M.Sc. Degree

IN

<u>Physics</u>

SYLLABUS

FOR

CREDIT BASED CURRICULUM

(From the academic year 2014-15 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

PH672 MICROPROCESSORS

PH674 COMPUTER APPLICATIONS IN PHYSICS

PH676 NON-DESTRUCTIVE TESTING

PH678 LASERS AND APPLICATIONS

PH680 ADVANCED STATISTICAL METHODS AND PHASE TRANSITION

PH682 SEMICONDUCTOR PHYSICS

PH684 NANOSCIENCE AND TECHNOLOGY & APPLICATIONS

* 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.

Unit – I: 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.

Unit – II: 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.

Unit – III: 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.

Unit – IV: 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.

Unit-V: 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. Mathematical Methods in the Physical Sciences, 3rd edition, Mary L. Boas, Wiley-India (2011).

Reference Books
1. L.A. Pipes and L.R. Harvill, Applied Mathematics for Engineers and Physicists, McGraw-Hill (1970).

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

PH653 – CLASSICAL MECHANICS

<u>Objectives:</u>

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.

Unit – I: 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.

Unit – II: 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.

Unit – III: 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.

Unit – IV: Hamiltonian Formulation

Legendre transformation – Hamiltonian equations of motion – cyclic coordinates – phase space and Liouville's theorem – Poisson brackets.

Unit – V: Special Theory of Relativity

Internal frames – principle and postulate of relativity – Lorentz transformations – length contraction, time dilation and the Doppler effect – velocity addition formula – four-vector notation – energy-momentum – four-vector for a particle – relativistic invariance of physical laws.

Text Books

1. H. Goldstein, C. Poole and J. Safko, Classical Mechanics, 3nd edition, Addison & Wesley (2000).
2. W. Greiner, Classical Mechanics, Springer-Verlag (2003).
3. W. Greiner, Classical Mechanics – Point particles and Relativity, Springer (1989).

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, 4^{th} 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 mater-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.

Unit – I: 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.

Unit – II: 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.

Unit – III: 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.

Unit – IV: Angular Momentum and Spin

Eigenvalues of angular momentum **J** – matrix representation of **J** – electron spin – Stern – Gerlach experiment – Zeeman effect – addition of angular momentum – Clebsh-Gordan coeffecients – identical particles with spin – Pauli exclusion principle.

Unit – V: Approximation Methods

Perturbation theory for non-degenerate states – removal of degeneracy – Stark effect – variation method – WKB approximation – Bohr-Sommerfeld quantum condition –

pertubative 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, Aruldhas, 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), 3^{rd} edition, Elsevier (2011).

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.

Unit – I: Circuit Theorems and Special Diodes

Kirchoff's laws for current and voltage – Thevenin's and Norton's theorems, superposition and reciprocity theorems with examples – p-n junction diodes – Zener diode – tunnel diode – Schottky barrier diode – varactor diode-photodiode – solar cell – photodiodes and transistors – light emitting diode – semiconductor laser – UJT – opto-couplers.

Unit – II: Bipolar Transistor Amplifiers and FETs

Biasing characteristics of junction transistors – analysis using re model-fixed bias-voltage divider bias-emitter bias – direct coupled transistor amplifiers – single stage transistor amplifier – frequency response – feed back in amplifiers – effect of negative feedback in amplifiers – FETs – different types-low and high frequency FETs, frequency response of FET – applications

Unit-III: 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.

Unit – IV: 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.

Unit – V: 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-flops, 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, Tata McGraw-Hill (2007).
3. R.J. Higgins, Electronics with Digital and Analogue Integrated Circuits, Prentice Hall (1983).

Reference Books

1. R. L. Boylsted 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

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.

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II SEMESTER

PH652 – MATHEMATICAL PHYSICS - II

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

Unit – I: 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.

Unit – II: 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.

Unit – III: 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 derivates – application to differential equation.

Unit – IV: 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.

Unit – V: 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.

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).

Reference Books

1. L.A. Pipes and L.R. Harvill, Applied Mathematics for Engineers and Physicists, McGraw-Hill (1970).

Outcome: Students will acquire enough mathematical skills to handle variety of equations, 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.

