



UNIVERSITY OF KERALA

Senate House Campus, Palayam
Thiruvananthapuram 34, Kerala, India

കേരള സർവകലാശാല

സെനറ്റ് ഹൗസ് കാമ്പസ്, പാലായം
തിരുവനന്തപുരം 34, കേരളം, ഇന്ത്യ



<https://keralauniversity.ac.in>

Learning Outcomes-based Curriculum Framework (LOCF) for Post-graduate Programme

Name of the Programme:

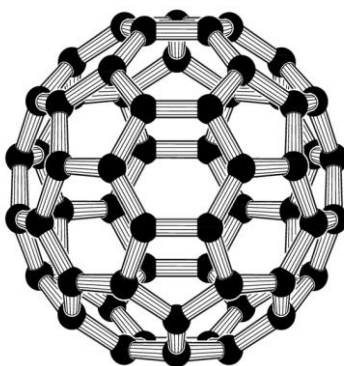
**M.Sc. Physics
(Specialization in Nanoscience)**

Offered by

Department of Nanoscience and Nanotechnology

jointly with

Department of Physics



(Syllabus effective from 2021 Admission onwards)



UNIVERSITY OF KERALA

2021

UNIVERSITY OF KERALA

Syllabus for M.Sc. Physics
(Specialization in Nanoscience)

Programme Specific Outcomes (PSO) for
M.Sc. Physics(Specialization in Nanoscience)

- PSO 1 To provide well defined study of theoretical and experimental physics to impart in depth understanding in fundamental aspects of all core areas of Physics and specific area of Nanoscience
- PSO 2 To equip the student to pursue research and development in any areas of theoretical, experimental and computational physics and nanoscience.
- PSO 3 To impart special training in theoretical and experimental aspects of Nanomaterials and Nanodevices.
- PSO 4 Gains expertise in emerging areas of research in nanomaterials and nanotechnology
- PSO 5 Analyzes the impact of emerging research areas in Nanoscience and Nanotechnology, in providing mankind with sustainable resources and cleaner environment
- PSO 6 To bridge the gap between text book knowledge and practical problems through well designed laboratory sessions.
- PSO 7 Develops innovative methodologies for the development of technological knowledge and intellectual property
- PSO 8 Understand, apply and verify the theoretical/empirical concepts by doing experiments.
- PSO 9 To introduce the student to the scientific research methodology, literature survey, technical writing, assimilation and dissemination of results, research ethics etc. through a project work.

Programme Structure of M.Sc. Physics (Specialization in Nanoscience)

Semester	Course Code	Name of the course	Credits
I	Core Courses (CC)		
	PHY-CC-511	Mathematical Physics I	4
	PHY -CC-512	Classical Mechanics	4
	PHY -CC-513	Electrodynamics	4
	PHY -CC-514	Electronic Devices and Circuits	4
	PHY -CC-515	Lab- Advanced Physics I	2
	PHY -CC-516	Lab-Basic Electronics I	2
II	Core Courses (CC)		
	PHY -CC-521	Mathematical Physics II	4
	PHY -CC-522	Quantum Mechanics I	4
	PHY-CC-523	Thermal and Statistical Physics	4
	PHY -CC-524	Atomic and Molecular Physics	4
	PHY -CC-525	Lab- Advanced Physics II	2
III	Core Courses (CC)		
	PHY -CC-531	Quantum Mechanics II	4
	PHY -CC-532	Solid State Physics	4
	PHY -CC-533	Nuclear and Particle Physics	4
	Discipline-Specific Elective (DE)		
	PHY -DE-534	Computational Methods	4

	NSP-DE-535	Physics of Nanomaterials	4
IV	Core Courses (CC)		
	NSP-CC-541	Project	6
	Discipline-Specific Elective (DE)		
	NSP -DE-542	Nanomaterials Synthesis and Characterization	3
	NSP -DE-543	Functional Nanomaterials and Nanotechnology	4
	NSP -DE-544	Lab- Nanoscience	4

NAME OF THE COURSE: MATHEMATICAL PHYSICS I**Course Outcomes**

1. To apply and analyze the various vector and matrix operations for solving physical problems.
2. To demonstrate and utilize the concepts of Fourier series, Fourier transforms and Laplace transform.
3. To apply partial differential equations and special functions for solving mathematical problems.

Course Content**Module I**

Vector Spaces and Matrices: Postulates – linear independence-subspace- ordered dimensions- Euclidian vector space- reciprocal basis- Hilbert space- linear equations- Eigen value problem- orthogonal matrices – Hermitian matrices and Unitary matrices – Diagonalization of matrices – Eigen vector and Eigen values – normal modes of vibration – singular matrices- inverse of matrix

Module II

Curvilinear Coordinates: Orthogonal curvilinear coordinates- Differential vector operator- Gradient, divergence, curl and Laplacian in Cartesian, cylindrical and spherical polar coordinates.

Partial Differential Equations: Linear second order partial differential equations – Solutions of partial differential equations- separation of variables- solution of wave equations.

Module III

Gamma, (Γ), Beta (β) and Delta (δ) functions: Gamma functions – Gauss λ functions, values of $\Gamma(1/2)$ – β functions- connection between β and Γ functions- Error function – Dirac delta function – representation of δ function – properties.

Module IV

Legendre differential equations: Series solution – Rodrigues formula for $P_n(x)$ - Generating function for $P_n(x)$ – Orthogonality of Legendre polynomials – Orthogonality of associate Legendre polynomial.

Bessel's equation: Series solution- Bessel function of second kind – Generating function for $J_n(x)$ – Bessel's integral representation – Recurrence formula for $J_n(x)$ – Orthogonality of $J_n(x)$ – Spherical Bessel function.

Module V

Hermite differential equation: Series solution – Rodrigues formula for Hermite polynomial $H_n(x)$ – recurrence relation for Hermite polynomial- Generating function – Orthogonality of Hermite equation.

Laguerre's differential equation:Series solution – generating function - $L_n^m(x)$ - Rodrigues formula- Associate Laguerre's function of integral order.

Module VI

Fourier series and Integrals: Periodic series and integrals – Periodic functions – Fourier series – Euler Fourier series- Convergence of Fourier series and Dirichlet's condition, half range Fourier series – change of interval – identity- integration and differentiation of Fourier series – Fourier integrals and Transforms – Application of the solution in one dimension – alternative form of Fourier sine and cosine series.

Laplace Transform:Definition – Existence – derivatives- elementary functions – periodic function – functions defined by integrals.

References

1. Arfken & Weber (2005). *Mathematical Methods for Physicists*, Academic Press, 6thed.
2. Pipes L.A. & Harvill L.R. (1982). *Applied Mathematics for Engineers and Physicists*, McGraw-Hill Book Company, 3rd ed.
3. Rajput, B. S. (2001). *Mathematical Physics*, Pragati Prakashan, 15thed.
4. Ghatak, A. K. et al. (2012). *Mathematical Physics: differential equations and transform theory*, Macmillan & Co. Ltd., 1sted.

Additional Reading

1. NIST Digital Library of Mathematical Functions dlmf.nist.gov/
2. GNU Scientific Library – Reference Manual: Special Functions <https://www.gnu.org/software/gsl/manual/html.../Special-Functions.html>
3. MIT 18.06 Linear Algebra Spring 2005 - Video Lectures. NET videolectures.net › ... › MIT Open Courseware
4. <https://www.physicsforums.com/threads/when-to-use-laplace-fourier-series-transforms.192535/>
5. Laplace and Fourier Transforms www.cambridge.org/us/features/chau/webnotes/chap2laplace.pdf

NAME OF THE COURSE: CLASSICAL MECHANICS**Course Outcomes:**

1. To introduce analytical methods of mechanics based on generalised coordinates momenta and solve the practical problems using these concepts.
2. Understand and demonstrate the classical concepts of Physics starting from Newtonian Mechanics.
3. Understand the drawbacks of Newtonian Mechanics and the establishment of Classical Mechanics.
4. Develop mathematical formulation of physical problems using Lagrangian and Hamiltonian formalisms.
5. Demonstrate and solve new problems dealing with the classical aspects of Physics.
6. Apply the concepts of Poisson's Bracket algebra and its implementation in Quantum mechanical formulation.

Course Content**Module I**

Lagrangian Formulation of Mechanics: Review of Newtonian Mechanics, Inertial and non-inertial frame of references, Generalize coordinates: Constraints, Virtual displacement, Principle of virtual work, D'Alembert's principle, Lagrange's equation of motion, Application of Lagrange's equation of motion to simple problems, Cyclic coordinates, Symmetric properties and Conservation laws.

Module II

Variational Principle and Hamiltonian Dynamics: Variational Principle and action Integral, Lagrange's equations of motion from Variational principle, Hamiltonian of a system, Hamilton's equation of motion, Canonical transformations, Generating function, Poisson Brackets and its fundamental properties, Integrals of motion, Canonical Invariance of Poisson Brackets, Lagrange Brackets.

