Fundamentals of Digital CircuitsNoida, India: Tata McGraw - Hill Education.

Transaction Mode: Lecture, demonstration, problem solving, PPT.

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
- Determine various parameters of solids such as Hall voltage, Dielectric constant, Curie temperature of solids.
- Determine susceptibility, retentively, coercivity, and saturation magnetization of magnetic materials
- Deterine magneto resistance, lattice vibration, specific heat, thermal expansion and conductivity, XRD pattern etc of solids

Student has to perform any of ten experiments from the following experiments:

Course Contents
1) Determination of carrier concentration and their sign in semiconductor atroom temperature by Hall Effect.
2) Determination of dielectric constant of PZT material with Temperature variation and thus determining Curie temperature.
3) Electrons spin resonance.
4) Magnetic parameters of a magnetic material by hysteresis loop tracer.
5) To determine the magnetic susceptibility of $NiSO_4$, $FeSO_4$, $CoSO_4$ by Gauy's method.

6) To determine magneto resistance of a bismuth crystal as a function of magnetic field.
7) Determination of critical temperature of high temperature superconductor and Meissner effect for a high Tc superconductor.
8) Determination of ferromagnetic to paramagnetic phase transition temperature (T_C = Curie temperature).
9) Determination of dielectric constant of solids.
10) 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.
11) Study of thermal expansion of solids.
12) Study of thermal conductivity of solids.
13) Study of specific heat of solids.
14) Study of X-ray diffraction pattern of NaCl.

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.526
Course Title: Measurement Science
Total Hours: 30

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

- Explain units and measurements.
- Explain measurement methods and characteristics of fundamental units.

Course Contents

Unit-I **15 hours**

Units of Measurement: Fundamental units, Derived units, Systems of units, Conversion of units, Accuracy, precision and errors in measurements, Dimensional analysis, and its applications.

Unit-II **15 hours**

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.

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	Cr
3	0	0	3

Course Code: PHY.527
Course Title: FunctionalMaterials and Devices
Total Hours: 45

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

- Assess important role in the growing field of materials research
- Judge of innovative/smart modern materials
- Explain fundamental principles of various advanced functional materials and Devices

Course Contents

Unit-I **11 hours**

Advanced Ceramic and Smart Materials: Ceramic Materials: Classification, Preparation and Properties, Composites, Smart Materials exhibiting: Ferroelectric, Dielectrics, Piezoelectric, Thermoelectric, Luminescence, Photocromics, Thermocromics and Electrocromic Materials, Phase Change Material, Shape Memory Alloys, Smart Structure and Robotics.

Unit-II **11 hours**

Magnetic and Multiferroics Materials: Ferrites, Gaint magnetoresistance (GMR), Magnetic materials for recording and computers,Spin Polarization, Colossal Magnetoresistance (CMR), La and Bi-based Perovskite, Spin-Glass, Spintronics:Magnetic tunnel junction, Spin transfer torque, Applications, Multiferroics: Types and Mechanism, $BiFeO_3$ and $BaTiO_3$ Multiferroics.

Unit-III **11 hours**

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, Film blowing, Melt spinning etc Composites: Varieties, Role of Matrix Materials, Mixing Rules, Polymer composites and nanocomposites (PNCs), PNCs for Li-ion battery, Supercapacitor, fuel cell, LED's and solar cell, synthesis and engineering of PNCs.

Unit-IV **12 hours**

Devices: Photovoltaic, Solar Energy, Nanogenerators, LED, Electrochromic displays (n & p-type materials, electrolytes, device fabrication and property measurements), Resistive switching, Supercapacitor and Li-ion batteries (Types and Properties: Crystallinity, Free ions and ion pair's contribution, Ionic radii of migrating species, Ionic Conductivity, Transport parameters, Transference Number, Thermal Stability, Porosity and Electrolyte Uptake/Leakage, Thermal Shrinkage, Glass transition temperature, Electrochemical Stability, Mechanical Stability) Advantages and Disadvantages, Ragone plot, Nyquist plot, Charging-discharging.

