

M.Sc. Degree

IN

Physics



SYLLABUS

FOR

CREDIT BASED CURRICULUM

(From the academic year 2018-19 onwards)

DEPARTMENT OF PHYSICS

**National Institute of Technology, Tiruchirappalli – 620015
Tamilnadu, India.**

THE INSTITUTE

Vision

To provide valuable resources for industry and society through excellence in technical education and research.

Mission

- To offer state-of-the-art undergraduate, postgraduate and doctoral programmes.
- To generate new knowledge by engaging in cutting-edge research.
- To undertake collaborative projects with academia and industries.
- To develop human intellectual capability to its fullest potential.

THE DEPARTMENT

Vision

- Provide a world class scientific platform for scientists and engineers.

Mission

- Establish the department as a global player in Science and Technology.
- Excel in scientific R&D and consultancy.
- Create an environment for society aimed at knowledge enhancement.

CURRICULUM

Total minimum credits required for completing M.Sc. Programme in Physics is **66**.

SEMESTER I

CODE	COURSE OF STUDY	L	T	P	C
PH651	MATHEMATICAL PHYSICS – I	3	0	0	3
PH653	CLASSICAL MECHANICS	3	1	0	4
PH655	QUANTUM MECHANICS	3	1	0	4
PH657	ELECTRONICS	3	0	0	3
PH659	GENERAL PHYSICS LABORATORY	0	0	6	2
	ELECTIVE – 1	3	0	0	3
TOTAL CREDITS					19

SEMESTER II

CODE	COURSE OF STUDY	L	T	P	C
PH652	MATHEMATICAL PHYSICS – II	3	0	0	3
PH654	ELECTROMAGNETIC THEORY	3	1	0	4
PH656	STATISTICAL MECHANICS	3	1	0	4
PH658	INSTRUMENTATION	3	0	0	3
PH660	ELECTRONICS LABORATORY	0	0	6	2
	ELECTIVE – 2	3	0	0	3
TOTAL CREDITS					19

SEMESTER III

CODE	COURSE OF STUDY	L	T	P	C
PH661	SOLID STATE PHYSICS	3	0	0	3
PH663	ATOMIC AND MOLECULAR SPECTROSCOPY	3	0	0	3
PH665	NUCLEAR AND PARTICLE PHYSICS	3	0	0	3
PH667	NUMERICAL AND COMPUTATIONAL METHODS	3	0	0	3
PH669	ADVANCED PHYSICS LABORATORY	0	0	6	2
	ELECTIVE – 3	3	0	0	3
TOTAL CREDITS					17

SEMESTER IV

CODE	COURSE OF STUDY	L	T	P	C
PH662	PROJECT WORK AND VIVA-VOCE	-	-	-	8
	ELECTIVE – 4	3	0	0	3
TOTAL CREDITS					11

LIST OF ELECTIVES^{*}

Odd Semester

- PH611 DIGITAL SIGNAL AND IMAGE PROCESSING
- PH613 BASICS OF ENGINEERING MATERIALS
- PH671 WAVEGUIDES AND MODERN OPTICS
- PH673 SOLAR PHOTOVOLTAIC TECHNOLOGY
- PH675 ADVANCED ELECTROMAGNETIC THEORY
- PH677 FIBER OPTIC SENSORS
- PH679 SENSORS AND TRANSDUCERS
- PH681 PHYSICS AND TECHNOLOGY OF THIN FILMS
- PH683 MAGNETISM AND SUPERCONDUCTING LEVITATION
- PH685 MICRO-ELECTRO-MECHANICAL SYSTEMS

Even Semester

- PH610 ELECTRICAL, MAGNETIC AND OPTOELECTRONIC MATERIALS
- PH674 COMPUTATIONAL TECHNIQUES
- PH676 NON-DESTRUCTIVE TESTING
- PH678 LASERS AND APPLICATIONS
- PH680 ADVANCED STATISTICAL METHODS AND PHASE TRANSITION
- PH682 SEMICONDUCTOR PHYSICS
- PH684 NANOSCIENCE AND TECHNOLOGY
- PH686 QUANTUM COMPUTATION AND QUANTUM INFORMATION

* Electives are not limited to the given list. Courses from other PG programmes can also be chosen as subjects of study. The courses will be offered based on convenience of the faculty concerned.

I SEMESTER

PH651 – MATHEMATICAL PHYSICS - I

Objective: To introduce basic mathematical topics necessary to understand and appreciate various physical laws of nature.

Vector Analysis

Definition of vectors – scalar and vector product – triple products – gradient, divergence, curl – vector integration – Gauss's theorem – Green's theorem – Stoke's theorem – Dirac delta function – Helmholtz theorem.

Curved coordinates, Tensors

Orthogonal coordinates – differential vector operators: gradient, divergence, curl – special coordinate systems: rectangular, spherical, cylindrical – tensors of rank two – contraction, direct product – quotient rule.

Linear Algebra

Determinants – matrices – inner product, direct product – orthogonal matrices – Euler angles – symmetry properties – relation to tensors – Pauli matrices – eigenvalue equation and diagonalization – Cayley-Hamilton theorem – functions of matrices – Hermitian matrices.

Ordinary Differential Equations

First order equation – second order homogeneous equation – Wronskian – second solution – inhomogeneous equation – forced oscillation and resonance – power series method – Hermite and Legendre equations – Frobenius method – Bessel equation.

Probability

Definition – basic theorems – permutation and combination – method of counting – random variables – binomial and Poisson distributions – normal distribution – central limit theorem.

Text Books

1. G. B. Arfken and H.J. Weber, *Mathematical Methods for Physicists*, 5th edition, Academic Press (2001).
2. E. Kreyszig, *Advanced Engineering Mathematics*, 8th edition, John Wiley & Sons Inc. (1999).
3. Mary L. Boas, *Mathematical Methods in the Physical Sciences*, 3rd edition, Wiley-India (2011).
4. B. S. Grewal, *Advanced engineering mathematics*, 43rd edition, Khanna Publications.

Reference Books

1. L.A. Pipes and L.R. Harvill, *Applied Mathematics for Engineers and Physicists*, Dover (2014).

2. S. Lipschutz, D. Spellman and M. Spiegel, Schaum's Outline of Vector Analysis -, 2nd edition, Tata McGraw-Hill (2009).
3. V. Balakrishnan, Mathematical Physics with Applications, Problems and Solutions, Ane Books (2017).

Outcome: Students will be capable of handling variety of courses on mechanics and electromagnetic theory.

PH653 – CLASSICAL MECHANICS

Objectives:

1. To learn and use Newton's laws of motion to solve advanced problems involving the dynamic motion of classical mechanical systems.
2. To introduce differential calculus and other advanced mathematical techniques pertaining to the development of Lagrangian and Hamiltonian formulations of classical mechanics.
3. To solve the dynamical problems using conservation laws.

Lagrangian Formulation

Mechanics of a system of particles – constraints – Lagrangian equation of motion from D'Alembert's and Hamilton's principles – conservation of linear momentum, energy and angular momentum – applications of the Lagrangian formalism.

Central Force Problem

Reduction to an one body problem – equation of motion and first integrals – one dimensional problems and classification of orbits – Kepler problem – scattering in a central potential – Rutherford formula – scattering cross section – transformation to laboratory frames.

Rigid Body and Oscillating System

Elements of rigid-body dynamics – Euler angles – symmetric top and applications – small oscillations – normal mode analysis – normal modes of a linear tri-atomic molecule – forced oscillations – effect of dissipative forces on free and forced oscillations – damped driven pendulum.

Hamiltonian Formulation

Legendre transformation – Hamiltonian equations of motion – cyclic coordinates – phase space and Liouville's theorem – Poisson brackets-Hamilton-Jacobi Theory – Action angle variables.

Special Theory of Relativity

Internal frames – principle and postulate of relativity – Lorentz transformations – length contraction, time dilation and the Doppler effect – velocity addition formula –relativistic invariance of physical laws.

Text Books

1. H. Goldstein, C. Poole and J. Safko, Classical Mechanics, 3rd edition, Addison & Wesley (2000).
2. W. Greiner, Classical Mechanics, Springer-Verlag (2003).

3. W. Greiner, Classical Mechanics – Point particles and Relativity, Springer (1989).
4. J. C. Upadhyaya, Classical Mechanics, Himalaya Publishing House (2014).
5. D. Morin, Introduction to Classical Mechanics: With Problems and Solutions, Cambridge University Press (2008).
6. N. C. Rana and P. S. Joag, Classical Mechanics, 25th edition, Mc Graw Hill India (2013).
7. J. R. Taylor, Classical Mechanics, University Science Books (2005).

Reference Books

1. I.C. Percival and D. Richards, Introduction to Dynamics, Cambridge University Press (1983).
2. J.V. Jose and E.J. Saletan, Classical Dynamics: A Contemporary Approach, Cambridge University Press (1998).
3. E.T. Whittaker, A Treatise on the Analytical Dynamics of Particles and Rigid Bodies, 4th edition, Cambridge University Press (1989).

Outcome: Effective learning of items 1, 2 and 3 will enable the students to understand the complicated classical dynamical problems and find possible solutions for these problems.

PH655 – QUANTUM MECHANICS

Objectives:

1. To introduce the mechanics of matter-waves necessary for uncovering the mysteries of matter at atomic scale.
2. To understand the spectrum of hydrogen.
3. To introduce various approximate methods useful for more complex problems.

Schrödinger Equation

Inadequacy of classical theory – de-Broglie hypothesis of matter waves – Heisenberg's uncertainty relation – Schrödinger's wave equation – physical interpretation and conditions on wave function – eigenvalues and eigenfunctions – particle in a square-well potential – potential barrier – tunneling.

Operators and Eigenfunctions

Linear operator – orthogonal systems and Hilbert space – expansion in eigenfunctions – Hermitian operators – canonical commutation– commutations and uncertainty principle – state with minimum uncertainty.

Solvable Problems

Harmonic oscillator – operator method – Schrödinger equation for spherically symmetric potentials – angular momentum operator – condition on solutions and eigenvalues – spherical harmonics – rigid rotor – radial equation of central potential – hydrogen atom – degenerate states.

Angular Momentum and Spin

Eigenvalues of angular momentum \mathbf{J} – matrix representation of \mathbf{J} – electron spin – Stern – Gerlach experiment – Zeeman effect – addition of angular momentum – Clebsch-Gordan coefficients – identical particles with spin – Pauli exclusion principle.

Approximation Methods

Perturbation theory for non-degenerate states – removal of degeneracy – Stark effect – variation method – WKB approximation – Bohr-Sommerfeld quantum condition – perturbative solution for transition amplitude – selection rules – Fermi Golden rule – scattering of a particle by a potential.

