Physics

MINOR Courses

[with effect from 2024 – 2025 onwards]

DEPARTMENT OF PHYSICS
NATIONAL INSTITUTE OF TECHNOLOGY, TIRUCHIRAPPALLI.

LIST OF MINOR COURSES

Students who have registered for **Minor in Physics** can opt to study any 5 of the courses listed below.

Sl. No.	Course Code	Course Title	Credits	Remarks
1.	PHMI11	Quantum Mechanics	4	Compulsory
2.	PHMI12	Electromagnetic Theory	4	Compulsory
3.	PHMI13	Solid State Physics	3	Compulsory
4.	PHMI14	Statistical Mechanics	4	Compulsory
5.	PHMI15	Magnetism and Superconducting Levitation	3	Any one
	PHMI16	Lasers and Applications	3	
	PHMI17	Sensors and Transducers	3	
	PHMI18	Nano science and Technology and Applications	3	
	PHMI19	Physics and Technology of Thin Films	3	

PHMI11 QUANTUM Mechanics

Course Code	:	PHMI11
Course Title	:	Quantum Mechanics
Type of Course	:	MI
Prerequisites	:	-
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLOs)

CLO1	To introduce the mechanics of matter-waves necessary for uncovering the mysteries of matter at the atomic scale.
CLO2	To outline mathematical tools to understand quantum mechanics.
CLO3	To learn about solvable systems like Harmonic oscillator and Hydrogen atom using the Schrödinger method.
CLO4	To learn about angular momentum for matrix representation and introduce various approximate methods useful for more complex problems.

Course Content

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 J – matrix representation of J – electron spin – Stern – Gerlach experiment – Zeeman effect – addition of angular momentum – Clebsh-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-Summerfield quantum condition –perturbative solution for transition amplitude – selection rules – Fermi Golden rule – scattering of a particle by a potential.

Textbooks

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), 3rd edition, Elsevier (2011).

Course Outcomes (COs)

At the end of the course student will be able to

CO1	Know the concept of quantum mechanics for uncovering the mysteries of matter at the atomic scale.
CO2	Apply mathematical tools to understand eigenfunctions and eigenvalues.
CO3	Understand the spectrum of hydrogen using solvable methods.
CO4	Determine angular momentum matrix representation and apply approximate methods for simple and complex problems.

PHMI12 Electromagnetic Theory

Course Code	**:**	PHMI12
Course Title	**:**	Electromagnetic Theory
Type of Course	**:**	MI
Prerequisites	**:**	-
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLOs)

CLO1	To understand static electric fields and solve related problems.
CLO2	To understand the magnetic induction and Ampere's law.
CLO3	To learn the Faraday's law of induction and the energy of the electromagnetic field.
CLO4	To learn the wave propagation of electromagnetic fields through different media.

Course Content

Electrostatics

Electric field – divergence and curl – electric potential – Gauss's law – electric dipole – multipole expansion – solutions to Laplace equation – separation of variables – polarization – field of polarized object – electric displacement – Gauss's law in dielectric – dielectric constant – point charge in dielectric – dielectric sphere in uniform field – boundary conditions – electrostatic energy density – capacitors –thermodynamic interpretation.

Magnetostatics

Current density and equation of continuity – Lorentz force – magnetic induction – Biot-Savart law – application to the circular coil and solenoid – Ampere's circuital law – magnetic flux – vector potential – magnetization – magnetic intensity – susceptibility – boundary conditions – types of magnetic materials.

Maxwell's Equations

Faraday's law – inductance and magnetic energy – 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 of EM waves.

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.

Textbooks

1. D. J. Griffiths, Introduction to Electrodynamics, Prentice Hall of India, 4 th edition (2015).
2. J.R. Reitz., F.J. Milford and R.W. Christy, Foundations of Electromagnetic Theory, 4th SEMESTER II PH652– ELECTROMAGNETIC THEORY M.Sc. (Physics) Dept. of Physics, NIT-T 14 edition, Pearson (2010).