Fuel Cell (Alkaline Fuel Cell, Polymer Electrolyte Membrane Fuel Cell, Direct Methanol Fuel Cell, Solid Oxide Fuel Cell,).

Transaction Mode:

Lecture, PPT.

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 JusefHassoun.(2013). Lithium Batteries: Advanced Technologies and Applications.John Wiley & Sons, Inc.
4. Ogale S.B, Venkatesan T.V, BlamireM.(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. Cuility 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 Supercapacitors: Scientific Fundamentals and Technological Applications.* Springer.

L	T	P	Cr
3	0	0	3

Course Code: PHY:528
Course Title: Computational Solid State Physics
Total Hours: 45

Learning Outcomes: At the end of the course the students will learn to:

- Compute the properties of materials using modern computational methods.
- Apply the laws of quantum physics and the concepts of solid state physics to compute the properties of materials.
- Explain the details of density functional theory for electronic structure problems, pseudopotential approach, plane waves and localized orbitals basis sets methods.

Course Contents

Unit-I **12 hours**

Density Functional Theory (DFT): Electron density in DFT, Hohenberg-Kohn theorems, Kohn-Sham formulation, Exchange-correlation functionals: local density approximation and generalized gradient approximations.

Unit-II **11 hours**

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.

Unit-III **11 hours**

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.

Unit IV **11 hours**

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.

Transaction Mode:

Lecture, demonstration, tutorials, power point presentations.

Suggested Readings:

1. Gunn Lee June.(2011).*Computational Materials Science: An Introduction.*CRC Press.
2. KaxirasEfthimious.(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 Code: PHY.529
Course Title: Nanostructured Materials
Total Hours: 45

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

- Explain important role in the growing field of materials research

- Decide innovative/smart modern materials
- Justify nanomaterials and their properties
- Plan synthesis via different methods/rout
- Analyze different characterization tools that are used to probe the nanomaterials application/devices.

Course Contents

Unit I **12 hours**

Nanomaterials, Properties and Applications: Low-dimensional materials: Quantum dot, tube and well, Some special nanomaterials: Synthesis, properties and applications of Fullerenes, Carbon Nanotubes (SWCNT and MWCNT) and Nanowires, Graphene, Porous materials: Porous silicon, Aerogel, Quantum size effect, Self-assembly of Nanomaterials, Structural, Electrical, optical, mechanical, chemical, and magnetic properties at nanoscale, Applications and benefits of nanotechnology, Nanotechnology Ethics and Environment, Challenges and Future of nanotechnology.

Unit II **11 hours**

Synthesis of Nanomaterials: Fabrication methods i.e. top-down and bottom-up approach, Synthesis of nanomaterials by Physical, Chemical and Biological methods, Thin Film nanomaterials, Electrolytic deposition, Thermal evaporation, Spray pyrolysis, Sputtering, Pulse laser deposition, LB, Spin coating, Dip coating, Solution cast, Tape casting, Sol gel, Chemical vapour deposition, Molecular beam epitaxy, Cluster beam evaporation, Ion beam deposition, Chemical bath deposition with capping techniques.

Unit III **11 hours**

Characterization: Characterization of nanomaterials for the structure, X-Ray diffractogram (XRD), Transmission electron Microscopy (TEM), Fluorescent microscopy, Scanning electron microscopy (SEM), Scanning tunneling microscopy (STM), Scanning-probe microscopy (SPM), Atomic force microscopy (AFM), Impedance spectroscopy, Dielectric spectroscopy, Fourier transform infrared spectroscopy (FT-IR)**,** Raman Spectroscopy, Thermogravimetric Analysis (TGA), Differential scanning calorimetry (DSC), UV-Visible spectroscopy

UNIT-IV **11 hours**

Applications in Device Fabrication: Electrochromic devices based on nanostructures, Photovoltaic devices, LEDs, Solar cell, Memory devices, Supercapacitors, Lithium ion batteries, Fuel cells, Organic semiconductors.

