Central University of Punjab, Bathinda

Course Scheme & Syllabus

School of Basic and Applied Sciences
Department of Physical Sciences
M. Sc. Physics (Computational Physics)
2018-20

Semester-I

S. No.	Paper 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	C	0	0	6	3
6	PHY.511	Modern Physics Laboratory	C	0	0	6	3
7	XXX	Interdisciplinary Elective	IDE	2	0	0	2
				18	**0**	**12**	**24**

Semester-II

S No.	Paper Code	Course	Course Type	L	T	P	Cr
1	PHY.521	Numerical Methods	CF	2	0	0	2
2	PHY.522	Numerical Methods Laboratory	CF	0	0	4	2
3	PHY.523	Quantum, Atomic and Molecular 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	C	0	0	8	4
7	XXX	Interdisciplinary Elective	IDC	2	0	0	2
		Total		**16**	**0**	**12**	**22**

Semester-III

S. No.	Paper 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	C	0	0	8	4
4	PHY.XXX	Elective Course - I	DE	4	-	-	4
9	PCP.543	Seminar – I	SE	-	-	-	1
10	PCP.599	Project	EP	-	-	-	6
		Value Added Course	VAC	1	-	-	1
				13	**0**	**8**	**24**
PHY.XXX - Elective Course-I							
4	PHY.554	Advanced Solid State Physics	DE	4	-	-	4
5	PHY.555	Nuclear Techniques – I	DE	4	-	-	

6	PHY.556	Introduction to Computational Materials Physics	DE	2		-	2
	PHY.558(a)*	Computational Materials Physics Laboratory*	DE	-	-	4	2
7	PCP.561	Fundamentals of Molecular Simulations	DE	4	-	-	4
8	PHY.557	Functional Materials and Devices	DE	4	-	-	4

*Students opting PHY.556 need also to opt its laboratory course PHY.558(a)

Semester IV

S. No	Paper Code	Course Title	Course Type	L	T	P	Cr
1	PHY.571	Research Methodology	CF	4	-	-	4
2	PHY.XXX	Elective Course-II	DE	4	0	0	4
3	PCP.572	Molecular Simulation Lab	DE	-	-	4	2
4	PHY.576	The Enrich Physics Course – I	CF	2	-	-	2
5	PHY.577	The Enrich Physics Course – II	CF	2	-	-	2
6	PCP.544	Seminar-II	SE	-	-	-	1
4	PCP.599	Project	SE	-	-	-	6
		Value Added Course	VAC	-	-	-	1
				12		4	22
PHY.XXX -Elective Course-II							
1	PHY.574	Introduction to Mesoscopic Physics	DE	4	0	0	4
2	PHY.575	Nuclear Techniques – II	DE	4	0	0	4
3	PHY.576	Nanostructured Materials	DE	4	0	0	4
4	PCP.576	Basics of Computational Nanoelectronics	DE	4	0	0	4
5	PHY.577	Materials Characterization	DE	4			4

CF: Compulsory Foundation, **C**: Core, **DE**: Discipline Elective, **IDC**: Inter-Disciplinary Elective, **SE**:Skill-based
Elective, VAC: Value Added Courses
L: Lecture, **T**: Tutorial, **P**: Practical

Weightage (%):

Surprise Test (s): There is no limit for the surprise test and average of best two will be considered. Surprise tests are based on multiple choice questions and total weightage of surprise tests is 10%.

Term Paper(s): Each student will be given different topics. All detailed regarding term paper will be communicated to students at the start of teaching. Total weightage of term paper is 10%.

Assignment(s): All details regarding assignments will be communicated to students by the course coordinators. Total weightage of assignments is 5%.

Mid Semester Tests (MSTs): This continuous assessment is based on two pre-announced Tests. These tests are of subjective type and contain 02 long answer type questions of 5 marks each and 05 medium answer type questions of 3 marks each. Each MST carries 25% weightage and total weightage of MSTs is 50%.

End Semester Examination: End semester examination is conducted through online mode in university computer center. End semester examination is based on MCQs/fill-ups. Weightage of end semester examination is 25%.

Practical Course/Seminars: Based on Practical work performance/Written Test/Presentation/Viva-vice is 100%. **Project Work:** Project report will be evaluated on 5-point scale: Excellent, Very Good, Good, Average and Un-satisfactory.

Semester-I

Course Title: Mathematical Physics

Paper Code: PHY.506

L	T	P	Cr
4	0	0	4

Total Lectures: 60

Course Objective: The course on Mathematical Physics is introduced to familiarize the students with the idea about transformation of coordinates and complex functions, special functions, group theory, and tensors which will be useful in understanding theoretical treatment and for developing a strong background to pursue research in theoretical physics.

Unit-I **15 hours**

Vector Calculus, Matrices & Tensors : Vector calculus: properties of Gradient, divergence and Curl, matrix algebra, Caley-Hamilton theorem, Eigen values and Eigen vectors, curvilinear coordinates.(spherical and cylindrical coordinates) Tensors, Symmetric and antisymmetric, kronecker and Levi Civita tensors.

Elements of group theory: Group postulates, Lie group and generators, representation, Commutation relations, SU(2), O(3).

Unit-II **15 hours**

Delta, Gamma, and Beta Functions: Dirac delta function, Properties of delta function, Gamma function, Properties of Gamma and Beta functions.

Special Functions: Legendre, Bessel, Hermite and Laguerre functions, recurrence relations, Orthogonality and special properties. Associated Legendre functions: recurrence relations, Parity and orthogonality, functions, Green's function,

Unit-III **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.

Unit-IV **15 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.

Differential Equations Solutions of Hermite, Legendre, Bessel and Laugerre Differential equations, basics 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.

Suggested Readings

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

2. E. Kreyszig, *Advanced Engineering Mathematics* (Wiley India Pvt. Ltd., New Delhi, India) 2011.
3. L. A. Pipes, *Applied Mathematics for Engineers and Physicist* (McGraw-Hill, Noida, India) 1985.
4. D. G. Zill, *Advanced Engineering Mathematics* (Jones & Barlett Learning, Massachusetts, USA) 2012.
5. P. K. Chattopadhyay, *Mathematical Physics* (New Age International (P) Ltd., New Delhi) 2000
6. Mathematical Physics, B.S. Rajput, Pragati Prakashan

Course Title: Classical Mechanics
Paper Code: PHY.507

L	T	P	Cr
4	0	0	4

Objective and Learning Outcomes: The overall goal of this course is to provide tools and applications of classical mechanics that student can use these in various branches of physics. Student will learn solid understanding of classical mechanics (Newton's laws, Lagrangian mechanics, conservation principles, Hamiltonian formalism, Hamilton - Jacobi theory, central force, scattering, rigid body dynamics, small oscillations and special relativity). Establish firm physics and math foundation on which student can build a good carrier in physics.

