CENTRAL UNIVERSITY OF PUNJAB, BATHINDA

M.SC. PHYSICS

ACADEMIC SESSION 2020 – 22

DEPARTMENT OF PHYSICAL SCIENCES

SCHOOL OF BASIC AND APPLIED SCIENCES

Learning Outcomes of the Programme:

The students will be able to have:

- enhanced basics and advanced knowledge related to various subjects of physics.
- Students completing this programme will be competitive enough to work in the industry, education, and research.
- Students will be able to apply the knowledge of physics in various area 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	C	4	0	0	4
2	PHY.507	Classical Mechanics	C	4	0	0	4
3	PHY.508	Quantum Mechanics	C	4	0	0	4
4	PHY.509	Electronics	C	4	0	0	4
5	PHY.510	Electronics Laboratory	SE	0	0	6	3
6	PHY.511	Modern Physics Laboratory	SE	0	0	6	3
7	XXX	IDC to be opted by Students from other Departments	IDC	2	0	0	2
		Total Credits		**18**	**0**	**12**	**24**
	PHY.512	Physics in Everyday Life (For students of other departments)	IDC	2	0	0	2

SEMESTER-II

Sr. No	Course Code	Course Title	Course Type	L	T	P	Cr
1	PHY.521	Numerical Methods	CF	2	0	0	2
2	PHY.522	Numerical Methods laboratory	SE	0	0	4	2
3	PHY.523	Quantum and Atomic Physics	C	4	0	0	4
4	PHY.524	Electromagnetic Theory	C	4	0	0	4
5	PHY.525	Solid State Physics	C	4	0	0	4
6	PHY.526	Solid State Physics Laboratory	SE	0	0	8	4
7	XXX	IDC to be opted by Students from other Departments	IDC	2	0	0	2
		Total Credits		**16**		**12**	**22**
	PHY.527	Introduction to Nanotechnology (For students of other departments)	IDC	2	0	0	4

SEMESTER-III

Sr. No	Course Code	Course Title	Course Type	L	T	P	Cr
1	PHY.551	Statistical Mechanics	C	4	0	0	4
2	PHY.552	Nuclear and Particle Physics	C	4	0	0	4
3	PHY.553	Nuclear Physics Laboratory	SE	0	0	8	4
4		Elective Course-I, Opt Any One*/MOOC#	DE	4	0	0	4
	PHY.554	Advanced Solid State Physics					
	PHY.555	Nuclear Techniques					
	PHY.557	Functional Materials and Devices					
	PHY.559	Computational Solid State Physics					
5	PHY.543	Seminar-I	SE	0	0	0	1
6	PHY.599	Project Work-I	SE	0	0	0	6
7	PHY504	Units, Measurement and Measurement Characteristics	VAC	1	0	0	1
Total Credits				**13**	**0**	**8**	**24**

SEMESTER-IV

Sr. No	Course Code	Course Title	Course Type	L	T	P	Cr
1	PHY.571	Research Methodology	CF	4	0	0	4
2	PHY.572	Advanced Physics-I	DEC	2	0	0	2
3	PHY.573	Advanced Physics-II	DEC	2	0	0	2
4		Elective Course-II	DE	4	0	0	4
	PHY.574	Introduction to Mesoscopic Physics					
	PHY.575	Particle Physics					
	PHY.576	Nanostructured Materials					
	PHY.577	Materials Characterization					
5	PHY.544	Seminar-II	SE	0	0	0	1
6	PHY.599	Project Work-II	SE	0	0	0	6
7	PHY505	Units, Measurement and Measurement Characteristics	VAC	1	0	0	1
Total Credits				**13**	**0**	**0**	**20**
Total Credits for M.Sc. Physics Program: 90							

*These course will be offered as per the facilities and expertise available in the department.

In addition to the above elective courses, students can opt any MOOC course related to Physics and the syllabus of MOOC course should not overlap with any course already taught in the M.Sc. Physics program.
CF: Compulsory Foundation, **C**: Core, **DE**: Discipline Elective, **IDC**: Inter-Disciplinary Elective, **SE**: Skill-based Elective, **VAC**: Value Added Courses, **MOOC:** Massive Open Online Course, **DEC:** Discipline Enrichment Corse, **L**: Lecture, **T**: Tutorial, **P**: Practical.

Evaluation Criteria for Theory Courses

A	**Continuous Assessment**	25 Marks
	i. Surprise Test (minimum three) - Based on Objective Type Test	10 marks
	ii. Term Paper	10 marks
	iii. Assignment(s)	5 marks
B	**Mid Semester Test:** Based on Subjective Type Test	25 marks
C	**End Semester Test:** Based on Subjective Type Test	25 marks
D	**End Semester Examination:** Based on Objective Type Test	25 marks

SEMESTER-I

Course Code: PHY.506
Course Title: Mathematical Physics
Total Hours: 60

L	T	P	Cr
4	0	0	4

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

- Learn about the transformation of coordinates, matrix algebra, complex functions, symmetry, Group theory, tensors,
- Develop a strong background to pursue research in theoretical physics.

Course Contents

Unit-I **15 hours**
Vector Calculus, Matrices & Tensors: Vector calculus: properties of Gradient, divergence and Curl, matrix algebra, Solution of linear equations. Linear transformations. Change of Basis. Caley-Hamilton theorem, Eigen values and Eigen vectors, curvilinear coordinates (spherical and cylindrical coordinates).

Unit-II **15 hours**
Tensor: Tensors, Symmetric and antisymmetric, kronecker and Levi Civita tensors.
Delta, Gamma, and Beta Functions: Dirac delta function, Properties of delta function, Gamma function, Properties of Gamma and Beta functions.

Unit-III **15 hours**
Symmetry and Elements of group theory: Symmery elements, Point groups, Character tables for some point groups and the orthogonality theorem. Group postulates, Lie group and generators, representation, Commutation relations, SU(2), O(3).