Module III

Two-body Central Force Problem: Reduced mass and equation of motion, Central force and equation of motion, it's general properties, classification of orbits, Virial Theorem, inverse square law of force – Kepler's laws of planetary motion, Scattering in a central force field.

Module IV

Hamilton-Jacobi Theory: Hamilton-Jacobi equation, Hamilton's principal function, Hamilton's characteristic function, Separation of variables in Hamilton-Jacobi method, Action angle variables and it's applications.

Module V

Rigid Body Motion: Independent co-ordinates, Moments of Inertia, Angular momentum, Kinetic energy, Euler's angles, Euler's equation of motion, Force free motion of a rigid-body.

Module VI

Small Oscillations: Potential energy concept, Stability and Equilibrium, Theory of small oscillations, Modes of vibration, Coupled harmonic oscillator problem.

LEARNING RESOURCES

References

1. Goldstein, Herbert, et al. (2012). Classical Mechanics, Pearson Education, 3rded.
2. Rana, N.C. & Joag, P.S (2011). Classical Mechanics, Tata McGraw-Hill Publishing Co., 1sted.
3. Bhatia, V.B. (1997). Classical Mechanics with introduction to non-linear oscillations and chaos, Narosa Publishing House, 1sted.
4. Aruldas, G. (2012). Classical Mechanics, Prentice - Hall of India, 1sted.
5. Vimal Kumar Jain (2009), Classical Mechanics, Anne Books Pvt. Ltd.
6. SrinivasaRao, K. S.,(2003) Classical Mechanics, Universities press
7. D. Kleppner and R. Kolenkow, An introduction to Mechanics, McGraw -Hill Science/Engineering/Math, 1973
8. R.Shankar, Fundamentals of Physics, Yale Press

On-line Sources:

1. <http://www.damtp.cam.ac.uk/user/tong/dynamics.htm>
2. http://www.onlinevideolecture.com/physics/nptel-iit-madras/special-topics-in-classical-mechanics/?course_id=780

NAME OF THE COURSE: ELECTRODYNAMICS**Course Outcomes:**

1. To provide basic understanding of the concepts of electricity, magnetism and electromagnetic waves.
2. To introduce the concepts of non-relativistic and relativistic electrodynamics
3. To analyse the theory of guided waves and radiation systems.
4. To introduce the elements of relativistic electrodynamics.

Course Content**Module I**

Electrostatics: Electrostatic boundary value problems: Uniqueness theorems- Formal solution with Green's function- Method of Images, Point charge near an infinite conducting plane, Point charge near a grounded conducting sphere, Point charge near charged insulated conducting sphere, Conducting sphere in a uniform electric field; Laplace's equation in spherical coordinates- Multipole expansion-Electrostatic multipole moments- Work and energy in electrostatics -Energy of charge distribution in an external field-Electrostatics of macroscopic media: electric polarization and electric displacement, dielectric constant; Boundary condition at dielectric interface.

Module II

Magnetostatics and dynamics: Biot Savart's law and its differential statement-Ampere's theorem-Magnetic vector potential- Magnetic charge- Faraday's law-Energy in magnetic field- Displacement current-Maxwell's equations-Scalar and Vector potentials-Wave equation in terms of scalar and vector potentials-Gauge transformation -Gauge invariance-Coulomb Gauge-Lorentz Gauge- Boundary condition on fields at interfaces-Conservation of electromagnetic energy-Poynting theorem-Poynting vector.

Module III

Electromagnetic waves: Waves in vacuum-Monochromatic plane waves-Plane electromagnetic waves in non-conducting medium: linear and circular polarization, reflection and transmission at dielectric interface, Polarization by reflection, Total internal reflection; Electromagnetic waves in conductors: skin depth, Reflection at a conducting surface.

Module IV

Guided waves and Radiation systems: Rectangular and circular waveguides:TE and TM modes-Cavity resonators-Q factor; Concepts on transmission lines-transmission line parameters-Transmission line equations; Simple radiating systems: Green's function for wave equation-

fields and radiation of a localized oscillating source-Electric dipole field and radiation- Magnetic dipole and radiation-Retarded potentials.

Module V

Special theory of relativity: Postulates of relativity-Lorentz transformation-Four vector – Addition of velocities-Four velocity- Relativistic energy and momentum- Matrix representation of Lorentz transformation-Dynamics of relativistic particles; Motion of charged particle in uniform electric and magnetic field.

Module VI

Relativistic Electrodynamics: Magnetism as a relativistic problem-Transformation of the fields- Electric field of a uniformly moving point charge-Electromagnetic field tensor- Electrodynamics in tensor notation-Potential formulation of electrodynamics

References

- Cheng, D. K.(2015). Field and wave Electromagnetics, Pearson Education, 2nded.
- Griffiths, D. J. (2012). Introduction to Electrodynamics, Prentice-Hall of India, 3rded.
- Jackson, J. D. (2011). Classical Electrodynamics, Wiley Eastern Ltd., 3rded.
- Sadiku, M. N. O. &Kulkarni, S. V. (2015). Principles of Electromagnetics, Oxford University Press, 6thed.

Additional References

- Basic Plasma Physics <http://www.plasmas.org/plasma-physics.htm>
- Classical Electrodynamics <http://www.thp.unikoeln.de/alexal/pdf/electrodynamics.pdf>
- Special Relativity and Electrodynamics <http://theoreticalminimum.com/courses/special-relativity-and-electrodynamics/2012/spring>
- Electromagnetic theory NPTEL lectures by Dr. D.K.Ghosh, <https://nptel.ac.in/courses/115/101/115101005/#>

Transmission lines and electromagnetic waves, NPTEL lectures by Prof. Ananth Krishnan, <https://nptel.ac.in/courses/108/106/108106157/>

NAME OF THE COURSE: ELECTRONIC DEVICES AND CIRCUITS**Course Outcomes:**

1. Ability to design RC filter circuits and appraise the working of BJT amplifiers
2. Ability to distinguish Class A, B, C and D power amplifiers
3. Explain construction and working of OP-AMPs and design waveform generator circuits
4. Describe the construction and working of FLIP FLOPS.
5. Explain the theory and working of IC 555 and design multi-vibrator circuits using IC 555.
6. Explain construction and working of microwave devices and optical fibre.

Course Content**Module I:**

Frequency response of amplifiers: Review of frequency response of CR circuits – Cut off frequencies – band width – Bode plots – single pole and two pole transfer functions – Dominant pole – gain round off- Frequency response of BJT amplifiers- Series capacitance and low frequency response – Shunt capacitance and high frequency response- high frequency characteristics of transistors.

Module II:

Field Effect Transistor: Biasing of FET, small signal model, analysis of common source and common drain amplifiers, high frequency response – FET and VVR and its applications, CMOS logic and logic packages

Power Amplifiers: Types of power amplifiers, series fed class A amplifier- series fed transformer coupled Class B – Push-Pull circuits- harmonic distortion in amplifiers- Class C and D amplifiers- Design considerations.

Module III

Operational Amplifier: Ideal op-amp – inverting, non-inverting, voltage follower, differential configuration, real op-amp- inverting configuration, non-inverting configuration, op-amp parameters, effect of Offset, frequency response, active filters – low pass, high pass, band pass, band reject filters, analogue computations

Module IV

Operational Amplifier applications: Buffer amplifier, Mathematical operations- summing, differentiator, integrator, log amplifier, antilog amplifier, comparators – zero crossing detector, Schmitt trigger, wave form generators- phase shift oscillator, twin-T oscillator, astable multi vibrator, mono-stable multi vibrator, bi-stable multi vibrator, triangular wave generator, sample and hold circuit, voltage regulators.

Module V

Microwave and Optoelectronic Devices: Tunnel diode, Transfer electron device (Gunn diode) – optical fibre as a wave guide- mode theory of circular wave guides- wave guide equation – modes in step index fiber – graded index fiber – single mode fiber – mode characteristic and cut off frequencies.

Module VI

Optical sources: LEDs, Device configuration and efficiency – LED structures – Hetero-junction LED, surface emitting LED, edge emitting LED, Junction Laser- Operating principle – Hetero-junction Laser Photodetectors, photoconductors, PIN photodiode, heterojunction diodes, avalanche photodiodes, basic idea of photo transistors

References

1. Millman, J. & Halkias, C. C. (2000) Integrated Electronics: analog and digital circuits and systems, Tata McGraw Hill Publishing Co. Ltd., 1sted.
2. Boylestad, R. L & Nashelsky, L. (2009). Electronic devices and circuit theory, Dorling Kindersley (India) Pvt. Ltd., 10thed.
3. Gayakwad, R.A. (2016). Op-Amps and Linear Integrated Circuits, Pearson Education, 4thed.
4. Ryder, J. D. (2000). Electronic fundamentals and applications, Prentice-Hall of India Pvt. Ltd., 5thed.
5. Pallab Bhattacharya (2000). Semiconductor Optoelectronic Devices, Prentice-Hall of India Pvt. Ltd., 1sted.
6. Keiser, Gerd (2000). Optical Fiber Communications, McGraw-Hill book Co, Inc, 3rded.
7. Senior, John M. (1994). Optical Fiber Communications: principles and practice, Prentice-Hall of India Pvt. Ltd., 2nded.