Transaction Mode:

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

Suggested Readings:

1. Ogale S. B., Venkatesan T. V., and Blamire,Functional M. G. (2013) Metal Oxides: New Science and Novel Applications : Wiley-VCH
2. Chan R. W. and Hassen P. (1983). North Holland Physical Metallurgy: Vol. 1 and Vol. 2 New York Publishing Company.
3. Smallman R. E. (1999). Modern Physical Metallurgy and Materials Engineering: 6th Edition Butterworth-Heinemann
4. Greg Haugsta (2012). Atomic Force Microscopy: Understanding Basic Modes and Advanced Applications :John Wiley & Sons,
5. Murty B.S, Shankar P., Raj B., Rath B. B., and Murday J., (2013) Textbook of Nanoscience and Nanotechnology: Springer.
6. Klaus D. Sattler. (2010). Handbook of Nanophysics : CRC press,
7. Claudia Gutirrez-Wing, Jos Luis Rodrguez-Lpez, Olivia A. Graeve, and Milton Muoz-Navia. (2013)Nanostructured Materials and Nanotechnology : Cambridge University Press.
8. Surender Kumar Sharma (2018), Handbook of Materials Characterization, Springer

L	**T**	**P**	**Cr**
3	0	0	3

Course Code: PHY.530
Course Title: Nonlinear and Quantum Optics
Total Hours: 45

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

- Understand the non-linear optical phenomenon, Kerr optics, optical amplification, optical parametric amplification, ultrafast optics, and stimulated Brilluoin scattering.
- Develop a strong background to pursue research in optics and laser physics.

Course Contents

Unit I **11 hours**

Nonlinear optics basics: Simple Harmonic Oscillator model, Anharmonic oscillator model, Nonlinear polarization, Nonlinear wave equation, Nonlinear susceptibilities and mixing coefficients.

Unit II **11 hours**

Second order nonlinear effects: Second harmonic generation, Phase matching condition, Various phase matching techniques, Characterization of second order nonlinear optical materials, Periodically poled materials and their applications in non-linear optical devices. Sum and difference frequency generation, Optical parametric amplification (OPA) and oscillation (OPO), Analysis of OPA and OPO; practical device configurations and applications.

Unit III **11 hours**

Third order and Higher order effects: Third harmonic generation, Four wave mixing and Self-phase-modulation Optical Kerr effect, Self-focusing, Optical Solitons; Optical phase conjugation and Optical bistability. Stimulated Raman Scattering and Stimulated Brilluoin Scattering.

UNIT-IV **12 hours**

Ultrafast and Quantum Optics: Introduction to ultrashort pulses, Ultrashort pulse generation through mode-locking, Nonlinear Schrödinger equation, Supercontinuum generation. Review of Quantum Mechanics basics, Quantization of electromagnetic fields, Number states, Coherent states and squeezed states of light and their properties, Beam splitters and interferometers, spontaneous parametric down conversion, concept of quantum entanglement, application of optical parametric processes to generate squeezed states of light and entangled states, applications of quantum optics.

Transaction Mode:

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

SEMESTER-III

L	T	P	Cr
3	0	0	3

Course Code: PHY.551
Course Title: Statistical Mechanics
Total Hours: 45

Learning Outcomes:

At the completion of course students will be able to:

- Explain the basics of thermodynamics and physical significance of various statistical quantities.
- Explain ensemble theory required for macroscopic properties of the matter in bulk in terms of its microscopic constituents.
- Summarize the Fermi-Dirac and Bose-Einstein distributions.

Course Contents

Unit-I **12 hours**

Basics of Thermodynamics: Laws of thermodynamics and their consequences, Thermodynamic potentials and Maxwell relations.

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.

Unit-II **11 hours**

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.

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.

Unit-III **11 hours**

Elements of Quantum Statistics: Quantum statistics of various ensembles, Ideal gas in various ensemble, statistics of occupation number, Thermodynamics of black body radiations.

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.

Unit-IV **11 hours**

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.

Thermodynamic Fluctuations: Diffusion equation, Random walk and Brownian motion, Introduction to nonequilibrium processes.

Transaction Mode:

Lecture, tutorial, problem solving.