Reference Books

1. J.D. Jackson, Classical Electrodynamics, Wiley-India, (2020).
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, 2 nd edition, Elsevier (2008).

Course Outcomes (COs)

At the end of the course student will be able to

CO1	Understand electric and magnetic force fields and the intricate connection between them.
CO2	Understand the energy of electromagnetic fields.
CO3	Appreciate the electromagnetic nature of radiation and its propagation in media.
CO4	Solve practical problems involving electromagnetic potentials and the associated fields.

PHMI13 Solid State Physics

Course Code	**:**	PHMI13
Course Title	**:**	Solid State Physics
Type of Course	**:**	MI
Prerequisites	**:**	-
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLOs)

CLO1	Appreciate the crystal structure of all materials.
CLO2	Compare the properties of different types of materials, such as conductors, semiconductors, and dielectrics.
CLO3	Imbibe the significance of lattice with various models.
CLO4	Recognize the origin of magnetism and develop a basic interest in superconductivity.

Course Content

Introduction
Solids – crystalline and amorphous – crystal structure and symmetries – reciprocal lattice – defects and dislocations – Brillouin Zone and its properties – Bonding in Solids – atomic scattering factor – geometric structure factor – X-ray diffraction – powder-Laue and rotation or oscillation method – liquid crystals.

Conductors, Semiconductors and Dielectrics
Conductors: Free electron theory – classical and quantum theory, band theory of solids –Tight binding model -effective mass of an electron– Fermi surface - Bloch theorem – Kronig-Penny model – Hall effect. 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 – heavy Fermions –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 Atomic theory of magnetism– Hund's rules – Curie-Weiss law – Langevin's classical and quantum theories of dia and para magnetism –Weiss Molecular field - concept of domain and hysteresis of ferromagnetism – Heisenberg model of exchange interaction – antiferro and ferrimagnetism

Superconductivity
Superconductivity – Meissner and isotope effect – thermodynamical and optical properties –– Coherence length -London's equations and penetration depth - critical field – types of superconductors –flux quantization – BCS theory- –Normal tunneling and Josephson Junctions – AC and DC – high Tc superconductors -superfluidity.

Textbooks

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, 7 th 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).

Course Outcomes (COs)

At the end of the course student will be able to

CO1	Grasp the significance of the structure and property relationship.
CO2	Describe the classification of materials with the theories for applications.
CO3	Understand the transport and thermodynamic properties of materials and the underlying physics.
CO4	Realize different types of magnetic phenomena in classical and quantum aspects.
CO5	Design superconducting materials for future technology.

PHMI14 Statistical Mechanics

Course Code	:	PHMI14
Course Title	:	Statistical Mechanics
Type of Course	:	MI
Prerequisites	:	-
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLOs)

CLO1	To learn the connection between macroscopic and microscopic states of a system of a large number of particles and to understand the concept of ensemble average.
CLO2	To understand the thermodynamic equilibrium of a system from a statistical point of view.
CLO3	Calculate the microcanonical, canonical, grand-canonical and isothermal-isobaric partition functions.
CLO4	Learn Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac distribution functions and compute the thermodynamic variables for a wide range of natural systems.

Course Content

Review of Thermodynamics

Zeroth, First, Second and Third Laws – Entropy and Clausius' inequality – Concept of Thermodynamic Equilibrium - Thermodynamic potentials – Maxwell's Relations –– Ideal and Real gases – Phase transition

Theory of Ensembles

Need for Statistical Mechanics - 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 – isothermal-isobaric 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 – electron gas in white dwarf stars – Polytropic Equation of State - electronic specific heat – thermionic emission – Pauli paramagnetism – Landau diamagnetism.

Textbooks

1. M. W. Zeemansky and R.H. Dittman, Heat and Thermodynamics, 8th edition, Mc-Graw Hill (2011).
2. K. Haung, 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).

