UNIVERSITY OF KERALA

Senate House Campus, Palayam
Thiruvananthapuram 34, Kerala, India

കേരള സർവകലാശാല

സെനറ്റ് ഹൗസ് കാമ്പസ്, പാളയം
തിരുവനന്തപുരം 34, കേരളം, ഇന്ത്യ

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

Name of the Programme:

M.Sc. Physics

(Syllabus effective from 2020 Admission onwards)

UNIVERSITY OF KERALA

2020

UNIVERSITY OF KERALA

Syllabus for M.Sc. Physics

(Specialization in Renewable Energy)

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 Renewable Energy.
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

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**
	Discipline-Specific Elective (DE)		
	PHY-DE-516	Renewable Energy-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	**4**
	Discipline-Specific Elective (DE)		
	PHY-DE-526	Renewable Energy 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		
	PHY -DE-534	Computational Methods	**4**

	PHY -DE-535	Renewable Energy III	**4**
IV	**Core Courses (CC)**		
	PHY -CC-541	Project	**10**
	Discipline-Specific Elective (DE)		
	PHY -DE-542	Fundamentals of Photovoltaic Technology	**3**
	PHY -DE-543	Renewable Energy IV	**3**
	PHY -DE-544	Lab- Renewable Energy	**4**
	PHY -DE-545	Case Study/ Data Analysis	**3**
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**
	PHY-GC-506	Mathematical Tools, Statistical Methods and their application in Physics, Chemistry and Biology	**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, 6th ed.
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, 15th ed.
4. Ghatak, A. K. et al. (2012). Mathematical Physics: differential equations and transform theory, Macmillan & Co. Ltd., 1st ed.

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., 1st ed.
2. Boylestad, R. L &Nashelsky, L. (2009). Electronic devices and circuit theory, Dorling Kindersley (India) Pvt. Ltd., 10th ed.
3. Gayakwad, R.A. (2016). Op-Amps and Linear Integrated Circuits, Pearson Education, 4th ed.
4. Ryder, J. D. (2000). Electronic fundamentals and applications, Prentice-Hall of India Pvt. Ltd., 5th ed.
5. Pallab Bhattacharya (2000). Semiconductor Optoelectronic Devices, Prentice-Hall of India Pvt. Ltd.,
   1st ed.
6. Keiser, Gerd (2000). Optical Fiber Communications, McGraw-Hill book Co, Inc, 3rd ed.
7. Senior, John M. (1994). Optical Fiber Communications: principles and practice, Prentice-Hall of India Pvt. Ltd., 2nd ed.

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 –I	Course Code: PHY-DE-516	Credits: 2

NAME OF THE COURSE: RENEWABLE ENERGY-1

Course Outcomes:

1. Describe various conventional and non-conventional energy sources.
2. Understand energy policy perspectives.
3. Understand basic techniques for energy and environmental analysis of industrial processes.

Course Content

Module I

Energy Sources: Energy Sectors: Domestic, Transportation, Agriculture and Industry. Availability of Conventional & Non-Conventional Energy Resources. Conventional Energy Sources : Fossil Fuel, Hydro Resources, Nuclear Resources, Coal, Oil, Gas, Thermal Power Stations. Comparison of various conventional energy systems, their prospects and limitations. Advantages and Disadvantages of Conventional Energy Sources. Non-Conventional Energy Sources: Solar Energy, Wind Energy, Energy from Biomass & Biogas, Ocean Thermal Energy Conversion, Tidal Energy, Geothermal Energy, Hydrogen Energy, Fuel Cell, Magneto Hydro-Dynamics Generator. Advantages & Limitations of Non-Conventional Energy Sources.