Unit – I: 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.

Unit – II: 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.

Unit – III: 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.

Unit – IV: 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.

Unit – V: 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, 3nd edition (1999).
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.

Unit – I: Thermodynamics
Ideal gas law – exact differentials – first law, internal energy, heat capacity – second law, Carnot's cycle, Carnot's theorem, absolute temperature – Clausius theorem, entropy – thermodynamic potentials, Maxwell's relations – chemical potential – third law.

Unit – II: 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 – grand canonical ensemble.

Unit – III: Maxwell-Boltzmann Statistics
Boltzmann system (identical, distinguishable particles) – Maxwell-Boltzmann distribution – Lagrange's multipliers – partition function (single particle) – thermodynamics of gases – equipartition theorem – paramagnetic susceptibility.

Unit – IV: Bose-Einstein Statistics
Principle of indistinguishability – Bosons – Bose-Einstein distribution – Planck's law of radiation – Stefan's law – Einstein model of phonons (semi-classical) – Debye's theory of heat capacity of solids.

Unit – V: Fermi-Dirac Statistics
Fermions – Fermi-Dirac distribution – Fermi energy – electron gas in metals – thermionic emission – Pauli paramagnetism.

Text Books

1. M.W. Zeemansky and R.H. Dittman, Heat and Thermodynamics, 8^{th} edition, Mc-Graw Hill (2011).
2. K. Haung, Statistical Mechanics, 2^{nd} edition, Wiley India (2010).
3. F.W. Sears and G.L. Salinger, Thermodynamics, Kinetic Theory and Statistical Thermodynamics, 3^{rd} edition, Narosa Publishing House (1998).

Reference Books

1. Enrico Fermi, Thermodynamics, Dover (1956).
2. R.K. Pathria and Paul D. Beale, Statistical Mechanics, 3^{rd} 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.

Unit – I: 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.

Unit – II: Vacuum Systems

Principle and operation of various pumps: rotary, diffiusion, 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.

Unit – III: 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.

Unit – IV: 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.

Unit – V: Electronics and Experimental Methods
Error analysis: linear and nonlinear curve fitting, chi-square test. *Signal conditioning:* impedance matching, filtering, noise reduction, shielding and grounding, lock-in detector, box-car integrator.

Text Books

1. A.K. Sawhney and Puneet Sawhney, A Course in Mechanical Measurement and Instrumentation, DhanpatRai&Sons, New Delhi 2000.
2. Dennis Roddy and John Coolen, Electonic communication, 4^{th} 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, 6^{th} 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, low temperatures which will benefit them 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.

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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.

Unit – I: Introduction

Solids – crystalline and amorphous – crystal structure and symmetries – reciprocal lattice – defects and dislocations – Brillouine 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.

Unit – II: Conductors, Semicoductors 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 ferroelctricity.

Unit – III: 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.

Unit – IV: 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 – antiferro and ferrimagnetism – theories.

Unit – V: 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 Tc superconductors – Josephson Junctions – AC and DC – superfluidity.

Text Books

1. Charles Kittel, Introduction to Solid State Physics, Wiley Eastern, 5th edition, (1983).

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.

Unit – I: 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.

Unit – II: 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.

Unit – III: 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.

Unit – IV: Raman Spectroscopy

Raman effect – quantum theory of Raman effect – rotational Raman spectra – vibrational

Raman apectra – Raman spectra of polyatomic molecules – Raman spectrometer – hyper-Raman effect – experimental techniques.

Unit – V: 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. Aruldhas, Molecular Structure and Spectroscopy, Prientice Hall of India, NewDelhi (2002).

Reference Books

1. Manas Chanda, Atomic Structure and Chemical Bond, Tata McGraw-Hill, New Delhi (2003).
2. Arthur Beiser, Concepts of Modern Physics, 6th edition, Tata McGraw-Hill, New Delhi (2003).
3. B.P. Straughan & S. Walker, Spectroscopy: Vol. I, Chapmen and Hall (1976).
4. 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.

Unit – I: 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.

Unit – II: 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.

Unit – III: 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.

Unit – IV: 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.

Unit – V: 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.