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).

Hamiltonian Formalism: Variational principle, 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, Dynamical systems, Phase space dynamics and stability analysis.

Unit-II **14 hours**

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

Unit-III **15 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, Condition for closed orbits (Bertrand's theorem), Virial theorem, Kepler's laws and their derivations, Classification of orbits, Two body collisions, Scattering in laboratory and centre-of-mass frames.

Unit-IV **15 hours**
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, Double pendulum and N-Coupled oscillators.
Special Theory of Relativity: Lorentz transformations and its consequences, Relativistic kinematics and mass energy equivalence, Relativistic Lagrangian and Hamiltonian, Four vectors, Covariant formulation of Lagrangian and Hamiltonian.

Suggested Readings

1. S.T. Thornton and J.B. Marion, *Classical Dynamics of Particles and Systems* (Cengage Learning, Boston/Massachusetts, United State), 5th edition, 2013.
2. J. Safko, H. Goldstein and C. P. Poole, *Classical Mechanics* (Pearson, New Delhi, India) 2011.
3. G. Walter, *Systems of Particles and Hamiltonian Dynamics* (Springer, New York, USA) 2010.
4. P.S. Joag and N.C. Rana, *Classical Mechanics* (Tata McGraw-Hill, Noida, India) 1991.
5. S.T. Thornton and J.B. Marion, *Classical Dynamics of Particles and Systems* (Cengage Learning, Boston/Massachusetts, United State), 5th edition, 2013.
6. J. Safko, H. Goldstein and C. P. Poole, *Classical Mechanics* (Pearson, New Delhi, India) 2011.
7. G. Walter, *Systems of Particles and Hamiltonian Dynamics* (Springer, New York, USA) 2010.
8. P.S. Joag and N.C. Rana, *Classical Mechanics* (Tata McGraw-Hill, Noida, India) 1991.

Course Title: Quantum Mechanics
Paper Code: PHY.508
Total Lectures: 60

L	T	P	Cr
4	0	0	4

Course Objective: The objective of this course is to develop familiarity with the physical concepts of quantum mechanics and its mathematical formulation. Student will learn basics of the subject and make them understand the concept of operators, observables, Schrodinger equation and its applications to simple physical systems. Also angular momentum and scattering theory with emphasis on the physical structure of the theory and their applications will be introduced.

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 Jz, 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.

Suggested Readings

1) N. Zettili, *Quantum Mechanics-Concepts and Applications* (John Wiley & Sons Ltd., Sussex, U.K.) 2009.
2) E. Merzbacher, *Quantum Mechanics* (Wiley India Pvt. Ltd., New Delhi, India) 2011.
3) L.I. Schiff, *Quantum Mechanics* (Tata McGraw-Hill Education, Noida, India) 2010.
4) K. Venkatesan, P.M. Mathews, *A Textbook of Quantum Mechanics* (Tata McGraw - Hill Education, Noida, India) 2010.
5) J. J. Sakurai, *Modern Quantum Mechanics* (Pearson Education, India) 2009.

6) D. J. Griffiths, *Introduction to Quantum Mechanics*, 2nd Ed. (Pearson Education, India) 2015.
7) G. D. Mahan, Quantum Mechanics in a Nutshell (Princeton University Press) 2009.
8) P.M. Mathews & K. Venkatesan, Tata-McGraw Pub. N. Delhi
9) V.K. Thankappan, Quantum Mechanics, New Age Pub. N. Delhi.

Course Title: Electronics
Paper Code: PHY.509

L	T	P	Cr
4	0	0	4

Total Lectures: 60

Course Objective: The course on Electronics and Digital Electronics Circuits Theory is introduced to familiarize the students with the idea of electronic devices, circuits, operations, signal processing and applications.

Unit-I **20 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 and applications.

Unit-II **12 hours**

Optoelectronic Devices and Transducers: Solar cell, Photo detector and LEDs, Transducers, Measurement and control, Shielding and grounding.

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 **18 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 **10 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, Logic families, Microprocessors and micro controller basics.

Suggested Readings

J. Millman, C. Halkias and C. Parikh, *Integrated Electronics : Analog and Digital Circuits and Systems* (Tata McGraw - Hill Education, Noida, India) 2009.

R.L. Boylestad and L. Nashelsky, *Electronic Devices and Circuit Theory* (Pearson, New Delhi, India) 2009.

B. L. Theraja, *Basic Electronics: Solid State* (S. Chand & Company Ltd., New Delhi, India) 2010.

D. Chattopadhyay and P. C. Rakshit, *Electronics: Fundamentals and Applications* (New Age International, New Delhi, India) 2008.

G. Saha, A.P. Malvino and D.P. Leach, *Digital Principles and Applications* (Tata McGraw - Hill Education, Noida, India) 2011.

P. Malvino and J.A. Brown, *Digital Computer Electronics* (Tata McGraw - Hill Education, Noida, India) 2011.

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

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

L	T	P	Cr
0	0	6	3

Course Objective: The laboratory exercises have been so designed that the students can verify some of the concepts learnt in the electronic circuit theory classes. During these laboratory they will get sufficient training to carrying out precise measurements and handling sensitive equipment. 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. Perform the logic state tables of RS and JK flip-flops using NAND & NOR gates.
18. Perform the logic state tables of T and D flip-flops using NAND & NOR gates.
19. Perform the Verification of logic state tables of master slave flip flop using NAND & NOR gates.
20. Triggering mechanism of flip flop.
21. Perform the Realization of Half adder and full adder.
22. Perform the Half substractor and full substractor.
22. Decoders and code converters.
23. Up/Down Counters.
24. Shift Resistor.

Suggested Readings

1. J. Millman, C. Halkias and C. Parikh, *Integrated Electronics : Analog and Digital Circuits and Systems* (Tata McGraw - Hill Education, Noida, India) 2009.
2. R.L. Boylestad & L. Nashelsky, *Electronic Devices and Circuit Theory* (Pearson, New Delhi) 2009.
3. B. L. Theraja, *Basic Electronics: Solid State* (S. Chand & Company Ltd., New Delhi) 2010.
4. D. Chattopadhyay and P. C. Rakshit, *Electronics: Fundamentals and Applications* (New Age International, New Delhi, India) 2008.
5. G. Saha, A.P. Malvino and D.P. Leach, *Digital Principles and Applications* (Tata McGraw - Hill Education, Noida, India) 2011.
6. P. Malvino and J.A. Brown, *Digital Computer Electronics* (Tata McGraw - Hill Education, Noida, India) 2011.
7. C. Hawkins and J. Segura, *Introduction to Modern Digital Electronics* (Scitech Publishing, New York, USA) 2010.