Other References

[Introduction to the Amplifier](http://www.electronicstutorials.ws/amplifier/amp_1.html)[Amplifier Tutorial](http://www.electronicstutorials.ws/amplifier/amp_1.html). http://www.electronicstutorials.ws/amplifier/amp_1.html What is op-amp?

<http://www.engineersgarage.com/tutorials/op-amp-basics>

Opto electronics devices - Slide Share

www.slideshare.net/SiddharthPanda1/opto-electronics-devices

NAME OF THE COURSE: LAB- ADVANCED PHYSICS I**Course Outcome**

1. To measure calculate and analyze various physical quantities.
2. To develop experimental skills
3. To calculate error in various advanced physics experiments.

List of Experiments

(Any 6 experiments from the list)

1. Determination of $\frac{e}{k}$ of Silicon.
2. Calibration of Scale Using He-Ne Laser.
3. Determination of Young's Modulus by Cornus Method.
4. Determination of Planck's constant (Photoelectric effect).
5. Measurement of Magnetic Susceptibility of a Solution by Quincke's Method.
6. Frank Hertz Experiment.
7. XRD Data Analysis I, II, III
8. Determination of Band Gap.
9. Faradays Rotation Apparatus.
10. Constant Deviation Spectrometer- Arc Spectrum of Copper
11. Constant Deviation Spectrometer- Arc Spectrum of Iron
12. Constant Deviation Spectrometer- Arc Spectrum of Brass
13. Any experiment of similar standard

NAME OF THE COURSE: LAB – BASIC ELECTRONICS I**Course Outcomes:**

1. Understand the construction and working of full wave rectifiers using filter circuits.
2. Design and construct amplifiers and oscillators
3. Ability to construct and working astablemultivibrator using transistor and IC 555.
4. Ability to construct adder, scaler and Buffer amplifier using Op amp.
5. Understand the working of differentiator and integrator

List of Experiments

1. Fullwave rectifier with Filter circuits
2. Clipper, clamper and voltage doubler
3. Zener voltage regulator
4. RC coupled common emitter transistor amplifier
5. Negative feedback amplifier
6. RC phase shift oscillator
7. Emitter follower
8. Any experiment of similar standard

References

1. Navas, K. A. (2013). Electronics Lab Manual Vol.1, Rajath Publishers, 5thed.
2. Navas, K. A. (2009). Electronics Lab ManualVol.2, Rajath Publishers, 4thed
- 3.Zbar, Paul B, et al. (1994), Basic Electronics: a text – lab manual, Tata McGraw-Hill Publishing Co.7thed.

NAME OF THE COURSE: MATHEMATICAL PHYSICS II**Course Outcome**

1. Develop analytical skills in order to solve problems in different branches of Physics.
2. Perform complex integrations using the contour integral method.
3. Perform Taylor/Laurent expansion of complex functions.
4. Learn how to apply symmetry operations using group theory.

Course content**Module I**

Complex Analysis: Complex variables and Complex functions, Analyticity and Singularity of a Complex function, Cauchy-Reimann Condition in both Cartesian and plane-polar representations, Harmonic functions, Singular points: Poles, simple pole, Isolated Singularity, Removable Singularity, Essential Singularity, Branch Points, L-Hospital's rule, Cauchy's theorem, Cauchy's Integral Formula, Taylor series and Laurent series expansion, Calculus of residues: Cauchy's residue theorem, Evaluation of complex integrals using the contour integral method.

Module II

Tensor Analysis: Transformation of co-ordinates, summation convention, Tensors as classification of transformation laws, contra-variant and covariant tensors, Rank of a tensor, Symmetric and Anti-symmetric tensors, Invariant tensors, Pseudo tensors, Fundamental tensors, Algebraic operations on tensors, Christoffel's symbols of first kind and second kind, covariant differentiations.

Module III

Green's Function Techniques: Green's function in one dimension: Motion of a damped harmonic oscillator, Green's function in three dimensions: Solution of Poisson's equation.

Module IV

Group Theory: Definition of a group, elementary properties of a group, Abelian group, Multiplication table (Cayley table), Rearrangement Theorems, permutation groups: Symmetry operation of an equilateral triangle (S_3), Symmetry operation of a square (C_{4v}).

Module V

Group Representation: Generators of a finite group, Conjugate elements and Classes, Cyclic group, subgroup, normal subgroups and Cosets, Isomorphism and Homomorphism, Group representation, Lie groups.

Module VI

Probability: Laws of probability, Discrete and continuous probability distributions, Moments and Standard deviations: Binomial distributions, Poisson distributions and Normal distributions.

LEARNING RESOURCES

References

1. Churchill, R. V. & Brown, J. W. (1996). Complex Variables and Applications, McGraw-Hill Book Co. Inc., 6thed.
2. Spiegel, M. R. (1981). Schaum's Outline of Theory and Problems of Vector Analysis and an Introduction to Tensor Analysis, Schaum Publishing Co., 1sted.
3. Arfken & Webber (2005). Mathematical Methods for Physicists, Academic Press, 6thed.
4. Joshi, A. W. (2000). Matrices and Tensors in Physics, New Age International Publishers (P) Ltd., 3rd ed.
5. Joshi, A.W. (2015). Elements of group theory for physicists, New Age International Publishers (P) Ltd., 4thed.
6. Tung, Wu-Ki (2014). Group Theory in Physics, World Scientific, 1sted.
7. Pipes L.A. & Harvill L.R. (1982). Applied Mathematics for Engineers and Physicists, McGraw-Hill Book Company, 3rd ed.
8. B. D Gupta, Mathematical Physics.

Online Resources:

1. www.physics.miami.edu/~nearing/mathmetho1.ds/complex_algebra.pdf
2. <https://web.math.princeton.edu/~nelson/books/ta.pdf>
3. Murray Spiegel, Seymour Lipschutz, John Schiller and Dennis Spellman, Schaum's Outline of Complex Variables, 2ed (Schaum's Outline Series).

NAME OF THE COURSE: QUANTUM MECHANICS I**Course Outcomes:**

1. Examine physical situations to understand wave-particle duality (Analysis)
2. Analyze Schrodinger equation and interpret the concept of a wave packet. (Analyze)
3. Demonstrate and practice the operator method in quantum mechanics (Application)
4. Illustrate the formulation and solution of exactly solvable 1-D problems and interpret the results (Application)
5. Illustrate the formulation and solution of exactly solvable 3-D problems and interpret the results (Application)
6. Demonstrate the matrix formulation of quantum mechanics (Application)

Coursecontent**Module I**

Origin of Quantum Physics: In adequacy of Classical Physics: Particle aspect of radiation- Black body radiation- Max Planck's quantum hypothesis, Photoelectric effect- Einstein's explanation, Compton Effect, Pair production, Quantum theory of specific heat of solids. [*Experimental results and qualitative discussion only, Derivations not required*]. Frank-Hertz experiment- existence of atomic energy levels, Bohr's atom model, Wilson-Sommerfeld quantum conditions – Elliptical orbits of hydrogen atom, Particle in a box, Rigid rotator, Linear harmonic oscillator- Bohr's Correspondence principle, Limits of applicability of classical theory, Inadequacy of old quantum theory- Practical and Conceptual difficulties. **Wave aspect of Particles:** De Broglie's hypothesis of matter waves, The Davisson-Germer experiment, G. P. Thomson's experiment, Matter waves for macroscopic objects. Particle versus Waves – Classical view of particles and waves, Quantum view of particles and waves, Wave-particle duality, Complementarity principle, Principle of linear superposition, Heisenberg's uncertainty principle, Position-momentum uncertainty, Uncertainty relation for other variables, Explanation of single slit diffraction experiment, double slit diffraction experiment and interference experiment (Michelson interferometer) using corpuscular picture and uncertainty principle.

Module II

Wave Mechanical Concepts: Time dependent Schrödinger equation – Development of time dependent Schrödinger equation, Physical significance of the wave function, ψ - Probability interpretation, orthogonal, normalized and orthonormal functions, Probability current density, Limitations on ψ , Expectation value of dynamical quantities, Ehrenfest's theorem. The general solution of time depended Schrödinger equation for a free particle (one dimensional), Free

particle propagator, Wave packet, Time dependent evolution of a wave packet, Group velocity and Phase velocity, Time independent Schrödinger equation, Stationary states.

Module III

Wave Mechanics - Operator Method in Quantum Mechanics: Definition of an operator, Operator algebra, Eigenvalues and Eigenfunctions, Properties of Eigenfunctions, Vector representation of Orthogonality relation, Expansion theorem, Vectors in a complex n-dimensional space, Hilbert space, Different types of operator- linear operator, Hermitian operator, Adjoint or Hermitian conjugate of an operator, Parity operator, Projection operator, Identity operator, Inverse operator, Unitary operator, Properties of Hermitian operator, Schwartz inequality, Quantum Mechanical operators and observables, - Fundamental postulates of wave mechanics – Schrödinger equation and Probability interpretation for an N-particle system, The Superposition principle, Exact proof and statement of uncertainty principle, Classical Poisson Bracket, Quantum Poisson Bracket and equation of motion, Commutation rules for components of angular momentum.

