INDIAN INSTITUTE OF TECHNOLOGY MADRAS
CHENNAI 600 036

International Interdisciplinary Master's Programs
Curriculum
Master of Technology in Advanced Materials and Nanotechnology
(2022-2024)

Curriculum (Master of Technology in Advanced Materials and Nanotechnology) (2022-2024)

Overview

The International Interdisciplinary Master's Programs (I2MP) are specially curated two-year programs that provide international students from any engineering background with a great opportunity to be part of the vibrant and world-class learning environment at IIT Madras. This document is aimed at providing a brief overview of the syllabus for the program.

IIT Madras is one of the only educational Institutions in India to offer this Interdisciplinary Master's Degree, providing students an unprecedented level of academic flexibility to learn and work in current areas that would define the future of global engineering and technology.

The International Interdisciplinary Master's degrees are available in nine interdisciplinary areas:

- Energy systems,
- Robotics,
- Quantum Science and Technology,
- Computational Engineering,
- **Advanced Materials and Nanotechnology**,
- Data Science,
- Cyber Physical Systems,
- Complex Systems and Dynamics, and
- Biomedical Engineering.

The International Interdisciplinary Master's Program provides a platform for international students with exceptional performance in their undergraduate programs to participate in these activities. In addition to courses in Data Science, and Biomedical Engineering, among others, the international students will take up courses in Indian culture as well. A dedicated research skills course will prepare them for their master's thesis work.

IIT Madras is constantly striving to expand the horizons of traditional engineering education and research and is home to the best and brightest. The institute has a rich culture of deep research, technology development and entrepreneurship, which have been developed over the decades without compromise on the teaching/learning of foundational science and engineering.

The Interdisciplinary Master's programs - offered to international students via the I2MP (International Interdisciplinary Master's Program), and to Indian students through the hugely popular Interdisciplinary Dual Degree (IDDD) - represent the culmination of decades of excellence at IIT Madras.

The first batch of foreign students joined the program in July 2022.

Program Structure:

The 2-year program is offered over 4 semesters. Students complete Core Courses, Electives (Free and Core) and a Research project.

The core courses are designed to give a complete overview of the entire domain, the students are free to choose electives that will enable them to chalk out a further path of their choice. A large set of carefully selected electives are provided which will the student to explore a particular aspect of the program according to their area of interest. I2MP Core/Core courses should be completed during four semesters with the approval of faculty advisors and the ID coordinator.

Students will learn the skills of carrying out research in the research skills course. It is designed to build a foundation for the thesis work that will be completed in the third and fourth semester.

The thesis will involve one year of work completed in third and fourth semester and will be supervised by faculty from IIT Madras.

***Note:** This document is meant to be a guide and is subject to final approval by departments. There may be periodic revisions to the syllabus. Students are requested to confirm their course choices and electives with their respective program coordinators before registering.

Topic	Page

Basket of I2MP Core Courses

Course No.	Course Name	Semester	Course No.	Course Name	Semester
CH5020	Statistical Design and Analysis of Experiments	Jul - Nov	CE5235	Introduction to Climate Dynamics and its Mysteries	Jul – Nov
CH5650	Molecular Data Science and Informatics	Jan - May	ED5015	Computational Methods in Design	Jan – May
CH5170	Process Optimization	Jan –May	ED5017	Digital Signal Processing for Engineering Design	Jan – May
CH5019	Mathematical Foundations of Data Science	Jan - May	ED5317	Strategies for Managing innovation	Jul – Nov
CH5023	Unconventional Oil and Gas Resources	Jan - May	ED5340	Data Science: Theory and practice	Jul – Nov
EE6432	Stochastic Control	Jul - Nov	ED6002	Optimization methods in Engineering Design	Jul – Nov
EE6180	Advanced Topics in Artificial Intelligence		ED5318	Biomimetic Design	Jan –May
EE6150	Stochastic Modeling and the Theory of Queues		PH5820	Classical Physics	Jul - Nov
EE5413	Linear Dynamical Systems	Jul - Nov	PH5825	Quantum Physics	Jan-May
EE5412	Mathematical Methods in System Engineering	Jul - Nov	EE5120	Applied Linear Algebra	Jul – Nov
EE5401	Measurements and Instrumentation	Jul - Nov	ED5012	Advanced Applications of Human Factors	Jan –May
EE5121	Convex Optimization	Jul - Nov	ME5201	Computational Methods in Engineering	Jul - Nov
EE6430	Fundamentals of Linear Optimization	Jan - May	ME5204	Finite Element Analysis	Jul - Nov

EE6415	Nonlinear Control Systems	Jan - May	ME5207	Design with Advanced Engineering Materials	Jul - Nov
EE6412	Optimal Control	Jan - May	ME6355	Topology optimization	Jan –May
EE6150	Stochastic Modeling and the Theory of Queues	Jan - May	ME6127	Energy & Environment	Jan – May
EE6112	Topics in Random Processes and Concentrations	Jan - May	ME5204	Finite Element Analysis	Jan – May
EE5180	Introduction to Machine Learning	Jul – Nov	MA5892	Numerical Methods in Scientific Computing	Jul - Nov
AM6016	Convective Transport Processes	Jul – Nov	AM5090	Flow Visualization and Imaging Techniques	Jan – May
MA5910	Data Structures in Scientific Computing	Jul - Nov	MA5470	Numerical Analysis	Summer
PH6012	Fundamentals of Semiconductor Physics and Devices	Jan - May			

