CURRICULUM & SYLLABI

Minor in

APPLIED PHYSICS

Effective from AY: 2024-25

(for all B.Tech. students)



NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

WARANGAL, TELANGANA

CURRICULUM
Minor in Applied Physics

S.No.	Code	Course Title	L-T-P	Credits
1	PH1M01	Physics of Semiconductor Devices	3-0-0	3
2	PH1M02	Fabrication and Testing of Optical Materials and Devices	3-0-0	3
3	PH1M03	Science and Applications of Luminescence	3-0-0	3
4	PH1M04	Physics of Nanomaterials and Applications	3-0-0	3
5	PH1M05	Computational Physics	3-0-0	3
			Total Credits	**15**

SYLLABI
Minor in Applied Physics

PH1M01 **3-0-0 (3)**

Physics of Semiconductor Devices

Pre-Requisites: None

Course Outcomes:

CO-1	Understand the basic properties of semiconductors including the band gap, charge carrier
CO-2	Knowledge of semiconductor carrier properties and statistics.
CO-3	Analyze PN junctions in semiconductor devices under various conditions.
CO-4	Explain the working, design considerations and applications of various semiconducting devices including p-n junctions, BJTs and FETs.
CO-5	Understand BJT switching

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	3	2	-	-	-	–	–	–	–	–	–	–	–	–	–	–
CO-2	3	3	3	-	-	–	–	–	–	–	–	–	–	–	–	–
CO-3	2	3	2	3	2	–	–	–	–	–	–	–	–	–	–	–
CO-4	3	3	3	2	2	–	–	–	–	–	–	–	–	–	–	–
CO-5	3	2	-	-	-	–	–	–	–	–	–	–	–	–	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Semiconductors: Energy Band and Charge Carriers: Energy bands in semiconductors, Types of semiconductors, Charge carriers, Intrinsic and extrinsic materials. Carrier concentration: Fermi Level, Electron and hole concentration equilibrium, Temperature dependence of carrier concentration, compensation, and charge neutrality. Conductivity and mobility, Effect of temperature, Doping and high electric field.

Optical Excitation in Semiconductor: Optical absorption, carrier generation, Carrier lifetime, diffusion length and photo conductivity, Direct and indirect recombination and trapping, Photoconductive devices. Diffusion of carriers, Einstein relation, Continuity equation, Carrier injection, Diffusion length. Haynes-Shockley experiment.

Junctions: p-n junction and contact potential, Fermi levels, Space charge, Reverse and Forward bias, Zener, and Avalanche breakdown. Capacitance of p-n junction, Schottky barriers; Schottky barrier height, C-V characteristics, current flow across Schottky barrier: thermionic emission, Rectifying contact and Ohmic contact.

Field Effect Transistors: JEFT amplifying and switching, Pinch off and saturation, Gate control, I-V characteristics. MOSFET, Operation, MOS capacitor, Debye screening length, Effect of real surfaces; Work function difference, Interface charge, Threshold voltage and its control, MOS C-V analysis and time dependent capacitance. Output and transfer characteristics of MOSFET.

Bipolar Junction Transistors (BJT): Fundamentals of BJT operation. Minority carrier distribution, Solution of diffusion equation in base region, Terminal current, Current transfer ratio, Ebers-Moll equations, Charge control analysis. BJT switching: Cut off, Saturation, Switching cycle.

Learning Resources:

Text Books:

1. Sze, S.M., Physics of Semiconductor Devices, John Wiley, 2008, Third Edition.
2. Tyagi, M.S., Introduction to semiconductor materials and devices, John Wiley, 2008, First Edition.

Reference Books:

1. Mishra, Umesh K., Singh, Jaspreet, Semiconductor Device Physics and Design, Springer, 2008, First Edition.
2. Pierret, R.F., Semiconductor Device Fundamentals, Pearson, 2006, First Edition.

Others Suggested Readings:

1. https://nptel.ac.in/courses/108/108/108108122/
2. https://www.coursera.org/specializations/semiconductor-devices#courses

PH1M02 **3-0-0 (3)**

Fabrication and Testing of Optical Materials and Devices

Pre-Requisites: **PH17003**

Course Outcomes:

CO-1	Understand types of IR materials, optical crystals, optical plastics, metals, their properties and applications
CO-2	Select production methods for Optical glass, optical crystals, IR materials and Optical plastics
CO-3	Identify the shop supplies for making optical components
CO-4	Analyse/ Validate the optical components by Interferometry, spherometry, autocollimator and surface analyser
CO-5	Design optical systems

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	2	2	2	1
CO-2	3	2	3	2	2	2
CO-3	3	2	3	3	2	2
CO-4	2	3	2	2	2	2
CO-5	3	3	2	2	2	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Optical glass: types, composition, chemical behaviour, mechanical and thermal properties, low expansion materials, fused quartz, crystal quartz, mirror materials.