Fourier techniques and momentum Representation: Momentum Eigenfunctions and their significance, The Kronecker delta and Dirac's delta functions, Coordinate and momentum representations, Schrödinger wave equation in momentum representation, Significance of momentum wave functions, Box normalization, Momentum wave function for a free particle.

Module IV

One-Dimensional Energy Eigenvalue Problems:(Exactly solvable) – Properties of one dimensional motion- Discrete spectrum (Bound state), Continuous spectrum (Unbound state), Mixed spectrum, Symmetry potentials and parity, Free particle: continuous state, The potential step, Boundary condition at the surface of an infinite potential, Square well potential with rigid walls, Square well potential with finite walls, Square potential barrier, Alpha emission, Bloch waves in a periodic potential, Attractive square well potential, Kronig-Penney square well periodic potential, Linear harmonic oscillator- Schrödinger method and Operator method.

Module V

Three-Dimensional Energy Eigenvalue Problems:(Exactly solvable) Particle moving in a spherically symmetric potential, System of two interacting particles – Rigid rotator, Hydrogen atom, The free particle.

Module VI

Heisenberg Method – Matrix formulation of Quantum Mechanics: Matrix algebra, Special matrices, Eigenvalues and eigenvectors of matrices, Linear vector spaces, Hilbert space, Linear operators: Linear transformations, Matrix representation of wavefunction, Matrix representation of operators, Properties of matrix elements, Normalization and Orthogonality of wavefunctions in matrix form, Average value of a dynamical variable in matrix form, Product of two linear

transformations, Dual space – Dirac’s Bra and Ket notations, Change of basis, Unitary and similarity transformations, Schrödinger equation and the Eigenvalue problems in Matrix method, Quantum dynamics- Schrödinger picture, Heisenberg picture, Interaction picture, One dimensional linear harmonic oscillator solution using matrix mechanics.

Symmetry and Conservation Laws: Symmetry transformations, Translation in Space: Conservation of linear momentum, Translation in time: Conservation of energy, Rotation in Space: Conservation of angular momentum, Space inversion: Parity conservation, Time reversal.

REFERENCES

1. Schiff Leonard I (2010) Quantum Mechanics, McGraw-Hill Book Company, India 3rded.
2. Aruldas G (2011) Quantum Mechanics, Prentice - Hall of India, 2nded.
3. Mathews P M and Venkatesan K, (1976), A text Book of Quantum Mechanics, Tata McGraw-Hill Publishing Company Ltd.
4. ZettiliNouridine (2009) Quantum Mechanics, John Wiley and Sons Ltd Publishing.
5. AjoyGhatak and Lokanatha S (2007) Quantum Mechanics Theory and Applications, Macmillan India Ltd, 5thed.

ADDITIONAL REFERENCES

AjoyGhatak (1996) Introduction to Quantum Mechanics, Mcmillan India Ltd.

Merzbacher E (1997) Quantum Mechanics, John Wiley.

Greiner W (1994) Quantum Mechanics- An Introduction, Springer 3rded.

Waghmare Y R (1997) Fundamentals of Quantum Mechanics, Wheeler Publishing.

Thankappan V K (1985) Quantum Mechanics, Wiley Eastern Ltd.

Quantum Physics I / Physics / MI OpenCourseWareocw.mit.edu > Courses > PhysicsLecturewww.phy.iitb.ac.in/~dkg/qmech/Lecture5.pdf*hyperphysics.phy-astr.gsu.edu/hbase/mod6.html*

onlinelibrary.wiley.com/doi/10.1002/prop.2190390304/pdf- .On Solutions of Quantum Eigenvalue Problems

NAME OF THE COURSE: THERMAL AND STATISTICAL PHYSICS**Course Outcome:**

Describe the statistical basis of Thermodynamics

Discuss and apply uniform, micro canonical, canonical and grand canonical ensemble theory

Explain and apply ensemble theory to simple gases

Review and apply quantum statistics to various indistinguishable systems

Describe the behaviour of Bose gas and apply Bose-Einstein statistics to black body radiation

Discuss the behaviours of Fermi gas and apply Fermi Dirac statistics to electron gas in a metal.

Summarize the phenomena of Phase Transition

Course Content**Module I**

Thermal Physics: Laws of thermodynamics- thermodynamic functions of an ideal gas – thermodynamic potentials- Maxwell's relations – Entropy of ideal gas- T.dS equations – Entropy and disorder – Heat capacity of equations.

Module II

Classical Statistics: Phase space- density of distribution in phase space – Liouville's theorem- statistical equilibrium – micro-canonical ensemble – Maxwell Boltzmann distribution law- Evaluation of Maxwell Boltzmann constants- Maxwell's law of distribution of velocities – mean values – principles of equipartition of energy- grand canonical ensemble.

Module III

Quantum Statistics: Indistinguishability of similar particles – probability of Eigenstates- Bose Einstein statistics, Fermi-Dirac Statistics- Maxwell Boltzmann statistics – comparison of three statistics – Number of Eigen states in an energy range – Eigen states and the Maxwell-Boltzmann equation.

Module IV

Applications of Bose-Einstein Statistics: Bose-Einstein system- gas-degeneration- Bose-Einstein statistics and radiation- Bose-Einstein condensation.

Applications of Fermi-Dirac Statistics: Fermi-Dirac system– Extreme gas degeneration- electron gas in metals– thermionic emission of electrons from metals.

Module V

Statistical Thermodynamics: Entropy and probability-Entropy and number of Eigen states-thermodynamic functions of a monatomic gas – partition function – entropy and free energy-energy and heat capacity- effect of zero energy level – separation of partition function-translational partition function-translational thermodynamic functions-rotational partition function-nuclear spin effects-vibrational partition function.

Module VI

Phase transitions: Phase diagram of a simple substance- Clausius – Clapeyron's equation-phase diagram of Helium – Classification of phase transitions- superconducting phase transition.

References

1. Zemansky, M.W. (1997). Heat and Thermodynamics, McGraw-Hill International Book Co., 7th ed.
2. Pathria, R.K. (1999). Statistical Mechanics, Butterworth-Heinemann Books, 2nd ed.
3. Pippard, A.B. (1966). Elements of classical thermodynamics for advanced students of physics, Cambridge University Press, 1st ed.

Other References

Blackbody Radiation - Hyper Physics hyperphysics.phy-astr.gsu.edu/hbase/mod6.html

Probability theory - hyperphysics.phy-astr.gsu.edu/hbase/math/probas.html

Handout 6. Thermodynamics - Stanford

Universitymicro.stanford.edu/~caiwei/me334/Chap6_Thermodynamics_v04.pdf

Statistical Mechanics | Chemistry | MIT OpenCourseWare ocw.mit.edu › Courses › Chemistry

Phase Changes - HyperPhysics hyperphysics.phy-astr.gsu.edu/hbase/thermo/phase.html

NAME OF THE COURSE: ATOMIC AND MOLECULAR PHYSICS**Course outcome:**

1. Ability to describe theories explaining the structure of atoms and the origin of the observed spectra.
2. Analyze the information obtained from rotational spectroscopy to determine the bond lengths of heteronuclear diatomic molecules and the effect of isotopic substitution on rotational constants.
3. Understand molecular vibrations with the interaction of matter and electromagnetic waves and will be capable to visualize the vibrational spectrum of diatomic and polyatomic molecules.
4. Understand the working principle of spectroscopic techniques, such as Raman, IR, NMR and Mossbauer spectroscopy and interpret the data.

Course Content**Module I**

Electronic structure of Atoms: Quantum state of an electron system in an atom, electronic wave functions– The shape of atomic orbitals- Hydrogen atom spectrum- Electronic angular momentum- orbital angular momentum- electron spin angular momentum- total electronic angular momentum- the fine structure of hydrogen atom. Stern-Gerlach experiment- Spin-orbit coupling- relativistic correction.

Module II

Electronic Spectra of Atoms: Spectroscopic terms– selection rules– exchange symmetry of wave functions- Pauli's exclusion principle. Many electron atoms- Building principle- the spectra of Li and hydrogen like elements, The L-S and j-j coupling schemes- total angular momentum – term symbols- The spectra of helium - Zeeman effect – The magnetic moment of atom, Lande g factor- The normal Zeeman effect- Emitted frequencies in anomalous Zeeman transitions- Nuclear spin and Hyperfine structure.

Module III

Rotation of Molecules: The rotation of molecules – Rotational spectra of diatomic molecules – Rigid Rotator- The intensities of spectral lines – The effect of isotopic substitution – The non-rigid rotator, The spectra of non-rigid rotator – rotational spectra of linear and symmetric top molecules- experimental techniques of MW spectroscopy- structure determination.