Course Outcomes (COs)

At the end of the course student will be able to

CO1	Know the concept of thermodynamic equilibrium of a system and the corresponding thermodynamic variables and the relations between them.
CO2	Understand the theory of ensembles governing the equal a priori probabilities of the microstates of a system corresponding to a given microstate.
CO3	Find the partition function of any thermodynamic system consisting of classical particles (Maxwell-Boltzmann) and quantum particles (Bose-Einstein and Fermi-Dirac) in various ensembles (microcanonical, canonical, grand-canonical and isothermal-isobaric).
CO4	Get the required thermodynamic variables from the partition function and apply this procedure to get the general properties of various physical, chemical and biological systems.

PHMI15 Magnetic Characterization and Superconducting Materials
New Title: MAGNETIC CHARACTERIZATION AND SUPERCONDUCTING MATERIALS

Course Code	:	PHMI15
Course Title	:	Magnetic Characterization and Superconducting Materials
Type of Course	:	MI
Prerequisites	:	-
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLOs)

CLO1	Comprehend the types of magnetism and various magnetic phenomena
CLO2	Understand various magnetic characterization techniques.
CLO3	Evaluate the magnetic properties of various materials.
CLO4	Identify various types of superconducting materials and their applications.

Course Content

Fundamentals of Magnetism

Magnetic moment – magnetic field – field produced by electromagnets– VSM- AGM - Faraday method- Guoy method- field and moment measurement – demagnetizing field – origin of magnetism – g-factor – FMR – theory of diamagnetism.

Types of Magnetism

Langevin's theory of paramagnetism – quantum theory of paramagnetism – Brillouin function – molecular field theory of ferromagnetism – exchange interaction –Bethe-Slater – sublattice magnetization – internal fields – Antiferromagnetic susceptibility- crystal field effects- magnetism in metals and alloys-Slater-Pauling curve.

Magnetic Phenomena

Magnetic anisotropy – magnetocrystalline and shape anisotropy – Torque magnetometry- random anisotropy model – magnetostriction – domains – rotation- curling-buckling- pinning- mechanism -effects on hysteresis loop– fine particle magnetism – magnetocaloric effect.

Magnetic Characterization

Mössbauer effect – Instrumentation – isomer shift- quadrupole splitting – hyperfine splitting – applications – muon spin resonance – spin precession and relaxation – muonium – applications in magnetism – Neutron diffraction.

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- Levitation - types -Maglev vehicle.

Textbooks

1. B. D. Cullity and C.D. Graham, Introduction to Magnetic Materials, Wiley (2009).
2. S. Blundell, Magnetism in Condensed Matter, Oxford University Press (2001).
3. C. Kittel, Introduction to Solid State Physics, 7 th edition, Wiley (2006).

Reference Books

1. S. Chikazumi, Physics of Ferromagnetism, Oxford University Press (1997).
2. Ed. Charles P. Poole, Jr., Handbook of Superconductivity, Academic Press (2000).
3. Nicola. A. Spaldin, Magnetic Materials: Fundamentals and Applications, 2nd Edn., CambridgeUniv. Press (2002).
4. G. K. Wertheim, Mössbauer Effect: Principles and Applications, Academic Press Inc. (1964).
5. F. C. Moon, Superconducting Levitation, Wiley (2004).

Course Outcomes (COs)

At the end of the course student will be able to

CO1	Define various types of magnetism and magnetic phenomena.
CO2	Recognize ferromagnetic and superconducting materials.
CO3	Develop knowledge about various magnetic characterization techniques.
CO4	Analyze the origin of magnetism in various materials.

PHMI16 Lasers and Applications
New Title: Quantum Electronics and Laser Application

Course Code	**:**	PHMI16
Course Title	**:**	Lasers and Applications
Type of Course	**:**	MI
Prerequisites	**:**	-
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLOs)

CLO1	To introduce the basics and usage of lasers in science and industry.
CLO2	To understand resonator –cavity and high power lasers.
CLO3	To familiarize fiber optics and devices
CLO4	To learn non-liner optics and applications of lasers.