Module II

Energy Policy: Overview of world energy scenario; Energy Demand- present and future energy requirements. Importance of energy management. Relevance of economic and financial viability evaluation of renewable energy technologies. Concepts of pollution and climate change, 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 III

Energy and environmental analysis of industrial processes: Industrial energy use and its disaggregation (in terms of production dependent, weather dependent and independent etc.

components), Energy intensity, Pinch analysis, Lean energy analysis, Thermodynamics and energy analysis, Life cycle energy analysis, Energy analysis and energy management, Energy audits, Managing energy efficiency in the industry, Identifying opportunities for improving energy efficiency in industrial energy systems. Basic approaches and tools for environment analysis, life cycle analysis and environmental impact assessment of industrial products and processes, Inventory of materials and energy inputs and environmental emissions, Emission factors, Relevant ISO standards (such as ISO 14040 and ISO 14044), Potential of energy and materials recovery.

References:

1. Energy for the 21st century: a comprehensive guide to conventional and alternative sources, (2nd Edition), R. Nersesian, Routledge, Taylor & Francis Group, New York, 2014.
2. Renewable energy: sources and methods, A.E. Maczulak, Infobase Publishing, 2010.
3. Renewable Energy Sources and Climate Change Mitigation: Special Report of the Intergovernmental Panel on Climate Change, O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow, P. Matschoss, Cambridge University Press, 2011.
4. Non-conventional energy resources, B.H. Khan, Tata McGraw-Hill Education, 2006.
5. Z. Morvay, D. Gvozdenac, Applied Industrial Energy and Environmental Management, John Wiley & Sons, 2008.

Additional References:

1. Energy management and conservation handbook, F. Kreith, D.Y. Goswami, CRC Press, 2007.
2. Industrial ecology and global change, R. Socolow, C. Andrews, F. Berkhout, V. Thomas, Cambridge University Press, 1997.
3. Energy Security: Policy challenges and solutions for resource efficiency, N. Mouraviev, A. Koulouri, Springer, 2018.
4. A dynamic analysis of financing conditions for renewable energy technologies, F. Egli, B. Steffen, T.S. Schmidt, Nature Energy. 3 (2018) 1084–1092.
5. Comprehensive review on India's growth in renewable energy technologies in comparison with other prominent renewable energy based countries, R.M. Elavarasan, Journal of Solar Energy Engineering. 142 (2020).

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
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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.

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2. Merzbacher E (1997) Quantum Mechanics, John Wiley.
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6. *Quantum Physics I | Physics | MI OpenCourseWareocw.mit.edu › Courses › PhysicsLecturewww.phy.iitb.ac.in/~dkg/qmech/Lecture5.pdfhyperphysics.phy-astr.gsu.edu/hbase/mod6.html*
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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, 2nded.
3. Pippard, A.B. (1966). Elements of classical thermodynamics for advanced students of physics, Cambridge University Press, 1sted.

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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.

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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 –II	Course Code: PHY-DE-526	Credits: 2

NAME OF THE COURSE: RENEWABLE ENERGY II

Course Outcomes:

1. Understand combustion and combustion generated air pollution.
2. Appraise wind, hydro and ocean energy conversion.
3. Illustrate photovoltaic conversion mechanism.

Course Content

Module I

Combustion and air pollution: Fuels, Basics of flames and Flammability limits. Ideal gases and mass conservation, Basics of thermodynamics, Combustion stoichiometry. Thermochemical calculations- Enthalpy and Enthalpy of formation, Internal Energy, Entropy. Kinetic theory of gases, Chemical Kinetics, Reaction kinetics. Chemical equilibrium- Basic equations, Equilibrium modelling, Equilibrium composition and temperature, Conservation, energy and equilibrium equations. Air quality and air pollution**.** Pollutant formation and oxidation kinetics. Pollutant emission reduction techniques- Combustion modification for NO_x reduction, Post combustion technique for NO_x reduction, Sulphur compounds reduction techniques.

Module II

Wind, Hydro and Ocean Energies: Wind Energy: 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. Hydro-electricity: Overview of micro mini and small hydro systems, Basic criteria, Penstocks and turbines, Speed and voltage regulation, Investment issues, load management and tariff collection, Distribution and marketing issues, Wind and hydro based stand-alone / hybrid power systems, Control of hybrid power systems. 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.

Module III

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; First, Second and Third Generation PV Devices, Basics of Design and Fabrication, Energy Losses and Efficiency.