Unit-IV **15 hours**
Complex Variable: Elements of complex analysis, Analytical functions, Cauchy-Riemann equations, Cauchy theorem, Properties of analytical functions, Contours in complex plane, Integration in complex plane, Deformation of contours, Cauchy integral representation, Taylor and Laurent series, Isolated and essential singular points, Poles, Residues and evaluation of integrals, Cauchy residue theorem and applications of the residue theorem.

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.

Course Code: PHY.507
Course Title: Classical Mechanics
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning Outcomes: The learners will be able to

- Explain tools of classical Mechanics such as Newton's laws, Lagrangian mechanics and Hamiltonian formalism.
- Extend Hamiltonian formulations to Hamilton - Jacobi theory.
- Apply the formulations of classical Mechanics to the central force problem.
- Solve scattering theory problems and small oscillation's problems.
- Formulate the problems of rigid body dynamics based on Lagrangian.

Course Contents

Unit-I **16 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 **16 hours**

Hamiltonian Formalism: Variational principle and Problems, Principle of least action, Hamilton's principle, 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, Relativistic Lagrangian and Hamiltonian, Dynamical systems, Phase space dynamics and stability analysis.

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-III **14 hours**

Canonical Transformations and Poisson Brackets: Canonical transformation and problems, Poisson brackets, 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 **16 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 symmetrical top under the action of gravity.

Two Body Problems: Central force motions, Reduction to the equivalent one-body problem, Differential equation for the orbit and classification of orbits, Condition for closed orbits (Bertrand's theorem), 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.(1991). *Classical Mechanics.* Noida, India:Tata McGraw-Hill.

5. Thornton S.T and Marion J.B.(2013). *Classical Dynamics of Particles and Systems*. Boston/Massachusetts, United State: Cengage Learning.
6. Safko J, Goldstein H and Poole C. P.(2011). *Classical Mechanics.* New Delhi, India:Pearson.
7. Walter G.(2010). *Systems of Particles and Hamiltonian Dynamics.* New York, USA:Springer.

Course Code: PHY.508
Course Title: Quantum Mechanics
Total Hours: 60

L	T	P	Cr
4	0	0	4

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.
- Outline WKB method and bound states of potentials well.
- Explain scattering theory for various kind of potential problems.

Course Contents

Unit-I **14 hours**
Mathematical Formulation and Postulates of Quantum Mechanics: Limitations of Classical Mechanics and foundation of Quantum Mechanics, Review of linear vector spaces and related algebra and Hilbert space, Dirac notation, Operators: Hermitian, Unitary & Projection operators, Matrix representations of kets, bras and operators, Change of basis, Basic postulates of quantum mechanics, Schrödinger wave equation (time dependent and time independent), Expectation values, Commutation relations, Ehrenfest theorem. Generalized Heisenberg uncertainty principle, density matrix, Schrodinger, Heisenberg and Interaction pictures.

Unit-II **16 hours**
Applications of Schrödinger Wave Equation: Solution of Harmonic oscillator using wave mechanics and matrix mechanics: matrix representation and eigen values of various operators, Anisotropic and isotropic harmonic oscillator, The box potential.
Hydrogen Atom: Motion in central potential, Solution of Schrodinger equation for hydrogen atom. energy spectra of Hydrogen atom.
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.

Unit-III **16 hours**

Addition of Angular Momenta: 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. Wigner-Eckart Theorem (statement only)

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.

Unit-IV **14 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, Breit-Wigner resonance formula (statement only), Green's functions in scattering theory, Born approximation and its validity, Scattering for different kinds of potentials, Scattering of identical particles.

Transaction Mode:

Lecture, demonstration, tutorial, problem solving.

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.

Course Code: PHY.509
Course Title: Electronics
Total Hours: 60

L	T	P	Cr
4	0	0	4

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.
- 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 **16 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 **14 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 **16 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, lockin detector , Box Car integrator and modulation techniques.

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.

Unit-IV **14 hours**

Combinational and Sequential Logic: Adders-subtractors, Carry look ahead adder, BCD adder, Magnitude comparator, Multiplexer/demultiplexer, Encoder/decoder, Comparator Asynchronous/ripple counters, Synchronous counters, Shift counters, Shift registers, Universal shift register.

Data Converters: Analog to digital (A/D) data converters, Digital to analog (D/A) data converters.

Transaction Mode:

Lecture, demonstration, problem solving, PPT.

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.
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 C and Segura J.(2010). *Introduction to Modern Digital Electronics.* New York, USA: Scitech Publishing.

Course Code: PHY.510
Course Title: Electronics Laboratory
Total Hours: 90

L	T	P	Cr
0	0	6	3

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.
- Agree with magic of performance of Operational Amplifier
- Explain practically logic gate, flip-flop, counter, resister and different digital operations through different ICs.
- Test precise measurements and sensitive equipment.

Course Contents

The student has to perform any of eleven experiments from 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. 17.Perform the logic state tables of RS and JK flip-flops using NAND & NOR gates.
18. 18.Perform the logic state tables of T and D flip-flops using NAND & NOR gates.
19. 19.Perform the Verification of logic state tables of master slave flip flop using NAND & NOR gates.
20. 20.Triggering mechanism of flip flop.
21. 21.Perform the Realization of Half adder and full adder.
22. 22.Perform the Half substractor and full substractor.
23. 23.Decoders and code converters.
24. 24.Up/Down Counters.
25. 25.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. Boylestad 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 C and Segura J.(2010). *Introduction to Modern Digital Electronics.* New York, USA: Scitech Publishing.

Evaluation Criteria for Practical Courses

Sr. No.	**SECTIONS**	**MARKS**
A	**Continuous Assessment: Practical Day to Day‡**	**60**
	i. Lab Practical Records	30
	ii. Viva-voce	30
B	**End Term Practical Examination**	**30**
C	**Viva-voce in End Term Practical Examination**	**10**

‡ The evaluation of Lab Practical Records and Viva-voce have to be carried out after the successful completion of allotted experiment. The internal evaluation of practical to be considered for 100 marks. But, it will scale down out of 60 marks.