IR materials: Ge-Si – gallium arsenide, zinc selenide, zinc sulphide, optical crystals, alkaline earth fluorides, Alkali Halides, KDP and homologs, optical plastics, metal optics, ceramic materials.

Material production:
(a) glass making, dry and continuous tank methods, limitations, inspection for flaws
(b) IR materials manufacturing, chemical vapor deposition, CZ method, float zone refining, casting of silicon, horizontal Bridgeman, liquid encapsulated Czochralski.
(c) Growth methods for optical crystals, hydrothermal process, heat exchanger method, solution grown crystals.

Optical shop supplies: abrasives, polishing compounds, pitch, cements, coolants and solvents.

Tools and fixtures: spherical and plano tools, spot blocks, diamond tools

Optical fabrication: shaping-milling-grinding-polishing, centering, cementing, thin film coating

Optical shop testing: interferometric testing, spherometers, autocollimator, surface analysis, testing after assembly.

Learning Resources:

Text Books:

1. Hank H. Karow, Fabrication Methods for Precision Optics, John Wiley and Sons, New York, 1993

Reference Books:

1. David Malacara, Optical shop testing, John Wiley and Sons, New York, 1992.
2. Marvin J. Weber, Handbook of Optical Materials

Other suggested Readings:

1. Michael Hausner, Optics Inspections and Tests: A Guide for Optics Inspectors and Designers

PH1M03 **3-0-0 (3)**

Science and Applications of Luminescence

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the luminescence phenomenon in bulk and nanoforms.
CO-2	Understand the synthesis processes of phosphors at lower dimensions.
CO-3	Understand the importance of photometry and colorimetry in day-to-day scenario.
CO-4	Understand the structures of typical inorganic pc-LEDs and their characteristics
CO-5	Understand the basics of device physics and different strategies of making white-LEDs

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	2	2	1	1
CO-2	2	2	3	2	1	2
CO-3	3	2	2	3	2	1
CO-4	3	1	1	2	2	1
CO-5	2	2	1	1	1	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Fundamentals of Luminescence: Absorption and emission of light, electronic states and optical transition of solid crystals, Selection Rules, Luminescence of a localized centre, Impurities and luminescence in semiconductors, Luminescence mechanisms, Factors affecting the emission colour, Excitation energy transfer and cooperative optical phenomena, Inorganic electroluminescence, Luminescence quantum yield and quenching processes.

Phosphors at Lower Dimensions: Introduction to nanostructured materials and quantum dots, Structure and properties relationship, Quantum confinement effects on band gap, Relaxation processes of excitons, General synthesis routes: Top-down and bottom-up approaches, Types of surface passivation, Optical properties and applications

Materials for phosphor-converted LEDs: Inorganic LED structures and efficiencies, Typical LEDs and their characteristics, Requirements of colour conversion phosphors, Phosphor synthesis, Single and multi-phosphor converted LEDs, Quantum Dots LEDs.

Photometry and Colorimetry: Photopic and scotopic visions, photometric parameters and their measurement methods, colorimetry parameters, Colour space & its evolution by CIE, Measurement of CIE colour coordinates, Correlated colour temperature (CCT), and Colour rendering index (CRI), Spectral power distribution of LEDs.

Phosphor-converted LEDs and Other Devices: Phosphors for converting the colour of light emitted by inorganic LEDs, Commonly, used dopants in colour conversion phosphors, Strategies for generating white light from LEDs, Design and placement of phosphor in LEDs, Characteristics of n-

UV and blue to white LEDs, Applications of white and coloured LEDs, Future Prospects of other devices.

Learning Resources:

Text Books:

1. Luminescence of Inorganic Solids, Paul Goldberg, Academic Press, 1st edition, 1966.
2. Solid State Luminescence: Theory, Materials and Devices, A. H. Kitai, Ed., Springer, second edition, 2012.

Reference Books:

1. Luminescence of Liquids and Solids and its Practical Applications, Peter Pringsheim and Marcel Vogel, Interscience Publishers, 1st edition,1943.
2. Phosphor Handbook, William M. Yen, Shigeo Shionoya, Hajime Yamamoto, CRC Press, second edition, 2006.
3. Handbook of Luminescence, Display Materials and Devices, 3-Volume set, Hari Singh Nalwa, Lauren Shea Rohwer, American scientific publishers, 2003.

Other Suggested Readings:

1. https://www.britannica.com
2. https://www.rp-photonics.com

PH1M04 **3-0-0 (3)**

Physics of Nanomaterials and Applications

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand why nanomaterials exhibit varying properties compared to their bulk
CO-2	Distinguish various nanostructured materials based on size, shape, properties and functionalities
CO-3	Comprehend and choose appropriate method for synthesis of nano-structured materials
CO-4	Understand characterization techniques and estimate grain size and bandgap using formulations
CO-5	Understand and appreciate applications of various nanomaterials in a variety of fields

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	2	3	3	2	–	–	–	–	–	–	–	–	–	–	–	–
CO-2	3	3	3	2	–	–	–	–	–	–	–	–	–	–	–	–
CO-3	3	3	3	1	–	–	–	–	–	–	–	–	–	–	–	–
CO-4	2	3	3	2	–	–	–	–	–	–	–	–	–	–	–	–
CO-5	2	3	4	2	–	–	–	–	–	–	–	–	–	–	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to miniaturization: Historical background, Development of nanomaterials, units, Scaling laws, organization of matter- atoms, molecules, clusters and supramolecules.- Structure and Bonding, Hierarchical, molecular and crystalline structures - Bulk to surface transition, Quantum size effects, density of states, band gap and dimensionality, surface reconstruction, self-assembly.