Course Tile: Modern Physics Laboratory
Paper Code: PHY.511

L	T	P	Cr
0	0	6	3

Total Hours: 90

Course Objective: The laboratory exercises have been so designed that the students can verify some of the concepts learned in Modern Physics. During this laboratory they will get sufficient training to carrying out precise measurements and handling sensitive equipment.

Student has to perform any of seven practicals 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

Suggested Readings

1. R.A. Serway, C.J. Moses & C.A. Moyer, *Modern physics,* Brooks Cole, Massachusetts,USA2012.
2. S.T. Thornton, *A. Rex Modern Physics for Scientists and Engineers* (Thomson Brooks/Cole, Massachusetts, USA) 2012.
3. K.S. Krane, *Modern Physics* (Wiley India (P) Ltd., New Delhi, India) 2012.
4. A. Beiser, *Concepts of Modern Physics* (Tata McGraw - Hill Education, Noida, India) 2007.

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

L	T	P	Credits
2	0	0	2

Course Objective: Physics is playing an important role in the everyday life of human beings. Therefore, this course is design to introduce students with physics and science in everyday life by considering objects from our daily environment and focuses on their principles of operation and relationships to one another. Out of these considerations arise better understanding of physics principles spanning motion, forces, heat, electromagnetism optics and modern physics.

Unit-I **15 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.

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-II **15 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.

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.

Suggested Readings

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

Semester II

Course Title: Numerical Methods

L	T	P	Cr
2	0	0	2

Paper Code: PHY.521
Total Hours: 30

Course Objective: The course on Numerical Methods has been framed to equip the students of M.Sc. Physics with knowledge of programming in C, roots of equation, interpolation, curve fitting, numerical differentiation, numerical integration, solution of ordinary differential equations.

Unit-I **8 hours**

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.

Suggested Readings

1. Y. Kanetkar, *Let Us C* (BPB Publications, New Delhi, India) 2012.
2. E. Balaguruswamy, *Numerical Methods* (Tata McGraw Hill, Noida, India) 2009.
3. S. S. Sastry, *Introductory Methods of Numerical Analysis,* PHI Learning Pvt.Ltd., NewDelhi,2012.
4. R. C. Verma, P. K. Ahluwalia & K. C. Sharma, Computational Physics, New Age, 1st edition,1999.
5. Tao Pang, an Introduction to Computational Physics (Cambridge University Press) 2nd edition, 2006.

Course Title: Numerical Methods Laboratory

Paper Code: PHY.522

L	T	P	Cr
0	0	4	2

Total Hours: 60

List of Experiments

Course Objective: The laboratory exercises have been so designed that the students learn the usage of C language to numerical methods and various physics problems, so that they are well equipped in the use of computers for solving physics based problems.

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 airdrag 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.

Suggested Readings

1. Y. Kanetkar, *Let Us C* (BPB Publications, New Delhi, India) 2012.
2. E. Balaguruswamy, *Numerical Methods* (Tata McGraw Hill, Noida, India) 2009.
3. S. S. Sastry, *Introductory Methods of Numerical Analysis,* PHI Learning Pvt.Ltd., NewDelhi,2012.
4. R. C. Verma, P. K. Ahluwalia & K. C. Sharma, Computational Physics, New Age, 1st edition,1999.
5. Tao Pang, an Introduction to Computational Physics (Cambridge University Press) 2nd edition, 2006.

Course Tile: Fundamentals of Molecular Simulations

Paper Code: PHY.561

Total Lecture: 72

L	T	P	Cr
4	0	0	4

Course Objective and Learning outcomes: The objective of this subject is to ensure that a student learns modelling of molecular structures and understanding the dynamics of the structural transitions, which will help them use the techniques of molecular simulations in their further potential careers in academia and industry.

Unit-I **18 hours**

Molecular Modeling and Structure - molecular modeling today: overview of problems, tools, and solution analysis, minitutorials with protein and nucleic acid structure as example.

Force Fields and Molecular Representation – (a) Intramolecular Interactions, (b) Non-bonded Interactions – London (van der Waals) Interactions, Electrostatic Interactions, (c) Hydrogen Bonds,

(d) Constraints and Restraints, (e) United Atom and Other Coarse-Grained Approaches, (f) Non-pairwise Interactions, (g) How accurate are force fields? Example: Protein, Nuclic Acid, Small Molecule Force Field, Water Models.

Unit-I **18 hours**

Methods for Simulating Large Systems

(a) Non-bonded Cutoffs – Shifted Potential and Shifted Force, Switching Functions, Neighbor Lists,

(b) Boundaries – Periodic Boundary Conditions, Stochastic Forces at Spherical Boundary, (c) Long-range Interactions – The Ewald Sum, The Reaction Field Method

Unit-II **18 hours**

Energy Minimization and Related Analysis Techniques

(a) Steepest Descent, (b) Conjugate Gradient, (c) Newton-Raphson, (d) Comparison of Methods, (e) Advanced Techniques: Simulated Annealing, Branch-and-bound, Simplex, (f) What's the big deal about the minimum?

Introduction to Equilibrium Statistical Mechanics

(a) Phase space, Ergodicity, and Liouville's theorem, (b) Ensemble theory, Thermodynamic averages - Microcanonical Ensemble, Canonical Ensemble, Other MD Simulation Related Ensembles (c) Statistical Mechanics of Fluids

Unit IV **18 hours**

Simulation Methods:

Monte Carlo: (a) MC integration and Markov chains, (b) The Metropolis method, (c) Biased MC

Molecular Dynamics: (a) Classical Mechanics: Equations of Motion, (b) Finite Difference

Methods: Verlet Algorithm, Velocity Verlet, The Time Step: Practical Issues, Multiple time-step algorithms (c) Constraint Dynamics: Fundamental concepts, SHAKE and RATTLE, (d) Temperature: Maxwell-Boltzmann distribution of velocities, (e) Temperature Control: Velocity Scaling, Andersen's Method, Nose-Hoover Dynamics, (f) Pressure Control: Andersen's Method, Nose-Hoover Method, Rahman-Perrinilo Method, (g) Calculating properties from MD trajectories, (h) Hybrid MC,

Free Energy: (a) Perturbation Methods, (b) TI (Thermodynamic Integration) Brownian dynamics and the Langevin Equation.