Course Code: PHY.511
Course Tile: Modern Physics Laboratory
Total Hours: 90

L	**T**	**P**	**Cr**
0	0	6	3

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 at least seven experiments from the following list of 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. Beiser A.(2007). *Concepts of Modern Physics.* Noida, India. Tata McGraw - Hill Education.

Evaluation Criteria for Practical Courses

Sr. No.	SECTIONS	MARKS
A	**Continuous Assessment: Practical Day to Day‡**	**60**
	i. Lab Practical Records	30
	ii. Viva-voce	30
B	**End Term Practical Examination**	**30**
C	**Viva-voce in End Term Practical Examination**	**10**

‡ The evaluation of Lab Practical Records and Viva-voce have to be carried out after the successful completion of allotted experiment. The internal evaluation of practical to be considered for 100 marks. But, it will scale down out of 60 marks.

Course Code: PHY.512
Course Tile: Physics in Everyday Life
Total Hours: 30

L	T	P	Cr
2	0	0	2

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 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 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

Course Code: PHY.521
Course Title: Numerical Methods
Total Hours: 30

L	T	P	Cr
2	0	0	2

Learning Outcomes: The students will learn to:

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

Course Contents

Unit-I **8 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 **7 hours**

Roots of Nonlinear Equations: Element of computational techniques: Error analysis, Propagation of errors. Roots of functions, Bracketing and open end methods: Bisection Method, False position method and Newton Raphson method.

Unit-III **8 hours**

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 **7 hours**

Numerical Solution of Ordinary Differential Equations: Euler method and Runge-Kutta method.

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

Transaction Mode:

Lecture, demonstration, PPT.

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*. 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.

Course Code: PHY.522
Course Title: Numerical Methods Laboratory
Total Hours: 60

L	T	P	Cr
0	0	4	2

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.

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.

Transaction Mode:
Demonstration, experimentation.

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,* NewDelhi: PHI Learning Pvt.Ltd.
4. Verma R. C,Ahluwalia P. K. & SharmaK.C.(1st edition,1999).Computational Physics. New Age.
5. Tao Pang.(2nd edition, 2006). an Introduction to Computational Physics. Cambridge University Press.

Evaluation Criteria for Practical Courses

Sr. No.	**SECTIONS**	**MARKS**
A	**Continuous Assessment: Practical Day to Day‡**	**60**
	i. Lab Practical Records	30
	ii. Viva-voce	30
B	**End Term Practical Examination**	**30**
C	**Viva-voce in End Term Practical Examination**	**10**

‡ The evaluation of Lab Practical Records and Viva-voce have to be carried out after the successful completion of allotted experiment. The internal evaluation of practical to be considered for 100 marks. But, it will scale down out of 60 marks.

Course Code: PHY.523
Course Title: Quantum and Atomic Physics
Total Hours: 60

L	**T**	**P**	**Cr**
4	0	0	4

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

- 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.
- Apply quantum mechanical concepts in atomic spectra.

Course Contents

Unit-I **16 hours**

Relativistic Quantum Mechanics: Klein-Gordon equation, Dirac relativistic equation, Gamma Matrices, Significance of negative energy.

Time-independent Perturbation Theory: Non-degenerate (1st and 2nd order) and degenerate case, Application of perturbation theory: charged oscillator in an electric field, Stark effect, Paschen-Bach Effect and Zeeman effect in hydrogen atom, Width of spectral lines.

Unit-II **14 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.

Unit-III **16 hours**

The Variational Method: Theory and its applications to ground state of harmonic oscillator and hydrogen atom, the ground state of helium and hydrogen molecule ion.

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.

Unit-IV **14 hours**

Atomic Spectra: Revision of quantum numbers, Electron configuration, Hunds rule etc, Origin of spectral lines, Electron spin, Spectroscopic terms, Spin-orbit interaction, Relativistic correction, LS & JJ coupling, Selection rules, Fine structure of hydrogen atom, Spectrum of helium and alkali atoms, X-ray spectra, Hyperfine structure and isotopic shift, Width of spectral lines.

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

Course Code: PHY.524
Course Title: Electromagnetic Theory
Total Hours: 60

L	T	P	Cr
4	0	0	4

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 **16 hours**

Electrostatics: Gauss's law and its applications, Work and energy in electrostatics, Electrostatic potential energy, Poisson and Laplace equations, Uniqueness theorem I & II, Energy density and capacitance.

Boundary Value Problems: General methods for the solution of boundary value problems, Solutions of the Laplace equation, various boundary value problems.

Multipoles and Dielectrics: Multipole expansion, Multipole expansion of the energy of a charge distribution in an external field, Dielectrics and conductors, Gauss's law in the presence of dielectric, Boundary value problems with dielectrics, , Electrostatic energy in dielectric media.

Unit-II **14 hours**

Magnetostatics: Biot-Savart law and Ampere's theorem, Electromagnetic induction, Vector potential and magnetic induction for a circular current loop,

Magnetic fields of a localized current distribution, Boundary condition on B and H, Uniformly magnetized sphere.
Magnetic Fields in Matter: Magnetization, Dia, para and ferro-magnetic materials, Field of a magnetized object, Magnetic susceptibility and permeability.

Unit-III **16 hours**
Maxwell's Equations: Maxwell's equations in free space and linear isotropic media, Boundary conditions on the fields at interfaces.
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, EM fields.

Unit-IV **14 hours**
Plane Electromagnetic Waves and Wave Equations: EM wave in free space, Dispersion characteristics of dielectrics, Waves in a conducting and dissipative media, Reflection and refraction, Polarization, Fresnel's law, Skin effect, Transmission lines and wave guides, TE mode, TM mode, Cut off wavelength, Phase Velocity, Group velocity and Guide wave length.
Radiation from Moving Point Charges and Dipoles: Retarded potentials, Lienard-Wiechert potentials, Radiation from a moving point charge and oscillating electric and magnetic dipoles, Dipole radiation, Multipole expansion for radiation fields.