Suggested Readings:

1. Pathria R.K and Beale Paul D.(2020). *Statistical Mechanics.*USA:Elsevier.
2. Huang K.(2007). *Statistical Mechanics.* New Delhi, India: Wiley India Pvt. Ltd.
3. SwendsenR.H.(2018). *An Introduction to Statistical Mechanics and Thermodynamics.* Oxford, U.K:Oxford University Press.
4. SadovskiiM.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. F. Rief. (2019) *Fundamentals of Statistical and Thermal Physics. Waveland press incorporation, NY, USA*

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:

- Students will able to explain nuclear shape, size, properties, interactions and decay.
- Students will compare among nuclear models
- Students will analyze types of nuclear detectors
- Students will solve different nuclear reactions
- Students will discuss about elementary particles

Course Contents

Unit-I **11 hours**

Nuclear size, shape and charge distribution, Mass and binding energy, Liquid drop model, semi-empirical mass formula,Spin, Parity and symmetry, Magnetic dipole moment and electric quadrupole moment.

Unit-II **11 hours**

Two Nucleon Problems: Nature of nuclear forces, Deuteron problem, Magnetic moment and electric quadrupole moment of deuteron, Scattering cross-section, n-p scattering, Partial wave analysis and phase shifts, Scattering length, Magnitude of scattering length and strength of scattering.

Unit-III **12 hours**

Nuclear Model: Evidence of shell structure, Shell model, Single particle shell model, its validity and limitations, Collective model, Vibrational and Rotational spectra, Exchange force model.

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.

Unit-IV **12 hours**

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.

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. BertulaniC.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. HeydeK.(2004). *Basic Ideas and Concepts in Nuclear Physics* An Introductory approach.London, U. K:CRC Press.
6. Povh B, Rith K, ScholC.(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:
Explain atomic, molecular, electronic, rotational, vibrational, and Raman spectra.

Unit I **12 Hours**

Electrons Systems: Quantum state of an electron in an atom, Spectrum of hydrogen, helium and alkali atoms, Electron spin, Spin - orbit coupling, Mass correction term, Relativistic correction for energy level of hydrogen atom, Lamb shift, Paschen-Back effect, Stark effect, and isotopic shift, Independent particle model, Central field approximation for many electron atom, Slater determinant, Equivalent and nonequivalent electrons, Energy levels and spectra, Spectroscopic terms.

Unit II **11 Hours**

Atomic Structure and Atomic Spectra: Revision of quantum numbers, Pauli's exclusion principle, electron configuration, Hund's rule etc. origin of spectral lines, selection rules, some features of one-electron, two-electron spectra and X-ray spectra, fine spectra, hyperfine structure, Level scheme for two electron atoms- LS and JJ coupling – multiplet splitting – Lande's 'g' factor, Lande's interval rule, Zeeman effect, Width of spectral lines.

Unit III **11 Hours**

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.

Unit IV **11 Hours**

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.

Transaction Mode:
Lecture, tutorial, problem solving.

Recommended books:

1. C.J. Foot, Atomic Physics (Oxford University Press, Oxford, U. K.) 2005.
2. W. Demtroder, Molecular Physics (Springer, New York, USA) 2008.
3. J.M. Hollas, Basic Atomic and Molecular Spectroscopy (Royal Soc. of Chemistry, London,2002.
4. G. Herzberg, Atomic Spectra and Atomic Structure (Dover Publications, New York, USA) 2010.
5. Introduction to Atomic Spectra, H. E. White, (McGraw Hill International Ed.)
6. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, (Tata, McGraw Hill Publishing Company Limited).

L	T	P	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

- Perform the various experiments related with G.M counter.
- Perform the various experiments related with gamma ray spectrometer.

Course Contents

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

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
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.

Transaction Mode:
Demonstration, experimentation.

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

L	T	P	Cr

3	0	0	3

Course Code: PHY.555

Course Title: Advanced Solid State Physics

Total Hours: 45

Learning Outcomes: The students will be able to

· Explain Fermi surfaces and their construction and the experimental methods used for detection of fermi surfaces.

· Explain the theories of magnetism.

· Explain plasmons, color centres, excitons, Raman effect, luminescence and optical properties of solids.

· Outline the theory of dielectrics and ferroelectrics.

Course Contents

Unit-I 11 hours

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.