HSS Elective Courses Basket

Course Number	Course Number	Semester
HS6080	An Intro. to Classical Sanskrit Literature	
HS6026	Indian Aesthetic Thought	
HS5711	Ethics	Jul - Nov
HS5650	Drama	Jul - Nov
HS5712	Advanced Topics in Economic Development	Jul - Nov
HS5813	Post-Colonial & New Writings	Jul - Nov
HS6520	Culture and Development	Jan – May
HS6160	The Literature of Environmental Justice	Jul – Nov
HS5060	Technology & Sustainable Development	Jan – May

*All courses will be taken with the prior approval of faculty advisors and the ID coordinator.

Advanced Materials and Nanotechnology

Understanding the physics and chemistry of matter and processes at the nanoscale is essential to all scientific disciplines. Advanced Materials and Nanotechnology are both interdisciplinary research fields with opportunities to collaborate across diverse research areas and to share knowledge, tools, and techniques. The International Interdisciplinary Master's Program in Advanced Materials and Nanotechnology is carefully tailored to provide avenues to explore the rapidly expanding scientific horizons in these research areas where great strides are expected in the coming decades. The core courses of this program lay a solid foundation in this research area. The student can subsequently leverage upon the large basket of electives and choices of pursuing final year projects across participating departments.

S. No.	Course No.	Course Name	L	T	E	P	O	C
Semester 1								
1	GN5004	Research Skills	0	0	0	3	0	3
2		I2MP Core 1*						9 to 12
3	HS Elective							9 to 12
4	PH5011	Core 1: Science and Technology of Solid State	3	1	0	0	6	10
5	PH6022	Core 2: Introduction to Nanoscience	3	0	0	0	6	9
		Total Credits						40 to 46
Semester 2								
1	HS5050	Indian Culture	0	0	0	3	0	3
2		I2MP Core 2*						9 to 12
3	PH6011	Nanomaterials and Nanotechnology	3	0	0	0	6	9
4	PH6015	Advanced Materials and Nanotechnology Lab	0	0	0	6	2	8
5	Elective 1		3	0	0	0	6	9
6	Elective 2		3	0	0	0	6	9
		Total Credits						47 to 50
Summer								
1	PH5361	Project I (Summer) (in IITM)	0	0	0	0	25	25
		Total Credits						25
Semester 3								
1	Elective 3		3	0	0	0	6	9
2	Elective 4		3	0	0	0	6	9
3	PH5362	Project II (in IITM)	0	0	0	0	20	20
		Total Credits						38

Semester 4								
1	PH5363	Project III (in IITM)	0	0	0	0	40	40
		Total Credits						40

- Electives as per *Pg 57 & 58 of DD curriculum 2019*
- I2MP & HSS courses as mentioned in Pg 4-5 (PH courses may be preferred for the I2MP Core)

List of Electives								
1	PH5310	Synthesis of Functional Materials	3	0	0	0	6	9
2	PH5320	Techniques of Physical measurements	3	0	0	0	6	9
3	PH5730	Methods of Computational Physics	3	0	0	0	6	9
4	PH5670	Physics and Technology of Thin Films	3	0	0	0	6	9
5	PH5690	Applied Magnetics	3	0	0	0	6	9
6	PH5600	Physics at Low Temperatures	3	0	0	0	6	9
7	PH5680	Superconductivity and applications	3	0	0	0	6	9
8	PH6013	Functional materials, Sensors and Transducers	3	0	0	0	6	9
9	PH5813	Principles of nano photonics	3	0	0	0	6	9
10	PH5462	Magnetism in solids	3	0	0	0	6	9
11	PH5660	Non-linear Optical Processes & Devices	3	0	0	0	6	9
12	EE5347	Electronic and Photonic nanoscale devices	3	0	0	0	6	9
13	EE6500	Integrated Optoelectronics Devices and Circuits	3	1	0	0	6	10
14	ID6102	Principles and techniques of Transmission Electron Microscopy	3	0	0	0	6	9
15	ID5010	Advanced materials and processing	3	0	0	0	6	9
16	ID6050	Chemical Physics of Modern Technical Ceramics	3	0	0	0	6	9
17	ID6105	Computational Tools: Algorithms, Data Structures and Programs	3	0	0	0	6	9
18	MM5210	X-ray diffraction techniques	3	0	0	0	6	9
19	MM5680	Smart Materials	3	0	0	0	6	9
20	MM5700	Topics in nanomaterials	3	0	0	0	6	9
21	MM5017	Electronic materials devices and Fabrication	3	0	0	0	6	9

