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

Name of the Programme:

M.Sc. Physics

(Specialization in Space Physics)

(Syllabus effective from 2020 Admission onwards)

UNIVERSITY OF KERALA

2020

UNIVERSITY OF KERALA

Syllabus for M.Sc. Physics

(Specialization in Space Physics)

Programme Specific Outcomes (PSO) for

M.Sc. Physics

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
PSO 2	To equip the student to pursue research and development in any areas of theoretical, experimental and computational physics.
PSO 3	To impart special training in different areas of electronics.
PSO 4	To bridge the gap between text book knowledge and practical problems through well designed laboratory sessions.
PSO 5	Understand, apply and verify the theoretical/empirical concepts and experimental facts by practical.
PSO 6	To introduce the student to the scientific research methodology, literature survey, technical writing, assimilation and dissemination of results, research ethics etc. though a project work.

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

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-Basic Electronics	**4**
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	**4**
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**
	PHY -SDE-535	Physics of the Atmosphere	**4**
IV	**Core Courses (CC)**		
	PHY -CC-541	Project	**6**
	Discipline-Specific Elective (DE)		

	PHY -SDE-542	Space Physics	**4**
	PHY -SDE-543	Earth’s Upper Atmosphere and Space Weather	**4**
	PHY-SDE-544	Introduction to Astrophysics	**4**
	PHY -SDE-545	Lab- Space Physics	**4**
Any semester (I-IV)	**Generic Courses (GC)**		
	PHY -GC-501	Foundations of Astronomy	**2**
	PHY -GC-502	Renewable Energy	**2**
	PHY -GC-503	Introduction to Materials Characterization Techniques	**2**
	PHY -GC-504	Vacuum Science and Technology	**2**
	PHY-GC-505	Artificial Intelligence through Brain Initiative	**2**

SEMESTER I	Course Code: PHY-CC-511	Credits: 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 Γ1/2 – 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 Dirchlet'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& Webber (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, PragatiPrakashan, 15thed.
4. Ghatak, A. K. et al. (2012). Mathematical Physics: differential equations and transform theory, Macmillan & Co. Ltd., 1sted.
Additional References

1.NIST Digital Library of Mathematical Functions*dlmf.nist.gov/*
2.GNU Scientific Library – Reference Manual: *Special Functions*<u>*https://www.gnu.org/software/gsl/manual/html.../Special-Functions.html*</u>
3. MIT 18.06 Linear Algebra Spring 2005 - *VideoLectures*.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*

SEMESTER I	Course Code: PHY-CC-512	Credits: 4

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 noninertial frame of references, Generalize coordinates: Constraints, Virtual displacement, Principle of virtual work, D'Alemberts 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 it's 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.

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. Aruldhas, G. (2012). Classical Mechanics, Prentice - Hall of India, 1sted.
5. Vimal Kumar Jain (2009), Classical Mechanics, Anne Books Pvt. Ltd.
6. Srinivasa Rao, 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

Additional References

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

SEMESTER I	Course Code: PHY-CC-513	Credits: 4

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 it's 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 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

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

Additional References

1. Basic Plasma Physics http://www.plasmas.org/plasma-physics.htm
2. Classical Electrodynamics http://www.thp.unikoeln.de/alexal/pdf/electrodynamics.pdf
3. Special Relativity and Electrodynamics http://theoreticalminimum.com/courses/special-relativity-and- electrodynamics/2012/spring
4. Electromagnetic theory NPTEL lectures by Dr.D.K.Ghosh, https://nptel.ac.in/courses/115/101/115101005/#
5. Transmission lines and electromagnetic waves , NPTEL lectures byProf. Ananth Krishnan, https://nptel.ac.in/courses/108/106/108106157/

SEMESTER I	Course Code: PHY-CC-514	Credits: 4

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 souse 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 photo diode, 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.

Additional References

1. Introduction to the *Amplifier* an *Amplifier Tutorial*. http://www electronics-tutorials.ws/amplifier/amp_1.htmlWhat is op-amp? http://www.engineersgarage.com/tutorials/op-amp-basics
2. Opto electronics devices - Slide Share
3. www.slideshare.net/SiddharthPanda1/opto-electronics-devices

SEMESTER I	Course Code: PHY-CC-515	Credits: 4

NAME OF THE COURSE: LAB – BASIC ELECTRONICS

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. 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. Astablemultivibrator using transistor
9. Inverting amplifier
10. Non inverting amplifier
11. Adder and scaler
12. Buffer amplifier
13. Astablemultivibrator using 555
14. Differentiator and integrator

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 II	Course Code: PHY-CC-521	Credits: 4

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/Lauraent 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 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, Algebric 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(S3), Symmetry operation of a square (C4v). Generators of a finite group, Conjugate elements and Classes, Cyclic group, subgroup, normal subgroups and Cosets, Isomerphisim and Homomorphisim, Group representation, Lie groups.

Module V

Group Representation: Generators of a finite group, Conjugate elements and Classes, Cyclic group, subgroup, normal subgroups and Cosets, Isomerphisim and Homomorphisim, 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).