References

1. Fundamentals and technology of combustion, F. El-Mahallawy, S.-D. Habik, Elsevier, 2002.
2. Renewable energy: sources and methods, A.E. Maczulak, Infobase Publishing, 2010.
4. Non-conventional energy resources, B.H. Khan, Tata McGraw-Hill Education, 2006.
5. Solar photovoltaics: fundamentals, technologies and applications, C.S. Solanki, PHI Learning Pvt. Ltd., 2015.

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1. Green Energy Advances, D. Enescu, IntechOpen, 2019.
2. Challenges and solution technologies for the integration of variable renewable energy sources—a review, S.R. Sinsel, R.L. Riemke, V.H. Hoffmann, Renewable Energy. 145 (2020) 2271–2285. https://doi.org/10.1016/j.renene.2019.06.147.
3. Review on recent trend of solar photovoltaic technology, M. Gul, Y. Kotak, T. Muneer, Energy Exploration & Exploitation. 34 (2016) 485–526.
4. Fundamentals of Photovoltaic Generation: A Review, in: Solar Photovoltaics, N.D. Kaushika, A. Mishra, A.K. Rai, Springer, 2018: pp. 27–41.

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.
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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.
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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.
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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. solveeigen values and eigen vectors of matrices numerically
4. interpolatea 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., 5thed.

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OtherReferences

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http://archives.math.utk.edu/visual.calculus/
http://tutorial.math.lamar.edu/Classes/CalcI/CalcI.aspx

SEMESTER –III	Course Code: PHY -DE-535	Credits: 4

NAME OF THE COURSE: RENEWABLE ENERGY III

Course Outcomes:

1. Understand solar thermal power technology.
2. Describe biomass production and utilization.
3. Illustrate energy systems modeling and analysis.
4. Understand advanced materials for energy applications
5. Illustrate materials characterization techniques for energy applications

Course Content

Module I

Solar Thermal Power Technology: Solar radiation, Solar angles, classifications of Solar thermal collectors, Non-concentrating and concentrating collectors, Heat transfer fluids, Tracking mechanisms, Emerging solar thermal technologies, Application of solar thermal technologies: Power generation, Industrial process heating, Water distillation, Refrigeration, Building heating and cooling, Cooking, Drying, Thermal energy storage systems: Sensible, Latent and Thermochemical energy storage, Integration of thermal energy systems with various end use applications, Economic analyses of solar thermal energy systems, Life cycle assessment of solar thermal energy systems.

Module II

Bioenergy: Introduction to bioenergy; biomass harvesting; characterization of biomass feedstock (physico-chemical properties, ultimate, proximate, compositional, calorific value, thermogravimetric, differential thermal and ash fusion temperature analyses); classification of biomass feedstock: first, second and third generation biofuels; Different pre-treatment processes of biomass; different production routes for biomass conversion to biofuels: biochemical methods (anaerobic, enzymatic- saccharification and fermentation process, and dark fermentation, ABE fermentation); chemical processes (transesterification, hydro-processing, micro-emulsification); thermochemical methods (combustion, gasification, pyrolysis, partial oxidation, auto-thermal reforming) for biofuels production including synthesis gas, bio-hydrogen, ethanol, butanol, biogas, methanol, dimethyl ether and paraffinic fuels.

Module III

Energy Systems Modeling and Analysis

Energy Chain, Primary energy analysis. Modelling overview- levels of analysis, steps in model development, examples of models. Quantitative Techniques: Interpolation- polynomial, lagrangian, curve fitting, regression analysis, solution of transcendental equations. Systems Simulation- information flow diagram, solution of set of nonlinear algebraic equations, successive substitution, Newton Raphson. Examples of energy systems simulation Optimisation: Objectives/constraints, problem formulation. Unconstrained problems- Necessary & Sufficiency conditions. Constrained Optimisation lagrange multipliers, constrained variations, Kuhn-Tucker conditions. Linear Programming - Simplex tableau, pivoting, sensitivity analysis. Dynamic Programming. Search Techniques-Univariate/Multivariate.