22	ME7023	Foundations of Computational Materials Modeling	3	0	0	0	6	9
23	CY6380	A Chemical Approach to Nanomaterials	3	0	0	0	6	9
24	CH5012	Modeling and Simulation of Particulate Processes	3	0	0	0	6	9
25	CH5021	Molecular Simulation of Soft Matter	3	0	0	0	6	9
26	CH5270	Polymers for Devices	3	0	0	0	6	9
27	CY6118	Experimental methods in chemistry	3	0	0	0	6	9
28	ID6030	Introduction to nano science and nanotechnology	3	0	0	0	6	9
29	EE5343	Solar Cell Device Physics and Materials Technology	3	0	0	0	6	9
30	EE5346	Introduction to plastic electronic	3	0	0	0	6	9
31	EE5340	Micro Electro Mechanical Systems	3	0	0	0	6	9
32	EE5312	VLSI Technology	3	1	0	0	6	10
33	CH5190	Introduction to Macromolecules	3	0	0	0	6	9
34	MM5041	Medical Materials	3	0	0	0	6	9
35	MM5460	Physical Ceramics	3	0	0	0	6	9
36	AM5470	Analysis & Design of Smart Material Structure	3	0	0	0	6	9
37	AM6190	Cellular structures and mechanics	3	0	0	0	6	9
38	AM6512	Application of Molecular Dynamics	3	0	0	0	6	9

Detail Syllabus of courses

Classical Physics - PH5820	
Description	A first course on classical physics for non-physics majors, covering the Lagrangian and Hamiltonian formulations, statistical mechanics and special relativity.
Course Content	Calculus of Variations, the action principle, the Lagrangian formulation, symmetries and conserved quantities, the Hamiltonian formulation, statistical physics, and special relativity.
Text Books	(1) S. T. Thornton and J. B. Marion, Classical Dynamics of Particles and Systems (Cengage Learning, Singapore, 2004). (2) H. Goldstein, C. Poole and J. Safko, Classical Mechanics, Third Edition (Pearson Education, Singapore, 2002). (3) F. Reif, Statistical Physics, Berkeley Physics Course, Volume V (Tata McGraw-Hill, New Delhi, 2008). (4) R. Resnick, Introduction to Special Relativity (Wiley Eastern, New Delhi, 1985).
Reference Books	(1) L. D. Landau and E. M. Lifshitz, Mechanics, Course of Theoretical Physics, Volume 1, Third Edition (Pergamon Press, New York, 1976). (2) D. Kleppner and R. J. Kolenkow, An Introduction to Mechanics (Tata McGraw-Hill, New Delhi, 1999). (3) C. Kittel, Elementary Statistical Physics (Wiley, New York, 1966). (4) A. P. French, Special Relativity (W. W. Norton, New York, 1968).
Prerequisite	

Introduction to Nanoscience - PH6022	
Description	To develop an understanding of the science behind various unique physical phenomena associated with the nano-metric scale.
Course Content	1. What is Nanoscience: Bulk, polycrystalline and single crystalline materials. Bulk physical properties -- electrical conductivity, thermal conductivity, specific heat, bandgap, reflectivity,

	magnetic property etc. Brief Historic perspective of nanoscience: Colored Glasses, IC Chips. Physics of low dimensional systems. [12 classes] 2.Band Theory, Optical and Electronic Properties at the Nanoscale: Band theory considerations to understand nanoscience. Schrödinger equation, quantum confinement effects: particle in a box, energy level quantization, Tunneling, Electronic band structure, Brillouin zone boundary scattering, basic aspects of diffraction. A complete account of the density of states formalism for low-dimensional systems. [12 classes] 3. Low Dimensional Systems: Dependence of key physical properties on dimensionality: Classification of nanomaterials - 2D, 1D, 0D systems with examples. 0D materials. Nano-clusters of metals and semiconductors, Bandgap tuning, Oxide Nanoparticles and their Optical Properties. 1D materials: Nanowires. Charge Transport in Nanowires. 2D materials: 2D electron gas, Hall effect, quantum Hall effect, Heterostructures and interfacial epitaxy, blue LED, Q-cascade lasers. Classical Interpretation of Magnetic Phenomena. Magnetism in low-dimensional systems. Magnetic Nanostructures. [10 classes] 4. Structure and Kinetics at the Nanoscale: Macro-, micro-, crystal- and atomic-structure aspects. Types of nanomaterials and nanostructures. Different shapes and sizes of nano systems. Geometric Surface-to-Volume Ratio. Diffusion kinetics in nanoparticles, theories to explain size-dependent cohesive energy. [10 classes]
Text Books	1. Introduction to Nanoscience and Nanotechnology, By Gabor L. Hornyak, H.F. Tibbals, Joydeep Dutta, John J. Moore, CRC Press, (2008). 2. Nanoscience and Nanotechnology: Fundamentals to Frontiers, M.S. Ramachandra Rao, Shubra Singh, Wiley India Pvt. Ltd., (2013).
Reference Books	1. Introduction to Nano: Basics to Nanoscience and Nanotechnology, A. Sengupta (Editor), C.K. Sarkar (Editor), Springer, (2015). 2. Nanostructures and Nanomaterials: Synthesis, Properties and Applications (World Scientific Series in Nanoscience and Nanotechnology), G. Cao, Y. Wang, World Scientific, (2011). 3. Introduction to Nanoscience, Stuart Lindsay, OUP Oxford, (2009).
Prerequisite	