Transaction Mode:
Lecture, Demonstration, Power point Presentations.

Suggested Readings:

1. Heald M.A and Marion J.B.(2012). *Classical Electromagnetic Radiation.*New York, USA:Dover Publications.
2. Griffiths D.J.(2012). *Introduction to Electrodynamics*. New Delhi: Prentice Hall of India Pvt.Ltd.
3. Zangwill A.(2012). *Modern Electrodynamics.* Cambridge, U.K: Cambridge University Press.
4. Jackson J.D.(2004). *Classical Electrodynamics.* New Delhi, India: Wiley India (P) Ltd.
5. Lifshitz E.M, Landau L.D and Pitaevskii L.P.(1984). *Electrodynamics of Continuous Media.* New York, USA:Elsevier.

Course Code: PHY.525
Course Title: Solid State Physics
Total Hours: 60

L	T	P	Cr
4	0	0	4

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.
- Elaborate various types of magnetism, magnetic properties and magnetic resonance of solids.
- Outline the different types of Defects, Dislocations and various phenomenon and application of superconductivity.

Course Contents

Unit-I **17 hours**

Crystal Structure and its determination: Bravais lattices, Crystal structures, Reciprocal lattices, Ewald sphere, X-ray diffraction, Lattice parameter determination, Atomic and crystal structure factors, Intensity of diffraction maxima, Electron and neutron diffraction, Bonding of solids, Ordered phases of matter: translational and orientational order, kinds of liquid crystalline order, Quasi crystals.

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.

Unit-II **15 hours**

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

Band Theory of Solids: Electrons motion in periodic potentials, Bloch theorem, Kronig Penny model, Band theory for Nearly free electron, Band gap, Number of states in a band, Tight binding method, Effective mass of an electron in a band, Classification of metal, Semiconductor (Direct and Indirect) and insulator.

Unit-III **13 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, Spin waves, Bloch $T^{3/2}$ law, ESR, NMR and chemical shifts.

Unit-IV **15 hours**

Defects and Dislocations: Point defects (Concentration of Frenkel and Schottky), Line defects (slip, plastic deformation, Edge and Screw dislocation, Burger's vector, Concentration of line defects, Estimation of dislocation density, 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.(2011). *Principles of the Theory of Solids.* Cambridge, U.K: Cambridge University Press.
2. Kittel C.(2007). *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.* Thomson Press.

Course Code: PHY.526
Course Tile: Solid State Physics Laboratory
Total Hours: 120

L	T	P	Cr
0	0	8	4

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. J. Ziman, *Principles of the Theory of Solids* (Cambridge University Press, New Delhi) 2011.
2. J.P. Srivastava, *Elements of Solid State Physics* (PHI Learning, New Delhi, India) 2011.
3. R.J. Singh, *Solid State Physics* (Pearson, New Delhi, India) 2011.
4. C. Kittel, *Introduction to Solid State Physics* (Wiley India (P) Ltd., New Delhi, India) 2014.

Evaluation Criteria for Practical Courses

Sr. No.	SECTIONS	MARKS
A	**Continuous Assessment: Practical Day to Day‡**	**60**
	i. Lab Practical Records	30
	ii. Viva-voce	30
B	**End Term Practical Examination**	**30**
C	**Viva-voce in End Term Practical Examination**	**10**

‡ The evaluation of Lab Practical Records and Viva-voce have to be carried out after the successful completion of allotted experiment. The internal evaluation of practical to be considered for 100 marks. But, it will scale down out of 60 marks.

Course Code: PHY.527
Course Tile: Introduction to Nanotechnology
Total Hours: 30

L	T	P	Cr
2	0	0	2

Learning outcomes: The students will be able to

- Outline types of nanomaterials and their properties based on their dimensionality, the importance of reduction in materials dimensionality and the challenges and future of nanotechnology.
- Explain the various physical, chemical and biological synthesis approaches for nanomaterial preparation.
- Outline the various applications of nanomaterials in various scientific areas such as engineering, physics, chemistry, biology, and computer science.

Course Contents

Unit I **7 hours**

Basics of Nanotechnology: Definition, Overview: Why and How, History of Nanotechnology, Types of nanomaterials (i.e. Zero (0), One (1), Two (2), and Three (3) dimensional), Carbon based Nanomaterial's synthesis, properties and applications: Graphene, Fullerenes, Single and Multi-wall Carbon Nanotube, and Porous Silicon: Synthesis, Properties and Applications.

Unit II **8 hours**

Applications of Nanotechnology: Lotus, Rose Petal and Gecko effect, Applications of Nanotechnology in textile, paints, Health Care, Cosmetics, Sports, Food, Water Purification, Use of nanosilver, Nano-Robotics, Defense, Agriculture, Construction and space, Use and Benefits of Nanotechnology, Challenges and Future of nanotechnology, Bio and Environmental Nanotechnology, Advantages and Disadvantages, Global ethics of nanotechnology. Devices by nanotechnology: Solar Cell, Fuel Cell, and LED.

Unit III **8 hours**

Synthesis of Nanomaterials: Fabrication methods i.e. top-down and bottom-up approach: Ball Milling, Sol-Gel method, Colloidal Method, Hydrothermal, Sonochemical, Biological Methods Using Plant Leaf and Microorganism, Micro-Emulsion Method, Core-shell particles, Nanocomposites, Nanomaterials reinforced polymers nanocomposites.

Unit IV **7 hours**

Properties of Nanomaterials: Self Assembly, Structural, electrical, optical, mechanical, chemical, and magnetic properties at nanoscale.

Transaction Mode:

Lecture, demonstration, PPT.