Text Books

1. P.M. Mathews and K. Venkatesan, A Textbook of Quantum Mechanics, Tata McGraw-Hill (1976).
2. J.L. Powell and B. Crasemann, Quantum Mechanics, Narosa Publishing House (1993).
3. J.J. Sakurai, Modern Quantum Mechanics, Addison-Wesley (1999).
4. Quantum Mechanics, Aruldas, Prentice Hall of India (2006).

Reference Books

1. L.I. Schiff, Quantum Mechanics, McGraw-Hill (1968).
2. D.J. Griffiths, Introduction to Quantum Mechanics, Pearson Education (2005).
3. N. Zettili, Quantum Mechanics: Concepts and Applications, John Wiley (2009).
4. L.D. Landau and E.M. Lifshitz, Quantum Mechanics (Non-relativistic Theory), 3rd edition, Elsevier (2011).
5. R. Shankar, Principles of Quantum Mechanics, 2nd edition, Springer (2012).

Outcome: Intriguing probabilistic nature of matter at atomic scale will be understood. Students will be capable of handling courses like Statistical Mechanics, Solid State Physics, Spectroscopy and Nuclear Physics.

PH 657 – ELECTRONICS

Objective: To impart a diversified knowledge on circuit analysis, the semiconductor devices, FETs, operational amplifiers and digital circuits and their applications.

Circuit Theorems

Kirchoff's voltage law-voltage division- power in series circuit- Kirchoff's current law –parallel resistance – current division- Star-Delta Transform-Thevenin's and Norton's theorems, superposition and reciprocity theorems with examples-maximum power transfer theorem.

Semiconductor Devices: Diodes and Transistors

p-n junction diodes – Zener diode – tunnel diode – Schottky barrier diode – varactor diode- UJT. Transistors - Biasing characteristics of junction transistors – analysis using re model-fixed bias-voltage divider bias-emitter bias – feedback in amplifiers – effect of negative feedback in amplifiers – FETs – different types –applications.

Oscillators

Oscillator principle – oscillator types – frequency stability, RC oscillators – phase shift oscillator – Wein bridge oscillator – LC tunable oscillators – limitations – multivibrators – monostable and astable – 555 IC timer – sine wave and triangular wave generation – crystal oscillators and their applications.

Operational Amplifiers

Basis of operational amplifier – characteristics – CMRR – inverting and non-inverting modes – sum and difference amplifiers – integrating and differentiating circuits – feedback types – current to voltage (ICVS) and voltage to current (VCIS) conversion — op-amp application – instrumentation amplifiers – low pass and high pass active filters.

Digital Circuits

Logic gates: De Morgan's law, binary adder, comparators, decoders, multiplexers.

Flip-flops: RS flip-flop, JK flip-flop, JK master-slave flip-flop, T flip-flop, D flip-flop. Shift registers – synchronous and asynchronous counters – registers – A/D and D/A conversion.

Text Books

1. J. Milman and C.C. Halkias, Electronic Devices and Circuits, McGraw-Hill (1981).
2. Albert Malvino, David J Bates, Electronics Principles, 8th edn., McGraw-Hill Education (2015).
3. R.J. Higgins, Electronics with Digital and Analogue Integrated Circuits, Prentice Hall (1983).

Reference Books

1. R. L. Boylested and L. Nashelsky, Electronic Device and Circuits, Pearson Education (2003).
2. C. L. Wadhwa, Network Analysis and Synthesis, New Age International Publishers, (2007).
3. G.B. Calyton, Operation Amplifiers, ELBS (1980).

Outcome: On successful completion of this course, students would be able i) to understand the construction, working function, characteristics and applications of various semiconductor devices and ii) to describe the design and applications of various digital circuits.

PH659 – GENERAL PHYSICS LABORATORY

Objective: To introduce the basic concepts of physics through hands on experience and impart experimental skill to students.

List of Experiments

1. Hall Effect in Semiconductor
2. Non-Destructive Testing – Ultrasonics
3. Two Probe Method for Resistivity Measurement

4. Wavelength Measurement of Laser using Diffraction Grating
5. Numerical Aperture of an Optical Fiber
6. Electron Spin Resonance
7. Specific Heat Capacity of Solids
8. Half Shade Polarimeter and Strain Viewer
9. Michelson Interferometer
10. Acoustic Diffraction
11. Vacuum Pumps – Low Pressure Measurement and Determination of Pumping Speed
12. Zeeman effect
13. Hydrogen Spectra and Rydberg Constant
14. Forbe's Method – Thermal Conductivity of Metal
15. Kundt's Tube
16. Solar-Cell Characteristics
17. Magnetic Susceptibility of Liquids – Quincke's Method
18. Curie Temperature of Magnetic Materials
19. Dielectric Constant and Curie Temperature of Ferroelectric Ceramics
20. Hysteresis (B – H Curve)
21. Helmholtz Galvanometer
22. Faraday Effect
23. Millikan Oil Drop Experiment – e/m of Electron
24. Determination of Planck's Constant
25. Cornu's Method – Determination of Elastic Constants of Transparent Materials
26. Stefan's Constant
27. Gouy Balance
28. Experiments using Geiger Muller Counter (GM)
 - a. Efficiency of GM counter for various sources
 - b. Shelf Ratio and verification of inverse square law
 - c. Backscattering
 - d. Absorption coefficient
 - e. Half-life of Ba-137

29. Anderson Bridge
30. Kerr effect –determination of Kerr constant of a Liquid
31. Pockel effect- electro-optic property of a crystal

Text Books

1. General Physics Laboratory Manual, Department of Physics, NITT.

Reference Books

1. R. A. Dunlap, Experimental Physics: Modern Methods, Oxford University Press, New Delhi (1988).
2. E.V. Smith, Manual for Experiments in Applied Physics, Butterworths (1970).
3. D. Malacara (ed.), Methods of Experimental Physics, Series of Volumes, Academic Press Inc. (1988).

Outcome: The student will be able to understand the fundamental physics behind many scientific discoveries through hands on experience.

* * * * *

II SEMESTER

PH652 – MATHEMATICAL PHYSICS - II

Objective: To introduce basic mathematical topics necessary to understand and appreciate various physical laws of nature.

Infinite Series

Fundamental concepts – convergence test: Cauchy's ratio test, Gauss's test – alternating series – algebra of series – Taylor expansion – Binomial theorem – power series – asymptotic series – Stirling's formula.

Complex Analysis

Functions of complex variable – derivative and Cauchy-Riemann equation–line integral – Cauchy's integral theorem – Cauchy's integral formula –Laurent series – Cauchy's residue theorem – poles– evaluation of residues – evaluation of definite integrals.

Integral Transforms

Fourier series – convergence– functions of any period –complex form – Fourier integral theorem – Fourier transform – Dirac delta function –Laplace transform – convolution theorem – transform of derivatives – application to differential equation.

Group Theory

Introduction to group theory – generators of continuous groups – rotation groups and angular momentum – SU(2)-SO(3) homomorphisms – orbital angular momentum – discrete groups – character table – irreducible representation.

Partial Differential Equations

Vibrating string – d'Alembert's solution of wave equation – diffusion equation – solution by Fourier series – Poisson equation – method of separation of variables – Green's function method – introduction to nonlinear equations and chaos.

Text Books

1. G. B. Arfken and H.J. Weber, Mathematical Methods for Physicists, 5th edition, Academic Press (2001).
2. E.Kreyszig, Advanced Engineering Mathematics, 8th edition, John Wiley & Sons Inc. (1999).
3. Mathematical Methods in the Physical Sciences, 3rd edition, Mary L. Boas, Wiley-India (2011).
4. V. Balakrishnan, Mathematical Physics with Applications, Problems and Solutions, Ane Books (2017).

Reference Books

1. L. A. Pipes and L. R. Harvill, Applied Mathematics for Engineers and Physicists, 3rd edition, Dover (2014).

Outcome: Students will acquire enough mathematical skills to handle variety of equations that appear in various physical situations with ease.

PH654 – ELECTROMAGNETIC THEORY

Objective: To understand the nature of electric and magnetic force fields and the intricate connection between them.

Electrostatics

Electric field–divergence and curl –electric potential – conductors – Laplace equation (1D, 2D and 3D) – uniqueness theorem – separation of variables: Cartesian and spherical coordinates – field of an electric dipole – polarization –Gauss’s law in dielectrics – linear dielectrics – energy density – boundary value problems.

Magnetostatics

Lorentz force – magnetic induction – electric current – equation of continuity –Biot-Savart law – magnetic potential – magnetization – Ampere’s law in magnetized material – energy density – linear and nonlinear media.

Maxwell’s Equations

Faraday’s law – generalization of Ampere’s law –Maxwell’s equations – boundary conditions – scalar and vector potentials – gauge invariance – electromagnetic energy – Poynting’s theorem.

Electromagnetic Waves

Electromagnetic wave equation (without source)–solution of 3D wave equation–propagation of EM waves in non-conducting media –waves in conducting media – polarization.

Waves in Bounded Region

Reflection and refraction at the boundary of non-conducting media – Fresnel’s coefficients – Brewster’s angle and critical angle – reflection from a conducting plane – wave guide – TE and TM waves – rectangular wave guide.

Text Books

1. D. J. Griffiths, Introduction to Electrodynamics, Prentice Hall of India, 4th edition (2014).
2. J.R. Reitz., F.J. Milford and R.W. Christy, Foundations of Electromagnetic Theory, 4th edition, Pearson (2010).

Reference Books

1. J.D. Jackson, Classical Electrodynamics, Wiley-India, 3rd edition (2011).
2. E.C. Jordon and K.G. Balmain, Electromagnetic Waves and Radiating Systems, 2nd edition, Prentice Hall of India (1998).
3. W. Greiner, Classical Electrodynamics, 3rd edition, Springer (2010).
4. L.D. Landau and E.M. Lifshitz, Electrodynamics of Continuous Media, 2nd edition, Elsevier (2008).

Outcome: Electromagnetic nature of radiation and its propagation in media will be understood.

PH656 – STATISTICAL MECHANICS

Objectives:

1. To learn the connection between macroscopic and microscopic state of a system of large number of particles.
2. To understand thermal equilibrium of a system in statistical sense.

Thermodynamics

Preliminaries – first law – ideal gas – Carnot cycle – second law and Clausius theorem – entropy and properties – thermodynamic potentials – Maxwell's relations – chemical potential – real gas – phase transition.

Theory of Ensembles

Postulates: phase space, microstates, density of states, ensemble average – Liouville's theorem – microcanonical ensemble – quantum phase space – canonical ensemble – partition function (N particle) – ideal gas law – thermal wavelength – grand canonical ensemble.