SEMESTER II	Course Code: PHY-CC-522	Credits: 4

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. (Analyse)
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 3rd ed
2. Aruldhas G (2011) Quantum Mechanics, Prentice - Hall of India, 2nd ed
3. Mathews P M and Venkatesan K, (1976), A text Book of Quantum Mechanics, Tata McGraw-Hill Publishing Company Ltd.
4. ZettiliNourdine (2009) Quantum Mechanics, John Wiley and Sons Ltd Publishing.
5. AjoyGhatak and Lokanatha S (2007) Quantum Mechanics Theory and Applications, Macmillan India Ltd, 5th ed.

Additional References

1. AjoyGhatak (1996) Introduction to Quantum Mechanics, Mcmillan India Ltd.
2. Merzbacher E (1997) Quantum Mechanics, John Wiley.
3. Greiner W (1994) Quantum Mechanics- An Introduction, Springer 3rd ed.
4. Waghmare Y R (1997) Fundamentals of Quantum Mechanics, Wheeler Publishing.
5. Thankappan V K (1985) Quantum Mechanics, Wiley Eastern Ltd.
6. *Quantum Physics I | Physics | MI OpenCourseWare ocw.mit.edu › Courses › Physics Lecture www.phy.iitb.ac.in/~dkg/qmech/Lecture5.pdf hyperphysics.phy-astr.gsu.edu/hbase/mod6.html*
7. *onlinelibrary.wiley.com/doi/10.1002/prop.2190390304/pdf- .On Solutions of Quantum Eigenvalue Problems*

SEMESTER II	Course Code: PHY-CC-523	Credits: 4

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: Indistingushibility 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.

Additional References

1. *Black body Radiation* - Hyper Physics*hyperphysics.phy-astr.gsu.edu/hbase/mod6.html*
2. *Probability theory* - *hyperphysics.phy-astr.gsu.edu/hbase/math/probas.html*
3. Handout 6. Thermodynamics - Stanford Universitymicro.stanford.edu/~caiwei/me334/Chap6_Thermodynamics_v04.pdf
4. *Statistical Mechanics* | Chemistry | MIT OpenCourseWare*ocw.mit.edu ›* Courses › Chemistry
5. *Phase* Changes - *HyperPhysicshyperphysics.phy-astr.gsu.edu/hbase/thermo/phase.html*

SEMESTER II	Course Code: PHY-CC-524	Credits: 4

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 heliumZeeman effect – The magnetic moment of atom, Launde's 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 anharmonic oscillator- 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.Aruldhas (2006) Molecular Structure and Spectroscopy. PHI India 1st edition.

Additional References

1. *Raman Scattering - HyperPhysicshyperphysics.phy-astr.gsu.edu/hbase/atmos/raman.html.*Mod-05 Lec-35 Introduction to Nuclear Magnetic ...*freevideolectures.com/Course/3029/Modern-Instrumental-Methods.../35On Solutions of Quantum Eigenvalue Problems: A ...onlinelibrary.wiley.com/doi/10.1002/prop.2190390304/pdf*
2. *Fourier transform spectroscopy* https://www.princeton.edu/.../docs/Fourier_transform_spectroscopy.htm
3. Electron spin - HyperPhysics*hyperphysics.phy-astr.gsu.edu/hbase/spin.html*

SEMESTER II	Course Code: PHY-CC-525	Credits: 4

NAME OF THE COURSE: LAB- ADVANCED PHYSICS

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 12 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. Constant Deviation Spectrometer.- Absorption spectrum
14. Constant Deviation Spectrometer.- Hydrogen spectrum
15. Millikan's Oil Drop Experiment.
16. Particle Size Analyzer (Using Diode Laser).
17. Zeeman Effect
18. Michelson's Interferometer
19. e/m by Thomson method
20. UV-Visible spectrometer-Verification of BEER-Lambert's law
21. UV-Visible spectrometer- Band gap
22. Photo luminescent Spectrum
23. Blackbody spectrum
24. Raman spectrum
25. IR spectrum

SEMESTER III	Course Code: PHY-CC-531	Credits: 4

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: Clebsh 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 Ineteractions: 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, Briet-Wigner formula, Zero energy scattering, scattering length, First Born approximation, validity of Born approximation.

Module VI

Relativistic wave equations: Klein-Jordan equations, Interpretation and it's 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.

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. Liftshitz, 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. Aruldhas 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. AjoyGhatak (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.

Additional References

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

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. Appy 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 earner 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 sub-lattice 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 Solid State 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.

Additional References

1. http://www.physics.udel.edu/~bnikolic/teaching/phys624/lectures.html
2. http://web.mit.edu/redingtn/www/netadv/solidstate.html
3. http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html
4. Dr. PrathapHaridoss, Physics of materials, NPTEL https://nptel.ac.in/courses/113/106/113106040/#

SEMESTER III	Course Code: PHY-CC-533	Credits: 4

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-Weizscaker 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^o decay-Unification of weak and electromagnetic interactions - Neutral currents. Standard model

References

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

Additional References

1. http://www.analchem.ugent.be/radiochemie/funct_beeldvorming/Let's_Play_PET_static/laxmi.nuc.ucla.edu_8000/lpp/nuclearphysics/imagerecon.html
2. http://www.antonine-education.co.uk/Pages/Physics_5/Nuclear_Physics/NUC_01/Nuclear_1.htm
3. http://www2.lbl.gov/abc/Basic.html

SEMESTER III	Course Code: PHY-DE-534	Credits: 4

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 $(\text{delta})^2$ 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 fonnulae-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 Differentiationand Integration: Derivation of numerical differentiation formula fromNewton's difference formulae - Cubic spline method Numerical Integration Trapezoidal rule- Simpson's 1/3 rule- Simpson 378 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- Picaid'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., 5th ed.
2. Arumugam, S, et al. (2009). Numerical Methods, Scitech Publications (India) Pvt. Ltd., 2nd ed.