Unit-II 11 hours

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 $T^{3/2}$ law, brief discussion of Kondo effect.

Unit-III 12 hours

Optical Processes, Exciton, Color Centres 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 centres 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, Thermoluminescence, mechanism and applications in dosimetry and dating.

Unit-IV **11 hours**

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.

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	Cr
3	0	0	3

Course Code: PHY:556
Course Title: Materials Characterizations
Total Hours: 45

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

- Analyze Microscopy analysis of the nanomaterials
- Interpret Spectroscopic analysis of the nanomaterials
- Interpret Surface Probe analysis of the nanomaterials
- Interpret Thermal and Transport analysis of the nanomaterials

Course Contents

Unit I **12 hours**

Microscopy: Optical Microscopy, Scanning Electron Microscopy (SEM), Field Emission Scanning Electron Microscopy (FESEM), Energy-dispersive X-ray spectroscopy (EDS), Transmission Electron Microscopy (TEM), High resolution TEM, Selected area electron diffraction (SAED).

Diffraction Methods: Generation and detection of X-rays, Diffraction of X-rays, X-ray diffraction techniques, Electron diffraction.

Unit II **11 hours**

Surface Probe Analysis: Atomic Force Microscope (AFM), Scanning Tunneling Microscope (STM), X-ray photoemission spectroscopy (XPS), Angle Resolved XPS (ARPS), Rutherford Back Scattering, Carbon Dating, Ion Beam (Low energy and high energy) irradiation.

Unit III **11 hours**

Spectroscopy: IR Spectroscopy, FTIR, UV-Visible spectroscopy, Raman Spectroscopy, Auger Spectroscopy, Impedance Spectroscopy (Nyquist Plot, Bode Plot, Electrical {: electronic, ionic, cationic} conductivity estimation, ac conductivity and Jonscher Power law), Dielectric Spectroscopy (Cole-Cole Plot, Cole-Davidson plot, Debye Plot, loss tangent, sigma representation, relaxation time), Modulus spectroscopy.

Unit IV **11 hours**

Thermal Analysis: Thermogravimetric analysis, Differential thermal analysis, Differential Scanning calorimetry, Modulated DSC, Dynamic Thermal Analysis, Universal tensile testing.

Transport Number Analysis: Transference Number(Electron, ion, cation transport measurement) Analysis, IV characteristics, Activation Energy Estimation (VTF and Arrhenius), Transport Parameters analysis.

Transaction Mode:
Lecture, demonstration, PPT

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

L	T	P	Cr
3	0	0	3

Course Code: PHY.557
Course Title: Nuclear Techniques
Total Hours: 45

Learning Outcomes: Students will explain the design of electron and ion accelerators.

- Students will analyze types of nuclear detectors
- Students will discuss the Interaction of radiation with matter
- Students will find importance Reactors and artificial radioisotopes
- Students will Analysis Nuclear reaction

Unit: I **12 hours**
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)

Unit: II **11 hours**
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.
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.

Unit: III **11 hours**

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.

Unit: IV **11 hours**

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.

Transaction Mode:

Lecture, demonstration, PPT.

Suggested Readings:

1. Kappor S. S and Rmanurthy V. S.(1986). Nuclear radiation detectors.NewDelhi: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:McGraw-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 Rmanurthy 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 Code: PHY:558
Course Title: Advanced Classical Mechanics
Total Hours: 30

Learning Outcomes: Student will able to

- Extend Hamiltonian formulations to Hamilton - Jacobi theory.
- Explain Rigid Body Dynamics.
- Elaborate concept of special theory of relativity in terms of formulations of classical Mechanics.
- Apply special theory of relativity to electrodynamics.

Course Contents

Unit-I **8 hours**

Hamilton-Jacobi Theory: Hamilton–Jacobi equation for Hamilton's principal function, Linear and damped harmonic oscillator problem by Hamilton-Jacobi method, Kepler's problem, Action angle variables, Application to Linear harmonic oscillator and Kepler's problem.