Maxwell-Boltzmann Statistics

Boltzmann system – Maxwell-Boltzmann distribution – Lagrange's multipliers – partition function (single particle) – thermodynamics of gases – velocity distribution – equipartition of energy – paramagnetism – Einstein model of solid.

Bose-Einstein Statistics

Principle of indistinguishability – Bosons – Bose-Einstein distribution – Planck's law of radiation – Stefan's law – Debye's theory of heat capacity – Bose-Einstein condensates.

Fermi-Dirac Statistics

Fermions – Fermi-Dirac distribution – Fermi energy – electron gas in metals – electronic specific heat – thermionic emission – Pauli paramagnetism.

Text Books

1. M. W. Zemansky and R.H. Dittman, Heat and Thermodynamics, 8th edition, Mc-Graw Hill (2011).
2. K. Haug, Statistical Mechanics, 2nd edition, Wiley India (2010).
3. F.W. Sears and G.L. Salinger, Thermodynamics, Kinetic Theory and Statistical Thermodynamics, 3rd edition, Narosa Publishing House (1998).
4. F. Mandl, Statistical Physics, 2nd edition, Wiley (2002).

Reference Books

1. Enrico Fermi, Thermodynamics, Dover (1956).
2. R.K. Pathria and Paul D. Beale, Statistical Mechanics, 3rd edition, Academic Press (2011).
3. F. Reif, Fundamentals of Statistical and Thermal Physics, International Students edition, Tata McGraw-Hill (1988).
4. S.J. Blundell and K.M. Blundell, Concepts in Thermal Physics, Oxford University Press (2006).

5. L.D. Landau and E.M. Lifshitz, Statistical Physics – Part I, 3rd edition, Elsevier (2010).

Outcome: Students will be able to understand various properties of matter and radiation in thermal equilibrium through appropriate statistics. Students will be prepared to understand Solid State Physics.

PH658 – INSTRUMENTATION

Objectives:

1. Students will study the major characteristics of measurement systems and errors involved in them.
2. Students will gain an understanding related to production and measurement of low temperatures and high pressure.
3. Student will read various spectroscopic techniques and detectors.

Generalized Characteristics of Instruments

Static characteristics: accuracy, precision, repeatability, reproducibility, resolution, sensitivity, linearity, drift, span, range. *Dynamic characteristics:* transfer function, zero order instruments, first order instruments – step, ramp, frequency responses – second order instruments – step-ramp response – dead time elements. *Types of Errors:* gross, systematic, random.

Vacuum Systems

Principle and operation of various pumps: rotary, diffusion, sorption, turbomolecular ionisation and cryopumping. *Gauges:* McLeod, diaphragm, thermocouple, pirani, penning, ionisation and hot and cold cathodes – design of high vacuum systems – high pressure cells – measurements at high pressures.

Thermal Systems

Temperature scales – liquefaction of gases, achieving low temperature – design of cryostats. *High temperature furnaces:* resistance, induction and arc furnaces – high temperature measurements – pyrometers – total and selective radiation pyrometers – optical pyrometer.

Detectors and Spectroscopy

Detectors: pyroelectric, thermoelectric, photoconducting, photoelectric, photomultiplier, scintillation types of detectors, photon counters. *Spectroscopy:* principles of atomic absorption spectroscopy – instrumentation – single and double beam spectrometers – theory and components of nuclear quadrupole resonance technique – applications.

Signal Conditioning and Error Analysis

Signal conditioning: Impedance matching, filtering, clipping and clamping, attenuators and its types, amplitude modulation and demodulation, lock-in detector, box-car integrator. *Error analysis:* Linear and nonlinear curve fitting, chi-square test.

Text Books

1. A.K. Sawhney and Puneet Sawhney, A Course in Mechanical Measurement and Instrumentation, Dhanpat Rai & Sons, New Delhi 2000.

2. Dennis Roddy and John Coolen, Electronic communication, 4th edition, PHI private Ltd., (1999).(Unit – II)
3. C.S. Rangan, G.R. Sharma and V.S.V. Mani, Instrumentation Devices and Systems, Tata McGraw-Hill (1983).
4. H.H. Willard, L.L. Merrit and John A. Dean, Instrumental Methods of Analysis, 6th edition, CBS Publishers & Distributors (1986).

Reference Books

1. D.V.S. Murty, Transducers and Instrumentation, Prentice – Hall of India(P) Ltd., New Delhi (1995).
2. Ernest O. Doebelin, Measurement System Applications and Design, McGraw Hill International Book Company, Singapore (1983).

Outcomes:

1. To fully appreciate the various techniques involved in production of vacuum and low temperatures, which will benefit the students to handle various instruments in a better way.
2. To really understand the characteristics of instruments and analysis of errors will help them in interpreting the obtained data more efficiently.

PH660 – ELECTRONICS LABORATORY

Objective: To introduce the various concepts of basic electronics and circuits through hands on experience.

List of Experiments

1. Solving Simultaneous Equations
2. Voltage Controlled Oscillator
3. Op-Amp Arithmetic Operations
4. Op-Amp Square, Ramp Generator and Wien Bridge Oscillator
5. Op-Amp Precision Full Wave Rectifier
6. Multiplexer and De-multiplexer
7. Regulated Power Supply using IC 723
8. UJT-Characteristics of Relaxation Oscillator
9. Logarithmic and Anti-logarithmic Amplifier
10. Phase Shift Oscillator
11. Astable and monostable Multivibrator using IC555
12. Combinational Logic Circuit Design

13. IC 555 timer – Schmitt Trigger
14. Wien's Bridge oscillator using operational amplifier
15. Characteristics of Photo Diode, Photo Transistor, LDR, LED
16. Series and Parallel Resonant Circuits
17. Silicon Diode as a Temperature Sensor
18. RC Coupled CE amplifier – Two stages with feedback – Frequency response and voltage gain
19. Push-pull amplifier using complementary – symmetry transistors power gain and frequency response.
20. Active filters – low pass and high pass-first and second order frequency response and roll off rate.

Text Books

1. Electronics Laboratory Manual, Department of Physics, NITT.

Reference Books

1. B.K. Jones, Electronics for Experimentation and Research, Prentice-Hall (1986).
2. P.B. Zbar, A.P. Malvino and M.A. Miller, Basic Electronics: A Text-Lab Manual, Tata Mc-Graw Hill, New Delhi (1994).

Outcome: The student will be able to understand the fundamental physics behind electronic circuits used in many modern devices through hands on experience.

* * * * *

III SEMESTER

PH661 – SOLID STATE PHYSICS

Objective: Students will have an appreciation on the physics and properties of different types of materials such as conductors, semiconductors, dielectric, magnetic and superconducting.

Introduction

Solids – crystalline and amorphous – crystal structure and symmetries – reciprocal lattice – defects and dislocations – Brillouin Zone – *types of bonds*: van der Waals, covalent, ionic and metallic – atomic scattering factor – geometric structure factor – electrons in aperiodic potential – X-ray diffraction – liquid crystals.

Conductors, Semiconductors and Dielectrics

Conductors: Free electron theory – classical and quantum theory, band theory of solids – effective mass of electron – Kronig-Penny model – Bloch theorem – Hall effect – thermopower. *Semiconductors*: Types – carrier and Fermi level statistics for intrinsic and extrinsic semiconductors – electrical conductivity. *Dielectrics*: Types of polarization – frequency dependence of polarization – local electric field – dielectric constant and polarizability – Clausius-Mossotti equation, piezo and ferroelectricity.

Transport and Thermodynamic Studies

Lattice vibrations – concept and momentum of phonons – vibrations of mono and di-atomic lattices, heat capacity – Einstein and Debye models – Dulong and Petit's law – Weidemann-Franz law – electronic heat capacity – experimental heat capacity of metals – resistivity – residual resistivity ratio – experimental electrical resistivity of metals – Matthiessen's rule – Magnetoresistance – Giant and colossal magnetoresistance.

Magnetism

Magnetic terminologies – types of magnetism – dia, para, ferro, ferri and anti-ferromagnetism – Hund's rules – Curie-Weiss law – Langevin's classical and quantum theories of dia and para magnetism – Weiss theory of ferromagnetism – Heisenberg model of exchange interaction – concept of domain and hysteresis

Superconductivity

Superconductivity– Meissner and isotope effect – thermodynamical and optical properties – supercurrents and penetration depth – London's equations – BCS model conventional – unconventional – critical field – types of superconductors– metal-to-insulator transition –flux quantization – vortex lattice – high T_c superconductors – Josephson Junctions – AC and DC – superfluidity.

Text Books

1. Charles Kittel, Introduction to Solid State Physics, Wiley Eastern, 8th edition, (2012).
2. T.H.K. Barron and G.K. White, Heat capacity and Thermal Expansion at Low Temperatures, Kluwer Academic/Plenum Publishers, New York (1999).
3. N.W. Ashcroft and N.D. Mermin, Solid State Physics, Cengage Learning (2010).

4. Ali Omar, Elementary Solid State Physics, Pearson Education India (1999).
5. J.S. Blakemore, Solid State Physics, 2nd edition, Cambridge University Press (1974).

Reference Books

1. B.S. Saxena, R.C. Gupta, P.N.Saxena, Fundamentals of solid state physics, Pragati Prakashan, 7th edition (1999).
2. A.J. Dekker, Solid State Physics, Prentice Hall of India (1971).
3. Helmut Kronmüller, Stuart Parkin, Handbook of Magnetism and Advanced Magnetic Materials, Wiley (2007)
4. Laurent-Patrick Lévy. Magnetism and superconductivity, Springer (2000).

Outcome: Grasping the significance of transport and thermodynamic properties of materials will enable students to understand the basics in physics of condensed matter.

PH663 – ATOMIC AND MOLECULAR SPECTROSCOPY

Objective: To understand in detail the structure of atoms and molecules.

Atomic Spectra

Quantum states of electron in atoms– hydrogen atom spectrum– electron spin – Stern Gerlach Experiment – spin-orbit interaction – Lande interval rule– two electron systems – LS-JJ coupling schemes–fine structure– spectroscopic terms and selection rules – hyperfine structure – exchange symmetry of wave function– Pauli's exclusion principle – periodic table.

Atoms in External Fields and Resonance Spectroscopy

Zeeman and Paschen Back Effect of one and two electron systems – selection rules – Stark effect– inner shell vacancy– X-ray– Auger transitions – Compton Effect – NMR – basic principles – classical and quantum mechanical description – spin-spin and spin-lattice relaxation times – magnetic dipole coupling – chemical shift – Knight shift – ESR – basic principles – nuclear interaction and hyperfine structure – g-factor – zero field splitting.