Module IV

Vibration of Molecules

Origin of infrared transitions- Experimental techniques of IR spectroscopy- the simple harmonic oscillator- the anharmonicoscillator- the diatomic vibration- rotation of diatomic molecules- selection rules- the vibration rotation spectrum of carbon monoxide- the interaction of rotations and vibration- the vibrations of the polyatomic molecules – the influence of rotation on the spectra of poly atomic molecules

Raman Spectroscopy

Classical theory of Raman effect- experimental techniques-Pure rotational Raman spectra- vibrational Raman spectra – Rule of mutual exclusion- Raman spectrometer, Structure determination from Raman and infrared spectroscopy- Basic ideas of surface enhanced Raman spectroscopy- Non-linear Raman spectroscopy- theory – hyper Raman effect.

Module V

Electronic Spectra of Diatomic molecules: The Born-Oppenheimer approximation- vibrational coarse structure- Frank Condon principle- Dissociation and pre-dissociation- rotational fine structure of electronic vibration transitions- Fortrat diagram-Electronic structure of diatomic molecules- Electronic angular momentum – Molecular hydrogen spectrum.

NMR spectroscopy: Nuclear magnetic resonance spectra- basic principle- experimental techniques – idea of chemical shift and spin orbit coupling – applications.

Module VI

ESR spectroscopy: Electronspin resonance spectra – basic principle-experimental techniques – idea of hyperfine structure- hydrogen applications.

Mossbauer spectroscopy: Principle- Applications – Structural methods- Quadrupole effects – The effect of magnetic fields.

References

1. Colin N Banwell and Elaine M Mac Coah (2001)Fundamentals of Molecular Spectroscopy, 4th Edition Tata McGraw Hill New Delhi, 4th Edition.
2. H E White (1934) Introduction to Atomic SpectroscopyMcGraw-Hill Inc. 1st Edition.
3. G.Aruldas (2006) Molecular Structure and Spectroscopy. PHI India 1st edition.

OTHER RESOURCES:

Raman Scattering - HyperPhysicshyperphysics.phy-astr.gsu.edu/hbase/atmos/raman.html.Mod-05 Lec-35 Introduction to Nuclear Magnetic ...freevidelectures.com/Course/3029/Modern-Instrumental-Methods.../35On Solutions of Quantum Eigenvalue Problems: A ...onlinelibrary.wiley.com/doi/10.1002/prop.2190390304/pdf

Fourier

transformspectroscopy[https://www.princeton.edu/.../docs/Fourier transform spectroscopy.htm](https://www.princeton.edu/.../docs/Fourier%20transform%20spectroscopy.htm)

Electron spin - HyperPhysicshyperphysics.phy-astr.gsu.edu/hbase/spin.html

NAME OF THE COURSE: LAB- ADVANCED PHYSICS II**Course Outcome**

1. To measure calculate and analyze various physical quantities.
2. To develop experimental skills
3. To calculate error in various advanced physics experiments.

List of Experiments**(Any 6 experiments from the list)**

1. Constant Deviation Spectrometer. Absorption spectrum
2. Constant Deviation Spectrometer. Hydrogen spectrum
3. Millikan's Oil Drop Experiment.
4. Particle Size Analyzer (Using Diode Laser).
5. Zeeman Effect
6. Michelson's Interferometer
7. e/m by Thomson method
8. UV-Visible spectrometer-Verification of Beer-Lambert's law
9. UV-Visible spectrometer- Band gap
10. Photo luminescent Spectrum
11. Blackbody spectrum
12. Raman spectrum
13. IR spectrum
14. Any experiment of similar standard

NAME OF THE COURSE: LAB – BASIC ELECTRONICS II**Course Outcomes:**

1. Understand the construction and working of full wave rectifiers using filter circuits.
2. Design and construct amplifiers and oscillators
3. Ability to construct and working Astable multivibrator using transistor and IC 555.
4. Ability to construct adder, scaler and Buffer amplifier using Op amp.
5. Understand the working of differentiator and integrator

List of Experiments

1. Astable multivibrator using transistor
2. Inverting amplifier
3. Non inverting amplifier
4. Adder and scaler
5. Buffer amplifier
6. Astable multivibrator using 555
7. Differentiator and integrator
8. Any experiment of similar standard

References

1. Navas, K. A. (2013). Electronics Lab Manual Vol.1, Rajath Publishers, 5thed.
2. Navas, K. A. (2009). Electronics Lab Manual Vol.2, Rajath Publishers, 4thed
3. Zbar, Paul B, et al. (1994), Basic Electronics: a text – lab manual, Tata McGraw-Hill Publishing Co.7thed.

SEMESTER III	Course Code: PHY-CC-531	Credits: 4
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NAME OF THE COURSE: QUANTUM MECHANICS II

Course Outcomes:

1. Apply and extend the quantum description to systems in 3-dimensional space.
2. Apply time-independent perturbation techniques and analyze the spectrum of Hamiltonians.
3. Use the time-dependent perturbation techniques for determining the transition rates and decay widths.
4. Apply scattering theory in elastic and inelastic collisions.
5. Solve the equation of motion in a centrally symmetric field.

Course content

Module I

Theory of Angular momentum: The angular momentum algebra, Fundamental commutation relations of angular momentum operators, Eigen values and Eigen states of angular momentum operator, General angular momentum, Eigen values and eigen states of general angular momentum operator, Spin angular momentum, Eigen values and Eigen states of spin angular momentum operator, The Stern-Gerlach experiment, Pauli's spin matrices, Addition of angular momenta: Clebsch-Gordan coefficients, Recursion relations.

Module II

Approximation Methods: Time Independent Perturbation Theory: Non-degenerate and degenerate case-first order and second order corrections, Applications: Anharmonic oscillator-first order corrections, Fine structure of Hydrogen atom, Variational methods and applications: Harmonic oscillator problem, Ground state of Helium. Semi-Classical (WKB) Approximation and applications: WKB Method, Tunneling, Transition probabilities, Bound-State energies.

Module III

Time dependent Hamiltonian and Interactions: Time dependent Perturbation Theory: Harmonic Perturbation, Transition probability and Transition rate, Interaction with classical radiation field: Fermi Golden rule, Transition rates, Absorption and Spontaneous emission, Electric dipole approximation, Einstein's A and B coefficients, Selection rules, Adiabatic approximation.

Module IV

Identical Particles: Indistinguishability and Permutation Symmetry, Fermion and Boson assemblies, Symmetric and Anti-symmetric wave functions, The exclusion principle, Slater determinant, Spin angular momentum, Spin matrices and Eigen functions, Two electron system: The Helium atom, Central field approximation: Hartree-Fock equation, direct term and exchange term.

Module V

Scattering Theory: Scattering cross-sections, The scattering amplitude, Method of partial waves, expansion of a plane wave in terms of partial waves, Scattering by a central potential: Phase shift, Optical theorem, Scattering by a hard sphere, low energy scattering, S-wave scattering by a square well, Scattering of neutrons by protons, Resonance scattering, Breit-Wigner formula, Zero energy scattering, scattering length, First Born approximation, validity of Born approximation.

Module VI

Relativistic wave equations: Klein-Gordan equations, Interpretation and its failure, Dirac's relativistic equation, Position probability density and Current density, α and β Matrix, Dirac solutions and Energy spectrum, Existence of states with negative energy, Spin of the Dirac particle, Significance of negative energy states.

LEARNING RESOURCES

References

1. J. J. Sakurai, Modern quantum mechanics, Addison-Wesley, 1994.
2. R. Shankar, Principles of quantum mechanics, Plenum Publishers, 1994.
3. Cohen-Tannoudji and Diu-Laloe, Quantum Mechanics (2 volumes), Wiley, 2000.
4. L. D. Landau and E. M. Lifshitz, Quantum Mechanics Vol-3 of course of theoretical physics, Butterworth-Heinmann, 2000.
5. Schiff Leonard I (2010) Quantum Mechanics, McGraw-Hill Book Company, India 3rded
6. Aruldas G (2011) Quantum Mechanics, Prentice - Hall of India, 2nded.
7. Mathews P M and Venkatesan K, (1976), A text Book of Quantum Mechanics, Tata McGraw-Hill Publishing Company Ltd.
8. Ajoy Ghatak (2007) Introduction to Quantum Mechanics, McMillan India Ltd.
9. Merzbacher E (1997) Quantum Mechanics, John Wiley.
10. Greiner W (1994) Quantum Mechanics- An Introduction, Springer 3rded.
11. Waghmare Y R (1997) Fundamentals of Quantum Mechanics, Wheeler Publishing.