Additional References

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

SEMESTER III	Course Code: PHY-SDE-535	Credits: 4

NAME OF THE COURSE: PHYSICS OF THE ATMOSPHERE

Course Outcome:

1. Understand the atmospheric composition, thermodynamics, dynamics, waves and oscillations, and their regional variations.
2. Study the properties of aerosols and clouds and Earth's hydrological cycle.
3. Analyse the climate change and its causes
4. Understand the observational techniques and remote sensing

Course Content

Module-I

Earth's Atmosphere: Introduction to Atmosphere, Evolution of Earth's atmosphere, Classification of atmospheric layers based on temperature, mixing and ionization, Altitude variation of pressure, temperature and density in the atmosphere, Causes for the altitude variation of temperature in the troposphere, stratosphere, mesosphere and thermosphere.

Module-II

Atmospheric Thermodynamics, Concept of an air parcel, Virtual temperature, Vertical motion of an air parcel, Dry adiabatic lapse rate, Potential temperature, Virtual potential temperature, Water vapour: altitude and horizontal variations, Saturated adiabatic and pseudo adiabatic processes, Saturated adiabatic lapse rate, Equations for relative humidity, specific humidity, absolute humidity, and saturation mixing ratio,

Module-III

Atmospheric Radiation Transfer: Atmospheric Radiation , Black body radiation laws, Solar spectrum and solar constant, Absorption and scattering of solar radiation in the atmosphere, Rayleigh and Mie scattering, Terrestrial emission of radiation, Atmospheric window, Absorption and emission of IR radiation from the atmosphere and surface, Radiation balance at the top-of-the-atmosphere, Components of atmospheric energy budget, Physics of global warming and Greenhouse effect, Aerosols and Clouds ,Physical, chemical and optical properties of aerosols. (Qualitative study only)

Module IV

Atmospheric Dynamics: Dynamics of the Troposphere and Stratosphere, Fundamental laws of conservation, Conservation of momentum, mass and energy, Navier – Stokes Equation, Atmospheric Waves and oscillations Description of general wave equation, generation sources of atmospheric waves, wave propagation, Characteristics of Acoustics waves, Gravity waves, Kelvin and Rossby waves.

Module V

Climate Dynamics, Factors controlling climate change, Climate monitoring, Past and present climate of Earth, Climate variability, Internally generated climate variability, Externally forced climate variability, Milankovich cycle, Assessment of global and regional climate change and prediction by IPCC.

Module VI

Observations and Modelling, Ground based Atmospheric Observations, Automatic weather stations for in situ measurements of temperature, pressure, humidity and wind, Principles of Atmospheric Radar, Lidar, Solar Radiometer, Satellite Remote Sensing Advantages and limitations of satellite remote sensing.

Books for Study

1. Atmospheric Science: An Introductory Survey¸ John Wallace and Peter V. Hobbs, Elsevier, Second Edition.
2. Physics of the atmosphere and climate, Murry L Salby, Cambridge University Press
3. Microphysics of cloud and Precipitation by Pruppacher and Klett, Springer
4. Atmospheric Chemistry and Physics: From Air Pollution to Climate Change by John H. Seinfeld, Spyros N. Pandis, Wiley.
5. An Introduction to Atmospheric Radiation, K N Liou, Academic Press
6. An Introduction to Dynamic Meteorology, James R. Holton and Gregory J. Hakim, Elsevier Science.
7. Fundamental of Remote Sensing, George Joseph, University Press
8. Satellite Meteorology – An introduction, S Q Kidder and Thomas H. Vonder Haar, Elsevier Science

SEMESTER IV	Course Code: PHY-CC-541	Credits: 6

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. Enable to familiarize with the tools of a researcher such as sophisticated instrumental techniques or computational methods related to space physics.

SEMESTER IV	Course Code: PHY-SDE-542	Credits: 4

NAME OF THE COURSE: SPACE PHYSICS

Course Outcome:

Detailed understanding on the following:

1. Earth's Thermosphere-Ionosphere-Magnetosphere system and its variability
2. Interaction of solar radiation and solar wind with Earth's environment and its impact
3. Ionospheric modeling
4. Observational techniques for ionosphere.
5. Applications of ionosphere-Magnetosphere studies

Course content

Module I

Physics of Plasmas: Introduction to plasma state: Composition and Characteristics; Basic definitions: Quasi-neutrality, Debye shielding; Source of space plasma: Interstellar space, Earth's atmosphere, atmosphere of other planets and nuclear reactions in stellar plasma, dusty plasma.

Module II: Dynamics of a charged particle: Effect of electric and magnetic fields, Basic charge motion in constant and uniform fields: in uniform magnetic field (E=0) and in uniform electric and magnetic field, Physical interpretation of electrical drift and conservation of energy.