Microwave Spectroscopy and IR Spectroscopy

Rotational spectra of diatomic molecules – rigid rotator – effect of isotropic substitution – non-rigid rotator – rotation spectra of polyatomic molecules – linear, symmetric top and asymmetric top molecules – experimental techniques – diatomic vibrating rotator– linear, symmetric top molecule – analysis by infrared techniques – characteristic and group frequencies.

Raman Spectroscopy

Raman effect– quantum theory of Raman effect– rotational Raman spectra – vibrational Raman spectra – Raman spectra of polyatomic molecules – Raman spectrometer – hyper- Raman effect – experimental techniques.

Electronic Spectroscopy

Electronic spectra of diatomic molecules – Frank-Condon principle – dissociation energy and dissociation products – rotational fine structure of electronic vibration transitions – Fortrat Diagram – predissociation.

Text Books

1. C.N. Banwell, Fundamentals of Molecular Spectroscopy, 4th edition, McGraw-Hill, New York (2004).
2. G. Aruldas, Molecular Structure and Spectroscopy, Prentice Hall of India, New Delhi (2002).
3. E. H. White, Introduction to Atomic Spectra, McGraw-Hill (2005).

Reference Books

1. Manas Chanda, Atomic Structure and Chemical Bond, Tata McGraw-Hill, New Delhi (2003).
2. B.P. Straughan & S. Walker, Spectroscopy: Vol. I, Chapman and Hall (1976).
3. G.M Barrow, Introduction to Molecular Spectroscopy, McGraw Hill(1986).

Outcome: The student will be able to gain sufficient knowledge on most common atomic and molecular spectroscopic methods and properties derived from them.

PH 665 – NUCLEAR AND PARTICLE PHYSICS

Objectives:

1. Introduce students to the fundamentals of nuclear and particle physics.
2. To understand the applications of nuclear and particle physics.

Nuclear Properties and Forces

Nuclear radius and charge distribution – angular momentum – parity – electromagnetic moments-isospin – binding energy – nature of the nuclear force – Yukawa's hypothesis – Deuteron and its properties – properties of nuclear forces – spin dependence – internucleon potential – charge independence and charge symmetry-polarization.

Nuclear Models

Liquid drop model – semi empirical mass formula – shell model – experimental evidence – magic numbers – spin-orbit coupling – angular momentum of the energy states – magnetic moments and Schmidt lines – electric quadrupole moments – excited states – collective model – nuclear vibration and rotation.

Radioactivity

Measurements of lifetimes – multipole moments – theoretical prediction of decay constants – selection rules – angular correlations – internal conversion – Geiger-Nuttel law – barrier penetrations applied to alpha, decay and beta decay – simple theory – Kurie plots – comparative half life – selection rules – internal conversion.

Nuclear Reactions

Reaction dynamics – Q-equation – theory of nuclear reaction – reaction cross sections-Rutherford cross section – compound nucleus reactions– direct reactions – resonance reaction – fission process – energy in fission and absorption cross section – neutron sources–fusion fundamentals – Lawson criterion – solar fusion.

Elementary Particles

Classification of elementary particles – types of interactions – conservation laws – momentum-parity and spin – isospin – baryon and lepton numbers – Gell-Mann-Nishijima relationship – mesons and baryons – CPT invariance – detection and properties of neutrino – concept of antiparticles – tau-theta puzzle – neutral kaon – quark model.

Text Books

1. Kenneth S. Krane, Introductory Nuclear Physics, John Wiley & Sons, New York (1988).
2. D. Griffiths, Introduction to Elementary Particles, Harper and Row, New York (1987).

Reference Books

1. B. L. Cohen, Concepts of Nuclear Physics, Mc-Graw Hill, New York (1971).
2. I. Kaplan, Nuclear Physics, Addison-Wesley, London (1977).
3. D. H. Perkins, Particle Astrophysics, Oxford University Press, New York (2003)
4. Samuel S. M. Wong, Introductory Nuclear Physics, Wiley, Weinheim (2004).

Outcome:

1. The students would have understood the fundamentals of nuclear and particle physics.
2. The role of nuclear and particle physics in applications such as radioactivity and nuclear reactions shall be understood.

PH667 – NUMERICAL AND COMPUTATIONAL METHODS

Objective: To introduce various numerical and computational techniques useful to handle complex problems.

Roots of Equations

Computer arithmetic – mathematical preliminaries – computation of errors – secant method – Newton-Raphson method – rate of convergence – polynomial equation – complex equation.

Linear Algebra

Gauss-elimination method – pivoting – LU decomposition – inverse and determinant of a matrix – eigenvalue equation – Jacobi method – QR decomposition – singular value decomposition.

Interpolation and Approximation

Lagrange interpolation – Newton's divided difference – finite difference methods – cubic spline – method of least squares: linear and nonlinear – Gram-Schmidt process – Legendre and Chebyshev polynomials.

Differentiation and Integration

Numerical differentiation by interpolation – method of finite differences – integration by–Simpson's rule – estimation of errors – double integration.

Differential Equations

Initial and boundary value problems – Euler-Cauchy method – Runge-Kutta methods: second and fourth orders – finite difference method – shooting method – solutions of PDEs: elliptic, parabolic and hyperbolic equations – basics of finite element method.

Text Books

1. Samuel D. Conte and Carl de Boor, Elementary Numerical Analysis, 3rd edition, Tata McGraw-Hill (2010).
2. M.K. Jain, S.R.K. Iyengar, R.K. Jain, Numerical Methods for Scientific and Engineering Computation, New Age International (1993).
3. Srimantha Pal, Numerical Methods, Oxford University Press (2009).

Reference Books

1. W.H. Press, S.A. Teukolsky, W.T. Vetterling and B.P. Flannery, Numerical Recipes in C: The Art of Scientific Computing, Cambridge University Press (1992).

Outcome: Students will be equipped with necessary numerical and computational techniques to handle various physical problems, where exact solutions are not possible.

PH669– ADVANCED PHYSICS LABORATORY

Objective: To introduce the basic concepts of various advanced experimental techniques used in research through hands on experience.

List of Experiments

1. MATLAB-1: Matrix operations
2. MATLAB-2: Digital Signal Processing
3. MATLAB-3: Solving Ordinary Differential Equations
4. MATLAB-4: Temperature conversion (Celsius to Fahrenheit and Fahrenheit to Celsius)
5. MATLAB-5: Projectile trajectory for different angles
6. MATLAB-6: Mosley's Law
7. MATLAB-7: Moment of inertia of different body
8. MATLAB-8: Radioactive decay
9. MATLAB-9: Rotating flower pot
10. MATLAB-10: Black body radiation
11. LABVIEW-1: Basic arithmetic operations
12. LABVIEW-2: Boolean operations
13. LABVIEW-3: Conversion of Binary, Hexadecimal, Octal to Decimal Numbers

14. LABVIEW-4: Operational Amplifier – Inverting, Non inverting, Differentiator, Integrator
15. LABVIEW-5: Temperature conversion – Celsius to Fahrenheit and Fahrenheit to Celsius
16. LABVIEW-6: Sum of ‘N’ natural numbers using for and while loops
17. LABVIEW-7: Factorial of a given number using for and while loop
18. LABVIEW-8: Design of 555 Timer Chip Astable Circuit
19. X-Ray Diffraction – Determination of lattice parameters of a crystalline solid
20. UV-Vis Spectrophotometer – Determination of absorption coefficient and bandgap
21. FTIR Spectrometer – Determination of vibration levels in a compound
22. Superconductivity– Determination of transition temperature
23. Contact Angle Measurement
24. Thin Film Deposition and Measurement of Electrical Conductivity– Four Probe Method

Reference Books

1. L.A. Leventhal, Micro Computer Experimentation with the Intel SDK-85 (1980).
2. Learning MATLAB – The MathWorks, Inc (1999).
3. Kenneth L. Ashley, Analog Electronics with LabVIEW, Pearson Education (2003).

Outcome: The student will be able to understand the fundamental physics behind modern scientific equipment used in research through hands on experience.

* * * * *

IV SEMESTER**PH662 – PROJECT WORK AND VIVA-VOCE**

In this course, students are required to do a project work on a research problem and submit their findings as a report followed by a presentation in front of viva-voce committee.

* * * * *

ELECTIVES

Odd Semester

PH611 – DIGITAL SIGNAL AND IMAGE PROCESSING

Objective: To introduce discrete signal and image processing concepts and their application.

Discrete Time signal and systems

Basics of signals – Periods, frequency, phase – Mathematical representation of signals – Discrete time signals, data acquisition – Sequences – Linear shift-invariant systems – Stability and Causality – Linear constant Co-efficient difference equations – Frequency-domain – Representation of Discrete-time systems and signals – Representation of discrete-time signals by Fourier transform – signal analysis - time-domain analysis- determination of signal power and energy – gating methods – time gate – peak determination- echo detection – time-frequency analysis – short time Fourier transform – wavelet.

Transform analysis of linear time invariant systems

Z-transform – Region of convergence – Relation between Z- transform and Fourier Transform – Frequency response – Phase distortion and delay – system functions – Frequency response of rational system functions–first-order systems – Basic Digital filter structures – FIR and IIR filters.

Filter Design Techniques and Fast Fourier Transform

Signal noise – inherent noise, EMI noise, random noise, speckle noise, process induced noises etc – Design of FIR filters by window method – Rectangle – Hanning – Hamming – Kaiser – IIR Filters design – Bilinear Transformation – Discrete Fourier Transform – Computation of DFT- Applications in NDT.

Continuous and Digital Image Characterization

Image representation - 2D-systems - 2D-Fourier Transform - Light perception - Eye Physiology - Visual phenomena - Monochrome vision model - 2D Image sampling & reconstruction - Image sampling systems - Aliasing effects - Image reconstruction systems - Vector-space Image representation - Image Quantization.

Linear Image Processing methods and Image Enhancement

Introduction to image representation – spatial and frequency domain –. Generalized 2D Linear operator - Superposition – Filtering – Convolution and De-convolution - Unitary transformations - Fourier Transform - Cosine Transformation - Image reconstruction and Enhancement - Contrast manipulation - Histogram modification - Noise cleaning – Image analysis – Edge detection and crispening –contour quantification –texture analysis– statistical analysis- Applications in NDT.