Research Skills - GN5004	
Description	This course is meant to build research skills in post-graduate students. For students entering postgraduate programs from a course-heavy undergraduate program, the basic tools for a healthy relationship with research need to be explicitly brought to bear. The course will involve the practice of research paper review and critical analysis, literature search, and communication & interpersonal skills for researchers. ● Understand the roles and responsibilities of researchers ● Identify attitudes and habits required for success in research ● Recognise ethical & safety issues ● Perform detailed literature search harnessing modern tools ● Practice reading and critical analysis of peer-reviewed research articles ● Communicate & analyse sample research findings in various format (posters, PPTs, reports)
Course Content	● Introduction to research ● Literature search ● Critical analysis of research articles ● Technical writing ● Lab safety ● Ethics, Workplace diversity
Text Books	● The Elements of Style by William Strunk Jr. and E. B. White, 2003 ● The Joy of Research by C. Balaji, 2015 ● The Grammar of Science - Karl Pearson ● Truth and Beauty - Aesthetics and Motivations in Science - S. Chandrasekhar ● Advice to a Young Scientist - P. B. Medawar ● Science and Hypothesis - H. Poincare
Reference Books	Will be shared as required
Prerequisite	

Science and Technology of Solid State - PH5011	
Description	The course will deal interesting phenomena that are not only relevant from a fundamental point of view, but often have important applications. The aim is to bring students into contact with modern research topics, and at the same time to lay a good foundation in the physics of atoms, molecules and condensed matter. The course deals with exploration of materials with novel physical characteristics, applying these fundamental properties in engineering artificial, mostly nanoscale, device structures.
Course Content	(1) Crystal Structure: Fundamental properties of condensed matter: Crystal systems, Bravais lattices, space groups, reciprocal lattice, crystal symmetries, packing fraction,), bonding in materials (covalent, ionic, metallic, van der Waals, hydrogen), X-ray diffraction for structure determination, neutron diffraction for (magnetic) structure determination and electron diffraction. Relate the reciprocal lattice to the crystal lattice (structure), lattice vibrations (thermal, acoustic and optical properties)(2) Physical Properties: From atoms to solids, classification of solids (crystalline, nanocrystalline, protocrystalline, amorphous), band structure of metals and semiconductors, superconductivity, dielectric and ferroelectrics and magnetic properties of materials; Density of States, mobility bandgap and optical bandgap

	(direct and indirect), Electrical conductivity in crystalline, polycrystalline and amorphous materials, Theory of optical absorption – absorption processes, direct and indirect, recombination processes in crystalline and amorphous materials, photoconductivity, luminescence. (3) Semiconductors: Introduction and basics of semiconductor physics, Metal/semiconductor junction, Ideal p-n junction, electrostatic and current conduction, effect of voltage and light bias, recombination at the junction.(4) Modern Condensed Matter, Devices and Applications: Various phenomena and solid state systems in modern condensed matter; the quantum Hall effect, single-electron tunneling, spintronics, plasmonics, (nano)photonics, photonic crystals, coherent atoms in optical lattices, quasicrystals, Hot carriers, Upconversion, Down conversion, Intermediate band gap (IBG), multiple carrier generation, metamaterials, phase change materials, plasma dust, quantum dots, quantum wires, (Carbon) nanotubes, graphene, nano-antenna, (moth-eye) ARC, organic semiconductor Device applications; semiconductor lasers, (O)LED, solar cells, TFT, Displays, memory, sensors, Plastic electronics
Text Books	J.R. Hook & H.E. Hall, Solid State Physics (Publisher: Wiley) (2nd Edition) (e.book available) Aschroft and Mermin Solid State Physics, Harcourt Asia PTE Ltd. (1976).
Reference Books	B.D. Cullity Elements of X-ray Diffraction, Addison-Wesley (1956).C. Kittel Introduction to Solid State Physics, John Wiley & Sons 8 Ed. (2004).M. Ali Omar Elementary Solid State Physics, Addison-Wesley (1975). A. J. Dekker Solid State Physics, Macmillan Publishers India (2000). F. Reif Statistical Physics: Berkeley Physics Course, McGraw-Hill (1967).Arthur Beiser Concepts of Modern Physics, McGraw-Hill (2006).Rolf E. Hummel Electronic Properties of Materials, Springer (2001). David J. Griffiths Introduction to Quantum mechanics, Prentice Hall (1994). David Jiles Electronic Properties of Materials, Nelson Thornes Ltd. (2001).B.D. Cullity Introduction to Magnetic Materials, Addison-Wesley (1972).S.M. Sze Physics of Semiconductor Devices, John Wiley & Sons 8 Ed. (2007).P.R.L. Regtien Measurement science for engineers, Springer-Verlag London Limited (2007).Stephen Blundell Magnetism in Condensed Matter, Oxford University Press (2001).
Prerequisite	