Suggested Readings

1. Computer Simulation of Liquids, by M.P. Allen and D.J. Tildesley, (QC 145.2.A43 1992)
2. Understanding molecular simulation, by Daan Frenkel and Berend Smit, (QD 461 F86 1996)
3. Andrew R.Leach Molecular Modelling Principles and applications . (2001) II ed . Prentice Hall.

L	T	P	Cr
4	0	0	4

Course Title: Quantum, Atomic and Molecular Physics

Paper Code: PHY.523

Total Lectures: 60

Course Objective: The objective of this course is to introduce the students about the relativistic quantum mechanics, variational principles and perturbation theories (both time independent and time dependent) and their importance to study atomic and molecular physics. Students will be equip with the knowledge of atomic, molecular, electronic, rotational, vibrational, and Raman spectra.

Unit-I **14 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.

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 spectrum lines.

Unit-II **16 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.

Relativistic Quantum Mechanics: Klein-Gordon equation, Dirac relativistic equation, Gamma Matrices, Significance of negative energy, Spin-orbit interaction, Relativistic correction, Fine structure of hydrogen atom.

Unit-III **16 hours**

Atomic Spectra: Revision of quantum numbers, electron configuration, Hund's rule etc. origin of spectral lines, LS & JJ coupling , selection rules, Spectrum of hydrogen, helium and alkali atoms, X-ray spectra, fine spectra, hyperfine structure, Width of spectrum lines.

Identical Particles: Spin-Statistics connection, Pauli's exclusion principle, Slater determinant, Exchange energy: Parahelium and orthohelium, Hartree-Fock equations, Elementary idea of density functional theory.

Unit-IV **14 hours**

Molecular Spectra: Molecular potential, Separation of electronic and nuclear wave functions, Born-Oppenheimer approximation, Electronic, Vibrational and rotational spectrum of diatomic molecules, Selection rules, Frank-Condon principle, Raman transitions and Raman spectra, Normal vibrations of CO2 and H2O molecules.

Electrons Systems: Quantum state of an electron in an atom, Electron spin, Mass correction term, Lamb shift, Independent particle model, Central field approximation for many electron atom.

Suggested Readings

1. K. Venkatesan, P.M. Mathews, *A Textbook of Quantum Mechanics* (Tata McGraw - Hill Education, Noida, India) 2010.
2. J.J Sakurai, *Advanced Quantum Mechanics* (Pearson, New Delhi, India) 2006.
3. J.J. Sakurai, J. Napolitano, *Modern Quantum Mechanics* (Pearson India, New Delhi,) 2014.
4. N. Zettili, *Quantum Mechanics: Concepts and Applications* (John Wiley & Sons Ltd., Sussex, U.K.) 2009.
5. D. J. Griffiths, *Introduction to Quantum Mechanics*, Second Edition (Pearson Education, India) 2015.
6. G. D. Mahan, Quantum Mechanics in a Nutshell (Princeton University Press) 2009.
7. V.K. Thankappan, Quantum Mechanics, New Age Pub. N. Delhi.
8. M.P. Khanna, Quantum Mechanics, Har Anand Pub. N. Delhi. (1999)
9. C.J. Foot, Atomic Physics (Oxford University Press, Oxford, U. K.) 2005.

10. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, (Tata, McGraw Hill Publishing Company Limited).

Course Title: Electromagnetic Theory

L	T	P	Cr
4	0	0	4

Paper Code: PHY.524
Total Lecture: 60
Course Objective: The Electromagnetic Theory is a course that covers electrostatics, magnetostatics, dielectrics, and Maxwell equations. The course has also been framed to solve the boundary value problems. The course contains the propagation of electromagnetic waves in dielectrics, metals and plasma. The course also covers the motion of relativistic and non- relativistic charged particles in electrostatic and magnetic fields.

Unit-I **18 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 **12 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.

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.

Unit-IV **14 hours**

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.

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.

Suggested Readings

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

Course Title: Solid State Physics
Paper Code: PHY.525

L	T	P	Cr
4	0	0	4

Total Lectures: 60
Course Objective:

The objectives of this physics course are to provide the student with a clear and logical presentation of the basic and advanced concepts and principles of solid state physics. The contents of the course are designed so that the students can learn topics like crystal structure, lattice vibrations, band theory of solids, magnetic properties of solids, defects, superconductivity so that they are able to use these techniques in investigating the aspects of the matter in condensed phase.

Unit-I **15 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 and Band Theory of Solids: Free electron theory, Density of states, Boltzmann transport equation (Response and relaxation phenomena), Drude model of electrical and thermal conductivity and Sommerfeld theory, Hall effect and quantum Hall effect, Electrons motion in periodic potentials, Bloch theorem, Kronig Penny model, Nearly free electron theory, 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, Thermoelectric power.

Unit-III **15 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 antiferromagnetism 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 TC superconductors and their applications (information only).

Suggested Readings

1. J. Ziman, *Principles of the Theory of Solids* (Cambridge University Press, Cambridge, U.K.) 2011.
2. C. Kittel, *Introduction to Solid State Physics* (Wiley India (P) Ltd., New Delhi, India) 2007.
3. R.J. Singh, *Solid State Physics* (Pearson, New Delhi, India) 2011.
4. A.J. Dekker, *Solid State Physics* (Macmillan, London, U.K.) 2012.
5. N. W. Ashcroft and N. D. Mermin, *Solid State Physics* (Thomson Press), 2003.

Course Tile: Solid State Physics Laboratory
Paper Code: PHY.526

L	T	P	Cr
0	0	8	4

Total Hours: 120

Course Objective: The Solid State Physics laboratory experiments have been so designed that the students learn basic concept of solid state physics learnt in the theory course.

1. Student has to perform any of ten experiments from the following experiments.
2. Determination of carrier concentration and their sign in semiconductor at room temperature by Hall Effect.
3. Dielectric constant of insulating and ferroelectric materials at room and elevated temperatures.
4. Electrons spin resonance.
5. Magnetic parameters of a magnetic material by hysteresis loop tracer.
6. To determine the magnetic susceptibility of NiSO4, FeSO4, CoSO4 by Gauy's method.
7. To determine magneto resistance of a Bismuth crystal as a function of magnetic field.
8. Determination of critical temperature of high temperature superconductor and Meissner effect for a high Tc superconductor.
9. Determination of ferromagnetic to paramagnetic phase transition temperature (TC = Curie temperature).
10. Photoconductivity measurements.
11. NMR spectrometer.
12. UV-Visible spectral analysis of nanomaterials and thin films.
13. FTIR studies of nanomaterials and thin film.
14. Dielectric studies of nanomaterials, thin films and liquid crystals.
15. FESEM micrograph study of nanomaterials and thin films.
16. TGA analysis of polymers.