Text Books

1. A.V. Oppenheim and R. W. Schaffer, Digital Signal Processing, Prentice-Hall of India (2000)
2. W. K. Pratt, Digital Image Processing, 3rd edition, John Wiley & Sons (2001).
3. R. C. Gonzalez and R. E. Woods, Digital Image Processing, 3rd edition, Pearson Education (2008).
4. R. Crane, A Simplified Approach to Image Processing: Classical and Modern Techniques in C, Prentice Hall, (1997)

Reference Books

1. L.R. Rabiner and B. Gold, Theory and Applications of Digital Signal Processing, Prentice-Hall Englewood Cliffs (1975).
2. T. Bose, Digital Signal and Image Processing, 1st edition, John Wiley (2003).
3. A.V. Oppenheim, A. S. Will Sky and S. H. Nawab, Signals and Systems, 2nd edition, Prentice-Hall of India (2004).
4. N. Efford, Digital image processing: a practical introduction using Java, Addison-Wesley (2000).

Outcome: Upon completion of the course, the student will be able to:

1. Design digital signals filters.
2. Use different image processing techniques for specific applications.
3. Apply applications like signal processing of ultrasonic signals and image processing of radiographic images.

PH613 BASICS OF ENGINEERING MATERIALS

Objectives: This introductory course is aimed to obtain basic exposure to the concepts of crystalline solids, its imperfections and basics of various advance engineering materials finding wide spread application in several industries. Understanding these material systems are vital for investigating the defects and their nature on these classes of materials.

Structure of Metals

Crystal structure– Imperfections in crystals – dislocation theory - Principles of Alloying – Solid solutions– Gibbs phase rule and equilibrium diagram - types of binary phase diagrams – Eutectic – Peritectic and eutectoid reactions.

Steel and Heat Treatment of Steels

The Iron-carbon system – structural changes on slow and rapid cooling - martensitic transformation –concept of hardenability – TTT and CCT diagrams. Effects of carbon and alloying elements – Classification of steels.

Heat Treatment of Steels: Annealing -normalizing, quenching and tempering – Case hardening, Austempering and martempering – Solidification of Metals and alloys – Nucleation and crystal growth from the liquid phase –Segregation effects and grain size control – strength mechanisms – solute, dispersion and precipitation hardening.

Mechanical behavior of materials

Elements of elastic and plastic deformation – stress-strain relation-work hardening, recovery, recrystallization and grain growth, types of fractures in materials and their identification.

Non-Ferrous Metals & Ceramics

Significance of light metals in engineering industries, Aluminum, Aluminum alloys, strengthening mechanism of aluminum alloys and heat treatment methods- Copper & Copper Alloys- Titanium & Titanium Alloys, Advantages & Applications. Industrial importance of engineering ceramic materials, refractories, cement and concrete, damages & degradation of concrete. Application of engineering ceramic materials.

Composites

Importance of composites – constituents – functions of fiber and matrix –types of fibers-glass fiber, carbon fiber, metallic fibers, ceramic fibers-Matrix materials – Metallic and Polymer matrix composites – Manufacture methods – hand lay up & prepreg techniques —pulforming, theforming, resin-transfer moulding, injection moulding.

Text Books

1. W. D. Callister, Materials Science and Engineering: An Introduction, 7th edition, Wiley (2006).
2. V. Raghavan, Materials Science and Engineering, 5th edition, Prentice Hall of India (2013).
3. G.E. Dieter, Mechanical Metallurgy, 3rd edition, Mc-Graw Hill (2004).
4. A.V.K. Suryanarayana, Testing of Metallic Materials, 2nd edition, Prentice -Hall of India (2007).
5. V. B. John, Introduction to Engineering Materials, 3rd edition, Palgrave Macmillan Limited (1992).
6. J. Wanberg, Composite materials, Wolfgang Productions (2012).

Reference Books

1. Robert E. Reed Hill and R. Abbaschian, Physical Metallurgy Principles, 3rd edition, PWS-Kent Publishing Company (1992).
2. L. H. Van Vlack, Elements of Materials Science and Engineering, 6th edition, Addison Wesley (1989).
3. I. J. Polmear, Light Alloys: Metallurgy of the Light Metals, 3rd edition, Wiley (1995).
4. V. Raghavan, Physical Metallurgy: Principles and Practice, 2nd edition, PHI Learning Private Limited (2006).

Outcome: Upon completion of the course, the student will be able to:

1. Select different materials and emphasize the need of modern materials other than conventional metals and alloys for specific engineering applications.
2. Understand the heat treatment of steels using TTT and CCT diagrams.
3. Analyze the various metallurgical factors influencing the performance of materials for different structural engineering applications.
4. Define various mechanical properties of materials and their importance in materials selection criteria.
5. Classify different mechanical properties and how they can influence the materials behavior with respect to applied load.

PH671 – WAVEGUIDES AND MODERN OPTICS

Objective: The course aims at to expose students to applications of electromagnetic theory concepts in developing wave guides for communication, optical applications. Advanced technologies such as optical image processing, non-linear optics are covered in modern optics for students learning latest technologies.

Electromagnetic Fields and Waves

Maxwell's equations and boundary conditions –energy density and poynting vector – monochromatic field and complex function formalism – wave equation and monochromatic plane waves –chromatic dispersion and group velocity.

Waves in Dielectric Slabs

Introduction – TE and TM confined modes in symmetric slab – waveguides –TE And TM confined modes in asymmetric slab waveguides.

Anisotropic Media

Plane wave in homogeneous media and normal surface – orthogonality of normal modes (eigenmodes) – classification of media – the index ellipsoid – plane waves in uniaxially anisotropic media phase retardation.

Nonlinear Optics

Introduction – physical origin of nonlinear polarization –second order nonlinear phenomena – general methodology –electromagnetic formulation and optical second – harmonic generation – other second-order nonlinear processes –quasi phase matching – third order nonlinear optical processes – stimulated brillouin scattering – four wave mixing and phase conjugation – frequency tuning in parametric oscillation.

Fourier Optics

One dimensional transforms – transform of Gaussian function – two dimensional transforms – transform of cylinder function – lens as a Fourier transformer – Dirac delta function – displacements and phase shifts – sines and cosines – optical application – transfer function.

Text Books

1. Amnon Yariv and Pochi Yeh, Photonics – Optical Electronics in Modern Communication, 6th edition, Oxford University Press (2007).
2. Eugene Hecht and A.R. Ganesan, Optics, 4th edition, Pearson Education Inc. (2002).
3. Clifford R. Pollock and Richard D. Irwin, Fundamentals of Optoelectronics (1995).

Reference Books

1. D. J. Griffiths, Introduction to Electrodynamics, 4th edition, Prentice Hall of India, (2014).

Outcome: Student will be able to understand design concepts in optical wave guides as well as generation of stimulated lights, optical non-linear phenomena.

PH673 – SOLAR PHOTOVOLTAIC TECHNOLOGY

Objectives: To introduce the basic physics and technology of photovoltaic science and systems for solar energy harnessing.

The Sun Light

World Energy scenario – Advantages and challenges of solar energy harnessing - Source of radiation – solar constant– solar intensity at earth’s surface – direct and diffuse radiation – apparent motion of sun-solar insolation data –solar charts – measurement of diffuse, global and direct solar radiation: pyrheliometer, pyranometer, pyregeometer, net pyradiometer-sunshine recorder.

Semiconductors

Crystals structures, atomic bonding, energy band diagram – direct & indirect band gap – p & n doping and carrier concentration – intrinsic & extrinsic semiconductor – compound semiconductors – diffusion and drift of carriers, continuity equation – optical absorption – carrier recombination – effect of temperature – p-n junction in equilibrium conditions – p-n junction in non-equilibrium condition – p-n junction under illumination.

Semiconductors for Solar Cell

Silicon: preparation of metallurgical, electronic and solar grade silicon -*Production of single crystal silicon:* Czokralski (CZ) and Float Zone (FZ) method– imperfections – carrier doping and lifetime – Germanium –compound semiconductors – growth & characterization– amorphous materials – transparent conducting oxides – anti-reflection principles and coatings – organic materials.

Characterization and Analysis

Device isolation & analysis – ideal cell under illumination – solar cell parameters short circuit current, open circuit voltage, fill factor, efficiency; optical losses, electrical losses, surface recombination velocity, quantum efficiency – measurements of solar cell parameters; I-V curve

& L-I-V characteristics, internal quantum yield measurements – effects of series and parallel resistance and temperature.

Design of Solar Cells

Upper limits of solar cell parameters – losses in solar cells – Solar Cell design: Design for High I_{sc} – Design for High V_{oc} – Design for High FF – Si based solar cell Technology: process flow of commercial Si Cell Technologies – high efficiency Si Solar cells. Thin film solar cell technologies: Common features of thin film Technologies – aSi technology – CdTe, CIGS, Epitaxial Si. Other technologies: DSSC.

Text Books

1. C. S. Solanki, Solar Photovoltaics: Fundamentals, Technologies And Applications 2nd edition, Prentice Hall of India, New Delhi (2011).
2. H. J. Moller, Semiconductors for solar cells, Artech House Inc., MA, USA (1993).
3. M. Green, Solar Cells: Operating principles, Technology and Systems Applications, UNSW, Australia (1997).

Reference Books

1. Larry D. Partain (ed.), Solar Cells and their Applications, John Wiley and Sons, New York (1995).
2. J. Nelson, The Physics of Solar Cells, Imperial College Press (2006).
3. R. H. Bube, Photovoltaic Materials, , Imperial College Press (1998).

Outcome: Students will be able to understand the science and technology of solar cells and its design. Students can also appreciate various material properties which are used in photovoltaic devices.

PH675 – ADVANCED ELECTROMAGNETIC THEORY

Objectives:

1. To introduce elementary ideas of plasma, method of solving inhomogeneous wave equation, basics of radiating source and field equations in different inertial frames.
2. To understand optical dispersion of radiation in a media.

Physics of Plasmas

Electrical neutrality in plasma – particle motion in electric field – Larmor radius – particle in crossed electric and magnetic fields – hydromagnetic equation – plasma oscillations and waves.

Optical Dispersion

Drude-Lorentz harmonic oscillator model – resonance absorption by bounded charges – normal and anomalous dispersion – Cauchy relation – plasma frequency – skin depth – dielectric relaxation.

Potentials and Fields

Maxwell's equation – scalar and vector potentials – gauge invariance – Coulomb gauge and Lorentz gauge – solution of inhomogeneous wave equation– retarded potentials.

Radiating System

Radiation from an arbitrary source – special cases: oscillating dipole, accelerated point charge – radiation damping – Thomson cross section.

Special Theory of Relativity

Lorentz transformation and Einstein's postulates – geometry of space-time – Lorentz transformation as orthogonal transformation – covariant form of electromagnetic equations – transformation laws for electromagnetic fields – field of a moving point charge.