Advanced Materials and Nanotechnology Lab - PH6015	
Description	To introduce laboratory techniques for the synthesis and characterization of advanced materials, and techniques in nanotechnology.
Course Content	Growth of thin films using PVD, synthesis of materials such as carbon nanomaterials, magnetic nanoparticles and 2D systems. Characterization of the above materials using techniques such as SEM, TEM, Raman spectroscopy, XRD, magnetization studies, XPS, AFM and electrical transport. Hardness test and electrical transport studies on nanocrystalline diamond. Photo I-V characterization of solar cells.
Text Books	Handout notes will be provided.
Reference Books	Handout notes will be provided.
Prerequisite	

Application of Molecular Dynamics - AM6512	
Description	The primary objective of this course is to introduce the concept, theory and applications of Molecular Dynamics to the students of different departments such as Applied Mechanics, Chemistry, Biotechnology, Materials Science etc. Another objective is to help students in developing fundamental skill of building models, running simulations and analyzing Molecular Dynamics (MD) data which will be extremely helpful in their future research.
Course Content	Introduction; Concept of Length Scale & Time Scale; Hierarchy in materials (e.g. bone, nanocomposites, clay); Different material characterization techniques (e.g SEM, TEM, AFM, Nanoindentation, etc); Limitations of experimental techniques and necessity of molecular modelling for further details; Introduction to different modeling (simulation) techniques (e.g. MD, CG, DEM, FEM etc); Concept of multiscale modeling. Theory of Molecular Dynamics (MD); MD and its general applications; mathematical formulation of MD; Energy terms and Concept of force field; Different potentials (bonded and non-bonded) and their suitability to material types; PBC; Ewalds summation techniques; Force field parameter derivations; Steps in running MD. Application of MD; Lipid protein interaction; Surface modifications – organic and inorganic; Functionalization of polymers; Interactions in Polymer clay nanocomposites; Protein-ligand interactions; Clay water interactions; Ion channels; Artificial bone. Analysis of MD Data; Auto correlation functions; Radial Distribution Functions; Thermodynamic properties; Binding Energy & Total Free energy; Mechanical properties; Interface adhesion
Text Books	**1.** Molecular Dynamics Simulation: Elementary Methods, J. M. Haile, Wiley Professional, 1997. **2.** Molecular Modelling: Principles and Applications (2nd Edition): A. R. Leach, Prentice Hall, 2001

Reference Books	**1.** Understanding Molecular Simulation, Second Edition: From Algorithms to Applications. Frenkel & Smit, Academic Press, 2001
Prerequisite	NULL

Application of Molecular Dynamics - AM6512	
Description	The primary objective of this course is to introduce the concept, theory and applications of Molecular Dynamics to the students of different departments such as Applied Mechanics, Chemistry, Biotechnology, Materials Science etc. Another objective is to help students in developing fundamental skill of building models, running simulations and analyzing Molecular Dynamics (MD) data which will be extremely helpful in their future research.
Course Content	Introduction; Concept of Length Scale & Time Scale; Hierarchy in materials (e.g. bone, nanocomposites, clay); Different material characterization techniques (e.g SEM, TEM, AFM, Nanoindentation, etc); Limitations of experimental techniques and necessity of molecular modelling for further details; Introduction to different modeling (simulation) techniques (e.g. MD, CG, DEM, FEM etc); Concept of multiscale modeling. Theory of Molecular Dynamics (MD); MD and its general applications; mathematical formulation of MD; Energy terms and Concept of force field; Different potentials (bonded and non-bonded) and their suitability to material types; PBC; Ewalds summation techniques; Force field parameter derivations; Steps in running MD. Application of MD; Lipid protein interaction; Surface modifications – organic and inorganic; Functionalization of polymers; Interactions in Polymer clay nanocomposites; Protein-ligand interactions; Clay water interactions; Ion channels; Artificial bone. Analysis of MD Data; Auto correlation functions; Radial Distribution Functions; Thermodynamic properties; Binding Energy & Total Free energy; Mechanical properties; Interface adhesion
Text Books	**1.** Molecular Dynamics Simulation: Elementary Methods, J. M. Haile, Wiley Professional, 1997. **2.** Molecular Modelling: Principles and Applications (2nd Edition): A. R. Leach, Prentice Hall, 2001
Reference Books	**1.** Understanding Molecular Simulation, Second Edition: From Algorithms to Applications. Frenkel & Smit, Academic Press, 2001
Prerequisite	NULL

Fundamentals of Semiconductor Physics and Devices - PH6012	
Description	Learning Objectives: At the end of the course the students are expected to achieve- (a) Understanding of basic physical process in semiconductors (b) Analysis of the charge conduction across p-n junctions and devices (c) Designing of experiments for measuring semiconductor parameters and properties.