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.

Course Tile: Introduction to Nanotechnology

L	T	P	Cr
2	0	0	2

Paper Code: PHY.527
Total Lectures: 30
Objective and Leaning Outcomes: The objectives of this course are to provide the students with knowledge and the basic understanding of nanotechnology. This is an interdisciplinary course dealing with basics, applications of the nanotechnology, synthesis and properties of the nanomaterials. Since Nanotechnology is multidisciplinary in nature students from other courses can benefit from the opportunities offered by this course as it provides basic knowledge of nanotechnology. Nanotechnology is based on various disciplines comprising of engineering, physics, chemistry, biology, mathematics and computer science.

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), 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 that cleans air, 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 ofnanotechnology. 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

Unit IV **7 hours**

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

Suggested Readings

1) An introduction to Nanoscience and Nanotechnology by Alain Nouailhat, Wiley (2006)
2) Introduction to Nanotechnology by Henrik Bruus, Springer (2004)
3) NANOTECHNOLOGIES: Principles, Applications, Implications and Hands-on Activities by Luisa Filipponi and Duncan Sutherland, European Union, (2012) Luxembourg
4) Nanostructure and Nanomaterials (Synthesis, Properties and Applications) by Guozhong Cao, Imperical College Press (2004) London.
5) Nanotechnology and Nanoelectronics by W. R. Fahrner, Springer (2005) Berlin

Semester-III

Course Title: Statistical Mechanics
Paper Code: PHY.551
Total Lectures: 60

L	T	P	Cr
4	0	0	4

Course Objective: This course is designed to provide statistical basis of thermodynamics and physical significance of various statistical quantities. The course has been framed to teach the techniques of ensemble theory to understand the macroscopic properties of the matter in bulk in terms of its microscopic constituents

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.

Suggested Readings

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

Course Title: Nuclear and Particle Physics

Paper Code: PHY.552

L	T	P	Cr
4	0	0	4

Total Lectures: 60

Course Objective: The objective of the course on Nuclear and Particle Physics is to teach the students the basic of nuclear properties, nuclear interactions, nuclear decay, nuclear models, detectors, nuclear reactions and elementary particles.

Unit-I **12 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 **16 hours**

Nuclear Decay: Different kinds of particle emission from nuclei, Alpha decay Fine structure of 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 **14 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

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.

Suggested Readings

1. B. Martin, *Nuclear & Particle Physics* An Introduction : (John Wiley & Sons, Inc., New Jersey, USA) 2011.
2. K.S. Krane, *Introductory Nuclear Physics* (John Wiley & Sons, Inc., New Jersey, USA) 2008.
3. C.A. Bertulani, *Nuclear Physics in a Nutshell* (Princeton University Press, Princeton, USA) 2007.
4. S.S.M. Wong, *Introductory Nuclear Physics* (John Wiley & Sons, Inc., New Jersey, USA) 2008.
5. K. Heyde, *Basic Ideas and Concepts in Nuclear Physics* An Introductory approach : (CRC Press, London, U. K.) 2004.
6. B. Povh, K. Rith, C. Scholz, *Particles and Nuclei: An Introduction to the Physical Concepts* (Springer, New York, USA) 2012.
8. D.H. Perkin, *Introduction to High Energy Physics* (Cambridge University Press, Cambridge, U.K.) 2000.
9. I.S. Hughes, *Elementary Particles* (Cambridge University Press, Cambridge, U.K.) 1991.
10. W.R. Leo, *Techniques for Nuclear and Particle Physics Experiments* (Springer, New York, USA) 2009.
11. T. Stefan, *Experimental Techniques in Nuclear and Particle Physics* (Springer, New York, USA) 2010.
12. D.J. Griffiths, *Introduction to Elementary Particles* (Wiley-VCH Verlag GmbH, Germany) 2008.

Course Title: Nuclear Physics Laboratory

Paper Code: PHY.553

L	T	P	Cr
0	0	8	4

Total Hours: 120

Course objective: The nuclear physics laboratory experiments have been so designed that the students learn to decay process, detection, and absorption learnt in the theory course. 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.

Suggested Readings

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

Course Title: Advanced Solid State Physics
Paper Code: PHY.554

L	T	P	Cr
0	0	0	4

Total Lectures: 60

Course Objective: The purpose of this course is to introduce students to the fundamental and advanced concepts of solid state physics. The topics include Fermi surfaces and its determinations, band gap in semiconductor, Plasmons, Dielectric, Ferroelctrics and optical processes in crystalline and amorphous solids.

Unit-I **13 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 **13 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 **19 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

Suggested Readings

1. J. Ziman, *Principles of the Theory of Solids* (Cambridge University Press, Cambridge, U.K.) 2011.
2. C. Kittel, *Introduction to Solid State Physics* (Wiley India (P) Ltd., New Delhi, India) 2007.
3. R.J. Singh, *Solid State Physics* (Pearson, New Delhi, India) 2011.
4. A.J. Dekker, *Solid State Physics* (Macmillan, London, U.K.) 2012.
5. N. W. Ashcroft and N. D. Mermin, *Solid State Physics* (Thomson Press), 2003.

Course Title: Nuclear Techniques-I
Paper Code: PHY.555
Total Lectures: 60

L	T	P	Cr
0	0	0	4

Course Objective: This course aims to introduce different techniques use to study nuclear physics starting from design of different radiation source, detection, interaction and its applications.

Unit: 1 **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: 2 **15 hours**

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. Origin and characteristics of X-Rays, beta rays, alpha particles, and gamma-rays, Estimation of energies of charged particles from their trajectories in magnetic fields, Interaction of electrons, positrons, heavy ions, gamma rays and neutrons with matter.

Unit: 3 **15 hours**

Nuclear Electronics: Preamplifier, amplifier, pulse shaping networks, biased amplifier, pulse stretchers delay lines, discriminator. Pulse height analysis and coincidence technique, D/A, A/D converter, Single channel analyzer, multichannel analyzer, pulse shape discrimination, coincidence units, slow-fast coincidence circuits, anticoincidence circuit, Multichannel Analyzer Applications of radiation, gamma-ray and neutron radiography.