Module IV

Carbon Based Materials for Energy Applications: Introduction –Carbon molecules-nature of the carbon bond-new carbon structures-discovery of C60-structure of C60 and its crystal-From a Graphene Sheet to a Nanotube – Single wall and Multi-walled Nanotubes - Zigzag and Armchair Nanotubes - Euler's Theorem in Cylindrical and Defective Nanotubes, Structure and Bonding. Fullerenes: Structure and Bonding- Nomenclature, The Structure of C60, Structure of Higher Fullerenes - Growth Mechanisms; Production and Purification, Physical and Chemical Properties. Carbon nanotubes: Structure and Nomenclature of Carbon Nanotubes (SWCNT and MWCNT). Structure and production of other tubular carbon materials. Graphene: Structure of graphene; Preparation of graphene – synthesis of graphene by various physical and chemical methods and Purification; Electronic Properties - Band Structure of Graphene - Mobility and Density of Carriers - Quantum Hall Effect. Applications of carbon nanomaterials: Application of Fullerene, CNT, Graphene and other carbon nanomaterials - Mechanical, Thermal, Electronic and biological Applications.

Module V

Other Advanced Materials for Energy Applications: Microporous and Mesoporous Materials: Introduction of nanoscale porosity in organic and inorganic materials, surface acidity and basicity measurements. Impact of nanoscale porosity and surface acidity/basicity in the energy and environmental research. Nanomaterials: Size effect and properties of nanostructures- Top down and Bottom up approach. Quantum dots: Excitons and excitonic Bohr radius – difference between nanoparticles and quantum dots. Applications of nanoparticles, quantum dots, nanotubes and nanowires for nanodevice fabrication. Thin Film: Overview of physical and chemical methods of preparation, Applications of thin films. Ceramics: Oxide ceramics, Ferroelectric ceramics, Magnetic ceramics, Superconducting ceramics. Composites: Metal matrix composites, Polymer matrix composites, Ceramic matrix composites, Hybrid composites, Applications of composites.

Module VI

Materials Characterization Techniques for Energy Applications: Introduction to materials characterization Techniques, Structure analysis tool: X-ray diffraction, Phase identification, indexing and lattice parameter determination. Microscopy techniques: Introduction to Microscopes, Optical microscopy (OM), Transmission Electron Microscopy (TEM); Basic Electron scattering, Concepts of resolution, TEM instruments, Various imaging modes, Analysis of micrographs. Scanning Electron Microscopy, Rutherford backscattering spectrometry. Atomic Force Microscopy, Scanning Probe Microscopy. Thermal analysis techniques: Differential thermal analysis (DTA), Differential Scanning Calorimetry (DSC), Thermo-gravimetric analysis (TGA). Electrical characterization techniques: Electrical resistivity in bulk and thin films, Hall effect, Magnetoresistance. Optical characterization techniques: UV-VIS spectroscopy, Fourier transform infrared spectroscopy, Raman spectroscopy, X-ray photoelectron spectroscopy.

References

1. Large-scale solar thermal power: technologies, costs and development, W. Vogel, H. Kalb, John Wiley & Sons, 2010.
2. Advances in concentrating solar thermal research and technology, M. Blanco, L.R. Santigosa, Woodhead Publishing, 2016.
3. Biomass to renewable energy processes, J. Cheng, CRC press, 2017.

4. Recent Advancements in Biofuels and Bioenergy Utilization, P.K. Sarangi, S. Nanda, P. Mohanty, Springer, 2018.
5. Optimization of energy systems, I. Dincer, M.A. Rosen, P. Ahmadi, Wiley Online Library, 2017.
6. Intelligent renewable energy systems: modelling and control, G. Rigatos, Springer, 2016.
7. Innovative Advanced Materials for Energy Storage and Beyond: Synthesis, Characterisation and Applications, V.K. Thakur, Multidisciplinary Digital Publishing Institute, 2020.
8. Handbook of Materials Characterization, S.K. Sharma, D.S. Verma, L.U. Khan, S. Kumar, S.B. Khan, Springer, 2018.
9. Materials characterization techniques, S. Zhang, L. Li, A. Kumar, CRC press, 2008.