Course Content	Review of the Band theory of solids, Metal, Insulator and Semiconductor, Effect of temperature and electric field on the band structure, Concept of Fermi energy, Concept of electron and hole, concept of effective mass; p and n type doping, heavy doping and degeneracy. Direct and indirect band gap semiconductors and their identification. Allowed and forbidden transitions, phonon assisted transition and their spectral shapes, Burstein Moss effect; Excitons: free and bound. Electrical conductivity and mobility of charge carriers; mechanisms of scattering; Generation and recombination of charge carriers; Hall-Shockley-Reed theory of recombination Equilibrium and non-equilibrium processes, Charge transport equation Metal-semiconductor junctions, Ohmic and Schottky contacts, Schottky barrier and barrier lowering effects Theory of p-n junction, concept of depletion later, resistance and capacitance across the depletion layer Charge transport in a p-n junction; Practical junctions and Ideality factor; Space charge and diffusion capacitances. Surface states and related band bending Measurement of carrier type and mobility - Hall effect; Measurement of band gap-optical absorption spectroscopy; Effective mass- Cyclotron resonance experiment, Impurity profiling through capacitance measurements; Conductivity measurement Diodes – Zener, Tunnel, LED, Gunn, Laser and other diodes; Transistors – unipolar and bipolar; Solar cells, Photodetectors
Text Books	**1.** Semiconductor Physics and Devices by Donald Neaman (Tata McGraw Hill) **2.** Fundamentals of Semiconductor Devices by Achuthan and Bhat (Tata McGraw Hill)
Reference Books	**1.** Physics of semiconductor devices by S O Kasap **2.** Semiconductor Devices by S M Sze (Wliey) **3.** Physics of Semiconductor Devices by Michael Shur (Pearson)
Prerequisite	Basic solid-state physics, Familiarity with Band s

Indian Culture - HS5050	
Description	This course is an introduction to Indian culture, history, philosophy, religion, economy, society, art, architecture, fine arts, literature, science and technology. The course would be a survey of ancient, medieval, modern and contemporary India. The orientation of the course is to provide a practical understanding of India's "unity in diversity" while utilizing textual resources to provide a theoretical framework. Documentaries, films, field visits to museums, archaeological sites, historical places and music and dance concerts would form an integral part of the course work to show the linkages with the past and to analyze how relevant the past is to an understanding of contemporary India. **Outcomes**: Students would gain a nuanced understanding of the complex cultural history of the Indian subcontinent which possesses mind boggling diversity of religions, regions, languages, ethnicity and socio-economic groups. This course would also highlight the challenges of negotiating diversity in contemporary India. It would highlight how Indian democracy serves as the crucible of contestation and dialogue between variegated viewpoints.
Course Content	**1.** Ancient India - An overview of Indus Valley Civilization **2.** Political economy and society in Ancient India **3.** The origins of Art, culture, philosophy and religion in various regions of Ancient India **4.** An introduction to early Hinduism, Buddhism and Jainism 4. Early Medieval India - The history of three powerful kingdoms - Harshavardhana, Pulakesin-II and Mahendravarma and Narasimhavarma Pallava **5.** Medieval Art and Architecture - Ajanta, Ellora, Mamallapuram, Kailasanatha, Brihadeeswara, Gangaikonda Cholapuram, Srirangam, Madurai, Chidambaram and Darasuram **6.** Indo-Saracenic art and architecture - Taj Mahal, Agra and Delhi Red Forts, Jaipur Hawa Mahal, Bada Imambara Lucknow - Chikan **7.** Sufi Islam, Medieval devotional movements and the origins of Sikhism as a new faith **8.** Indian Medicine - Charaka, Susruta and Vagbhatta **9.** Science and Technology tradition in India - Bhaskara, Aryabhatta and Brahmagupta **10.** Mughal Empire - state and economy **11.** India under the British rule - East India Company, 1857 First War of Independence and India under the British Crown **12.** India's Freedom Movement, Round Table Conferences and Partition - Tilak, Gandhi, Nehru, Patel, Ambedkar, Jinnah, Azad and Prasad **13.** India's Constituent Assembly Debates **14.** Post-independence India - 1947 to 2021
Text Books	**1**. Basham, A.L., (ed) A Cultural History of India, Oxford: Oxford University Press, 1975. **2**. Guha, Ramachandra, India After Gandhi: The History of World's Largest Democracy, New Delhi: Picador India, 2017. **3**. Austin, Granville, Working in a Democratic Constitution: A History of the Indian Experience, Oxford: Oxford University Press, 2003.
Reference Books	**1**. Pulakkat, Hari, Space, Life, Matter: The Coming of Age of Indian Science, Gurugram: Hatchette India, 2021. **2**. Coomaraswamy, Ananda, The Dance of Shiva, New Delhi: Rupa Publications, 2013. **3**. Guha, Ramachandra, Gandhi Before India, New Delhi: Penguin India, 2013. **4**. Basham, A.L., The Wonder That Was India, New Delhi: Picador India, 2004. **5**. Austin, Granville, The Indian Constitution: Cornerstone of A Nation, Oxford: Oxford University Press, 1999. **6**. Nehru, Jawaharlal, The Discovery of India, New Delhi: Penguin India, 2008.