Module III : Description of plasma as a gas mixture, Properties of plasma in a magnetic field, force on plasma in a magnetic field, current in magnetised plasma, Pinch effect, Oscillations and waves in plasma: Plasma frequency and Maxwell's equation in homogenous plasma. Converging magnetic field: magnetic trap and double mirror.

Module IV : Distribution function: Boltzmann equation, Derivation of debye screening distance form energy consideration and by statistical mechanics, hydrodynamic description of the plasma, magneto hydrodynamic equations for one fluid model and two fluid model.

Module V : **Solar Physics** Sun the primary driver of solar system and life on earth, Basic solar properties, Nuclear reactions in the solar core, Black Body Radiation and the solar spectrum, Transport of Energy from core and Modelling the solar interior: Convective instability, Convective energy transfer, Sunspots, magnetic fields, Solar rotation and the solar cycle chromosphere and corona Elements of dynamo theory & Solar kinematic dynamos, Concentrating and expelling the magnetic field, Origin of solar wind, Magnetic field effects on the wind, Three-dimensional structure & Warped heliospheric current sheet, Various sources of fast and slow winds.

Module VI Observational Techniques and Models Observations of Sun and it’s interior from ground, Satellite based observations of Sun, Challenges and Technology, Modeling of Sun and Community models for solar processes.

Books for study

1. Chen, F. F., Introduction of Plasma Physics and Controlled Fusion, Plenum Press, 1984
2. Gombosi, T. I., Physics of the Space Environment, Cambridge University Press, 1998
3. Kellenrode, M-B, Space Physics, An Introduction to Plasmas and Particles in the Heliosphere and Magnetospheres, Springer, 2000.
4. Walker, A. D. M., Magnetohydrodynamic Waves in Space, Institute of Physics Publishing,2005.
5. A. F. Nagy, Comparative Aeronomy, Springer
6. S.N.Goswami., Elements of plasma physics, New central book agency (P) Ltd

Other References

1. Arvind Bhatnagar, William Livingston, Fundamentals of Solar Astronomy, World Scientific Series in Astronomy Astrophysics, Vol-6.
2. Arnab Rai Chowdhury, Nature’s Third Cycle, Oxford University Press.
3. C .J. Schrijver and C. Zwaan, Solar and Stellar Magnetic Activity, Cambridge University press
4. M. G. Kivelson and C. T. Russle, Introduction to Space Physics, Cambridge University Press
5. M. C. Kelley, The Earth’s Ionosphere, Plasma Physics and Electrodynamics, Elsevier Press
6. Vladislav Yu. Khomich·Anatoly I. Semenov, Nikolay N. Shefov, Airglow as an Indicator of Upper Atmospheric Structure and Dynamics, Springer
7. J. K. Hargreaves, The Solar Terrestrial Environment, Cambridge Atmospheric and space science series.

SEMESTER IV	Course Code: PHY-DE-543	Credits: 4

NAME OF THE COURSE: EARTH'S UPPER ATMOSPHERE AND SPACE WEATHER

Course outcome:

1. Earth's Thermosphere-Ionosphere-Magnetosphere system and its variability
2. Interaction of solar radiation and solar wind with Earth's environment and its impact
3. Ionospheric modeling
4. Observational techniques for ionosphere.
5. Applications of ionosphere-Magnetosphere studies

Course content

Module I

Geomagnetism and Upper Atmosphere, Earth's Magnetic Field, Introduction to Earth's magnetic field and its generation, Parameters of Earth's magnetic field, Geomagnetic equator and poles, Geomagnetic Dip angle, Difference between geographic and geomagnetic coordinates, Long-term variations in Earth's magnetic field,

Upper Atmosphere , Thermal structure of the atmosphere, Thermodynamics, chemical kinetics, atmospheric composition and chemistry of the upper atmosphere, Thermal structure and dynamics of the Mesosphere-lower thermosphere (MLT) region,

Module II

Earth's Ionosphere: Ionosphere, Solar radiation and production of ionization, Solar spectra responsible for ionization, Loss mechanisms, Chapman profile, Typical ionization profiles for equatorial, mid-latitude and polar ionospheres, Ion composition and chemistry, Ionospheric conductivity (Hall, Longitudinal, and Cowling conductivities), Ionospheric layers and their generation: D Region, E Region, F Region,

Module III

Ionospheric Modelling: Basic theory, Continuity equation, equations and parameters required for 1-Dimensional ionospheric model. The effect of horizontal and vertical transport, Basic principle and features of IRI model, Ionospheric conductivity and density models.

Module IV

Earth's Magnetosphere : Interaction of the Solar Wind with the terrestrial magnetic field, Bow Shock and Magnetopause, Magnetospheric cavity, Van-Allen Radiation Belts, Geomagnetic tail, Aurorae,Magnetic activity and sub-storms, Magnetic storms. Interaction of solar wind with unmagnetised body like our Moon

Module V

Observational Techniques & Applications

Radio wave Propagation through Ionosphere

Equation for refractive index in the atmosphere and ionosphere, Propagation of radio waves through ionosphere, Plasma frequency, Effect of ionosphere on communication in the HF, VHF, UHF and microwave frequencies. Dispersion relation for electromagnetic waves in the ionosphere.