Unit – I: Roots of Equations
Bracketing and bisection – false position method – Newton-Raphson method – iteration methods – acceleration of convergence – polynomial equations – complex roots and Muller method.

Unit – II: Interpolation and Integration
Introduction – Lagrange and Newton interpolations – least square fitting – rational approximation – numerical differentiation – numerical integration – trapezoidal rule, Simpson's rule.

Unit – III: Linear Algebra
System of linear equations – Gauss elimination method – pivoting method – triangularization (LU) method – eigenvalues and eigenvectors – Jacobi method for symmetric matrix – Rutishauser LU method for arbitrary matrices.

Unit – IV: Ordinary Differential Equations
Single step methods – Runge-Kutta (fourth orer) methods: fixed and controlled step size – Predictor-Corrector method – system of first order ODEs – finite difference method – finite element method.

Unit – V: Advanced Methods
Introduction to parallel computing – numerical operations in parallel computing – roots of an equation – interpolation and integration – system of linear equations – artificial neural network – learning.

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. Microprocessor-1: Stepper Motor Interface
5. Microprocessor-2: Traffic Control
6. Microprocessor-3: Interfacing Display
7. Microprocessor-4: Interfacing with Voltmeter
8. Labview-1: Operational Amplifier Circuits
9. Labview-2: Simulation of Diode characteristics
10. Labview-3: Design of Op-Amp AC Characteristics
11. Labview-4: Construction of OPAMP
12. Labview-5: Design of 555 Timer Chip Astable Circuit
13. X-Ray Diffraction – Determination of lattice parameters of a crystalline solid
14. UV-Vis Spectrophotometer – Determination of absorption coefficient and bandgap
15. FTIR Spectrometer – Determination of vibration levels in a compound
16. Superconductivity – Determination of transition temperature
17. Contact Angle Measurement
18. G.M. Counter
19. Thin Film Deposition and Measurement of Electrical Conductivity – Four Probe Method
20. Ellipsometer – Determination of *n* and *k* of a material.

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.

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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.

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ELECTIVES

Odd Semester

PH611 – DIGITAL SIGNAL AND IMAGE PROCESSING

Objective: To introduce some signal processing concepts, algorithms and their application for data analysis, image analysis, signal detection and classification. To create a broad awareness of the set of available signal processing methods for specific real world problems.

Unit – I: Discrete Time Signal and Systems
Basics of signals – period, frequency, phase – mathematical representation of signals – discrete time signals – data acquisition – sequences – linear shift-invariant systems – stability and causality – linear constant coefficient difference equations – frequency-domain – representation of discrete-time systems and signals – representation of discrete-time signals by Fourier transform.

Unit – II: 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.

Unit – III: 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 – decimation in time FFT and Frequency – introduction to optimal filters. *Signal Analysis methods:* Time and frequency domain analysis – STFT– wavelet.

Unit – IV: 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 quantisation – monochrome.

Unit – V: Linear Image Processing 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.

Text Books

1. William K. Pratt, Digital Image Processing, 3rd edition, John Wiley & Sons, Inc., USA (2001).
2. Alan V. Oppenheim and Ronald W. Schafer, Digital Signal Processing, New Delhi (2000).

Reference Books

1. L.R. Rabiner and B. Gold, Theory and Applications of Digital Signal Processing, Prentice Hall of India.
2. T. Bose, Digital Signal and Image Processing, 1st edition, John Wiley (2003).

Outcome: The student will be able to

1. identify, select and apply appropriate signal processing techniques to analyze signals for specific real-world applications and judge the image quality.
2. understand the advantages and limitations of advanced signal and image processing techniques for specific applications.
3. apply proper processing tools for a better quality of 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 class of materials.

Unit – I: Structure of Metals
Different types of bonding in solids - Elements of crystal structure- Imperfections in crystals – dislocation theory - Grain boundaries and poly crystalline aggregates - Principles of Alloying - Solid solutions and intermediate phases - Gibbs phase rule and equilibrium diagram - types of binary phase diagrams - Isomorphous - Eutectic - Peritectic and Peritectoid, eutectoid reactions.