On-line Sources:

1. <http://www.physics.umd.edu/perg/qm/qmcourse/NewModel/qmtuts.htm>
2. <http://electron6.phys.utk.edu/qm1/Modules.htm>
3. <http://physics.about.com/od/quantumphysics/p/quantumphysics.htm>

4. <http://www.livescience.com/33816-quantum-mechanics-explanation.html>

Semester III	Course Code: PHY-CC-532	Credits: 4
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NAME OF THE COURSE: SOLID STATE PHYSICS

Course Outcomes:

1. Understand the building block of a crystal and classification of crystal structures.
2. Identify the crystal structure of an unknown material using X-ray diffraction.
3. Explain the formation of band structure in a solid and the origin of band gap in semiconductors.
4. Differentiate between intrinsic and extrinsic semiconductors.
5. Apply Hall effect to measure the type and concentration of charge carriers in a semiconductor.
6. Explain the theory behind dielectric phenomenon, its classifications and its applications.
7. Understand the origin of different types magnetic materials.
8. Explain superconductivity phenomenon and its parameters related to possible applications

Course content

Module I

Crystal Physics: Periodicity in crystals - unit cell- Wigner Seitz cell - point group - space group - Number of lattice points per unit cell - symmetry elements - Bravais lattice in two dimensions- Bravais lattice in three dimensions- Miller indices-interplanar spacing- density of atoms in a crystal plane-structures of Diamond, ZnS, NaCl and CsCl. Bonding in solids -Cohesive energy- ionic bonding - evaluation of Madelung constant for NaCl - covalent bonding – electron-pair bond- sp^3 bond- sp^2 bond-Metallic bonding - Hydrogen bonding - Van der Waals bonding. Diffraction of X-rays by crystals - reciprocal lattice- structure determination by powder method, Laue method and rotating crystal method- construction of Ewald sphere – structure factor

Module II

Lattice vibrations: Vibrations of Monatomic and diatomic linear lattices-acoustical and optical phonons - phonon momentum - lattice specific heat of Einstein and Debye model -thermal conductivity-Free electron theory:Electron motion in one dimensional potential well- three dimensional potential well - Density of energy states - Fermi Dirac distribution - electronic specific heat - electrical conductivity and Ohm's law - thermal conductivity - Brillouin zone in two and three dimensions - Fermi surface.

Module III:

Band theory of solids: Nearly free electron model - origin of energy gap and Bragg reflection- Tight binding approximation- Momentum, crystal momentum, and physical origin of the effective mass- Bloch theorem- Kronig-Penney model - reduced zone scheme – periodic zone scheme.

Module IV

Semiconductors: Band gap-Intrinsic semiconductors - carrier concentration in intrinsic semiconductor - Fermi level - electrical conductivity of semiconductors - Extrinsic semiconductor -Alloy, amorphous semiconductors- carrier concentration - variation of carrier concentration with temperature - conductivity of extrinsic semiconductor carrier transport in semiconductors -Hall effect - Applications of Hall effect.

Module V

Dielectric Properties: Various polarization processes - Clausius – Mosotti relation - Dielectric loss - Ferro electricity – Piezo electricity-Pyroelectric material and their applications - Ferroelectric domain -Antiferroelectricity and Ferrielectricity -Applications of dielectric materials.

Module VI

Magnetic properties: Classification of magnetic materials - Langevin's theory of diamagnetism and paramagnetism- Quantum theory of paramagnetism - paramagnetism of free electrons - Ferromagnetism - Weiss molecular field theory - Curie-Weiss law- Ferromagnetic domains, Bloch and Neel walls - Soft and hard ferromagnetic materials -Anti-ferromagnetism, two sublattice model-Spin waves - magnons - Dispersion relation for magnons - magnon specific heat -- Applications of different magnetic materials. Superconductivity: Meissner effect - Type I and Type II superconductors - Thermal properties - Isotope effect- London equations - London penetration depth - coherence length- BCS theory- flux quantization - Josephson effect - Applications of Superconductors.

References

1. Kittel, Charles (2016). Introduction to Solid State Physics, John Wiley & Sons, 8thed.
2. Azaroff, L.V. (2012). Introduction to Solids, TATA McGraw-Hill Publishing Co., 1sted.
3. Dekker, A. J. (2012). Solid State Physics, Macmillan Co., 1sted.
4. Omar, M. A. (2013). Elementary SolidState Physics: principles and applications, Pearson Education.1sted.
5. Lynton, E. A. (1971). Superconductivity, Chapman & Hall Ltd., 3rded.
6. Blakemore, J. S. (1985). Solid State Physics, CBS Publishers & Distributors, 2nd ed.
7. Wahab, M. A. (2013). Solid State Physics: structure and properties of materials, Narosa Publishing House, 2nded.

8. J. M. D. Coey, Magnetism and Magnetic materials, Cambridge University Press, 2010
9. D.C. Jiles, D. C. Introduction to Magnetism and Magnetic Materials. New York: Chapman and Hall, 1991.

Other References

<http://www.physics.udel.edu/~bnikolic/teaching/phys624/lectures.html>

<http://web.mit.edu/redingtn/www/netadv/solidstate.html>

<http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html>

Dr. PrathapHaridoss, Physics of materials,

NPTEL <https://nptel.ac.in/courses/113/106/113106040/#>

SEMESTER III	Course Code: PHY-CC-533	Credits: 4
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NAME OF THE COURSE: NUCLEAR AND PARTICLE PHYSICS

Course outcome:

1. To understand the fundamental forces by studying nuclear and weak forces.
2. To outline nuclear reaction types and mechanisms
3. Ability to explain the origin of stellar energy
4. To grasp knowledge about nuclear models.
5. Ability to understand radioactive decays and its quantum mechanical formulations.
6. To differentiate elementary particles and discuss their interactions.
7. Basic understanding of Group theory and the special unitary group.
8. Acquire knowledge about Quark model and explain the standard model of particle physics.

Course Content

Module I

Nuclear Interactions: Characteristics of inter-nucleon potential: charge independence, charge symmetry. Spin dependence, saturation, short range, attractive and exchange nature-the deuteron-tensor forces- Meson theory of nuclear force-Low energy n-p scattering and effective range theory.

Module II

Nuclear Reactions: Energetic of nuclear reactions - Weisskopf diagram for reaction mechanisms, Partial wave method of calculating cross section - Reciprocity theorem-Compound nucleus hypothesis - Scattering matrix - Breit-Weigner one-level formula - Resonance scattering-Energy production in stars.

Module III

Nuclear Models and Nuclear Decay: Doublet method of mass spectroscopy- Hofstadter experiment - Bethe-Weizsacker formula for nuclear binding energy - Segre chart - Bohr & Wheeler theory of nuclear fission -Shell model-Magic numbers, Spin-orbit coupling, Magnetic moments and Schmidt lines –Collective model of Bohr and Mottelson.

Module IV

Nuclear Decay: Fermi's theory of β -decay - Kurie plot - Selection rules the ^{60}Co experiment - Helicity of neutrino - Multipole transitions in nuclei - Angular momentum and parity selection rules - Internal conversion - Nuclear isomerism.

Module V

Particle Physics: Sub-nuclear particles - Intrinsic properties and conservation laws - Symmetries;unitary symmetry SU(2) and SU(3) groups - Gell- Mann Okubo mass formula - Mesons and baryons in quark model

Module VI

Quantum chromodynamics: -Fundamental interactions electromagnetic weak and strong couplings - Quark jets in $e^+ - e^-$ annihilation - CP violation in K^0 decay-Unification of weak and electromagnetic interactions - Neutral currents. Standard model

References

- Blin-Stoyle, R. J. (1992)Nuclear and Particle Physics, Chapman & Hall Ltd., 1sted.
Burcham, W.E. &Jobes, A. (1998) Nuclear and Particle Physics, Addison-Wesley Publishing Co. Inc., 1st ed.
Fermi, E. (1951)Nuclear Physics, Universities of Chicago Press, 1sted.
Ghoshal, S. N. (2016)Nuclear Physics, S Chand & Co. Ltd., 2nded.
Halzen, Francis & Martin, A.D. (1984). Quarks and Leptons: An introductory course in modern particle physics, John Wiley & Sons Inc., 1sted.
Henley, E. M. & Garcia, A. (2007)Subatomic Physics, World Scientific, 3rded.
Ho-Kim, Quang& Pham, Xuan-Yem(1998). Elementary Particles and Their Interactions: concepts and phenomena, Springer-Verlag, 1sted.
Hughes, I.S. (1991) Elementary Particles, Cambridge University Press, 3rded.
Kachhava, C.M. (1997) Nuclear Physics and Applications, Raj Publications, 1sted.
Sharma, R.C. (1986)Nuclear Physics, K Nath& Company, 3rded.