Additional References

1. Solar energy technology handbook, E.W. Dickinson, CRC Press, 2018.
2. Biomass and bioenergy, K.R. Hakeem, M. Jawaid, U. Rashid, Springer, 2016.
3. Modeling Power electronics and interfacing energy conversion systems, M.G. Simões, F.A. Farret, John Wiley & Sons, 2016.
4. Rational design of carbon-rich materials for energy storage and conversion, D. Kong, Y. Gao, Z. Xiao, X. Xu, X. Li, L. Zhi, Advanced Materials. 31 (2019) 1804973.
5. Electrochemical energy: advanced materials and technologies, P.K. Shen, C.-Y. Wang, X. Sun, J. Zhang, CRC Press, 2018.
6. Materials characterization: introduction to microscopic and spectroscopic methods, Y. Leng, John Wiley & Sons, 2009.

1. L.L. Freris, Wind Energy Conversion Systems, Prentice Hall, 1990.
2. Renewable Energy, Bent Sorensen (2nd Ed), Academic press, New York, 2000
3. Konur O., Bioenergy and Biofuels, Taylor and Francis, CRC Press, 2018
4. Love J. and Bryant J. A., Biofuels and Bioenergy, John Wiley & Sons, 2017 4. Henderson O. P., Biomass for Energy, Nova Science Publishers, 2011

SEMESTER IV	Course Code: PHY-CC-541	Credits: 10

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.

3. Equip the student with industrial/research institute R&D training by encouraging off campus 4-5 month project works

4.Skill enhancement in specialized subject vide off campus endeavour.

5.Develop understanding on how to work in coordination with multiple teams through academia-industry-institute research projects

SEMESTER –IV	Course Code: PHY -DE-542	Credits: 3

NAME OF THE COURSE: RENEWABLE ENERGY IV

Course Outcomes:

1. Understand Hydrogen energy Systems.
2. Appraise Hydrogen energy utilization, storage and safety.
3. Illustrate energy storage technologies.
4. Describe battery storage mechanism.
5. Appraise super capacitors.
6. Comprehend electrochemistry and electroanalytical techniques

Module I

Introduction of Hydrogen Energy Systems: Properties of hydrogen as fuel, Hydrogen pathways introduction – current uses, General introduction to infrastructure requirement for hydrogen production, storage, dispensing and utilization, and Hydrogen production power plants. Hydrogen Production Processes: Thermal Steam Reformation – Thermo chemical Water Splitting – Gasification – Pyrolysis, Nuclear thermo catalytic and partial oxidation methods. Electrochemical – Electrolysis – Photo electro chemical. Biological – Photo Biological – Anaerobic Digestion – Fermentative Micro-organisms.

Hydrogen Storage & Safety: Physical and chemical properties – General storage methods, compressed storage – Composite cylinders – Glass micro sphere storage - Zeolites, Metal hydride storage, chemical hydride storage and cryogenic storage. Hydrogen Safety: Safety barrier diagram, risk analysis, safety in handling and refuelling station, safety in vehicular and stationary applications, fire detecting system, safety management, and simulation of crash tests.

Module II

Energy Storage: Introduction to electrochemical energy storage, Need for energy storage, Classifications of energy storage technologies based on the form of energy stored: Mechanical energy storage, Electrochemical energy storage, Chemical energy storage, Electrical energy storage, Thermal energy storage. Comparison of different energy storage technologies, Challenges and future prospects. Sensible Thermal Energy Storage, Latent Energy Storage, Thermal Management System design using Latent Thermal Energy Storage, Optimization of Thermal Energy Systems, Thermochemical heat storage system, Battery Electrical Energy Storage Systems, Pumped storage systems, Other electrical energy storage systems, Integration of energy storage systems, energy storage system optimization.