Unit – II: Mechanical Behavior of Materials
Elements of elastic and plastic deformation – stress-strain relation-work hardening, recovery, re-crystallization and grain growth, types of fractures in materials and their identification - Mechanical testing of metals - Tensile, Hardness, Fatigue, Creep tests and their interpretation. Mechanical testing on composites – compression, tension, ILSS, flexural.

Unit – III: 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 (various types), normalizing, quenching and tempering - Case hardening, Austempering and martempering - Solidification of Metals and alloys **-** Nucleation and crystal growth from the liquid phase - Ingot structure dendrite freezing - Segregation effects and grain size control – strength mechanisms – solute, dispersion and precipitation hardening.

Unit – IV: Non-Ferrous Metals & Ceramics
Aluminum, Aluminum alloys, Advantages and Application, Copper & Copper Alloys, Application and advantages, Titanium & Titanium Alloys, Advantages & Applications, Defects in Non ferrous metals – types, significance. Industrial importance of engineering ceramic materials, building stone, clay products, refractories, cement and concrete, ceramic matrix composite materials; high temperature ceramic materials. Application of engineering ceramic materials. Defects in ceramic materials

Unit – V: Composites
Importance of composites – constituents – functions of fiber and matrix – *properties of fibers:* aligned and random fiber composites – types of fibers-glass fiber, carbon fiber, metallic fibers, ceramic fibers-matrix materials – metallic and polymer matrix composites – manufacture methods – hand layup & prepeg techniques, pultrusion, pulforming, therforming, resin-transfer moulding, injection moulding, bulk moulding compound, sheet moulding compound- defects in composites – fabrication & in-service defects.

Text Books

1. W.D. Callister, Materials Science and Engineering: An Introduction, 7th edition Wiley, (2006).
2. V. Raghavan, Materials Science and Engineering, 4th edition, Prentice Hall (1998).
3. G.E. Dieter, Mechanical Metallurgy, 3rd edition, Mc-Graw Hill (2004).
4. A.V.K. Suryanarayana, Testing of Metallic Materials, Prentice Hall of India (1979).
5. V.B. John, Introduction to Engineering Materials, 3rd edition, Palgrave Macmillan Ltd. (1992).

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, New York (1989).
3. I.J. Polmear, Light Alloys: Metallurgy of the Light Metals, Wiley, 3rd edition, Edward Arnold (1995).
4. Raghavan, V. Physical Metallurgy: Principles and Practice, 2nd edition, Prentice Hall of India (2006).

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

- Select different materials and emphasis the need of modern materials other than conventional metals and alloys for specific engineering applications.
- Understand the heat treatment of steels using TTT and CCT diagrams.
- Analyze the various metallurgical factors influencing the performance of materials for different structural engineering applications.
- Define various mechanical properties of materials and their importance in materials selection criteria.
- Classify different mechanical properties and how they can influence the materials behaviour 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.

Unit – I: Electromagnetic Fields and Waves
Maxwell's equations and boundary conditions – energy density and poynting vector – monochromatic filed and complex function formalism – wave equation and monochromatic plane waves – chromatic dispersion and group velocity.

Unit – II: Guided Wave in Dielectric Slabs
Introduction – TE and TM confined modes in symmetric slab – waveguides – TE And TM confined modes in asymmetric slab waveguides.

Unit – III: Crystals Optics and Electromagnetic Propagation in 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.

Unit – IV: 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.

Unit – V: 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. Optics, Eugune Hecht and A.R. Ganesan, 4th Edition, Pearson Education Inc. (2002).
3. Fundamentals of Optoelectronics, Clifford R. Pollock and Richard D. Irwin, (1995).

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.

Unit – I: 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.

Unit – II: 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.

Unit – III: 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.

Unit – IV: 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.

Unit – V: Design of Solar Cells
Upper limits of solar cell parameters – losses in solar cells – Solar Cell design: Design for High Isc – Design for High Voc – 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. Solar Photovoltaics: Fundamentals, Technologies And Applications 2nd ed., Chetan Singh Solanki, PHI, New Delhi (2011).
2. Seminconductors for solar cells, H. J. Moller, Artech House Inc., MA, USA (1993).
3. Solar Cells: Operating principles, Technology and Systems Applications, Martin Green, UNSW, Australia (1997).