	7. Narayan, R.K., Malgudi Days, Mysore: Indian Thought Publications, 1943. **8**. Eck, Diana L., India: A Sacred Geography, New York: Three Rivers Press, 2012. **9**. Lahiri, Nayanjot, Time Pieces: A Whistle-Stop Tour of Ancient India, Gurugram: Hachette India, 2018. **10**. Singh, Upinder, A History of Ancient and Early Medieval India: From Stone Age to the 12th Century, New Delhi: Pearson Education India, 2009.
Prerequisite	

Nanomaterials and Nanotechnology - PH6011	
Description	As a follow up of the first semester course where the students would have received nice introductory lectures on the basic aspects of low dimensional systems, quantum confinement etc., in this course, students will learn more about how to synthesize nanomaterials and how the synthesis methods influence the size and shape of nanosystems. They will learn about various characterization techniques. They will also get a glimpse of various technological aspects of nanosystems, including some useful industrial applications.
Course Content	Introduction to nanoscale objects: Nanoclusters, Nanosheets, Nanowires, Nanostructures. Basic synthesis methods of nanosystems: Top-down and bottom-up approaches. Experimental tools for nanoscience: Preparation, fabrication and manipulation of nanostructures. Lithography and etching processes: Photoresists, subtractive and additive pattern transfer, Lithographic methods; UV-and coherent UV lithography, electron beam lithography, x-ray and proton beam lithography, ion projection lithography, focused ion beam (FIB) lithography; Emerging nanolithographic methods; Nanoimprint Lithography, Nanoembossing, soft lithography, Near-Field lithography, Dip-pen lithography. Characterization of Nanomaterials and nanostrcutures: X-ray crystallography, peak broadening (Scherrer method), Optical techniques: Confocal Raman spectroscopy and Raman mapping, Time-resolved spectroscopy Electrical conductivity and Impedance, Specific heat measurements Electron microscopy (FESEM, HRTEM, STEM), and spectroscopy techniques (Atomic resolution EDS and EELS) , ARPES, XAS, EXAFS and atom probe techniques.

	SPM techniques (STM, AFM, PFM, MFM, SNOM, etc). Properties and Applications: Molecular electronics Nanomagnetism, nano-piezotronics and Spintronics Information storage; Magnetic recording. Magnetic nanoparticles, drug delivery, and cancer therapy. Optronics: Surface plasmons and nanoscale optics; semiconductor quantum dots; Photonic crystals Nanocrystalline diamond, nanostructured films for sensor and space applications. Nano Electromechanical systems (NEMS) etc.
Text Books	Nanoscience and Nanotechnology: Fundamentals to Frontiers , MSR Rao and Shubra Singh, Wiley
Reference Books	Nanomaterials: An Introduction to Synthesis, Properties and Applications, 2nd Edition, Dieter Vollath (2013) Nanoscience:Nanotechnologies and Nanophysics, C. Dupas P. Houdy M. Lahmani (Eds.), Springer 2004 Editions Belin, France. Nanophysics and Nanotechnology: An Introduction to Modern concepts in Nanoscience, Edward L. Wolf, Wiley-VCH Verlag GmbH and Co. (2004). Introduction to Nanoscience and Nanotechnology, Chris Binns, Wiley.
Prerequisite	

Computational Tools: Algorithms, Data Structures and Programs - ID6105	
Description	This is intended to be an intermediate course in the development of necessary tools for scientific problem-solving. The focus will be on learning data structures and algorithms through the code development process. The course would emphasize the self-learning aspect (need-based learning, on-demand learning) with reference to new programming paradigms and emerging coding practices from the Engineering industry.
Course Content	Fundamentals of programming, with emphasis on engineering problem solving; Broad spectrum of tools needed for Code development; Compilers, linkers, debuggers; Code (software) development process; Code optimization techniques, memory hierarchy, Performance measuring tools for programs; Utility of Data Structures such as Arrays and pointers, Linked lists, Queues, stacks and trees; Sorting and searching methods and their algorithmic efficiency; Implementation specific examples drawn from grid generators, mesh based and mesh-free methods used in engineering, other relevant engineering applications Introduction to Symbolic Computing; Using Maple and Mathematica for scientific problem solving; Demonstrating the utility and implementation of these tools in solving PDE’s.
Text Books	**1.** S R. Lerman, Problem solving and computation for scientists and engineers, PHI (1993).