Module III

Battery Storage: Primary Batteries, Secondary Batteries, Stationary Systems: Flow Batteries and Thermal Batteries. Rechargeable batteries and their Fundamental electrochemistry, Lithium batteries, Nickel metal hydride battery, Lead-acid battery, High temperature batteries for back-up applications, Flow batteries for load levelling and large scale grid application, Ni-Hydrogen batteries for space and marine applications, Manufacturing technologies of batteries, Sustainable design of batteries, Hybridization of battery, Battery recycling technologies, Battery applications for stationary and secondary use, Battery chargers and battery testing procedures, Battery management, Regulations and safety aspects of high voltage batteries.

Supercapacitors : Energy Storage in Supercapacitors, Significance of electrochemical energy storage, Plot of Energy Vs Power Density, Different types of supercapacitors (Electrochemical double layer capacitor, pseudocapacitor and hybrid capacitor), Components of supercapacitors, Asymmetric capacitors, Different models of electric double layer, Comparison of the performance of supercapacitors and batteries, Different applications.

Module VI (Non-Evaluative)

Introduction to Electrochemistry and Electroanalytical Techniques: Dynamic electrochemistry, Butler-Volmer and Tafel equations. Overpotentials. Kinetically and mass transport controlled electrochemical processes. Mass transport (migration, convection and diffusion), Solid state electrochemistry, Potentiostatic and galvanostatic methods. Electroanalytical techniques: Theoretical principles of electroanalytical chemistry, electrodes, polarization and depolarization, electrochemical cell, Electrode reactions, kinetics, reversibility and irreversibility. Electrochemical methods: ion-selective potentiometry, chronoamperometry, chronocoulometry, cyclic voltammetry, pulse voltammetry, ion-transfer voltammetry, impedance spectroscopy, Charge/ discharge cycles. Instrumentation: rotating disk electrodes, microelectrodes, chemically modified electrodes, scanning electrochemical microscopy (SECM), EC-STM, and quartz crystal microbalance.

References:

1. The hydrogen economy: opportunities and challenges, M. Ball, M. Wietschel, Cambridge University Press, 2009.
2. Hydrogen energy: challenges and prospects, D.A.J. Rand, R.M. Dell, Royal Society of Chemistry, 2007.
3. Alternative transportation fuels: utilisation in combustion engines, M.G. Babu, K.A. Subramanian, CRC Press, 2013.
4. Electrochemical energy storage, J.-M. Tarascon, P. Simon, John Wiley & Sons, 2015.
5. Energy storage devices for electronic systems: rechargeable batteries and supercapacitors, N. Kularatna, Academic Press, 2014.
6. Instrumental methods in electrochemistry, D. Pletcher, R. Greff, R. Peat, L.M. Peter, J. Robinson, Elsevier, 2001.
7. Electrochemical methods fundamentals and applications, J.B. Allen, R.F. Larry, John Wiley & Sons, 2001.

Additional References:

1. Handbook of hydrogen energy, S.A. Sherif, D.Y. Goswami, E.L. Stefanakos, A. Steinfeld, CRC Press, 2014.
2. Nanostructured materials for electrochemical energy production and storage, E.R. Leite, Springer Science & Business Media, 2010.
3. Advances in thermal energy storage systems: Methods and applications, L.F. Cabeza, Elsevier, 2014.
4. Handbook of electrochemistry, C.G. Zoski, Elsevier, 2006.
5. Electrochemical techniques in battery research: a tutorial for nonelectrochemists, X. Yang, A.L. Rogach, Advanced Energy Materials. 9 (2019) 1900747.

SEMESTER –IV	Course Code: PHY -DE-543	Credits: 3

NAME OF THE COURSE: FUNDAMENTALS OF PHOTOVOLTAIC TECHNOLOGY

Course Outcomes:

1. Recognize transport properties of p-n junction.
2. Appraise working of Si Solar cells.
3. Evaluate electrical characteristics of solar cells
4. Comprehend working of non-conventional solar cells

Module I

Review of Semiconductor Physics: Direct and indirect semiconductors, Variations of energy bands with alloy composition, Charge carriers in semiconductor, Fermi level, Equilibrium Fermi level, Charge carrier generation and recombination, carrier transport phenomena, drift and mobility, diffusion, conductivity and mobility, effect of temperature and doping on mobility, Hall Effect, Recombination, Generation, and Carrier Lifetimes, Basic operational principle of a solar cell, The thermodynamic limit, Shockley-Queisser Limit, p-n junction model and depletion capacitance, Current voltage characteristics in dark and light, steady state carrier injection and diffusion length.