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

Unit – I: 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.

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

Unit – III: Potentials and Fields
Maxwell's equation – scalar and vector potentials – gauge invariance – Coulomb gauge and Lorentz gauge – solution of inhomogenous wave equation – retarded potentials.

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

Unit – V: 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

1. J.R. Reitz., F.J. Milford and R.W. Christy, Foundations of Electromagnetic Theory, 3rd edition, Narosa Publishing House (1979).
2. D. J. Griffiths, Introduction to Electrodynamics, Pearson Prentice Hall, 3rd edition, (1999).

Reference Books

1. J.D. Jackson, Classical Electrodynamics, John Wiley & Sons, 2nd edition (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.

Unit – I
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.

Unit – II
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.

Unit – III
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.

Unit – IV
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.

Unit – IV
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, Peason 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.

Unit – I: Temperature Sensors
Introduction to sensors – classification of sensor – sensor characteristics **-** physical principles of sensing **–** thermal sensors gas thermometric sensors – thermal expansion type sensors – thermoresistive Sensors – resistance temperature detectors – silicon resistive sensors – thermistors – thermoelectric contact sensors – thermoelectric law – thermocouples – thermocouple assemblies – semiconductor p-n junction sensors – optical

temperature sensors – interferometric sensors – thermochromic solution sensor – acoustic temperature sensor – piezoelectric temperature sensors.

Unit – II: 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 - eddy current sensors – transverse inductive sensor – Hall effect sensors – magnetoresistive sensors – magnetostrictive detector – optical sensors – optical bridge-proximity detector with polarized light – fiber optic sensors – radar sensors – thickness and level Sensors – liquid-level sensors.

Unit – III: Acceleration and Pressure Sensors
Accelerometer characteristics – capacitive accelerometers – piezo-resistive accelerometers – piezoelectric accelerometers – thermal accelerometers – heated plate accelerometer – heated gas accelerometer – gyroscopes – rotor gyroscope - monolithic silicon gyroscopes – optical gyroscopes – piezoelectric cables. Strain Gauges - tactile sensors – piezoelectric force sensors – pressure gauges: mercury pressure sensor – bellows, membranes and thin plates – piezo-resistive sensors – capacitive sensors – VRP Sensors – optoelectronic sensors.

Unit – IV: Flow, Acoustic and Humidity Sensors
Basics of flow dynamics – pressure gradient technique – thermal transport sensors – ultrasonic sensors – electromagnetic sensors – microflow sensors – breeze sensor – coriolis mass flow sensors – drag force flow sensors. Acoustic sensors: resistive microphones – condenser microphones – fiber optic microphone – fiezoelectric microphones – electric microphones – solid state acoustic detectors – humidity and moisture sensors – concept of humidity – capacitive sensors – electrical conductivity sensors – thermal conductivity sensor.

Unit – V: 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 – enhanced catalytic gas 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 ed., 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 ed., Tata Mc-Grow Hill (2012)
2. Ian R. Sinclair, Sensors and Transducers, 3rd ed., 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 and applications of thin films.

Unit – I: Preparation of Thin-films
Kinetic aspects of gases in a vacuum chamber – classifications of vacuum ranges – production of vacuum – pressure measurement in vacuum systems – thin film (epitaxy) – definition – 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, ellipsometry, interferometry.

Unit – II: 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 (cap, disc and cubic shaped). *Growth Kinetics*: Kinetics of binary (GaAs, InP, etc.), ternary ($Al_{1-x}Ga_xAs$, $Ga_{1-x}In_xP$, $InAs_{1-x}P_x$, etc.) and quaternary ($Ga_{1-x}In_xAs_{1-y}P_y$, etc.) semiconductors – derivation of growth rate and composition expressions.

Unit – III: Characterization
X-ray diffraction – photoluminescence – UV-Vis-IR spectrophotometer – Atomic Force Microscope – Scanning Electron Microscope – Hall effect – Vibrational Sample Magnetometer – Secondary Ion Mass Spectrometry – X-ray Photoemission Spectroscopy.

Unit – IV: Properties of Thin films
Dielectric properties – experimental technique for the determination of dielectric properties – optical properties – experimental technique for the determination of optical constants – mechanical properties – experimental technique for the determination of mechanical properties of thin films – magnetic and superconducting properties.