Classification of Nanomaterials: Nomenclature of nanomaterials, 2D materials, Carbon based materials, self-assembled nanomaterials, core-shell particles, Nano metals, Nano- composites, contemporary nano-structured / nano-dimensional thin films

Physical and chemical methods for synthesis of Nanomaterials: Top down and bottom up approaches - Mechanical milling, evaporation, IGCT, vapour transport, molecular beam epitaxy, laser deposition, Colloidal and sol-gel techniques, size distribution, properties variation and yield of nanomaterials, Bio-inspired and template methods.

Nanomaterial characterization techniques: X-Ray Diffraction, Grain Size estimation, UV- Vis spectroscopy, Effect of grain size - Scanning and Transmission electron microscopy, Particle size analyzer, scanning probe/tunneling and Atomic force microscopy and surface techniques.

Applications of Nanomaterials: Mechanical, magnetic, electrical, optical, biocompatibility, toxicity, chemical, gas and bio-sensing, battery and energy harvesting applications, textiles, cosmetics, drug delivery, Magnetic hyperthermia, defense, and other contemporary applications.

Learning Resources:

Text Books:

1. Sulabha K. KulkarnI, Nanotechnology: principles and practices Springer publications, 2019, Third Edition.
2. T. Pradeep, NANO, The Essentials, Tata McGraw-Hill, 2008

Reference Books:

1. Edward L. Wolf, Nanophysics and Nanotechnology, Wiley-VCH, 2015, Third Edition.
2. Robert Vajtai, Springer Handbook of Nanomaterials, 2013.
3. B. Rogers, J Adams, S. Pennathur, Nanotechnology the Whole Story, CRC Press, 2013.

Others Suggested Readings:

1. https://www.classcentral.com/subject/nanotechnology

PH1M05 **3-0-0 (3)**

Computational Physics

Pre-Requisites: **Introductory Statistical Physics and Quantum Mechanics**

Course Outcomes:

CO-1	Understand basic C++ programming Language and Numerical Methods.
CO-2	Apply lattice Monte Carlo technique and Metropolis algorithm for thermal fluctuation.
CO-3	Numerical methods for solving stochastic differential equations using Runge–Kutta method.
CO-4	Understand Classical Molecular Dynamics simulations.
CO-5	Solve eigenvalue equation using matric diagonalization method.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6	PO-7	PO-8	PO-9	PO-10	PO-11	PO-12	PSO-1	PSO-2	PSO-3	PSO-4
CO-1	2	3	3	2	–	–	–	–	–	–	–	–	–	–	–	–
CO-2	3	3	3	2	–	–	–	–	–	–	–	–	–	–	–	–
CO-3	3	3	3	1	–	–	–	–	–	–	–	–	–	–	–	–
CO-4	2	3	3	2	–	–	–	–	–	–	–	–	–	–	–	–
CO-5	2	3	4	2	–	–	–	–	–	–	–	–	–	–	–	–

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Quick revision basic C++ programming Language and Numerical Methods. Basic Plotting software. Random Number: generation, testing, and plotting of uniform and given distribution of Numerical Integrations using deterministic and stochastic methods.

Monte Carlo: Phase transition in Ising model using lattice Monte Carlo technique and Metropolis algorithm. Computational implementing detailed balance and self-avoidance due to finite size. Implementing thermal fluctuations and calculating the average properties of the thermodynamic variables.

Differential Equation: Solving differential equations Linear, non-linear, and coupled differential equations. Numerical methods for solving stochastic differential equations using Runge–Kutta method.

Molecular Dynamics: Classical Molecular Dynamics simulations: Brownian Dynamics, Langevin Dynamics. Use of using Lennard-Jones' potential with Weeks Chandler Andersen (WCA) approximated potential.

Quantum Mechanics: Schrodinger Equation in Quantum Mechanics with Numerov's algorithm and a variational principle. Solving eigenvalue equation using matric diagonalization methods.

Learning Resources:

Reference Books:

1. Understanding Molecular Simulation, Daan Frenkel and Berend Smit, 2nd edition, 2002, Academic Press
2. An Introduction to Computational Physics Paperback, Tao Pang, 3rd edition, 2010, Cambridge University Press
3. Numerical Recipes, by William H. Press, Saul A. Teukolsky, William T. Vetterling, Brian P. Flannery, 3rd edition, 2007, Cambridge University Press