Suggested Readings:

1. Alain Nouailhat.(2008).An introduction to Nanoscience and Nanotechnology. Wiley online Library.
2. Bruus Henrik.(2004). Introduction to Nanotechnology.Springer.
3. Luisa Filipponi and Duncan Sutherland.(2012).NANOTECHNOLOGIES: Principles, Applications, Implications and Hands-on Activities.European Union, Luxembourg.
4. Guozhong Cao,(2004).Nanostructure and Nanomaterials(Synthesis, Properties and Applications. London: Imperical College Press.
5. Fahrner W. R.(2005). Nanotechnology and Nanoelectronics. Springer Berlin.

SEMESTER-III

Course Code: PHY.551
Course Title: Statistical Mechanics
Total Hours: 60

L	T	P	Cr
4	0	0	4

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 **14 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 **16 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 **14 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 **16 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.(2011). *Statistical Mechanics.* USA:Elsevier.
2. Huang K.(1987). *Statistical Mechanics.* New Delhi, India: Wiley India Pvt. Ltd.
3. Swendsen R.H.(2012). *An Introduction to Statistical Mechanics and Thermodynamics.* Oxford, U.K:Oxford University Press.
4. Sadovskii M.V.(2012). *Statistical Physics*. Berlin/Boston, USA: Walter de Gruyter GmbH and Co.
5. Laud B.B.(2012).*Fundamentals of Statistical Mechanics* .New Delhi*:* New Age International.

Course Code: PHY.552
Course Title: Nuclear and Particle Physics
Total Hours: 60

L	T	P	Cr
4	0	0	4

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 **15 hours**

Basic Nuclear Properties: Nuclear size, shape and charge distribution, Form factor, Mass and binding energy, Saturation of nuclear force, Abundance of nuclei, Spin, Isospin, Mirror nuclei, Parity and symmetry, Magnetic dipole moment and electric quadrupole moment.

Two Nucleon Problems: Nature of nuclear forces, Deuteron problem, Spin dependence of nuclear forces, Form of nucleon-nucleon potentials, Electromagnetic moment and magnetic dipole moment of deuteron, General form of nuclear force. Experimental n-p scattering data, Partial wave analysis and phase shifts, Scattering length, Magnitude of scattering length and strength of scattering, Charge independence, Charge symmetry and iso-spin invariance of nuclear forces.

Unit-II **15 hours**

Nuclear Decay: Different kinds of particle emission from nuclei, Alpha decay Fine structure of α spectrum, 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.

Nuclear Models: Evidence of shell structure, Single particle shell model, its validity and limitations, Rotational spectra, Shell model, Liquid drop model, Collective model, Semi empirical mass formula. Exchange force model. Double beta decay.

Unit-III **15 hours**

Nuclear Reactions: Types of Nuclear Reactions and conservation laws, Energetic of Nuclear reactions, Isospin, Reaction Cross sections, Coulomb Scattering, Optical model, Compound nucleus reactions, Direct Reactions, Resonance reactions, Heavy Ion reactions,

Neutron Physics: Neutron Sources, absorption and moderation of neutrons, Introduction to nuclear fission and fusion.

Unit-IV **15 hours**

Elementary Particle Physics: Classification of particles: Fermions and bosons, Elementary Particles and antiparticles, Quarks model, baryons, mesons and leptons, Classification of fundamental forces: Strong, Electromagnetic, Weak and Gravitational. Conservation laws of momentum, energy, Angular momentum, Parity non conservation in weak interaction, Pion parity, Isospin, Charge conjugation, Time reversal invariance, 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. 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

Course Code: PHY.553
Course Title: Nuclear Physics Laboratory
Total Hours: 120

L	T	P	Cr
0	0	8	4

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, Emfietzoglou D.(2012). *Interaction of Radiation with Matter.* London, U.K:CRC Press.

Evaluation Criteria for Practical Courses

Sr. No.	**SECTIONS**	**MARKS**
A	**Continuous Assessment: Practical Day to Day‡**	**60**
	i. Lab Practical Records	30

	ii. Viva-voce	30
B	**End Term Practical Examination**	**30**
C	**Viva-voce in End Term Practical Examination**	**10**

‡ The evaluation of Lab Practical Records and Viva-voce have to be carried out after the successful completion of allotted experiment. The internal evaluation of practical to be considered for 100 marks. But, it will scale down out of 60 marks.

Course Code: PHY.554
Course Title: Advanced Solid State Physics
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning Outcomes: The students will be able to

- Explain Fermi Surfaces and their construction and the experimental methods used for detection of fermi surfaces.
- Outline the various types of semiconductor, their theory and Thermoelectric effects and Theory of Dielectrics and Ferroelectrics.
- Explain plasmons, color centres, excitons, Raman Effect and optical properties of solids.
- Analyze diffraction pattern of amorphous solids.

Course Contents

Unit-I **15 hours**

Fermi Surfaces and Metals: Zone schemes, Construction of Fermi surfaces, Electron orbits, Hole orbits and open orbits, Calculation of energy bands: Wigner-seitz Method, Pseuopotential Method, Experimental methods in Fermi surface studies: De Haas-van Alphen Effect, Fermi Surface of Cu and Au, Magnetic Breakdown.

Unit-II **15 hours**

Semiconductor Crystals: Direct and indirect band gap, Equation of motion, Intrinsic and extrinsic semiconductors, Physical interpretation of effective mass, Effective masses in semiconductors, Cyclotron resonance, Intrinsic carrier concentration, Fermi level and electrical conductivity, Metal-metal contacts, Thermoelectric effects: Diode and transistors.

Unit-III **15 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, Transverse optical modes in plasma, Interaction of EM waves with optical modes: Polaritons, LST relation, Electron-electron interaction, Electron-phonon interactions: Polarons.

Unit-IV **15 hours**

Plasmons and Optical Processes: Connection between optical and dielectric constants, Optical reflectance, Optical properties of metals, Luminescence, Types of luminescent systems, Electroluminescence, Color centers, Production and properties, Types of color centers, Excitons (Frenkel, Mott-Wannier), Experimental studies (alkali halide and molecular crystals), Raman effect in crystals, Diffraction pattern and low energy excitations in amorphous solids.