Unit – V: 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) – sensors – fabrication and characterization of thin film transistor and FET – quantum dot.

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. Ludminla 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).

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.

Unit – I: 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.

Unit – II: 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.

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

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

Unit – V: 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, 7^{th} edition, Wiley (2006).
3. F. C. Moon, Superconducting Levitation, Wiley (2004).

Reference Books

1. S. Chikazumi, Physics of Ferromagnetism, Oxford University Press (1997).

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.

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

Unit – II: Bulk micro machining
Introduction – etch-stop techniques – dry etching – buried oxide process – silicon fusion bonding and anodic bonding.

Unit – III: Surface micro machining
Introduction – sacrificial layer technology – material systems in sacrificial layer technology – plasma etching – combined IC technology and anisotropic wet etching.

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

Unit – V: MEMS Devices
Electronic interfaces – design, simulation and layout of MEMS devices using CAD tools.

Text Books

1. M. Elwenspoek and R.Wiegerink, 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.

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Even Semester

PH610 – ELECTRICAL, MAGNETIC AND OPTOELECTRONIC MATERIALS

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

Unit – I: 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) – $BaTiO_3$ – dielectric loss, dielectric breakdown – ferro electricity – piezo and pyro electricity.

Unit – II: 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.

Unit – III: Superconducting and Semiconducting Materials

Concept of super conductivity – theories and examples for high temperature superconductivity – discussion on specific super conducting materials – Nb_3Sn – YBCO – MgB_2 – 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.

Unit – IV: 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.

Unit – V: 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. Kittel C, Introduction to Solid State Physics, 6th Edition, Wiley Eastern, New International Publishers, 1997.
2. Dekker A.J, Solid State Physics, MacMillan India, 1995.
3. L.H. Van Vlack, Elements of Materials Science and Engineering, Addison-Wesley, NY (1990).

Reference Books

1. Raghavan V, Materials Science and Engineering, 4^{th} 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.

PH672 – MICROPROCESSORS

Objective: To impart the basic knowledge on 8085 processor and its applications and gain an overview on its peripheral devices and its advancements

UNIT – I
Basic components of a digital computer – CPU-ALU – timing and control unit memory – bus architecture – I/O devices – 8085 microprocessor architecture, various registers, stacks

UNIT – II
8085 addressing modes – instruction set – instruction cycle – timing diagram – subroutines, programming examples – memory and I/O interfacing – memory mapped I/O, I/O mapped I/O schemes – data transfer schemes.

UNIT – III
Interrupt structure in 8085 – hardware and software interrupt, I/O Ports – DMA principles – Serial I/O: Basic concepts, asynchronous and synchronous communication.

UNIT – IV
Programmable Peripheral Interfacing(PPI) – 8255, pins and signals, operation, interfacing – programmable 8253 – timer/counter, Programmable Interrupt Controller (PIC), 8259A – programmable 8237 – DMA controller – special purpose interfacing devices.

UNIT – V
8086 internal architecture – addressing modes, bus cycles – bus controller – 8086 instruction set, programming examples – 8086 interrupts – protected mode operation – virtual memory, mulitasking – special features and overviews of 80286, 80386, 80486 – Pentium, and Pentium-IV processors.

Text Books

1. R.S. Gaonkar, Microprocessor Architecture: Programming and Applications, 3rd edition, Penram International Publishing India (1997).
2. B. Ram, Fundamentals of Microprocessors and Microcomputers, 5th edition, Dhanpat Rai publication, India (2001).
3. N. Mathivanan, Microprocessors: PC Hardware and Interfacing, Prentice Hall of India (2005).

Reference Books

1. Yu Cheng Liu and G.A. Gibson, Microprocessor Systems: The 8086 /8088 Family: Architecture, Programming and Design, Prentice Hall of India (1994).
2. B.B. Brey, The Intel Microprocessors: 8086/8088, 80186/80188,80286,80486 Pentium and Pentium Pro Processor – Architecture, Programming and Interfacing, 4th edition, Prentice Hall of India.