Unit: 4 **15 hours**

Dosimetry and radiation protection units: Roentgen, RAD, Gray, Sievert, RBE, BED, REM, REP, kerma, Cema, energy deposit and energy imparted, exposure, absorbed dose, equivalent dose, radiation protection, organ dose, effective dose equivalent effects and dose limits, assessment of exposure from natural manmade sources and working principle of pocket dosimeter.

Suggested Readings

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

Course Title: Introduction to Computational Materials Physics
Paper Code: PHY.556
Total Hours: 30

L	T	P	Cr
2	0	0	2

Course Objective: The aim of the course is to outline nuts and bolts of physics required to compute the properties of materials using modern computational methods. It is possible to compute the properties of materials by applying laws of quantum physics and using concepts of solid state physics. This course will introduce about basics of density functional theory for electronic structure problems, pseudopotential approach, plane waves and localized orbitals basis sets methods.

Unit-I **8 hours**

Elementary Density Functional Theory (DFT): Electron density in DFT, Hohenberg-Kohn theorems, Kohn Sham approach, Exchange-correlation functionals: local density approximation and genitalized gradient approximation, Solving Kohn-Sham equations, Extension and limitations of DFT.

Unit-II **7 hours**

Treatment of Solids: Pseudopotential approach, Types of pseudopotentials, Reducing the calculation size: supercell approach, 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 III **8 hours**

Electronic Structure of Solids: Origin of energy gap, Wave equation of electron in periodic potential, empty lattice approximation, Electronic structure of metals and semiconductors, Optical processes: Kramers-Kronig relations, electronic interband transitions, Dielectric functions and absorption spectra, Excitons, Energy loss of fast particles in a solid.

Unit IV **7 hours**

Electronic Structure Methods: Bloch theorem: Fourier expansion and Fast Fourier transformation, Matric expression for Kohn-Sham equations, Tight binding method, Determination of electronic structure: plane waves and localized orbitals methods.

Suggested Readings

1. June Gunn Lee, *Computational Materials Science: An Introduction*, (CRC Press 2011)
2. Efthimious Kaxiras, *Atomic and Electronic Structure of Solids* (Cambridge Unive. Press) 2007.
3. Richard M. Martin, *Electronic Structure: Basic Theory and Practical Methods*(Cambridge University Press) 2008.
4. David S. Sholl and Janice A. Steckel, *Density Functional Theory: A Practical Introduction* (John Wiley and Sons, 2009).
5. Feliciano Giustino, *Materials Modelling Using Density Functional Theory: Properties and Predictions*, Wiley (2009).

6. Rajendra Prasad, *Electronic Structure of Materials*, Taylor and Francis (2013).

Course Title: Computational Materials Physics Laboratory
Paper Code: PHY.558(a)

L	T	P	Cr
0	0	4	2

Total Hours: 60

Course Objective: The modelling and simulation laboratory experiments have been so designed that the students learn materials modelling and simulations using first principles method.

List of Practical's

1. Plot Total Energy Vs k-points for different Bulk materials to test the convergence of your result.
2. To find the optimized geometry of Bulk materials such Fe, Au, Co, NaCl and etc.
3. Compute and analyze the electronic structure of semiconductors such as Si and Ge.
4. Compute and analyze the electronic structure of metals such as Au and Pt.
5. Electronic structure of graphene using density functional calculations.
6. Electronic structure of 1D lattice such as Carbon nanotube
7. Determine the magnetic ground state of different magnetic systems.

Suggested Readings

1. June Gunn Lee, *Computational Materials Science: An Introduction*, (CRC Press 2011)
2. Efthimious Kaxiras, *Atomic and Electronic Structure of Solids* (Cambridge Unive. Press) 2007.
3. Richard M. Martin, *Electronic Structure: Basic Theory and Practical Methods*(Cambridge University Press) 2008.
4. David S. Sholl and Janice A. Steckel, *Density Functional Theory: A Practical Introduction* (John Wiley and Sons, 2009).
5. Feliciano Giustino, *Materials Modelling Using Density Functional Theory: Properties and Predictions*, Wiley (2009).
6. Rajendra Prasad, *Electronic Structure of Materials*, Taylor and Francis (2013).

Course Tile: Functional Materials and Devices
Paper Code: PHY.557

L	T	P	Cr
4	0	0	4

Total Lectures: 60

Course Objective: Physicists and Chemists are now playing an important role in the growing field of materials research. The aim of this course is to introduce students to this area of modern materials. This class will review the fundamental principles of various advanced functional materials and Devices.

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,).

Suggested Readings

1. Mel Schwartz, Smart Materials, CRC Press, Boca Raton, 2009
2. Handbook of Inorganic Electrochromic Materials, by C.G. Granqvist; Elsevier Science, 1995.
3. Lithium Batteries: Advanced Technologies and Applications, by Bruno Scrosati, K. M. Abraham, Walter Van Schalkwijk, and Jusef Hassoun; John Wiley & Sons, Inc, 2013.
4. Advanced functional materials: a perspective from theory and experiment. Edited by Biplab Sanyal, and Olle Eriksson
5. S.B. Ogale, T.V. Venkatesan, M. Blamire, *Functional Metal Oxides* (Wiley-VCH Verlag GmbH, Germany) 2013.
6. S. Banerjee and A.K. Tyagi, *Functional Materials: Preparation, Processing and Applications* (Elsevier, Insights, Massachusetts, USA) 2011.

7. D.D.L. Chung, *Composite Materials: Functional Materials for Modern Technologies* (Springer, New York, USA) 2003.
8. Deborah D. L. Chung, *Functional Materials: Electrical, Dielectric, Electromagnetic, Optical and Magnetic Applications* (World Scientific Publishing Company, Singapore) 2010.
9. B.D. Cuility and C.D. graham, *Introduction to Magnetic Materials* (Willey, New Jersey) 2009.
10. K.C. Kao, *Dielectric Phenomena in Solids* (Elsevier, Academic Press, London, U. K.) 2004.
11. S. O. Kasap, *Principles of Electronic Materials and Devices* (McGraw Hill Publications)
12. B E Conway Brian E Conway Conway, *Electrochemical Supercapacitors: Scientific Fundamentals and Technological Applications* (Springer) 1999.

Course Title: Seminar-I
Paper Code: PCP.543

L	T	P	Cr
-	-	-	1

Total Hours: 15

Course Objective: Seminar has been introduced to make students well versed with the communication and presentations skills. Students will make presentation on the Physical concepts and research related topics.