Text Books

2. J. R. Reitz., F. J. Milford and R. W. Christy, Foundations of Electromagnetic Theory, 4th edition, Pearson (2010).
3. D. J. Griffiths, Introduction to Electrodynamics, 4th edition, Prentice Hall of India, (2014).

Reference Books

1. J. D. Jackson, Classical Electrodynamics, 2nd edition, John Wiley & Sons (1990).
2. E. C. Jordon and K. G. Balmain, Electromagnetic Waves and Radiating Systems, 2nd edition, Prentice Hall of India (1998).
3. L. D. Landau and E. M. Lifshitz, The Classical Theory of Fields, 4th edition, Elsevier (2010).

Outcome: Optical properties of a media, basics of antennas and relativistic nature of EM-field will be understood.

PH677 – FIBER OPTIC SENSORS

Objective: Fiber optics sensors are widely used and students are exposed to fundamentals, design principles, characteristics and applications of fiber optic sensors.

Characteristics of Light

Introduction – plane polarized wave – propagation of a light through a quarter wave plate – reflections at a plane interface – Brewster angle – total internal reflection-interference- refraction – concept of coherence – diffraction of Gaussian beam.

Fiber optic fundamentals

Numerical aperture – attenuation in optical fibers – pulsed dispersion in step index optical fiber – loss mechanisms – absorptive loss – radiative loss- principle of optical waveguides – characteristics of fibers – pulsed dispersion in planar optical waveguide – modes in planar waveguides – TE,TM modes – propagation characteristics of step index and graded index optical fibers.

Fiber optic Sensors

Intensity-modulated sensors – transmission concept – reflective concept – microbending concept-intrinsic concepts – transmission and reflection with other optical effects – source of error and compensation schemes – phase modulation mechanisms in optical fibers- optical fiber interferometers – optical fiber phase sensors for mechanical variables – the optical fiber sagnac interferometer – optical fiber interferometric sensors.

Frequency modulation in optical fiber sensors

Introduction – optical fiber Doppler system – development of the basic concepts. polarization modulation in fiber sensors- introduction – optical activity – Faraday rotation – electro-gyration – electro-optic effect- kerr effect – photoelastic effect – polarization modulation sensors.

Wavelength distribution and Bragg grating sensors

Wavelength distribution sensor – introduction – techniques for colour modulation – colour probes – Bragg grating concept – introduction – fabrication – application.

Reference Books

1. D.A. Krohn, Fiber Optic Sensors: Fundamentals and Applications, 2nd edition, Instrument Society of America (1992).
2. B. Culshaw, Optical Fiber Sensing and Signal Processing, Peter Peregrinus Ltd. (1984).
3. Djafar K. Mynbaev and Lowell L. Scheiner, Fiber-Optic Communications Technology, Pearson Education Asia (2001).

Outcome: Students will be able to propose new design of sensors for various applications.

PH679 – SENSORS AND TRANSDUCERS

Objective: To introduce the basic concepts and technology of modern sensors used in industrial applications and in scientific equipments.

Temperature Sensors

Introduction to sensors – classification of sensor – sensor characteristics– thermal sensors gas thermometric sensors – thermal expansion type sensors – thermoresistive Sensors – resistance temperature detectors – thermistors – thermoelectric contact sensors – thermocouples – thermocouple assemblies – semiconductor p-n junction sensors – optical temperature sensors - acoustic temperature sensor

Position and Displacement Detectors

Ultrasonic sensors – microwave motion detectors – capacitive occupancy detectors – tribo electric detectors – optoelectronic motion detectors – visible and near-infrared light motion detectors – far-infrared motion detectors – potentiometric sensors – gravitational sensors – capacitive sensors – inductive and magnetic sensors – LVDT and RVDT – Hall effect sensors – magnetoresistive sensors – magnetostrictive detector – optical sensors.

Acceleration and Pressure Sensors

Accelerometer characteristics – capacitive accelerometers – piezo-resistive accelerometers – piezoelectric accelerometers – gyroscopes – rotor gyroscope – monolithic silicon gyroscopes – optical gyroscopes. Strain Gauges – tactile sensors – piezoelectric force sensors – pressure gauges: mercury pressure sensor – bellows, membranes and thin plates – piezo-resistive sensors – capacitive sensors.

Flow, Acoustic and Humidity Sensors

Basics of flow dynamics – pressure gradient technique – thermal transport sensors – ultrasonic sensors – electromagnetic sensors – microflow sensors. Acoustic sensors: resistive microphones – condenser microphones – fiber optic microphone – piezoelectric microphones – electric microphones – solid state acoustic detectors – humidity and moisture sensors – concept of humidity – capacitive sensors – electrical conductivity sensors – thermal conductivity sensor.

Chemical Sensors and Smart Sensors

Chemical sensor characteristics – classification of chemical-sensing mechanisms – direct sensors – metal-oxide chemical sensors – chemfet – electrochemical sensors – potentiometric sensors – conductometric sensors – amperometric sensors – thermal sensors – optical chemical sensors – biochemical sensors – enzyme sensors – smart sensors – MEMS sensors – nano sensors.

Text Books

1. D. Patranabis, Sensors and Transducers, 2nd edition, Prentice-Hall of India (2005).
2. Jacob Fraden, Handbook of Modern Sensors: Physics, Design, and Application, 3rd edition, Springer (2004).

Reference Books

1. Ernest O. Deoblin, Measurement Systems, 6th edition, Tata Mc-Grow Hill (2012).
2. Ian R. Sinclair, Sensors and Transducers, 3rd edition, Newnes (2001).
3. M. J. Usher, Sensors and Transducers, Macmillan, London (1985).

Outcome: Students will be able to understand many modern devices and technologies used in sensors. Student can also appreciate various material properties which are used in engineering applications and devices.

PH681 – PHYSICS AND TECHNOLOGY OF THIN FILMS

Objective: To cater the post graduate students about fundamental to applications of thin films.

Preparation of Thin-films

Classifications of vacuum ranges – Vacuum pumps – Rotary, Diffusion, Turbomolecular and Ion Pumps – Thin film (epitaxy) – definition & advantages – Types of epitaxy. *Different Growth Techniques:* Liquid Phase Epitaxy, Vapour Phase Epitaxy, Molecular Beam Epitaxy, Metal Organic Vapour Phase Epitaxy, Sputtering (RF & DC), Pulsed Laser Deposition. *Thickness Measurement:* Microbalance technique, Photometry, Interferometry (MBI, FECO).

Kinetics of Thin films

Nucleation Kinetics: types of nucleation – kinetic theory of nucleation – energy formation of a nucleus – critical nucleation parameters; spherical and non spherical nucleus (cap, disc and cubic shaped) on the substrates. *Growth Kinetics:* Kinetics of binary (GaAs, InP, etc.), ternary ($\text{Al}_{1-x}\text{Ga}_x\text{As}$, $\text{Ga}_{1-x}\text{In}_x\text{P}$, $\text{InAs}_{1-x}\text{P}_x$, etc.) and quaternary ($\text{Ga}_{1-x}\text{In}_x\text{As}_{1-y}\text{P}_y$, etc.) semiconductors – derivation of growth rate and composition expressions.

Characterization

X-ray diffraction – Photoluminescence – UV-Vis-IR spectrophotometer – Atomic Force Microscope – Scanning Electron Microscope – Hall effect – Vibrational Sample Magnetometer – Secondary Ion Mass Spectrometry

Properties of Thin films

Dielectric properties – Important parameters, Measurement of dielectric properties- Effect of annealing and film thickness. Optical properties – Optical constants, determination of optical constants by Brewster angle method, Normal incidence method and graphical method- Mechanical properties – Concept and origin of stress and strain, Lattice misfit, Thermal misfit, Hardness test and Bulge test.

Applications

Optoelectronic devices: LED, LASER and Solar cell – Micro Electromechanical Systems (MEMS) – Fabrication of thin film capacitor – application of ferromagnetic thin films; Data storage, Giant Magnetoresistance (GMR).

Text Books

1. A. Goswami, Thin Film Fundamentals, New Age international (P) Ltd. Publishers, New Delhi (1996).

Reference Books

1. K. L. Chopra, Thin Film Phenomena, McGraw- Hill book company New York, (1969).
2. L. Eckertova, Physics of Thin Films, Plenum press, New York (1977).
3. Hari Singh Nalwa (ed.), Hand Book of Thin Films, Vol. 1 – 5, Academic Press (2002).
4. Milton Ohring, Material Science of Thin films, 2nd Edition, Academic Press (2002).

Outcome: Students are moulded to do high level research in thrust areas like LEDs, Laser, solar cells, storage devices etc.

PH683 – MAGNETISM AND SUPERCONDUCTING LEVITATION

Objective: To understand the magnetic behaviour of superconducting materials. To learn the fundamentals of magnetism, superconductivity and materials used for superconducting levitation applications.

Fundamentals of Magnetism

Magnetic moment – magnetic field – field produced by solenoids – Lorentz force laws – Biot-Savart law – field and moment measurement – demagnetizing field – Zeeman effect – origin of magnetism – g-factor – quantized angular momentum – theory of diamagnetism.

Types of Magnetism

Langevin's theory of paramagnetism – quantum theory of paramagnetism – Brillouin function – molecular field theory of ferromagnetism – exchange interaction – band theory – antiferromagnetism – sublattice magnetization – internal fields – crystal field effects.

Magnetic Phenomena

Magnetic anisotropy – magnetocrystalline and shape anisotropy – random anisotropy model – magnetostriction – domain theory – coercivity mechanism – fine particle magnetism – magnetocaloric effect.

Superconducting Materials

Superconductivity basics – physical properties below T_c – duration of persistent currents – Magnetic field effects on superconductors – high T_c Superconductors – cuprate superconductors – wires and tapes – MgB_2 – iron and carbon based superconductors – superconducting magnets.

Superconducting Levitation

Magnetic levitation systems – stability and levitation – superconducting bearings – levitation forces – static and dynamic – superconducting Maglev vehicles – equation of motion – aerodynamic effects – guideway.

Text Books

1. B. D. Cullity and C.D. Graham, Introduction to Magnetic Materials, Wiley, NJ (2009).
2. C. Kittel, Introduction to Solid State Physics, 7th edition, Wiley (2006).
3. F. C. Moon, Superconducting Levitation, Wiley (2004).

Reference Books

1. S. Chikazumi, Physics of Ferromagnetism, Oxford University Press (1997).
2. Charles P. Poole, Jr. (Ed.), Handbook of Superconductivity, Academic Press (2000).
3. Nicola. A. Spaldin, Magnetic Materials: Fundamentals and Applications, 2nd edition, Cambridge Univ. Press (2002).
4. S. Blundell, Magnetism in Condensed Matter, Oxford University Press (2001).