Understanding the p-n junction: Metal-semiconductor junctions, semiconductor-semiconductor junctions, p-n homojunctions, p-n hetrojunctions, Analysis of p-n junctions- Formation of a space-charge region in the p-n junction, p-n junction in the dark-under equilibrium and under applied bias, p-n junction under illumination, Quasi-Fermi levels, p-n junction as a photovoltaic cell, Effects on p-n junction characteristics-parasitic resistance, irradiation, temperature, Solar cell external parameters, equivalent circuit, Losses and efficiency limits, Other losses.

Module II

Silicon based solar cells : Purifying the Si, Single Crystal Silicon, Doping, Silicon Wafers, Wafer segregation, crystalline silicon as a photovoltaic material, Monocrystalline Si growth and wafering for photovoltaics, crystalline silicon as a photovoltaic material, doping in crystalline Si, Cell fabrication, Optimization of Si solar cell design- strategies to enhance absorption, reduce surface recombination and series resistance, Microcrystalline Si, ingot fabrication, solar cell design , Passivation with

Hydrogen, amorphous Silicon thin film solar cells- design concepts, chemical vapor deposition, Staebler–Wronski Effect, Future directions in the design of Si solar cells

Module III

Thin film solar cells: Solar radiation at earth's surface- Air Mass, Four generations of solar Cells, Crystalline solar cells- Si solar cells, Crystalline Si Structure and working, Cell fabrication, Optimization of Si solar cell design- strategies to enhance absorption, reduce surface recombination and series resistance, Microcrystalline Si solar cell design, Future directions in the design of Si solar cells, Thin film solar cell, Requirement for suitable materials, Defects in polycrystalline thin film solar cell, effect of grain boundaries on transport, effect of grain boundary recombination on solar cell performance, a-Si p-i-n structures, Fabrication of a-Si solar cells, Heterojunction in thin film solar cell design, CuInGaSe2 thin film solar cells, CdTe thin film solar cell design, III-V semiconductor material properties, GaAs solar cell design and optimization.

Module-IV

Non-conventional solar cells : Design and working principle of dye sensitized solar cells(DSSC), Challenges in the commercialization of DSSC, Quantum dot sensitized solar cells (QDSSC), Multiple electron-hole pairs per photon, Wurfel's analysis, Organic solar cell-principles of operation, Molecular Semiconductor picture of conjugated polymers, Carrier mobilities in organic semiconductors, Optimization of solar cell performance, Organic bulk heterojunction solar cells, Organic-Inorganic Hybrid Bulk Hetero Junction (BHJ-SC) Solar cells, Extremely thin absorber (ETA) solar cells, Perovskite solar cells-Evolution of device architecture.

References

1. The Physics of Solar Cells, Jenny Nelson (Imperial College Press, 2003).
2. Third Generation Photovoltaics: Advanced Solar Energy Conversion, Martin A Green, 2005.
3. Advanced Concepts in Photovoltaics, Arthur J. Nozik, Gavin Conibeer, Matthew C Beard, 2014
4. Handbook of Photovoltaic Science and Engineering, Antonio Luque, Steven Hegedus, 2003.

Other Books:

1. Silicon solar cells: advanced principles and practice, Martin A Green , 1995.
2. Solar Cells Operating Principles, Technology and System Applications, Martin A Green , 2009.
3. Handbook of the Physics of Thin-Film Solar Cells, Böer, Karl W., 2013.

4. Organic-Inorganic Halide Perovskite Photovoltaics, Park, Nam-Gyu, Grätzel, Michael, Miyasaka, Tsutomu, 2016.
5. Organic Photovoltaics: Concept and realization, C. J. Brabec, V.Dyakonov, J. Parisi, N.S.Sariciftci, 2003.