Module VI

Applications of Ionosphere-Magnetosphere Research: Impact of ionosphere on electromagnetic wave propagation, Correction of GNSS signals for global positioning and navigation: principle and applications, Effect of scintillation on satellite communication and its prediction, Space weather impacts on space assets and astronauts.
.

Books for study

1. H. Rishbeth and O. K. Garriott, Introduction to Ionospheric Physics (International Geophysics)
2. M. C. Kelley, The Earth's Ionosphere, Plasma Physics and Electrodynamics, Elsevier Press
3. J. K. Hargreaves, Upper Atmosphere and Solar-terrestrial Relations: Introduction to the Aerospace Environment, Cambridge Press
4. J. K. Hargreaves, The Solar Terrestrial Environment, Cambridge Atmospheric and space science series
5. M. G. Kivelson and C. T. Russle, Introduction to Space Physics, Cambridge University Press
6. Vladislav Yu. Khomich·Anatoly I. Semenov, Nikolay N. Shefov, Airglow as an Indicator of Upper Atmospheric Structure and Dynamics, Springer
7. Gombosi, T. I., Physics of the Space Environment, Cambridge University Press, 19

SEMESTER IV	Course Code: PHY-SDE-544	Credits: 4

INTRODUCTION TO ASTROPHYSICS

Course Outcome

(i) Discuss different celestial coordinate systems.
(ii) Apply Stefan – Boltzmann equation to get stellar luminosity.
(iii) Expalin different phases of interstellar medium.
(iv) Discuss energy generation in stars.
(v) Classify different types of galaxies and discuss evolution of Universe.

Module I

Understanding the Night Sky: Concept of celestial sphere; Celestial coordinate systems - alt-azimuth - right ascension-declination; Celestial time keeping – ecliptic and path of the Sun in the sky, rising and setting of stars in the sky, equinoxes and solstices.

Measurement of Light: Basic terms in astronomy - flux, luminosity, specific flux, specific luminosity, bolometric luminosity, inverse square law of light, apparent magnitude, absolute magnitude and the magnitude system, trigonometric parallax as a means to measure distances to nearby stars, definition of a light year, definition of a parsec, apparent magnitude – absolute magnitude – distance relation; Signals from Astronomical Sources - Electromagnetic frequencies and photon energies, the Earth's atmosphere and transparency to electromagnetic radiation; Telescopes (qualitative only) - optical telescopes, radio telescopes, X-ray telescopes, space based observatories with Hubble Space Telescope as an example, its advantages over ground-based telescopes.

Module II

Introduction to Stars: Stars as blackbody - Blackbody radiation - Planck's theory of black body radiation - Planck function - Rayleigh-Jeans and Wien approximations - Stefan-Boltzmann equation connecting stellar luminosity, radius, and surface temperature; Spectral classification of stars - absorption and emission spectra - description of how they are produced - understanding stellar spectra through Boltzmann equation - Saha equation of thermal ionization - Harvard system of classifying stars based on their spectra - spectral classes of stars and luminosity classes of stars.

Module III

Interstellar Medium and Formation of Stars: phases of the interstellar medium - their physical properties - distribution within the Galaxy; HII regions and Stromgen sphere - sizes of Stromgen sphere around stars of various spectral type; Interstellar dust composition - its distribution within the Galaxy - extinction and reddening of star light due to dust; Virial theorem - Jeans criterion for gravitational collapse - free-fall time scale as time-scale for star formation.

Stellar Nucleosynthesis: Energy generation mechanism in stars - nuclear fusion - mass defect - p-p chain - CNO cycle - energy generated from pp chain and CNO cycle; Energy transport within stars (conduction, convection, radiation) - time-scale for energy transport within stars - Nuclear time scale.

Module IV

Stellar Evolution: Hydrostatic equilibrium in stars - pressure equation of state; The Hertzsprung – Russell diagram, and the concept of main sequence; Post main-sequence evolution (qualitative) - He burning, and subsequent stages of nuclear burning in stars; Evolution of low mass stars – electron degeneracy pressure - white dwarfs – planetary nebulae; Evolution of high mass stars – supernova – neutron degeneracy pressure - neutron star – black holes, and Schwarzschild radius.

Module V

Milky Way Galaxy: The components of the Milky Way (qualitative based on observational evidence) – the Galactic Disk (young thin disk, old thin disk, thick disk, scale height, the distribution of stars and interstellar gas) - Galactic bulge - stellar halo - underlying stellar populations – size and shape of the Galaxy; Open star clusters and Globular star clusters - Kinematics of the Galaxy – differential rotation - rotation curve of the Galaxy – evidence for Dark Matter Halo; Galactic center – observational evidences for the presence of Super Massive Black Hole in the Galactic center.

Galaxies in our Universe: Distances to the nearest galaxies; Morphological classification of galaxies – the Hubble tuning form - trends in the Hubble sequence of galaxies based on color, stellar populations, gas fractions, dust, and star formation rates from spectra; Galaxy groups and galaxy clusters - Mass and size scales of groups and clusters – the Local Group galaxies (qualitative) - velocity dispersion measures of galaxies in clusters, virialization, comparison of luminous mass of galaxy clusters with dynamical mass, and the evidence for Dark Matter.