Course Content

Quantum Mechanics of Radiation and Matter

Wave particle dualism, Concept of wave packet, Boltzmann distribution law- Atoms – molecules energy transition, Spontaneous and stimulated emission Einstein's coefficients – Lifetime of excited state – Line Broadening mechanisms – Condition for producing laser – population inversion, gain and gain saturation – saturation intensity.

Cavity Optics and High-Power Lasers

Requirements for resonator –gain and loss in a cavity -characterization of resonator – resonator stability for Gaussian beams –common cavity configurations. Q switching-Modelocking- Types: ruby laser, helium-neon laser, CO2 laser, semiconductor lasers

Holography and Fiber Optics

Construction –reconstruction-inline, off axis holography applications of holography –HNDT (Holographic 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

Nonlinear optics, basics SHG –THG – excited state spectroscopy – time domain and its applications – Laser induced fluorescence spectroscopy, stimulated Raman emission – medical applications, photo-chemical applications.

Lasers in Industry

Materials processing, Lasers in 3D Machining –drilling, cutting, welding –hardening, alloying – annealing –Lasers in Non-destructive Evaluations: Ultrasonics, Laser Profilometry, Digital shearography

Textbooks

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).

Course Outcomes (COs)

At the end of the course student will be able to

CO1	Understand the light matter interaction and lasing principles
CO2	Appreciate the design concepts of high-power lasers
CO3	Understand the basics of fiber-optics based devices
CO4	Realize the non-linear optics and lasers in practical applications

PHMI17 Sensors and Transducers

Course Code	**:**	PHMI17
Course Title	**:**	Sensors and Transducers
Type of Course	**:**	MI
Prerequisites	**:**	-
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLOs)

CLO1	To introduce the basic concepts of various sensor transducers used in industrial applications.
CLO2	To introduce the concepts of thermal, position, displacement, acceleration, and pressure sensors
CLO3	To introduce the physics of flow, acoustic, humidity, and chemical sensors.
CLO4	To introduce the physics of flow, acoustic, humidity, and chemical sensors.

Course Content

Temperature Sensors

Introduction to sensors – classification of sensor – sensor characteristics– thermal sensors - gas thermometric sensors – thermal expansion type sensors – thermo-resistive 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 – farinfrared 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 – fiezoelectric 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.

Textbooks

1. D. Patranabis, Sensors and Transducers, 2 nd 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, 6 th 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).

Course Outcomes (COs)

At the end of the course student will be able to

CO1	Understand the working principle and applications of various types of sensors.
CO2	Appreciate the concepts of sensors used for temperature, pressure, position, and displacement.
CO3	Understand the basics of flow, acoustic, humidity and chemical sensors.
CO4	Understand the functioning of smart sensors.

PHMI18 Nanoscience and Technology

Course Code	**:**	PHMI18
Course Title	**:**	Nanoscience and Technology
Type of Course	**:**	MI
Prerequisites	**:**	-
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLOs)

CLO1	To impart basic knowledge on exotic properties of materials at nanoscale, and synthesis methods
CLO2	To teach various techniques available for the processing and characterization of nanostructured materials.
CLO3	To impart knowledge on materials, their behaviors at mesoscopic scale, magnetic measurements and applications in magnetic recording technology.
CLO4	To help students to understand the developments in nanoelectronics and biomedical field.

Course Content

Nanomaterials:

Introduction & Synthesis Structure and bonding in nanoscale- size effect on physical properties – Graphene, Fullerene, CNT – Quantum dots - Synthesis: top-down, bottom-up: nucleation & growth, gas condensation, Sol-gel, Chemical Vapor Deposition, Molecular Beam Epitaxy methods

Characterization Tools

Electron Microscopy Techniques – Scanning Electron microscopy, Tunneling Electron Microscopy, X-ray methods – optical methods: fluorescence Microscopy – single molecule surface enhanced resonance – Raman spectroscopy – Scanning probe Microscopy: Scanning Tunneling Microscopy, Atomic Force Microscopy.