Transaction Mode:

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

Suggested Readings:

1. Ziman J.(2011). *Principles of the Theory of Solids.*Cambridge,U.K: Cambridge University Press.
2. Kittel C.(2007). *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.* Thomson Press.

Course Code: PHY.555
Course Title: Nuclear Techniques
Total Hours: 60

L	T	P	Cr
4	0	0	4

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 **15 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 **15 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 **15 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 **15 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.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: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.

Course Code: PHY.557
Course Title: Functional Materials and Devices
Total Hours: 60

L	T	P	Cr
4	0	0	4

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 **15 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 **15 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 **15 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 **15 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 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. 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
4	0	0	4

Course Code: PHY:559
Course Title: Computational Solid State Physics
Total Hours: 60

Learning Outcomes: A
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 **16 hours**

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

Unit-II **14 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.

Unit-III **14 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 **16 hours**

Understanding why LDA works, Strengths and weaknesses of DFT. 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. 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.

Course Code: PHY.543
Course Title: Seminar-I
Total Hours: 30

L	T	P	Cr
0	0	0	1

Learning Outcomes:

- Students will be well versed with the communication and presentations skills required at different academic and research forum.
- Students will learn how to make presentation on the Physical concepts and research related topics.

Seminar Detail

Students will be given a topic by the respective supervisor related to research topics allotted to the students to prepare a presentation. The scheduled seminars will be conducted in the department in the present of faculties of the department every week as per the schedule fixed in the time table.

Transaction Mode:

Power Point Presentation, Group Discussion, Research Papers.

Evaluation Criteria for Seminar

Sr. No.	SECTIONS	MARKS
i.	Delivery (Voice, Pacing, Body Language, Preparation)	20
ii.	Organization (Introduction, Division of Themes, Conclusion, Discourse)	20
iii.	Knowledge (Depth, Level, Authority, Terminology, Ability to Answer Questions)	20
iv.	Language (Communicative Force, Pronunciation, Grammar, Vocabulary)	10
v.	Attendance (75-80% = 1, 81-85%= 2¸86-90% = 3¸ 91-95%=4¸ above 95%=5)	10
	TOTAL MARKS FOR PRESENTATION (40 marks for internal evaluation throughout the semester, and 30 marks for the presentation at the end of the semester)	70
vi.	Submission of Seminar Report at the end of the semester (Neat, Organized, Proper spelling and Grammar, Conclusion, References)	30
	TOTAL MARKS	**100**

Course Code: PHY.599
Course Title: Project Work-I
Total Hours: 180

L	T	P	Cr
0	0	0	6

Learning Outcomes: At the end of Project work-I students will be able to:

- Outline the literature on a specific research problem.
- Construct objectives and motivations of research problem to be carried out.
- Explain the nuts and bolts of the theoretical concepts of the problem (experimental or theoretical) to be carried out.

Transaction Mode:
Power point presentation, report writing.

Evaluation Criteria for Project Work

I. The time allowed to project work-I is equivalent to the one and half practical laboratory course per week.
II. The topic of the project will be decided by concerned supervisor and students will review literature in details.

Project work-I will be evaluated on following points through presentations:

S. No.	Sections	Marks
1.	Delivery of presentation and Communication skills	20
2.	Review of literature	40
3.	Introduction	20
4.	Objective are scientifically correct as per importance	10
5.	Basic theory	10

Project report will be evaluated on 5-point scale:

Excellent (above 80)
Very Good (71-80)
Good (56-70)
Average (41-55) and
Un-satisfactory (Below 40).

L	T	P	Cr
1	0	0	1

Course Code: VAC
Course Title: Units, Measurement and Measurement Characteristics
Total Hours: 15

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 **7 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 **8 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.

SEMESTER IV

L	T	P	Cr
4	0	0	4

Course Code: PHY.571
Course Title: Research Methodology
Total Hours: 60

Learning Outcomes:

- The course will introduce the students to basic concepts of research methods.
- The students will learn about the preparation of research plan, reading and understanding of scientific papers, scientific writing, research proposal writing, ethics, plagiarism, laboratory safety issues and intellectual property rights etc.

Course Contents

Unit-I **15 hours**

General principles of research: Meaning and importance of research, Different types and styles of research, Role of serendipity, Critical thinking,

Creativity and innovation, Formulating hypothesis and development of research plan, Review of literature, Interpretation of results and discussion.
Bibliographic index and research quality parameters- citation index, impact factor, *h* index, i10 index, etc. Research engines such as google scholar, Scopus, web of science, Scifinder etc.

Unit-II **15 hours**
Technical & scientific writing- theses, technical papers, reviews, electronic communication, research papers, etc., Poster preparation and presentation, and Dissertation. Making R and D proposals, Reference management using various softwares such as Endnote, reference manager, Refworks, etc. Communication skills–defining communication; type of communication; techniques of communication, etc.
Data Analysis: Graph plot, Error analysis, Curve fitting: linear and nonlinear.

Unit-III **15 hours**
Library: Classification systems, e-Library, Reference management, Web-based literature search engines.
Laboratory Safety Issues: Lab, Workshop, Electrical, Health and fire safety, Safe disposal of hazardous materials, Radiation safety.
Entrepreneurship and Business Development: Importance of entrepreneurship and its relevance in career growth, Types of enterprises and ownership.

Unit-IV **15 hours**
Plagiarism: Plagiarism, definition, Search engines, regulations, policies and documents/thesis/manuscripts checking through softwares, Knowing and Avoiding Plagiarism during documents/thesis/manuscripts/ scientific writing.
Intellectual Property Rights: Intellectual Property, intellectual property protection (IPP) and intellectual property rights (IPR), WTO (World Trade Organization), WIPO (World Intellectual Property Organization), GATT (General Agreement on Tariff and Trade), TRIPs (Trade Related Intellectual Property Rights), TRIMS (Trade Related Investment Measures) and GATS (General Agreement on Trades in Services), Nuts and Bolts of Patenting, Technology Development/Transfer Commercialization Related Aspects, Ethics and Values in IP.