Additional References

- [http://www.analchem.ugent.be/radiochemie/funct_beeldvorming/Let's Play PET stat](http://www.analchem.ugent.be/radiochemie/funct_beeldvorming/Let's_Play_PET_stat)
[ic/laxmi.nuc.ucla.edu_8000/lpp/nuclearphysics/imagerecon.html](http://laxmi.nuc.ucla.edu_8000/lpp/nuclearphysics/imagerecon.html)
http://www.antonine-education.co.uk/Pages/Physics_5/Nuclear_Physics/NUC_01/Nuclear_1.htm

NAME OF THE COURSE: COMPUTATIONAL METHODS

Course Outcome:

1. Apply numerical methods to solve physical problems
2. Apply numerical methods to solve nonlinear and transcendental equations and their systems.
3. Solve eigen values and eigen vectors of matrices numerically
4. Interpolate a set of given tabular values for equally and unequally spaced intervals
5. Evaluate errors in interpolation formulae
6. Fit curves of various nature depending on the types of data
7. Apply numerical methods to find out derivatives of different order based on a set of tabulated data
8. Apply numerical methods to evaluate definite integrals
9. Numerically solve ordinary differential equations

Course content

Module I

Non Linear Algebraic and Transcendent Equations: Introduction-Bisection method (Method of equal interval)- Iteration method (The method of successive approximation)-Convergence criterion- acceleration of convergence-Aitken's $(\Delta)^2$ process-The method of false position-Newton-Raphson method-Generalised Newton's method-Lin Bairstow method Solution of systems of Non-linear equations - The method of Iteration –Newton Raphson Method.

Module II

Eigen Values and Eigen Vectors of Matrices:Determinant of a Matrix - The eigen value problem- Power method to find the largest and smallest eigen values- House Holder's method- Eigen values of a symmetric tri-diagonal matrix - The QR method- Singular values of decomposition.

Module III

Interpolation: Introduction - Finite differences-Forward -Backward and Central Differences-Symbolic relations and separation of symbols- Differences of a polynomial-Newton's formula for Interpolation-Central Difference Interpolation Formulae-Gauss's Central difference formulae-Stirling's formula- Bessel's formula -Everette's formula- Interpolation of unevenly spaced points-

Lagrange's Interpolation formula- Divided differences and Newton's General interpolation formula- Interpolation with Cubic splines.

Module IV

Curve Fitting: Least square curve fitting procedure- Fitting a straight line- Non-linear curve fitting- Curve fitting by sum of exponentials- Weighted least square approximation- Linear and non-linear - Methods of least squares for continuous functions.

Module V

Numerical Differentiation and Integration: Derivation of numerical differentiation formula from Newton's difference formulae - Cubic spline method Numerical Integration Trapezoidal rule- Simpson's 1/3 rule- Simpson 3/8 rule- Use of cubic splines- Newton - Cotes Integration formula- Numerical calculation of Fourier Integrals - Trapezoidal rule- Filon's formula. Monte Carlo Method - Description of method- Applications- Numerical Integration- Monte Carlo Summation

Module VI

Numerical Solutions of ordinary Differential Equations: Introduction - Solution by Taylor's series- Picard's method of successive approximations- Euler's method- Modified Euler's method- Runge- Kutta method.

References

1. Sastry, S. S. (2017). Introductory Methods of Numerical Analysis, Prentice-Hall of India Pvt. Ltd., 5thed.
2. Arumugam, S, et al. (2009). Numerical Methods, Scitech Publications (India) Pvt. Ltd., 2nded.

OtherReferences

MIT open courseware: <http://ocw.mit.edu/courses/mathematics/18-03sc-differential-equations-fall-2011/Syllabus/>
<http://mathfaculty.fullerton.edu/mathews/numerical.html>
<http://archives.math.utk.edu/visual.calculus/>
<http://tutorial.math.lamar.edu/Classes/CalcI/CalcI.aspx>

NAME OF THE COURSE: Physics of Nanomaterials**Course Outcome:**

1. Explain the classification of nanomaterials and nanocomposites
2. Understand the idea of size dependent properties
3. Apply basic understanding of composite nanostructures in designing futuristic materials for myriad uses
4. Discuss the physics of quantum confinement effects and their consequences
5. Apply fundamental understanding of quantum transport in designing advanced electronic devices

Course Content**Module I - INTRODUCTION TO NANOMATERIALS (16 h)**

Zero-dimensional, one-dimensional, two-dimensional and three-dimensional nanomaterials– surface area and surface energy– reduction of surface energy–atomic, structural and system levels– sintering, Ostwald ripening and agglomeration– surface curvature and chemical potential–stabilization of nanoparticles

Size dependent properties – characteristic length scales – surface to volume ratio– lattice contraction–specific heat and melting point– mechanical properties –nanoceramics –catalytic properties – electrical, magnetic and optical properties

Module II - CARBON BASED NANOMATERIALS (12 h)

Fullerenes – graphene – carbon nanotubes (CNTs)– SWCNT– MWCNT – synthesis – methods of opening, filling and purifying carbon nanotubes – geometrical structure of CNTs – electronic structure of CNTs – metallic and semiconducting CNTs

Module III - NANOCOMPOSITES (12 h)

Ceramic/metal nanocomposites - thin-film nanocomposites: multilayers and granular films – carbon nanotube-based nanocomposites – inorganic nanocomposites for optical applications – inorganic nanocomposites for electrical applications – nanoporous structures and membranes – nanocomposites for magnetic applications – nanocomposite structures having miscellaneous properties

Module IV- QUANTUM CONFINED SYSTEMS (12 h)

Quantum confinement and its consequences – idealized quantum wells – idealized quantum wires –cubic quantum dots – artificial atoms – electron density of states from bulk to quantum dots – semiconductor nanoparticles – size quantization effects – electron states in direct gap semiconductors – strong and weak confinement

Module V - MANIFESTATIONS OF QUANTUM CONFINEMENT (12 h)

Manifestation of quantum confinement – Blue-shift of band-gap –superlattices and multiple quantum wells – two-dimensional electron gas – one-dimensional electron gas – Photo-transport in semiconductor quantum dots – quantum-confined structures as lasing media

Module VI - TRANSPORT IN QUANTUM CONFINED STRUCTURES (16 h)

Quantum transport in nanostructures – diffuse and ballistic transport – carrier scattering in nanomaterials – Fermi golden rule– Ionized impurity, neutral impurity, electron- electron and electron-phonon scattering – grain boundary scattering – electron and phonon mean free path – optical and acoustic phonon scattering – phonon scattering at low and high temperatures – Boltzmann transport equation (BTE) – Solution to BTE in relaxation time approximation – electrical and thermal conductivity in nanomaterials – Quantum of conductance –Coulomb blockade- single electron tunneling – resonant tunneling

REFERENCES

- G. Cao – Nanostructures & Nanomaterials-Synthesis, Properties and Applications, Imperial College Press, 2004.
- Peter J. F. Harris –Carbon Nanotubes and Related Structures- New Materials for the Twenty-first Century, Cambridge, 1999.
- R. Saito – Physical Properties of Carbon Nanotubes, Imperial College Press, 1998.
- P. M. Ajayan, L. S. Schadler, and P. V. Braun –Nanocomposite Science and Technology, Wiley VCH, 2003.
- D. M.Lannoo– Nanostructures Theory and Modelling, Springer, 2004.
- J.H.Davis – Physics of low dimensional structures, Cambridge, 1998.
- Mark Lundstrom – Fundamentals of Carrier Transport, Cambridge University Press, 2010.
- S. Datta–Lessons from Nanoelectronics: A New Perspective on Transport, World Scientific, 2012.
- C. P. Poole and F. J. Owens–Introduction to Nanotechnology, John Wiley & Sons, 2003.

SEMESTER IV	Course Code: NSP-CC-541	Credits: 6
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NAME OF THE COURSE: PROJECT

Course outcome:

- 1.Introduce the student to the scientific research methodology, literature survey, technical writing, assimilation, dissemination of results and research ethics etc.
- 2.Introduce the student to the field of research and development in the area of nanoscience and nanotechnology
- 3.Enable to familiarize with the tools of a researcher such as sophisticated instrumental techniques or computational methods.

NAME OF THE COURSE: Nanomaterials Synthesis and Characterization**Course Outcome:**

1. Understand different methods for synthesis of different classes of nanomaterials.
2. Understand different deposition techniques for nanostructured films.
3. Discuss various approaches towards nanolithography
4. Discuss the various characterization techniques for nanomaterials

Course content**Module I - SYNTHESIS OF NANOMATERIALS (12 h)**

Synthesis of nanomaterials - top-down approaches –exfoliation, mechanical grinding and attrition –ball milling, decrepitation – nanoparticles –properties of individual nanoparticles – consequences of small particle size – increase of mechanical frequencies in small systems – dominance of viscous forces – disappearance of frictional forces

Module II - SYNTHESIS OF ZERO-DIMENSIONAL NANOMATERIALS (16 h)

Synthesis of 0D nanomaterials- bottom-up approaches – Thermodynamic equilibrium and Kinetic approaches –colloidal technique – homogeneous nucleation – critical size and critical energy – subsequent growth – diffusion-controlled and surface-controlled processes – mononuclear and polynuclear growth –inorganic surface modification – shape control – phase transition and phase control – nanocrystal doping –synthesis of metallic (Au and Ag) and semiconductor (Si and CdSe) nanoparticles – heterogeneous nucleation –kinetically confined growth – aerosol synthesis, spray pyrolysis and micro emulsion synthesis
Sonochemical method – synthesis and properties of epitaxial core-shell nanoparticles–core-shell quantum dots –Type I and Type II core-shell quantum dots – stabilization of nanoparticles