Outcome: The fundamentals of magnetism, superconductivity and superconducting materials shall be understood. Student will acquire basic knowledge on science and technology of superconducting levitation.

PH685 – MICRO-ELECTRO-MECHANICAL SYSTEMS

Objective: To introduce the basic concepts of Micro-system and micro-sensors and their applications in modern scientific equipments and industrial products.

MEMS Basics

Emergence – devices and application – scaling issues – materials for MEMS – thin film deposition – lithography and etching.

Bulk micro machining

Introduction – etch-stop techniques – dry etching – buried oxide process – silicon fusion bonding and anodic bonding.

Surface micro machining

Introduction – sacrificial layer technology – material systems in sacrificial layer technology – plasma etching – combined IC technology and anisotropic wet etching.

Microstereo lithography

Introduction – scanning method – projection method – applications – LIGA process: introduction, basic process and application.

MEMS Devices

Electronic interfaces – design, simulation and layout of MEMS devices using CAD tools.

Text Books

1. M. Elwenspoek and R. Wierink, Mechanical Microsensors, Springer-Verlag (2001).
2. Massood Tabib-Azar, Microactuators - Electrical, Magnetic, Thermal, Optical, Mechanical, Chemical and Smart structures, Kluwer Academic Publishers (1997).

Reference Books

1. S.M. Sze, Semiconductor Sensors, John Wiley & Sons (1994).
2. Eric Udd, Fiber Optic Smart Structures, John Wiley & Sons (1995).

Outcome: The student will be able to understand the fundamentals of various technologies involved in the fabrication of MEMS sensor, which are used in many common applications.

* * * * *

Even Semester

PH610 – ELECTRICAL, MAGNETIC AND OPTOELECTRONIC MATERIALS

Objectives: To understand the fundamentals of electrical, magnetic and optical properties of materials for various applications.

Electrical and Dielectric Materials

Review of electrical conduction – discussion on specific materials used as conductors (OFHC, Ag, Al, other alloys) – temperature dependent resistivity of Copper and CuNi alloy – Nordheim rule – CuAu alloy – dielectric phenomena – concept of polarization – effects of composition, frequency and temperature on these properties – discussion on specific materials used as dielectrics (ceramics and polymers) – BaTiO₃– dielectric loss, dielectric breakdown – ferro electricity – piezo and pyro electricity.

Magnetic Materials

Introduction to dia, para, ferri and ferro magnetism – hard and soft magnetic materials – iron-silicon alloys – iron, nickel alloys – ferrites, garnets and LCMO – rare earth alloys – Pt alloys – fine particle magnetism – applications of hard and soft magnetic materials – Giant Magneto Resistance – magnetocaloric effect – spintronics – multiferroics – nanomagnetic materials.

Superconducting and Semiconducting Materials

Concept of super conductivity – theories and examples for high temperature superconductivity – discussion on specific super conducting materials – Nb₃Sn – YBCO – MgB₂– Carbon based – comments on fabrication and engineering applications – review of semiconducting materials – concept of doping – simple and compound semiconductors – amorphous semiconductor – oxide semiconductors – organic semiconductor – low dimensional semiconductor – materials for solar cell applications – Hall effect – homojunction – schottky barrier – heterojunction – materials and applications.

Production of Electronic Materials

Binary alloy phase diagram (PbSn and CuNi) – homogeneous and heterogeneous nucleation – methods of crystal growth for bulk single crystals – Czochralski – Bridgman – low and high temperature solution growth – floating zone method - synthesis of epitaxial films by LPE, VPE, PVD, MBE and MOCVD techniques – lithography – production of silicon – applications.

Optical and Optoelectronic Materials

Principles of photoconductivity – simple models – effect of impurities – principles of luminescence – types and materials, Laser Principles – ruby, He-Ne, injection, Nd-YAG and Dye lasers – LED materials – binary, ternary photo electronic materials – Optical storage materials – LCD materials – photo detectors – applications of optoelectronic materials – introduction to optical fibers – light propagation – electro optic effect – electro optic modulators – Kerr effect – Pockel's effect.

Text Books

1. C. Kittel, Introduction to Solid State Physics, 6th Edition, Wiley Eastern, New International Publishers, 1997.
2. A. J. Dekker, Solid State Physics, MacMillan India (1995).
3. L. H. Van Vlack, Elements of Materials Science and Engineering, Addison-Wesley, NY (1990).
4. Nicola. A. Spaldin, Magnetic Materials: Fundamentals and Applications, 2nd edition, Cambridge Univ. Press (2010).

Reference Books

1. Raghavan V, Materials Science and Engineering, 4th edition, Prentice Hall of India (1998).
2. B. G. Yacobi, Semiconductor Materials: An Introduction to Basic Principles, Kluwer, New York (2003).
3. S. Kasap and P. Capper (eds.), Springer Handbook of Electronic and Photonic Materials, Springer, New York (2006).

Outcome: The students would have obtained knowledge about the electrical, magnetic and optoelectronic materials, their properties and applications.

PH674 COMPUTATIONAL TECHNIQUES

Objectives: To introduce Programming tools in C language, MATLAB and LABView which will be useful for further research studies.

C programming

C programming basics - arithmetic operators – library functions – data input and output – relational operators – control statements – looping arrays functions – simple programs – user defined functions – pointers – passing pointers to functions – structures.

Introduction to MATLAB

MATLAB environment – working with data sets – data input/output – logical variables and operators – array and X-Y Plotting – simple graphics – data types matrix, string, cell and structure – file input and output – matlab files – simple programs.

Applications of MATLAB

Matrices and array operation – elemental matrix functions – file functions – application of matlab – solving linear algebraic equations – curve fitting – interpolation – numerical integration – basic 2D Plots – overlay plots – specialized 2D plots – 3D plots – view.

Introduction to LABVIEW

Introduction to LABVIEW tools palette, controls & functions palette, data types, conversion – front panel, block diagram construction, parallel data flow, create indicators/controls/constants math operations, booleans, arrays, case structures, sequences – for loops, while loops – I/O reading and writing to files, paths, graphing, timed loops, signal generation/processing, waveform types, connecting to hardware, DAQ.

Modeling Approaches

Finite Element Methods: Introduction to 1D FEM – Problems in wave propagation and structural mechanics using 2D elements- Plane stress and plane strain analysis, 3D stress analysis- Simulation packages – ABAQUS-COMSOL Multiphysics – Modeling Applications.

Text Books

1. S. Chandra, Applications of Numerical Techniques with C, Narosa Publishing House Pvt. Limited (2006).
2. R. Pratap, Getting Started with MATLAB: A Quick Introduction for Scientist and Engineers, Oxford University Press (2010).
3. K. L. Ashley, Analog Electronics with LabVIEW, Prentice Hall Professional (2003).
4. T. R. Chandrupatla and A. D. Belegundu, Introduction to Finite Elements in Engineering, 4th edition, Prentice Hall (2011).

Reference Books

1. V. K. Ingle and J. G. Proakis, Digital signal processing using MATLAB, 3rd edition, Cengage Learning (2011).
2. Ross L. Spencer and Michael Ware, Introduction to MATLAB, Brigham Young University (2010).
3. Rafael C. Gonzalez, Richard E. Woods and Steven L. Eddins, Digital Image Processing Using MATLAB, 2nd edition, Tata McGraw-Hill Education (2010).
4. Learning MATLAB – The MathWorks, Inc. (1999).
5. LabVIEW Basics I Course Manual, National Instruments Corporation.

Outcome: Upon completion of this class, the student will be able to:

1. Familiarize with the computational tools available in MATLAB, LabVIEW and COMSOL for variety of physical problems.
2. Model the structural behavior using various simulation tools.

PH676 – NON-DESTRUCTIVE TESTING

Objective: It is one of the applied physics subjects and conventional NDT techniques are widely practiced in industries.

Introduction to NDT

Introduction to NDT – Surface NDT - Principles – types and properties of liquid penetrants - developers – advantages and limitations of various methods - preparation of test materials - units and lighting for penetrant testing - dye penetrant process- Leak testing- MPI.

Ultrasonic Testing

Nature of sound waves, wave propagation - modes of sound wave generation - various methods of ultrasonic wave generation - piezo electric effect, piezo electric materials and their properties –principle of pulse echo method, through transmission method, resonance method – advantages,

limitations – contact testing, immersion testing, couplants – data presentation A, B and C scan displays – Time of Flight Diffraction (TOFD).

Radiography

Geometric exposure principles, shadow formation, shadow sharpness, etc – radioisotopic sources – types and characteristics – production and processing of radioisotopes – radiographic cameras – X-ray sources generation and properties – industrial X-ray tubes – target materials and characteristics – high energy X-ray sources – linear accelerators – principles and applications of fluoroscopy/real-time radioscopy – advantages and limitations – recent advances, intensifier tubes, vidicon tubes etc.

Eddy Current

Generation of eddy currents – effect of created fields – effect of change of impedance on instrumentation – properties of eddy currents – eddy current sensing elements, probes, type of arrangement – a) absolute b) differential lift off, operation, applications, advantages, limitations – through encircling or around coils – type of arrangements a) absolute b) differential fill factor, operation, application, advantages, limitations.

Advanced NDT

Thermography: Contact and non contact inspection methods – heat sensitive paints and other coatings – heat sensitive papers – advantages and limitation, instrumentations and methods, applications. *Optical holography*: recording and reconstruction – holographic interferometry – real-time, double-exposure & time-averaged techniques – holographic NDT – methods of stressing and fringe analysis. *Acoustical Holography*: Liquid Surface acoustical Holography – optical system – reconstruction.

Text books

1. R. Halmshaw, Non-destructive Testing, 2nd edition, Edward Arnold (1991).
2. P. J. Shull, Nondestructive Evaluation: Theory, Techniques, and Applications, CRC Press (2016).

Reference Books

1. American Metals Society, Non-Destructive Examination and Quality Control, Metals Hand Book, Vol.17, 9th edition, Metals Park, OH (1989).
2. Krautkramer, Josef and Hebert Krautkramer, Ultrasonic Testing of Materials, 3rd edition, New York, Springer-Verlag(1983).
3. R. Halmshaw, Industrial Radiography, Applied Science Publishers Inc., Englewood, NJ (1982).
4. Baldev Raj, T. Jayakumar and M. Thavasimuthu, Practical Non-Destructive Testing, 3rd edition, Narosa Publishing House (2007).
5. C. Hellier, Handbook of Nondestructive Evaluation, 2nd Edition, McGraw Hill Professional (2013).

Outcome: Students are taught working principles of different NDT methods and exposed to instrumentation.

PH678 – LASERS AND APPLICATIONS

Objective: To introduce basics and usage of laser in science and industry.