Transaction Mode:
Lecture, demonstration, PPT.

Suggested Readings:

1. Gupta S. (2005). Research Methodology and Statistical techniques New Delhi, India:Deep and Deep Publications (P) Ltd.
2. Kothari C. R. (2008). Research Methodology. New Delhi, India: New Age International.

3. **Web resources:** www.sciencedirect.com for journal references, www.aip.org and www.aps.org for reference styles.
4. **Web resources:** www.nature.com, www.sciencemag.org, www.springer.com, www.pnas.org, www.tandf.co.uk, www.opticsinfobase.org for research updates.

L	T	P	Cr
2	0	0	2

Course Code: PHY:572
Course Title: Advanced Physics-I
Total Hours: 30

Learning Outcomes: Student will able to

- Solve the problems related to Fourier and Laplace transforms.
- Solve differential equations.
- Elaborate concept of special theory of relativity in terms of formulations of classical Mechanics.
- Apply special theory of relativity to the electrodynamics.

Course Contents

Unit-I **8 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 and application

Unit-II **7 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.

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. Arfken G., Webe H. Harris r and F. (2012). *Mathematical Methods for Physicists* Massachusetts, USA : Elsevier Academic Press.
2. Joag P.S. and Rana N.C., (1991). *Classical Mechanics.* Noida, India: Tata McGraw-Hill.
3. Safko J, Goldstein H and Poole C. P. (2011). *Classical Mechanics.* New Delhi, India: Pearson.
4. Griffiths D.J.(2012). *Introduction to Electrodynamics*. New Delhi: Prentice Hall of India Pvt.Ltd.

Course Code: PHY:573
Course Title: Advanced Physics-II
Total Hours: 30

L	T	P	Cr
2	0	0	2

Learning Outcomes: Student will able to

- Learn advanced topics such as Molecular Spectra that will enrich their knowledge for competitive national exams and research programme.
- Evaluate Operation of Microprocessor.
- Learn about optoelectronic devices and transducers.

Course Contents

Unit-I **8 hours**
Molecular Spectra: Molecular potential, Separation of electronic and nuclear wave functions, Rotational and Vibrational spectrum of diatomic molecules, Selection rules.

Unit-II **7 hours**
Electronic Spectra: Frank-Condon principle, Raman transitions and Raman spectra, Normal vibrations of CO_2 and H_2O molecules.

Unit-III **8 hours**
Optoelectronic Devices and Transducers: Solar cell, Photo detector and LEDs, Transducers, Measurement and control, Shielding and grounding.

Unit-IV **7 hours**
Microprocessors and micro controller: Logic families, Microprocessors and micro controller basics.

Transaction Mode:
Lecture, demonstration, PPT

Suggested Readings:

1. Banwell C.N and McCash E. M.(1983). Fundamentals of Molecular Spectroscopy. Tata, McGraw Hill Publishing Company Limited.
2. Millman J., Halkias C. and Parikh C. (2009). *Integrated Electronics : Analog and Digital Circuits and Systems.* Noida, India: Tata McGraw - Hill Education.

Course Code: PHY:574
Course Title: Introduction to Mesoscopic Physics
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning Outcomes:
The students will learn to:

- Explain the transition regime between macroscopic and microscopic objects.
- Demonstrate the knowledge for quantum transport with illustrative examples showing how conductors evolve from the atomic to the ohmic regime as they get larger.
- Explain various phenomenon such as, quantization of electrical conductance in nanoscale conductors, Coulomb Blockade, quantum capacitance etc.

Course Contents

Unit I **15 hours**
Introduction, Why Electrons Flow, Conductance Formula, Ballistic Conductance, Diffusive Conductance, Connecting Ballistic to Diffusive, Dispersion Relation, Drude Formula

Unit II **15 hours**
Counting States, Density of States, Number of Modes, Electron Density, Conductivity vs. Electron Density, Quantum Capacitance, What and Where is the Voltage, A New Boundary Condition, Current from Quasi-Fermi Levels, Electrostatic Potential

Unit III **15 hours**
Boltzmann Equation, Semiclassical Model,Quantum Model, Landauer Formulas, NEGF Equations, Self-Energy, Surface Green's Function, Current Operator, Scattering Theory, Transmission, Golden Rule, Quantum Master Equations

Unit IV **15 hours**

Electronic Spin-Orbit Coupling, Spin Hamiltonian, Spin Density/Current, Spin Voltage, Spin Circuits, Seebeck Coefficient, heat Current, One-level Device, Second Law, Entropy

Transaction Mode:

Lecture, demonstration, PPT.

Suggested Readings:

1. Supriyo Datta, (2005). Quantum Transport Atom to Transistor. CAMBRIDGE
2. Supriyo Datta. (2008). Lessons from Nanoelectronics: A New Perspective on Transport: Volume 1 & 2 (World Scientific)
3. Yuli V. Nazarov and Yaroslav M, (2009). Quantum Transport: Introduction to Nanoscience Blanter :CAMBRIDGE)

Course Code: PHY.575
Course Title: Particle Physics
Total Hours: 60

L	T	P	Cr
4	0	0	4

Learning Outcomes: After a successful completion of the course, students will be able to

- Explain the basic properties of elementary particles,
- Discuss the various fundamental interactions (Strong, weak and electromagnetic and gravity).
- Explain kinematics of decay and scattering.
- Explain symmetries, and various aspects of quark models.

Course Contents

Unit-I **15 hours**

Particles and Forces: Production and basic properties of elementary particles in cosmic rays and accelerators experiments, mass spectra and decays of elementary particles, Fundamental interactions: basic properties of Strong, weak and electromagnetic and gravity. Yukawa theory of pion exchange.

Unit-II **15 hours**

Kinematics: Kinematics of decay and scattering, Scattering in lab and centre of mass frames, Two and Three body decay phase space, Dalitz plot.