Module VI

Cosmology and the Evolution of the Universe: Expansion of the Universe based on observations of redshifts of galaxies - redshift expression in terms of wavelength and recession velocity - Hubble's constant - Hubble time as a value for the age of the universe - scale factor – the concept of metric - cosmological redshift as due to expansion of space; Friedman equation based on Newtonian cosmology, critical density and density parameter, open, closed and flat universes; Cosmic Microwave Background (qualitative) - observations and the origin of the CMB, evidence for Dark Energy.

Books for study

1. Baidyanath Basu, Tanuka Chattopadhyay, Sudhindra Nath Biswas - An Introduction to Astrophysics - Prentice Hall India Learning Private Limited, 2010/2013

2. Bradley W. Carroll, and Dale A. Ostlie: Introduction to Modern Astrophysics, Addison Wesley (II Edition), 1997 – or – Pearson 2006

3. Arnab Rai Choudhuri – Astrophysics for Physicists, Cambridge University Press, 2010

4. Hannu Karttunen, Pekka Kröger, Heikki Oja - Fundamental Astronomy - Springer 2007

SEMESTER IV	Course Code: PHY-SDE-545	Credits: 4

NAME OF THE COURSE: LAB- SPACE PHYSICS

Course outcomes

1. Ability to use reasoning and logic to define a problem in terms of principles of physics.
2. Data handling skills such as making measurements with specialized equipment and computer applications.
3. Ability to handle and interpret satellite data.
4. Knowledge on methods and techniques of astronomical imaging using charged coupled device (CCD) detectors and computer controlled telescopes to obtain images of the moon, planets, stars and nebulae.

LIST OF EXPERIMENTS

1. Analysis of aerosols using aerosol spectrometer,
2. Aerosol properties using solar radiometer
3. Analysis of aerosols using satellite based sensors
4. Analysis surface meteorological data like temperature, pressure, wind speed, rainfall etc using Automatic Weather Station
5. Analysis of upper air data; using radiosondes, ozonesondes
6. Analysis of cloud characteristics using ground based instruments; Ceilometer (LIDAR)
7. Analysis of precipitation characteristics using disdrometer and MRR
8. Studies using Solar Spectrometer.
9. Time variations of components of geomagnetic field using magnetometer
10. Distance to the moon by Parallax
11. Characteristics of CCD camera
12. Polar Alignment of an astronomical telescope
13. Estimating relative magnitude by a group of stars by a CCD camera.
14. Experiments using photodiodes.
15. Image analysis stellar objects.
16. Experiments using photodiodes
17. Any other equivalent experiment in the relevant area of specialization

SEMESTER –I-IV (Any semester)	Course Code: PHY-GC-501	Credits: 2

NAME OF THE COURSE: FOUNDATIONS OF ASTRONOMY

Course outcome:

1. Identify and arrange different celestial objects by exploring the sky from moon to star clusters
2. Describe the formation and structure of stars
3. Describe the origin of solar system
4. Explain origin of life and possibility of life on other worlds

Course content

Module I

Exploring the Sky: Astronomy- Our position and time, relevance of astronomy. The sky- stars, sky and its motion, cycles of the sun, astronomical influences on the climate of earth. Cycles of the moon- the changeable moon, Lunar eclipse, solar eclipse, predicting eclipses. Origin of modern astronomy – Roots of astronomy, Copernician revolution, Planetary motion, Galileao's contribution, Modern Astronaomy. Gravity- Laws of motion due to Galileo and Newton, Orbital motion and tides, Einstein and relativity **Light and Telescopes**- Radiation- Information from space, Optical telescopes, special instruments, Radiotelescopes, Astronomy from space.

Module II

The Stars: Atoms and star light – Atoms, The interaction of light and matter, Stellar spectrum. The Sun – Solar atmosphere, nuclear fusion, solar activity. The family of stars, The interstellar medium, The formation and structure of stars, Stellar evolution, The death of stars, Newtron stars and black holes. **The Universe –** Milky way galaxy –Discovery , Structure , Spiral arms and star formation, the nucleus, Origin and history. Galaxies – The family of galaxies, measuring the properties of galaxies, evolution of galaxies. Active Galaxies and Supermassive Black Holes. Modern Cosmology – Big bang theory, Cosmic microwave background radiation.

Module III

The Solar System : The origin of solar system, Survey of solar system, Planet building. Earth – The standard of comparative planetology. Airless worlds – Moon and Mercury Venus and Mars, Moons of Mars. **Outer planets -** Jupiter and Saturn – Jupiter's family of moons, Saturn, Saturn's moons. Uranus, Neptune and Outer planets – Uranus, Neptune, The dwarf planets. Meteorites, Astroids and Comets., Impact of Asteroid and Comets. **Life-** Astrobilogy – Life on other worlds, The nature of life, life in the universe, intelligent life in the universe

References

1. Michael A Seeds and Dana E Backman (2011), Foundations of Astronomy, Cengage learning, 11th International Students Edition.
2. Abhayankar K D (2001), Astrophysics, University Press

Additional References

1. Space Physics and Space Astronomy – Michael D Pappagiannis (1972), Gordon and Breach Science Publishers Ltd.
2. Introduction to Cosmology- J. V. Narlikar (1993), Cambridge University Press.