SEMESTER –IV	Course Code: PHY -DE-544	Credits: 4

NAME OF THE COURSE: LAB- RENEWABLE ENERGY

Course outcomes:

1. Understand the working of solid-state energy generation and storage devices
2. Evaluate the properties of semiconductors for the application in the energy field.

LIST OF EXPERIMENTS

1. Determination of band gap of Si using p-n junction
2. Hall Effect
3. Elemental characterization of a fuel using CHNS(O) analyser.
4. Solar radiation measurement
5. Wavelength dependent energy conversions efficiency from solar cell
6. Determination of first and second figures of merit (F1 and F2) of a box type solar cooker.
7. Numerical simulation training for modelling a Solar cell
8. Identify the defects and ionization energy in CuInGaSe2 thin film using temperature dependent I-V measurement.
9. Evaluation of HOMO-LUMO levels of organic energy material using cyclic voltammetry.
10. Determine the characteristics of a supercapacitor.
11. Characterization of a Photo-electrochemical cell
12. Characterization of Battery- Charging Discharging efficiency
13. Fuel cell characteristics
14. Photocatalysis-Dye degradation
15. Redox potential Determination

SEMESTER –IV	Course Code: PHY -DE-545	Credits: 3

NAME OF THE COURSE : CASE STUDY & DATA ANALYSIS

1. Case study to be undertaken-Illustrative/Exploratory/ Critical Instance/ Program Implementation/Program Effects/Cumulative
2. Report on case study analysis - Introduction, Background, Evaluation of the case, Proposed solution/changes, recommendations.

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

<u>NAME OF THE COURSE: ARTIFICIAL INTELLIGENCE THROUGH BRAIN INITIATIVE</u>

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

SEMESTER –I-IV (Any semester)	Course Code: PHY-GC-506	Credits: 2

NAME OF THE COURSE: Mathematical Tools, Statistical Methods and their application in Physics, Chemistry and Biology

Course Outcomes:

1. Remember the basic concepts and fundamental methods of random no. generators.
2. Understand the key concepts and principles behind the operation of Brownian motors.
3. Apply tools and methods in formulating and modeling kinds of Brownian motors.
4. Understand the concept of polymerization in both synthesis of RNA/DNA molecule.
5. Apply the statistical methods and mathematical tools in modeling DNA replication/RNA transcription

Course Content:

Module I

Random Walk Problem: One dimensional random walk, Mean and Deviation, Diffusion Equation, Random walk in higher dimensions, Stochastic Processes, Brownian motion: Langevin's Theory, Concept of Noise, Einstein's Fluctuation-Dissipation Theorem.

Module II

Foundation of Brownian motor: Brownian Motor, Basic requirements of Brownian motor: Key ingredients, Role of noise, Operating principle of Brownian motor, Efficient operation, Coherence in transport, Diffusion, Motor in various aspects, Modeling or synthesis of Brownian motor using mathematical tools and statistical methods.

Module III

Polymerization-Synthesis of RNA/DNA Molecule: Polymerization, DNA Replication, Synthesis of RNA molecule:Transcription, Initiation, Elongation and Termination, Pauses/Errors, Backtracking, Origin of Pauses/Errors, Velocity and Accuracy: DNA replication/Transcription, Efficiency in Transcription, Transcriptonal Interference, Tools and method: Modeling of Transcription or DNA replication

References:

1. Spitzer and Frank, Principles of Random Walk (1976)

2. A. Bovier, D. Brydges, A Coja-Oghlan, D loffe, G. lawler: Random Walks, Random Fields, and Disordered Systems(2015)

3.. R. Zwanzig, Non Equilibrium Statistical Mechanics, Oxford University Press (2004).

4. J. K Bhattacharjee, Statistical Physics: Equilibrium and Nonequilibrium Aspects (2001).

5. The Theory of Polymer Dynamics: Doi and Edwards.

6. A. J. F Griffiths, J. H. Miller, D. T. Suzuki, et al, An introduction to Genetic Analysis, (2000).