Unit-II **7 hours**

Rigid Body Dynamics: Euler's angles, Euler's theorem, Moment of inertia tensor, Non- inertial frames and pseudo forces: Coriolis force, Foucault's pendulum, Formal properties of the transformation matrix, Angular velocity and momentum, Equations of motion for a rigid body, Torque free motion of a rigid body-Poinsot solutions, Motion of a symmetric top under the action of gravity.

Unit-III **8 hours**

Special Theory of Relativity: Lorentz transformations and its consequences: Length contraction, Time dilation, etc., Relativistic kinematics and mass energy equivalence, Four vectors, Covariant formulation of Lagrangian and Hamiltonian.

Unit-IV **7 hours**

Relativistic Electrodynamics: Lorentz transformation law for the electromagnetic fields and the fields due to a point charge in uniform motion, Field invariants, Covariance of Lorentz force equation and dynamics of a charged particle in static and uniform electromagnetic fields.

Transaction Mode:

Lecture, demonstration, PPT.

Suggested Readings:

1.Thornton S.T. and Marion J.B.(2013). *Classical Dynamics of Particles and Systems.* Boston/Massachusetts, United State: 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.Griffiths D.J.(2012). *Introduction to Electrodynamics*. New Delhi: Prentice Hall of 88 India Pvt.Ltd.
9.Einstein A. (2017), Relativity: The Special and the General Theory, Fingerprint Publishing, India.
10.Venkataraman G. (2018), At the Speed of Light, Universities Press Private Limited, India.

L	T	P	Cr
1	0	0	1

Course Title: Entrepreneurship

Course Code: PHY.559

Credit: 01

Course Outcomes: On the completion of this course, the learners will:

- Understand the basic concepts of entrepreneur, entrepreneurship and its importance.
- Aware of the issues, challenges and opportunities in entrepreneurship.

- Develop capabilities of preparing proposals for starting small businesses.

- Know the availability of various institutional supports for making a new start-up.

Unit – 1 **3 Hours**

Introduction to entrepreneur and entrepreneurship; Characteristics of an entrepreneur; Characteristics of entrepreneurship; entrepreneurial traits and skills; innovation and entrepreneurship; Types of entrepreneurial ventures; enterprise and society in Indian context; Importance of women entrepreneurship

Unit – 2 **5 Hours**

Promotion of a venture – Why to start a small business; How to start a small business; opportunity analysis, external environmental analysis, legal requirements for establishing a new unit, raising of funds, and establishing the venture - Project report preparation – format for a preliminary project report, format for a detailed/final project report.

Unit – 3 **4 Hours**

Physics as a tool for innovation, current challenges to be tackled in energy, health and environmental sectors, figuring out scientific needs of the society, physics in cross-disciplinary industries, examples of successful physics spin-offs, funding from scientific and governmental bodies.

Unit – 4 **3 Hours**

Communicating with data and statistics, hypothesis testing and modeling, importance of units and measurement, from idea to research to product design and development, scope of innovation in following areas: fusion and plasma physics, nanoscience and nanotechnology, condensed matter and materials physics, energy systems, biophysics, microsystems, optical physics, and quantum information science, molecular electronics, chip fabrication.

Suggested Readings:

1. Arora, Renu (2008). Entrepreneurship and Small Business, Dhanpat Rai & Sons Publications.

2. Chandra, Prasaaan (2018). Project Preparation, Appraisal, Implementation, Tata Mc-Graw Hills.

3. Desai, Vasant (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.

6. Iannuzzi, Davide (2017) Entrepreneurship for Physicists: A Practical Guide to Move Inventions from University to Market, IOP Science

7. Orville R. Butler, M. Juris, R. Joseph Anderson, (2013), Physics Entrepreneurship and Innovation, American Institute of Physics.

Course Code: PHY.600

L	T	P	Cr
0	0	0	4

Course Title: Research proposal

Total Hours: 120

Learning outcomes:

- Critically analyze, interpret, synthesize existing scientific knowledge based on literature review
- Demonstrate an understanding of the selected scientific problem and identify the knowledge gap
- Formulate a hypothesis and design an experimental/theoretical work

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.

Students will have an option to carry out dissertation work in industry, national institutes or Universities in the top 100 NIRF ranking. 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