SEMESTER –I-IV (Any semester)	Course Code: PHY-GC-502	Credits: 2

NAME OF THE COURSE: RENEWABLE ENERGY

Course Outcomes:

1. Understand Energy policy perspectives.
2. Classify technologies for conversion of solar energy resource.
3. Illustrate Photovoltaic conversion mechanism.
4. Appraise wind energy conversion.
5. Describe ocean energy conversion.

Course Content

Module I

Energy Policy: Overview of world energy scenario; Energy Demand- present and future energy requirements; Review of conventional energy resources- Coal, gas and oil reserves, Tar sands and Oil Shale, Nuclear energy; Global warming; Green House Gas emissions, impacts, mitigation; sustainability; United Nations Framework Convention on Climate Change (UNFCC); Sustainable development; Kyoto Protocol; Conference of Parties (COP); Clean Development Mechanism (CDM); Prototype Carbon Fund (PCF).

Module II

Solar Energy & Photovoltaic Conversion: Solar radiation, its measurements and prediction; Solar thermal collectors- flat plate collectors, concentrating collectors; solar heating of buildings; solar still; solar water heaters; solar driers; conversion of heat energy in to mechanical energy, solar thermal power generation systems;

Photovoltaic Conversion -Intrinsic, extrinsic and compound semiconductor; Absorption of light; Recombination process; p-n junction: homo and hetero junctions; Dark and illumination characteristics; Principle of photovoltaic conversion of solar energy, Figure of merits of solar cell; Efficiency limits;

Module III

Wind and Ocean Energy: Wind energy conversion principles; General introduction; Power, torque and speed characteristics. Atmospheric circulations; factors influencing wind, wind shear, turbulence, wind speed monitoring; Betz limit; Types and classification of WECS, characteristics and applications.

Ocean Energy - Ocean energy resources, ocean energy routes; Principles of ocean thermal energy conversion systems; ocean thermal power plants; Principles of ocean wave energy conversion and tidal energy conversion.

References

1. Non- conventional energy resources, B H Khan, Tata McGraw-Hill Publication 2006, ISBN 0-07-060654-4
2. Renewable Energy Resources Paperback John Twidell and Tony Weir , Routledge, Taylor& Francis, 2015 ISBN 9780415584388
3. Solar Photovoltaics: Fundamentals, Technologies And Applications, CHETAN SINGH SOLANKI, PHI Learning Pvt. Ltd., Third Edition 2015, ISBN 978-81-203-5111-0

Additional References

1. Non – Conventional Energy Resources: G. D. Rai, Khanna Publishers,2008.
2. L.L. Freris, Wind Energy Conversion Systems, Prentice Hall, 1990.
3. Renewable Energy, Bent Sorensen (2nd Ed), Academic press, New York, 2000

SEMESTER –I-IV (Any semester)	Course Code: PHY-GC-503	Credits: 2

NAME OF THE COURSE: INTRODUCTION TO MATERIALS CHARACTERIZATION TECHNIQUES

Course Outcome

1. Explain the classification of characterization techniques.
2. Describe the working principle and applications of microscopy techniques.
3. Explain the tools for the Phase identification of materials
4. Describe X-ray diffraction methods for different forms of materials
5. Distinguish between X-ray and electron diffraction methods
6. Explain optical spectroscopic techniques for material characterization.
7. Choose the characterization techniques for the morphological, chemical and structural analysis of materials during research activities.

Course Content

Module I

Microscopy Techniques: Optical microscope: Basic principles-components-resolution-numerical aperture, Different examination modes-advantages and limitations of optical microscopy- applications; Electron microscopy: working principle-basic components- resolution-Scanning electron microscopy-Transmission electron microscopy-Scanning transmission electron microscopy-Energy dispersive spectroscopy- Specimen preparationadvantages/disadvantages-Basic operation and applications of Atomic force microscopy and Scanning tunneling microscopy.

Module II

Diffraction techniques: X-ray diffraction: Properties of X-rays-Generation and detection of X-rays- Diffraction of X-rays, Bragg's law- X-ray diffraction techniques for single crystals, polycrystalline or powder-thin films and biological samples- Phase identification-indexing and Crystal structure determination; Electron diffraction- basic theory-Interpretation of data-applications

Module III

Spectroscopy: Working principle, basic components and applications of :-Atomic absorption spectroscopy, UV/Visible spectroscopy, Fourier transform infrared spectroscopy, Raman spectroscopy, photoluminescence spectroscopy and X-ray photoelectron spectroscopy

References

1. Materials Characterization: Introduction to Microscopic and Spectroscopic Methods by Y. Leng, 1st Edition, June 2008.
2. Materials Characterization Techniques by Sam Zhang, Lin Li, Ashok Kumar ,CRC Press, (2008).
3. Elements of X-ray diffraction by B.D Cullity, Addison-Wesley Publishing Company, INC
4. Electron Microscopy and analysis by P.J. Goodhew and F.J. Humpreys
5. Scanning electron microscopy and x-ray microanalysis by J.I. Goldstein
6. Introduction to spectroscopy by Donald L Pavia, 5th Edition.
7. Fundamentals of Molecular Spectroscopy by C N Banwell, 4th Edition