Course Title: Project Work-I
Paper Code: PHY.599

L	T	P	Cr
-	-	-	6

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

Course Title: XXX
Paper Code: XXX

L	T	P	Cr
1	-	-	1

Total Hours: 15

Course Objective: This course is introduce to enhance the value education among the students.

Students have to choose one of the courses from the pool of courses designed at university level.

Semester IV

Course Title: Research Methodology
Paper Code: PHY.571
Total Lectures: 60

L	T	P	Cr
4	0	0	4

Course Objective: The course Research Methodology has been framed to introduce basic concepts of Research Methods. The course covers 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.

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.

Suggested Readings

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

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

L	T	P	Cr
4	0	0	4

Course Objective: Mesoscopic physics is the area of solid state physics that covers the transition regime between macroscopic and microscopic object. The purpose of this course is to introduce the physical concepts underlying the phenomena in this field. In the mesoscopic regime, new topics arises such as: quantization of electrical conductance, Coulomb Blockade, quantum capacitance and etc.

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

Suggested Readings

1. Quantum Transport Atom to Transistor by Supriyo Datta (CAMBRIDGE)
2. Lessons from Nanoelectronics: A New Perspective on Transport: Volume 1 & 2 by Supriyo Datta (World Scientific)
3. Theory of Quantum Transport at Nanoscale: An Introduction by Dmitry A Ryndyk (Springer)
4. Quantum Transport: Introduction to Nanoscience by Yuli V. Nazarov and Yaroslav M. Blanter
(CAMBRIDGE)

Course Tile: Nuclear Techniques-II

Paper Code: PHY: 575

Total Lectures: 60

L	T	P	Cr
4	0	0	4

Course Objective: This course aims to introduce different techniques use to study nuclear physics starting from design of different radiation source, detection, interaction and its applications.

Unit: 1

Neutron Sources and Reactors: Neutron sources, radioactivity based neutron sources and laboratory neutron sources, Thermal and fast neutron detectors, Q values, Fission, Fusion, production of radioisotopes, Reactor operation, Power reactors.

Unit: 2

Measurement of Lifetime and Nuclear Levels: Basic concepts of half-life, mean lifetime of radioactive nuclei, Excited states of nuclei; Measurement of lifetime of the nuclear excited states, covering range from picoseconds to years using techniques such as recoil distance, delayed coincidence, activity measurement and others.

Unit: 3

Radiation detectors: Basic principle and design of radiation detectors, Gaseous detectors, Ionization chamber, proportional counter and GM counter, scintillation detectors, semiconductor detectors, surface barrier detector, Si(Li), Gel(Li), HPGe and detection efficiency for various types of radiations

Unit: 4

Applications: Elemental analysis by neutron activation analysis, proton induced X-ray emission, Nuclear Reaction analysis, Rutherford backscattering, Resonance nuclear reaction, Elastic RDA, ion scattering and Neutron Depth Profile, applications of radioisotopes in medical field, industries and agriculture, dating of archaeological and other ancient object, Carbon-14 and potassium-argon dating 39,40 method trace element studies, radiotherapy for cancer treatment.

Suggested Readings

1. Nuclear radiation detectors, S. S. Kapoor and V. S. Ramamurthy (Wiley Eastern Limited, New Delhi).
2. Introduction to radiation protection dosimetry, J. Sabol and P. S. Weng (World Scientific).
3. Techniques for nuclear and particle physics, W. R. Leo (Springer).
4. Nuclear Measurement Techniques, K. Sriram (Affiliated East-West Press, New Delhi).
5. Fundamentals of surface and thin analysis, Leonard C. Feldman and James W. Mayer (North Holland, New York).
6. Introduction to nuclear science and technology, K. Sriram and Y. R. Waghamare (A. M. Wheeler).
7. Nuclear radiation detection, W. J. Price (McGraw-Hill, New York).
8. Alpha, beta and gamma-ray spectroscopy, K. Siegbahn (North Holland, Amsterdm).
9. Introduction to experimental nuclear physics, R. M. Singru (John Wiley and Sons).
10. Radioactive isotopes in biological research, William R. Hendee (John Wiley and Sons).

Course Title: Nanostructured Materials
Paper Code: PHY.576
Total Lecture: 60

L	T	P	Cr
4	0	0	4

Course Objective: It aims to introduce basics of nanomaterials, their properties and synthesis via different methods and the applications of nanomaterials.

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**

Microscopy: Light Microscopy (Bright field, dark field, phase contrast), Fluorescence (wide-field, confocal, 2-photon) microscopy, Field Emission Scanning Electron Microscopy (FESEM), Energy-dispersive X-ray spectroscopy (EDS), Transmission Electron Microscopy (TEM), High resolution TEM, Selected area electron diffraction (SAED).

Surface Probe Analysis: Atomic Force Microscope (AFM), Scanning Tunnelling Microscope (STM), spectroscopy, X-ray photoemission spectroscopy (XPS).

UNIT-IV **15 hours**

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

Spectroscopy: IR Spectroscopy, FTIR, UV-Visible spectroscopy, Raman Spectroscopy, Auger Spectroscopy, Impedance Spectroscopy, Dielectric Spectroscopy.

Suggested Readings

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

Course Title: Materials Characterizations
Paper Code: PHY:577
Total Lecture: 60

L	T	P	Cr
4	0	0	4

Course Objective: It aims to make students familiar with the basic characterizations used for the different information and purpose of the prepared nanomaterials/thin films.

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.

Suggested Readings

1. Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, 2nd Edition, by Yang Leng, WILEY (2013).
2. Atomic Force Microscopy: Understanding Basic Modes and Advanced Applications, by Greg Haugstad, WILEY (2012)
3. Introduction to Scanning Tunneling Microscopy, by C. Julian Chen, Oxford Unive. Press (1993)
4. An Introduction to Surface Analysis by XPS and AES, by John F. Watts, and John Wolstenholme, WILEY (2003)

Course Title: The Enrich Physics Course-I

Paper Code: PHY:576

Total Lecture: 30

L	T	P	Cr
2	0	0	2

Course Objective: This course aims to enrich students through physics problems and exercises of importance for national level examination.

Unit-I **8 hours**

Vector calculus, matrices, differential equations, Fourier series, analytic functions, poles, residues and evaluation of integrals.

Unit-II **7 hours**

Lagrangian and Hamiltonian formalism,Central force motions, Conservation laws and, cyclic coordinates, Rigid body dynamics, small oscillations.