PH674 – COMPUTER APPLICATIONS IN PHYSICS

Objective: To introduce Programming tools in C language, MATLAB and LABView.

Unit – I: 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.

Unit – II: 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.

Unit – III: 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 – specialised 2D plots – 3D plots – view.

Unit – IV: 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, serial, GPIB, TCP/IP and USB interface

Unit – V: Computational Techniques
Artificial Intelligence: artificial neural networks, fuzzy logic, genetic algorithm; applications in NDT. *Finite Element Methods:* Introduction to I-D FEM. Problems in wave propagation and structural mechanics using 2D elements- Plane stress and plane strain analysis, 3D stress analysis – *Simulation packages:* ABAQUS, ANSYS, COMSOL multiphysics for structural health monitoring applications.

Text Books

1. Suresh Chandra, Applications of Numerical Techniques with C, Narosa (2006).
2. Rudra Pratap, Getting Started with MATLAB: A Quick Introduction for Scientist and Engineers, Oxford University Press (2010).
3. Kenneth L. Ashley, Analog Electronics with LabVIEW, Pearson Education, Inc. (2003).

Reference Books

1. Vinay K. Ingle, John G. Proakis, Digitals Signal Processing Using MATLAB, PWS Publishing Company (1997).
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, Prentice-Hall (2003).
4. Learning MATLAB – The MathWorks, Inc. (1999).
5. LabVIEW Basics I Course Manual, National Instruments Corporation.

Outcome: Students will be familiarized with computational tools available in MATLAB and LABView and COMSOL for simulating variety of physical problems.

PH676 – NON-DESTRUCTIVE TESTING

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

Unit – I: Liquid Penetrant Testing

Principles – types and properties of liquid penetrants - developers – advantages and limitations of various methods - preparation of test materials - application of penetrants to parts, removal of surface penetrants, post cleaning - selection of penetrant method - solvent removal, water washable, post emulsifiable – units and lighting for penetrant testing - dye penetrant process.

Unit – II: 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).

Unit – III: 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.

Unit – IV: 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.

Unit – V: 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.

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).

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.

Unit – I: Properties and Types of Lasers
Laser Fundamentals: spontaneous and stimulated emission, Einstein coeffecients, population inversion – *Properties:* temporal and spatial coherence, directionality – *Types:* ruby laser, helium-neon laser, CO_2 laser, dye lasers, semiconductor lasers.

Unit – II: Holography
Spatial frequency filtering – holography – applications of holography – HNDT (Holographic Non-Destructive Testing) – holographic storage – optical disk storage – laser speckle and speckle meteorology – SNDT (Speckle Non-Destructive Testing).

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

Unit – IV: 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

Unit – V: Lasers in Industry
Materials processing – drilling, cutting, welding – alloying – glazing – oblation – 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.

Unit – I: 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.

Unit – II: 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.

Unit – III: Statistical Mechanical Models
Ising, lattice gas, Heisenberg, XV and Potts models – transfer matrix method –illustration using one-dimensionallising model – duality in the two-dimensionallsing model – high and low temperature series expansions.

Unit – IV: 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.

Unit –V: 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.

Unit – I: 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.

Unit – II: 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.

Unit – III: 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.

Unit –IV: 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.

Unit – V: 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 ed., Tata Mc-Graw Hill (2012).

References Books

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

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

PH684 – NANOSCIENCE AND TECHNOLOGY & APPLICATIONS

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

Unit – I: Nanomaterials and Structures

Nanomaterials – *types:* nanowires, nanotubes, fullerenes, quantum dots, Dendrimers, nanocomposites – properties – *Methods of preparation:* top-down, bottom-up.

Unit – II: Characterization Tools

Electron Microscopy Techniques – SEM, TEM, X ray methods – optical methods – fluorescence Microscopy – single molecule surface enhanced resonance – Raman spectroscopy – Atomic Force Microscopy – MRI STM and SPM.

Unit – III: Nanomagnetism

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

Unit – IV: Nanoelectronics and Integrated Systems

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

Unit – V: 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. Introduction to Nanotechnology,C.P. Poole and F.J. Ownes, 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. Nano: The Essentials, T. Pradeep, Mc-Graw Hill India (2007).

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.