Additional References

1. An introduction to material characterization by P.R Khangaonkar
2. Fundamentals of Light Microscopy and Electronic Murphy, Douglas B, Wiley-Liss, Inc. USA, (2001).
3. Advanced Techniques for Materials Characterization, Tyagi, A.K., Roy, Mainak, Kulshreshtha, S.K., and Banerjee, S., Materials Science Foundations, Volumes 49 - 51, (2009).
4. Electron Diffraction in the Transmission Electron Microscope, P.E. Champness, 2001, Garland Science, USA.
5. NPTEL Lectures by Prof. S.Sankaran.https://nptel.ac.in/courses/113/106/113106034/.
6. Francesco Stellacci, Linn Hobbs, and SilvijaGradecak. *3.014 Materials Laboratory.* Fall 2006. Massachusetts Institute of Technology: MIT OpenCourseWare, https://ocw.mit.edu..

SEMESTER –I-IV (Any semester)	Course Code: PHY-GC-504	Credits: 2

NAME OF THE COURSE: VACUUM SCIENCE AND TECHNOLOGY

Course Outcomes:

1. Understand different modes of gas flow and tthe conductance through tubes and orifices.
2. Explain the creation of vacuum and calculate pumping -up and down-speeds of a vacuum system.
3. Understand the working principle of rotary and high vacuum pumps.
4. Differentiate between the gauges for measurement under high and low vacuum conditions.
5. Apply vacuum systems for the deposition and characterization of materials.

Course Content

Module I

Basic concepts: Kinetic theory of gases, Molecular distribution functions, Impingement rate of molecules on a surface, Mean free path of gas molecules, Diffusion of gases, Fick's law, vapour pressure-rate of evaporation, Gas viscosity and flow, pumping, gas conductance of a vacuum line, gas impedance of a vacuum line, flow of gases through apertures, elbows, tubes etc. for viscous and molecular flow regimes, Pump-down times and pumping speed-basic calculations.

Module II

Vacuum pumps: Vacuum – definitions, measuring units, Vacuum Pumps: Mechanical pumps, working principle of rotary oil pump, Hook and claws pump, Roots Pump, Molecular drag pump, Diffusion pump- back-streaming, baffles and traps , Cryosorption pumps, Getter pumps, getter ion pumps, Sorption pumps, Sputter ion pumps, Titanium sublimation pump

Module III

Pressure Measurements and applications of vacuum systems : Measurement of low pressure Pressure gauges for low to high vacuum, Mc Leod manometer, Thermal conductivity gauges, Pressure gauges for high to ultrahigh vacuum, Hot cathode ionization gauges, Cold cathode ionization gauges, Operation of High-vacuum gauges. Commonly used vacuum techniques for deposition of a material, application of vacuum in the material characterization techniques

References:

1. Handbook of Vacuum Technology, Karl Jousten, Wiley, 2016.
2. Modern Vacuum practice, Nigel Harris, McGraw-hill , 1989
3. Vacuum Technology: Practice for Scientific Instruments, Nagamitsu Yoshimura, Springer Science & Business Media, 2007.
4. Hand book of Thin Film Technology, L. I. Maissel and R. Glang, Mc Graw Hill Book Co. 1970.
5. Vacuum Physics and Techniques,T. A. Delchar, Chapman and Hall, 1993.
6. Vacuum Technology, A. Roth, (North Holland, Elsevier Science B.V. 1998)
7. High Vacuum Techniques,J.Yarwood, (Chapman and Hall, London, 1967)

SEMESTER –I-IV (Any semester)	Course Code: PHY-GC-505	Credits: 2

NAME OF THE COURSE: ARTIFICIAL INTELLIGENCE THROUGH BRAIN INITIATIVE

Course Outcomes:

1. What is Brain Initiative?
2. Solve the problem of finding Fourier Transform of given wave function?
3. Identify different properties of Sound Wave.
4. Compare and Contrast different Musical Instruments using Fourier Transform and relate to AI research

Course Content

Module I

Mind and Consciousness: Physicist viewpoint of Consciousness – Telepathy – Telekinesis – Dreams – Artificial Mind –Silicon Consciousness – Reverse Engineering the Brain for Artificial Intelligence.

Module II

Fourier Transform: Periodic series and integrals – Periodic functions – Fourier series –Fourier integrals and Transforms – Application of the solution in one dimension wave forms.
Sound and Hearing: The basics of sound-Waveform Characteristics- Amplitude-Frequency-Velocity-Wavelength-Phase-Phase shift-Harmonic Content-Loudness level-the decibel-Perception of direction and perception of space

Module III

Acoustic Measurement for AI Research: Analysis of Sound using Fourier Transform – Intensity and Loudness –Tones – Voices – Speech Sounds – Analysis of vowel sounds – Music - Musical instruments – Veena – Piano – Violin –Wind Instruments –Organ –Flute - Nadhaswaram – Examples and Exercise.

Reference:

1. David Eagleman (2011) Incognito: The Secret Lives of the Brain. New York: Pantheon Books.
2. Rajput, B. S. (2001). Mathematical Physics, PragatiPrakashan.
3. G. Aruldhas (2010). Enigneering Physics, PHI Learning Pvt. Ltd.,
4. David Miles Huber, Robert E Runstein (2017) Modern Recording Techniques, Audio Engineering Society