Unit-III: **8 hours**

Applications of Schrodinger's equation, Angular momentum, Scattering theory and relativistic quantum theory, perturbation theories, Atomic and Molecular Spectra.

Unit-IV: **7 hours**

Laws of thermodynamics, Ensemble theory, Phase transition, Bose gas, Fermi gas.

Suggested Readings

1. G. Arfken, H. Weber and F. Harris, *Mathematical Methods for Physicists* (Elsevier Academic Press, Massachusetts, USA) 2012.
2. P.S. Joag and N.C. Rana, *Classical Mechanics* (Tata McGraw-Hill, Noida, India) 1991.
3. N.Zettili, *Quantum Mechanics-Concepts and Applications* (John Wiley & Sons Ltd., Sussex, U.K.) 2009.
4. D. J. Griffiths, *Introduction to Quantum Mechanics*, 2nd Ed. (Pearson Education, India) 2015.
5. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, (Tata, McGraw Hill Publishing Company Limited).
6. R.K. Pathria and Paul D. Beale, *Statistical Mechanics* (Elsevier, USA) 2011.

Course Title: The Enrich Physics Course-II

Paper Code: PHY: 577

Total Lecture: 30

L	T	P	Cr
2	0	0	2

Course Objective: This course aims to enrich students through physics problems and exercises of importance for national level examination.

Unit-I **8 hours**

Electrostatics & magnetostatics, Maxwell's equations, electromagnetic waves, wave guides, radiation.

Unit-II **7 hours**

Two Nucleon Problems, Nuclear Decay, Nuclear models, Detectors, Accelerators, Nuclear Reactions,

Unit-III **8 hours**

Network Theorems, Semiconductor, transistors, OpAmp, binary and sequential logic

Unit-IV: **7 hours**

Diffraction and the structure factor, specific heat, Hall effect, band theory of solids, Superconductivity.

Suggested Readings

1. D.J. Griffiths, *Introduction to Electrodynamics*, Prentice Hall of India Pvt.Ltd., New Delhi,2012.
2. B. Martin, *Nuclear & Particle Physics* An Introduction : (John Wiley & Sons, Inc., New Jersey, USA) 2011.
3. J. Millman, C. Halkias and C. Parikh, *Integrated Electronics : Analog and Digital Circuits and Systems* (Tata McGraw - Hill Education, Noida, India) 2009.
4. C. Kittel, *Introduction to Solid State Physics* (Wiley India (P) Ltd., New Delhi, India) 2007.

Course Title: Seminar-II
Paper Code: PCP.544

L	T	P	Cr
-	-	-	1

Total Hours: 15

Course Objective: Seminar has been introduced to make students well versed with the communication and presentations skills. Students will make presentation related to their research project.

Course Title: Basics of Computational Nanoelectronics
Paper Code: PCP.576
Total Hours: 60

L	T	P	Cr
4	0	0	4

Course Objective: The purpose of this course is to introduce the physical concepts underlying the phenomena in the mesoscopic systems. The aim of the course is, how to model and solve nanojunctions. In this course, students will learn some new advanced topics such as: quantization of electrical conductance, Coulomb Blockade, quantum capacitance and etc.

Unit I

Introduction, Two Key Concepts, Why Electrons Flow, Conductance Formula, Ballistic Conductance, Diffusive Conductance, Connecting Ballistic to Diffusive, Drude Formula, Characteristic Length Scale, Transport Regime.

Unit II

Density of States, Number of Modes, Electron Density, Conductivity vs. Electron Density, Quantum Capacitance, Nanotransistors, What and Where is the Voltage, Spin Voltage, Current from Quasi-Fermi Levels, Electrostatic Potential

Unit III

What a Probe Measures, Boltzmann Equation, Semiclassical Model, Quantum Model, Landauer Formulas, NEGF Equations, Self-Energy, Surface Green's Function, Current Operator, Scattering Theory, Transmission, Rate Equations

Unit IV

Spin Transport, Vectors and Spinors, Spin-Orbit Coupling, Spin Hamiltonian, Spin Density/Current, Seebeck Coefficient, heat Current, Second Law, Entropy, Fuel Value of Information

Suggested Readings

1. Quantum Transport Atom to Transistor by Supriyo Datta (CAMBRIDGE), 2013.
2. Lessons from Nanoelectronics: A New Perspective on Transport: Vol. 1 & 2 by Supriyo Datta (World Scientific), 2017.
3. Theory of Quantum Transport at Nanoscale: An Introduction by Dmitry A Ryndyk (Springer), 2015.
4. Quantum Transport: Introduction to Nanoscience by Yuli V. Nazarov and Yaroslav M. Blanter (CAMBRIDGE), 2009.

Course Title: Molecular Simulation Laboratory
Paper Code: PCP.572
Total Hours: 60

L	T	P	Cr
0	0	4	2

Course Objective and Learning outcomes: The objective of this subject is to ensure that a student gains practical in-hand experience of various modeling and classical simulation tools, including, but not limited those that are used in macromolecular modeling. The course will help the students learn the use the techniques of molecular simulations, which will enhance their employability in their further potential carrers in academia and industry.

1. Linux basics and remote computing
2. Coordinate generations and inter-conversions of small molecules
3. Energy minimizations and optimization, ab initio methods
4. Advanced Visualization Software and 3D representations with VMD
5. Introduction to PDB Data
6. Secondary Structure Prediction, Fold Recognition
7. Molecular Dynamics with GROMACS

a. Water liquid structure and dynamics
b. Simulation of Ionic Solutions
c. Simulation of Protein in Water
d. Simulation of Membrane Proteins
e. Simulations of DNA

8. Review of Molecular Dynamics Principles

Suggested Readings

Andrew R.Leach Molecular Modelling Principles and applications. (2001) II ed . Prentice Hall.

Fenniri, H. “Combinatorial Chemistry – A practical approach”,(2000) Oxford University Press, UK.
Lednicer, D. “Strategies for Organic Drug Discovery Synthesis and Design”; (1998) Wiley International Publishers.
Gordon, E.M. and Kerwin, J.F “Combinatorial chemistry and molecular diversity in drug discovery” (1998) Wiley-Liss Publishers.

Course Title: Project
Paper Code: PCP.599

L	T	P	Cr
-	-	-	6

The time allowed to project work-II is equivalent to the one and half practical laboratory course per week. 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.

Course Title: XXX
Paper Code: XXX
Total Hours: 15

L	T	P	Cr
1	-	-	1

Course Objective: This course is introduce to enhance the value education among the students.
Students have to choose one of the course from the pool of courses designed at university level.