Symmetries and Conservation Laws: Space- time symmetries, Invariance Principles, Parity, Intrinsic parity, Parity constraints on the S- Matrix for Hadronic Reactions, Time – Reversal Invariance, conservation of Quantum Numbers, Isospin, Charge Conjugation, G- parity, CP and CPT Invariance (statement and consequences only).

Unit-III **15 hours**

Internal symmetries:, Isospin, strangeness, charm quantum numbers, unitary groups, Isospin and SU (2), SU(3), Octet and decuplet irreducible representations of SU(3), SU(3) classification of mesons and baryons, Applications of Flavor SU(3), Gell- Mann Okubo Mass Formula, omega-phi mixing, Isospin relations for Pion-nucleon strong interaction.

Quark Model: Quark structure of strange and nonstrange hadrons, need of colour quantum number. observation of new flavour states, charm, bottom hadrons, higher symmetries (brief description). Application of quark model for electromagnetic decays of vector mesons.

Unit-IV **15 hours**

Weak Interactions: Classification of weak Interactions; Leptonic Semi-Leptonic and Non- Leptonic Decay, Tau- Theta Puzzle, Parity Violation in Weak Decays Selection Rules Semileptonic Decays, and nonleptonic decays, Universality of Weak Interactions, Fermi Theory of weak interactions, Intermediate Vector – Boson Hypothesis, Helicity of Neutrino, Two Component Theory of Neutrino, K0-K0bar Mixing and CP Violation

Transaction Mode:

Lecture, demonstration, PPT.

Suggested Readings:

1. Griffiths D.J. (2008). *Introduction to Elementary Particles*. Germany: Wiley-VCH GmbH.
2. Perkin D.H., (2000). *Introduction to High Energy Physics.* U.K :Cambridge Univ. Press.
3. Mittal V.K., Verma R.C. & S.C. Gupta. (2015). Nuclear & Particle Physics. N. Delhi: 3rd edition Prentics Hall Pub.
4. Hughes I.S. (1991). *Elementary Particles.* Cambridge University Cambridge: U.K Press.
5. Khanna M.P. (1999). Particle Physics, N. Delhi: Prentics Hall. Pub.
6. Thankappan V.K. (2014).. Quantum Mechanics. N. Delhi : New Age Pub.
7. Khanna M.P. (1999). Quantum Mechanics, N. Delhi :Har Anand Pub.
8. Leo W. R. (2009). *Techniques for Nuclear and Particle Physics Experiments.* New York, USA: Springer.
9. Stefan T. (2010). *Experimental Techniques in Nuclear and Particle Physics* New York, USA: Springer.

Course Code: PHY.576
Course Title: Nanostructured Materials
Total Hours: 60

L	T	P	Cr
4	0	0	4

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 **15 hours**

Nanomaterials, Their Properties and Applications: Low-dimensional materials: Qunatum 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 **15 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 **15 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), Dynamic mechanical analysis, Universal tensile testing, Transport number analysis, UV-Visible spectroscopy

UNIT-IV **15 hours**

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.

Course Code: PHY:577
Course Title: Materials Characterizations
Total Hours: 60

L	T	P	Cr
4	0	0	4

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 **15 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 **15 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 **15 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 **15 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

Course Code: PHY.544
Course Title: Seminar-II
Total Hours: 30

L	T	P	Cr
0	0	0	1

Learning Outcomes:

- Students will be well versed with the communication and presentations skills required at different academic and research forum.
- Students will learn how to make presentation on the Physical concepts and research related topics.

Seminar Detail

Students will be given a topic by the respective supervisor related to research topics allotted to the students to prepare a presentation. The scheduled seminars will be conducted in the department in the present of faculties of the department every week as per the schedule fixed in the time table.

Transaction Mode:
Power Point Presentation, Group Discussion, Reading Research Papers.

Evaluation Criteria for Seminar

Sr. No.	SECTIONS	MARKS
i.	Delivery (Voice, Pacing, Body Language, Preparation)	20
ii.	Organization (Introduction, Division of Themes, Conclusion, Discourse)	20
iii.	Knowledge (Depth, Level, Authority, Terminology, Ability to Answer Questions)	20
iv.	Language (Communicative Force, Pronunciation, Grammar, Vocabulary)	10
v.	Attendance (75-80% = 1, 81-85%= 2¸86-90% = 3¸ 91-95%=4¸ above 95%=5)	10
	TOTAL MARKS FOR PRESENTATION (40 marks for internal evaluation throughout the semester, and 30 marks for the presentation at the end of the semester)	70
vi.	Submission of Seminar Report at the end of the semester (Neat, Organized, Proper spelling and Grammar, Conclusion, References)	30
	TOTAL MARKS	**100**

L	T	P	Cr
0	0	0	6

Course Code: PHY.599
Course Title: Project Work-II
Total Hours: 180

Learning Outcomes: At the end of Project work-II students will be able to:

- Explain the theoretical/experimental results through presentation and project report.

Elaborate the possible application of their research.

Transaction Mode:
Power point presentation, report writing.

Evaluation Criteria for Project Work

i. The time allowed to project work-II is equivalent to the one and half practical laboratory course per week.
ii. Students will continue their project work from the previous semester and prepare project report at the end of semester through group or independent research problems decided by the supervisor.

S. No.	Sections	Marks
1.	Introduction	10
2.	Objective are scientifically correct as per importance	15
3.	Basic theory	15
4.	Experimental method / simulation method	20
5.	Result / discussion (what / why / how)	30
6.	Direct application	10

Project report will be evaluated on 5-point scale:
Excellent (above 80),
Very Good (71-80),
Good (56-70),
Average (41-55), and
Un-satisfactory (Below 40).
The final grade of the project will be evaluated by the combining the grade of Project work-I and II.

Course Code: VAC
Course Title: Units, Measurement and Measurement Characteristics
Total Hours: 15

L	T	P	Cr
1	0	0	1

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 **7 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 **8 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.

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.

Transaction Mode: Lecture, PPT.