Nanomagnetism

Mesoscopic magnetism – mesoscopic magnetic materials –magnetic measurements: miniature Hall detector, integrated DC SQUID Microsusceptometry – magnetic recording technology: Giant Magnetoresistance, Tunneling magnetoresistance, magnetic read/write - biological magnets.

Nanoelectronics and Integrated Systems

Basics of nanoelectronics -single electron transistor – quantum computation & parallel architecture for nanosystems, MEMS/NEMS: micromachining-LIGA- Nano/Microfluidics: behavior of liquid in micro or nanosystems- lab-on-chip application

Biomedical Applications of Nanotechnology

Biological structures and functions – bio molecular motors: myosin, kinesin, ATP Synthase – drug delivery systems – organic-inorganic nanohybrids biosensors, magnetic hyperthermia

Textbooks

1. C.P. Poole and F.J. Ownes, Introduction to Nanotechnology, Wiley India (2007).
2. Cao G, Nanostructures and Nanomaterials: Synthesis, properties and applications, Imperial College Press (2004).
3. N. John Dinardo and Weinheim Cambridge, Nanoscale Characterisation of Surfaces & Interfaces, 2nd edition, Wiley-VCH (2000).
4. an Korvink and Andreas Greiner, Semiconductors for Micro and Nanotechnology – an Introduction for Engineers, Weinheim Cambridge: Wiley-VCH (2001).
5. Molecular Sensors and Nanodevices; Principles; Designs and Applications in Biomedical Engineering; JXJ Zhang, K Hoshino, Elsevier (2014).

Reference Books

1. Dieter Vollath, Nanomaterials: An Introduction to Synthesis, Properties and Applications, John Wiley and Sons (2013).
2. G. Timp (ed), Nanotechnology, AIP Press, Springer (1999).
3. M. Wilson, K. Kannangara, G. Smith, M. Simmons and B. Raguse, Nanotechnology: Basic Sciences and Energy Technologies, Overseas Press (2005).
4. M. S. Ramachandra Rao, Nanoscience and Nanotechnology: Fundamentals to Frontiers, Wiley (2013).
5. Nguyen, N-T and Wereley, S “Fundamentals and Applications of Microfluidics”, 2nd Edition, Artech House, Boston (2019).
6. H. Baltes et al, Enabling technology for MEMS and Nanodevices, Wiley-VCH (2008).

Course Outcomes (COs)

At the end of the course student will be able to

CO1	Describe material behaviors at the nanoscale and important experimental tools in the fields of nano-science.
CO2	Understand the quantum mechanical tunneling of electrons, oscillatory coupling GMR effect, and related applications in devices and MEMs.
CO3	Familiarize with the applications of nanotechnology in magnetic recording, quantum computation, and nanofluidics.
CO4	Understand specific applications in biological devices, drug delivery, biosensors, and magnetic hyperthermia.

PHMI19 Physics and Technology of Thin Films

Course Code	**:**	PHMI19
Course Title	**:**	Physics and Technology of Thin Films
Type of Course	**:**	MI
Prerequisites	**:**	-
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLOs)

CLO1	To understand the basic concept and kinetics of the thin films.
CLO2	To learn different thin film growth techniques.
CLO3	To study different characterization techniques of thin films.
CLO4	To gain knowledge on thin film device fabrication.

Course Content

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 (Al1-xGaxAs, Ga1-xInxP, InAs1-xPx, etc.) and quaternary (Ga1-xInxAs1-yPy, 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).

Textbook

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).
4. Milton Ohring, Material Science of Thin films, 2nd Edition Academic Press (2002)

Course Outcomes (COs)

At the end of the course student will be able to

CO1	Have thorough knowledge on the fundamental concept of thin films.
CO2	Have clear exposure and knowledge of different thin film growth techniques.
CO3	Earn good knowledge on the characterisation of thin films to investigate its properties.
CO4	Be moulded to do high-level research in thrust areas like LEDs, Laser, solar cells, storage devices etc.