Module III - SYNTHESIS OF ONE-DIMENSIONAL NANOMATERIALS (12 h)

Synthesis of 1D nanomaterials –nanowires and nanorods – spontaneous growth –vapour-liquid-solid growth – template-based synthesis –electrochemical deposition– electrophoretic deposition – electrospinning

Module IV - SYNTHESIS OF TWO AND THREE-DIMENSIONAL NANOMATERIALS (16 h)

Synthesis of 2D nanomaterials –nanostructured films – Langmuir-Blodgett films – sol-gel technique – chemical vapour deposition techniques – atomic layer deposition – physical vapour deposition techniques – thermal and e-beam evaporation – DC and RF magnetron sputtering – pulsed laser deposition – homo and hetero epitaxy – molecular beam epitaxy- fabrication of quantum wells – superlattices and multiple quantum well structures
Synthesis of 3D nanomaterials – nanocomposites – nanostructured bulk materials – organic-inorganic hybrid nanocomposites

Module V - NANOLITHOGRAPHY (16 h)

Cleanroom classifications – Nanostructures and devices fabricated by physical techniques – photolithography – positive and negative photoresists – photo mask and mask aligner – steps involved in photolithography – basic concepts of X-ray, e-beam and ion beam lithography – AFM and STM based lithography – nanolithography – soft lithography – microcontact printing – dip-pen nanolithography – assembly of nanostructures - self-assembly - molecular self-assembly in solutions – self-assembly of nanoparticles

Module VI - CHARACTERIZATION OF NANOMATERIALS (16 h)

Principle, working and interpretation of results of – XRD – SEM – EDS – XPS – AFM – UV-Vis – NIR spectroscopy – Photoluminescence – FTIR and Raman spectroscopy – BET surface area analysis

REFERENCES

- S. Edelstein and R.C. Cammarata – Nanomaterials: Synthesis, Properties and Applications, Taylor & Francis, 1996.
- Kathy Lu – Nanoparticulate materials: Synthesis, Characterization, and Processing, Wiley, 2013.
- G. Cao – Nanostructures & Nanomaterials-Synthesis, Properties and Applications, Imperial College Press, 2004.
- Janos. H. Fendler (Ed) – Nanoparticles and Nanostructured Films: Preparation, Characterization and Applications, Wiley – VCH, 1998.
- G.C. Hdjipanayis, R.W. Seigel – Nanophase Materials- Synthesis, Properties and Applications, Kluwer Academic Publishers, 1994.
- J. A. Venables – Introduction to Surface and Thin Film Processes, Cambridge University Press, 2000.
- J. L. Vossen and W. Kern (Eds) – Thin Film Processes I and II, Academic Press, 1978 and 1991.
- S. Zhang – Nanostructured Thin Films and Coatings: Functional Properties, CRC Press, 2010.
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NAME OF THE COURSE: Functional Nanomaterials and Nanotechnology**Course outcome:**

1. Discuss the construction and working of energy conversion devices employing nanomaterials
2. Discuss the application of nanomaterials for energy storage
3. Understanding magnetism at nanoscale
4. Understand the construction of spintronic devices and discuss the working of spintronic devices
5. Discuss the emerging area of nanoelectronics and nanophotonics

Course content**MODULE I - NANOMATERIALS FOR ENERGY CONVERSION (16 h)**

Solar cells – single crystalline, polycrystalline and amorphous Si solar cells – device structure – quantum efficiency and fill factor – thin film solar cells – compound semiconductor solar cells – GaAs, chalcopyrite, perovskite and organic solar cells – Dye Sensitized Solar Cells – structure, working principles and key efficiency parameters – flexible solar cells

Thermoelectrics– Figure of Merit- nanostructured bulk and thin film thermoelectrics – radioisotope thermoelectric generators (RTGs) – waste heat recovery – mechanical energy harvesting using Ferroelectrics, Piezoelectrics and Flexoelectrics– photovoltaics with Ferroelectrics

MODULE II - NANOMATERIALS FOR ENERGY STORAGE (16 h)

Energy storage devices – batteries – Li-ion, Na- ion, Li- air, Na -air and Li-S batteries – energy density and power density – Fuel cells – Proton Exchange Membrane (PEMFC) and Solid Oxide Fuel cells (SOFC) – working principle and efficiency – hydrogen evolution by photocatalytic water splitting – Supercapacitors – nanostructured electrode materials – flexible storage devices

MODULE III - NANOMAGNETICS (16 h)

Nanoscale magnetism –hysteresis–coercivity of small particles –direct exchange coupling – Heisenberg exchange interaction – oscillatory exchange coupling – RKKY interaction – single domain particles – superparamagnetism– spin glass systems.

Magnetic Multilayer structures – normal and anomalous magnetoresistance effects –giant magneto resistance (GMR)– mechanism of GMR- Tunneling magnetoresistance (TMR) – Ballistic magnetoresistance (BMR) ballistic spin transport

MODULE IV - SPINTRONICS (16 h)

Spintronics – Spin current – spin diffusion length – Parallel and perpendicular transport - generation, injection, transport and detection of spin current – Spin transfer torque –Diffuse spin dependent transport – spin dependent scattering – spin transfer oscillations – spin torque diode effect – Spin relaxations at metal-semiconductor junctions – diluted magnetic semiconductors –

Datta-Das spin field effect transistor – Magnetic Random Access Memory (MRAM) – Spin-transfer torque MRAM (STT-RAM)

MODULE V - NANO-ELECTRONICS (16 h)

Electrical conduction in bulk and nanostructured materials – charge transport in nanocrystalline films – diffuse transport regime – Single electron tunneling – single electron transistor – Electronic devices based on nanostructures – Modulation doped quantum well structures – two-dimensional electron gas (2DEGs) – Ballistic transport regime – MODFETs – heterojunction bipolar transistors – resonant tunnel effect – hot electron transistors – resonant tunneling transistor

Superconductivity in Nanomaterials – Meissner effect – dependence of superconducting properties on size effects – resistivity and sheet resistance – proximity effect – tunneling and Josephson junctions – superconducting quantum interference device (SQUID)

MODULE VI - NANOPHOTONICS (16 h)

Nanophotonics – foundations of nanophotonics – free-space propagation – confinement of photons and electrons – propagation through a classically forbidden zone – localization under a periodic potential – nanoscale optical interactions – plasmonics – plasmons and surface plasmon resonance – metallic nanoparticles and nanorods – metallic nano-shells – local field enhancement – plasmonic waveguides

Near field-optics – theoretical modeling of near-field nanoscopic interactions – photonic crystals – basic concepts – theoretical modeling of photonic crystals – features of photonic crystals – methods of fabrication – photonic crystals and optical communication

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NAME OF THE COURSE: LAB- NANOSCIENCE**Course outcomes**

1. Practice the different experimental techniques used for characterization of nanomaterials
2. Analyze the results various characterization tools and correlate them with theoretical explanation
3. Understand the advantages, limitations and specificities of different characterization techniques
4. Practice different thin film coating techniques
5. Practice chemical synthesis techniques of nanomaterials
6. Practice the scientific methods and analytic thinking.

LIST OF EXPERIMENTS (Any 10 Experiments)

1. Analysis of given X-ray diffraction pattern of nanocrystalline samples with different crystallite sizes – crystallite size and microstrain.
2. X-ray diffraction-structure evaluation and identification of material.
3. Interpretation of electron diffraction patterns (SAED pattern) of nanocrystalline samples with different sizes.
4. Determination of particle size of given material using He-Ne laser or diode laser
5. Photo current measurement in a nanostructured semiconductor
6. Measurement of magnetoresistance of nanostructured semiconductors
7. Determination of band gap of a semiconductor nanomaterial using UV-visible absorption spectra
8. Preparation of a thin film nanostructured sample using vacuum deposition technique and analysis of UV-visible spectrum
9. Determination of thickness of a thin film by envelope method and calculation of bank using the given transmittance spectrum of the film.
10. Preparation of a multilayered nanostructured thin film using vacuum deposition technique
11. Preparation of thin film sample by dip coating and measurement of thickness and UV-visible spectrum
12. Synthesis of metal nanoparticles using Turkevich procedure.
13. Synthesis of metal nanoparticle synthesis using Biphasic reduction.
14. Synthesis of CdSe quantum dots and its characteristics.
15. Synthesis of oxide nanomaterials through sol-gel route and characterization
16. Synthesis of nanomaterials through hydrothermal route
17. Synthesis and optical characterization of carbon quantum dots
18. Measurement of absorbance of Au nanoparticles
19. Calculate the concentration of Au/Ag nanoparticles using Beer' Law.
20. Demonstrate the working of the self-assembly of nanoparticles on a solid support.
21. Construct a simple nanostructured photovoltaic cell and study its basic characteristics.
22. Distinguish the characteristics of any three dyes and comment on your observations.
23. Any other experiment with equal standards can be included.