Properties and Types of Lasers

Laser Fundamentals: spontaneous and stimulated emission, Einstein coefficients, population inversion – *Properties:* temporal and spatial coherence, directionality – *Types:* ruby laser, helium-neon laser, CO₂ laser, dye lasers, semiconductor lasers.

Holography

Spatial frequency filtering – holography – applications of holography – HNNT (Holographic Non-Destructive Testing) – holographic storage – optical disk storage – laser speckle and speckle meteorology – SNNT (Speckle Non-Destructive Testing).

Fibre Optics

Optical fibre principle – types of fibres – properties – fiber optical communication – fibre amplifiers, fiber-optic sensors: intensity-phase polarization and frequency dependent techniques.

Lasers in Science

Saturation spectroscopy – excited state spectroscopy – nonlinear spectroscopy – time domain and its applications – stimulated Raman emission – laser fusion – isotope separation – medical applications, photo-chemical applications

Lasers in Industry

Materials processing – drilling, cutting, welding – alloying – glazing – ablation – laser chemical vapour deposition (LCVD) – laser thermal deposition – hardening, annealing – laser tracking – lidar.

Text Books

1. K. Thyagarajan and A.K. Ghatak, Lasers Theory and Applications, Mcmillan (1981).
2. K. Koebner (ed.), Industrial Applications of Lasers, Wiley (1984).

Reference Books

1. J.T. Cuxon and D.E. Parker, Industrial Lasers and their Applications, Prentice Hall (1985).
2. B. Culshaw, Optical Fiber Sensing and Signal Processing, Peter Peregrinus Ltd. (1984).
3. F.C. Appard, Fiber Optics Handbook, McGraw-Hill (1989).

Outcome: Students will understand wide applications of lasers in opto-electronic, non destructive testing, materials processing industry and its potential use as a scientific tool.

PH680 – ADVANCED STATISTICAL METHODS AND PHASE TRANSITION

Objectives:

1. To introduce the statistical methods and numerical tools needed to solve phase transitions of various kinds.

2. To learn the methods of constructing model systems and finding analytical solutions to these models to understand the phase transitions and critical phenomena around these transition points.

Probability and Random Process

Fluctuations and random processes – Brownian motion – diffusion – random walks – Langevin equation – fluctuation-dissipation theorem – irreversibility – Markov processes – master equation – Fokker -Planck equation.

Phase Transition Theories

Examples of first order and continuous phase transitions – mean field (van der Waals and Weiss molecular field) theories – fluid-magnet analogy – correlations – classical (Ornstein -Zernicke) theory.

Statistical Mechanical Models

Ising, lattice gas, Heisenberg, XY and Potts models – transfer matrix method – illustration using one-dimensional Ising model – duality in the two-dimensional Ising model – high and low temperature series expansions.

Critical Phenomena

Long-range order, order parameter, scaling, universality, critical exponents – Peierls argument for phase transitions – spontaneous breakdown of symmetry – Landau theory of phase transitions – role of fluctuations, lower and upper critical dimensions – Ginzburg-Landau model – Higgs mechanism – examples – Mermin-wagner theorem – topological (Berezinski-Kosterlitz-Thouless) phase transition.

Renormalization Group Theory

Elements of re-normalization group approach to continuous phase transitions – flows in parameter space, fixed points, epsilon expansion, real-space re-normalization – connection with Euclidean field theories – elementary ideas on percolation.

Text Books

1. N.G. Van Kampen, Stochastic Processes in Physics and Chemistry, North-Holland (1985).
2. H.E. Stanley, Introduction to Phase Transitions and Critical Phenomena, Clarendon Press, Oxford (1971).
3. J.M. Yeoman, Statistical Mechanics of Phase Transitions, Clarendon Press, Oxford (1992).

Reference Books

1. C.W. Gardiner, Handbook of Stochastic Methods, Springer-Verlag (1983).
2. C.J. Thompson, Classical Equilibrium Statistical Methods Springer-Verlag (1988).
3. D. Stauffer, Introduction to Percolation Theory, Taylor and Francis (1985).

Outcome: Students will gain confidence to pursue research careers in any areas of theoretical condensed matter physics.

PH682 – SEMICONDUCTOR PHYSICS

Objective: To introduce the basic properties of semiconductors and modern devices based on semiconductor materials.

Properties of Semiconductors

Crystalline and amorphous semiconductors – band structure – semiconductor in equilibrium – charge carriers in semiconductors – intrinsic Fermi level position – dopant atoms and energy levels - extrinsic semiconductor– statistics of donors and acceptors –charge neutrality –position of Fermi energy level.

Carrier Transport Phenomena

Carrier drift – drift current density – mobility effects –conductivity –carrier diffusion –diffusion current density – total current density – graded impurity distribution –induced electric field – Einstein relation –Hall Effect.

Nonequilibrium Excess Carriers

Carrier generation and recombination – semiconductor in equilibrium – excess carrier generation and recombination – characteristics of excess carriers –continuity equations –time-dependent diffusion equations –Ambipolar transport – derivation of the Ambipolar transport equation – dielectric relaxation time constant – quasi-Fermi levels.

The p-n Junction

Basic Structure of the p-n Junction – zero applied bias –built-in potential barrier – electric field –space charge width –reverse applied bias – space charge – width and electric field – junction capacitance –one-sided junctions – current – voltage characterization – photo –diodes – avalanche photodiode – semi-conductor lasers – transition process – population inversion – gain junction lasers – threshold current density.

Semiconductor Devices

Metal-semiconductor and Semiconductor heterojunctions – Schottky Barrier Diode –metal-semiconductor ohmic contacts –heterojunctions –bipolar transistor – Metal-Oxide-semiconductor Field-Effect Transistor – Junction Field-Effect Transistor – Solar cell- basic characteristics – spectral response – recombination current and series resistance.

Text Books

1. R. A. Smith, Semiconductors, Academic Publishers, Kolkota (1989).
2. Donald A. Neamen, Semiconductor Physics and Devices 4th edition, Tata Mc-Graw Hill (2012).

References Books

1. S. M. Sze and Kwok K. Ng, Physics of Semiconductor Devices, 3rd edition, Wiley (2012).
2. M. S. Tyagi, Introduction to Semiconductor Materials and Devices 1st edition, John Wiley and Sons (1991).

Outcome: Students will be able to understand and appreciate the functionality of modern semiconductor devices.

PH684 – NANOSCIENCE AND TECHNOLOGY

Objective: To impart the basic knowledge on nanoscience and technology which includes the exotic properties of materials at nanoscale, various techniques available for the processing and characterization of nanostructured materials, applications in selected fields such as magnetic recording technology, electronics and biomedical field

Nanomaterials and Structures

Nanomaterials – types: nanowires, nanotubes, fullerenes, quantum dots, Dendrimers, nanocomposites – properties – *Methods of preparation:* top-down, bottom-up – gas condensation, Sol-gel, Chemical Vapor Deposition, sputtering, Molecular Beam Epitaxy methods.

Characterization Tools

Electron Microscopy Techniques – SEM, TEM, X-ray methods – optical methods – fluorescence Microscopy – single molecule surface enhanced resonance – Raman spectroscopy – Scanning probe Microscopy: STM, AFM – MRI.

Nanomagnetism

Mesoscopic magnetism – mesoscopic magnetic materials - *magnetic measurements:* miniature Hall detectors, integrated DC SQUID Microsusceptometry – magnetic recording technology, biological magnets.

Nanoelectronics and Integrated Systems

Basics of nanoelectronics – single electron transistor – quantum computation – parallel architecture for nanosystem – nanolithography – basic and integrated structures – MEMS.

Biomedical Applications of Nanotechnology

Biological structures and functions – biomolecular motors – drug delivery systems – organic-inorganic nanohybrids – inorganic carriers – nanofluidics.

Text Books

1. Jan Korvink and Andreas Greiner, Semiconductors for Micro and Nanotechnology – an Introduction for Engineers, Weinheim Cambridge: Wiley-VCH (2001).
2. N. John Dinardo and Weinheim Cambridge, Nanoscale Characterisation of Surfaces & Interfaces, 2nd edition, Wiley-VCH (2000).
3. C.P. Poole and F.J. Ownes, Introduction to Nanotechnology, Wiley India (2007).

Reference Books

1. G. Timp (ed), Nanotechnology, AIP Press, Springer (1999).
2. M. Wilson, K. Kannangara, G. Smith, M. Simmons and B. Raguse, Nanotechnology: Basic Sciences and Energy Technologies, Overseas Press (2005).
3. T. Pradeep, Nano: The Essentials, Mc-Graw Hill India (2007).

4. M. S. Ramachandra Rao, Nanoscience and Nanotechnology: Fundamentals to Frontiers, Wiley (2013).

Outcome: On successful completion of this course, students would be able to:

1. describe important experimental tools in the fields of nano-science
2. understand the quantum mechanical tunnelling of electrons, oscillatory coupling GMR effect and related applications in devices and MEMs
3. familiarize with the applications of nano-technology in magnetic recording, quantum computation, drug delivery, nanofluidics and biological devices.

PH686 - QUANTUM COMPUTATION AND QUANTUM INFORMATION

Preliminaries

Review of quantum mechanics – measurements – density operator – Schmidt decomposition – Gleason's theorem – ambiguity of the ensemble interpretation – Kraus representation theorem.

Quantum Computation

Classical computation – Turing machine – circuit model of computation – computational complexity – computing dynamical system – quantum gates and circuits – adiabatic quantum computation – cluster state quantum computing – conditions for computation.

Quantum Information

Classical noise and Markov processes – quantum noise and examples – introduction to quantum error-correction – Fault-tolerant quantum computation – Shannon entropy – basic properties of entropy – von-Neumann entropy.

Quantum Entanglement

EPR paradox – local hidden variable theory – Bohm's experiment – Bell's inequality – entanglement in bipartite and multipartite states – classical and quantum correlation – nonlocality – separability and entanglement – CHSH inequality.

Quantification of Entanglement

LOCC operation – distillable entanglement – entanglement of formation – entropy of entanglement – concurrence – logarithmic negativity – geometric measure of entanglement – quantum discord.

References

1. M. A. Nielsen, I.L Chuang, Quantum Computation and Quantum Information, Cambridge University Press, Cambridge (2000).
2. J. Preskill, Lecture notes for Physics, Quantum computation (1999). <http://theory.caltech.edu/~preskill/ph229>.
3. A. Peres, Quantum Theory: Concepts and Methods, Kluwer Academic publishers, New York (2002).
4. R. Horodecki, P. Horodecki, M. Horodecki, K. Horodecki, Rev. Mod Phys. 81, 865 (2009).