	2. A.V. Aho et al., Data Structures and Algorithms, Pearson (2002). **3.** I.P.Stavroulakis and S.A. Tersian, Partial Differential Equations: An Introduction with Mathematica and Maple, World-Scientific (1999). **4.** R.E. Bryant and D.R.O'Hallaron, Computer Systems: A Programmers perspective, Pearson (2016). **5.** F.T. Willmore, et al., Introduction to Scientific and Technical Computing, CRC Press (2017).
Reference Books	**1.** J.A. Storer, An Introduction to Data Structures and Algorithms, Springer (2001). **2.** R Lohner, Applied CFD Techniques, Wiley (2008). **3.** I.K.Shingareva and C.Lizárraga-Celaya, Maple and Mathematica, 2nd Ed., Springer (2009). **4.** F.E. Harris, Mathematics for Physical Science and Engineering: Symbolic Computing, Elsevier (2014).
Prerequisite	Introduction to Computing or equivalent

Introduction of Macromolecules - CH5190	
Description	To give an overview of Polymers from a fundamental understanding based on the physics of macromolecules to graduate students doing research in the area of polymers. The course would be useful to understand how single polymer molecules of chains behave and how it is related to bulk properties and behaviour such as viscosity, mechanical/electric properties etc. Senior UG students can also benefit from this course since polymers are ubiquitous in nature and in a myriad of common as well as engineering applications.
Course Content	1. The structure of macromolecules, Terms and definitions, Degree of polymerization, Molecular weight and its distribution, Types and classification: thermoplastics, thermosets, elastomers, copolymers, natural polymers, biopolymers - polysaccharides, poly nucleic acids, lipids, proteins, applications of polymers, degradability 2. Configurations and conformations, three-dimensional structure of macromolecules 3. Polymer Single chain and its statistics, Ideal chain, Size of a polymer chain, Statistical properties, persistence length, Kuhn length, Entropy of a single chain, flexible, semi-flexible and rigid rod-like polymers 4. Interaction between macromolecules and solvents: molecular interactions, thermodynamics of mixing, multi-component mixtures, emulsions, dispersions, suspensions and solutions 4. Polymer blends and alloys, miscible and immiscible systems 5. Macromolecules in solid state, amorphous and crystalline polymers, glass transition, crystallization, liquid crystalline states

	6. Mechanical properties and linear viscoelastic properties of polymers 7. Proton and electron conduction in polymers 8. Flow behaviour of polymers
Text Books	
Reference Books	**1.** Fundamentals of Polymer Engineering, A Kumar and RK Gupta,Marcel Dekker 20032. **2.** Polymer Physics, UW Gedde, Chapman & Hall, 19953. Physics of Polymers, by G Strobel, SpringerVerlag, 19964. Molecular Biophysics, M Daune, Oxford University Press, 1999
Prerequisite	

Molecular Simulation of Soft Matter - CH5021	
Description	1. To introduce a range of molecular simulation techniques that are used in modeling soft matter in various time and length scales. 2. To demonstrate the predictive capabilities of these methods by considering a set of case studies.
Course Content	1. Introduction: Electronic, atomic, molecular and mesoscale soft-matter examples, interaction potentials [3 Lectures] 2. Essential principles of statistical mechanics: statistical ensembles, thermodynamic averages, fluctuations, structural quantities, time correlation functions and transport coefficients [8 Lectures] 3. Monte Carlo simulations: Metropolis algorithm in various ensembles, free energy calculations, configuration bias MC, reverse Monte Carlo, lattice Monte Carlo simulations [10 Lectures] 4. Molecular Dynamics: numerical algorithms to solve equation of motion, unconstrained and constrained dynamics (GROMACS package) [10 Lectures] 5. Brownian dynamics: over-damped dynamics (no hydrodynamics) [3 Lectures] 6. Applications: case studies on phase-equilibria, adsorption of polymers and surfactants of surfaces/interfaces, transport property calculations (diffusivity, viscosity), phase-behaviour of self-propelling colloids, self-assembly of surfactants and patchy colloids. [7 Lectures]
Text Books	**1.** Computer Simulation of Liquids, M. P. Allen., D. J. Tildesley, Oxford University Press,

	1989. **2.** Understanding Molecular Simulation, D. Frankel, B. Smit, Academic Press, 2001
Reference Books	**1.** Molecular Modeling: Principles and Applications, 2nd Ed., A. Leach, Prentice Hall, 2001. **2.** The Art of Molecular Dynamic Simulation, 2nd Ed., D. C. Rapaport, Cambridge University Press, 2004. **3.** Introduction to Modern Statistical Mechanics, D. Chandler, Oxford University Press, 1987. **4.** Introduction to Computational Chemistry, 2nd Ed., F. Jensen, Wiley, 2007. 5. Molecular Modeling Basics, J. H. Jensen, CRC Press, 2010.
Prerequisite	

Project I -PH5361, Project II – PH5362 & Project III – PH5363	
Description	Advanced Materials and Nanotechnology
Topic	Effect of Free Volume Distribution in Hydrogels Using Molecular Dynamics Simulations
Abstract	The polymer melts and hydrogel study with the help of free volume characterization and its effect on the polymer properties. The latest study involves the importance of the geometrical influence of pore size distribution on the relaxation of the polymer as well as their mechanical properties, such as modulus of elasticity. This also involves the types of water present in the hydrogel, such as tightly bonded water and bulky water. This is mainly focused on the atomistic study by molecular dynamics simulations. A brief insight into different types of probes and their corresponding free volume, as well as the sensitivity of the probe diameter. The temperature variation in an anhydrous system and the hydration percentage variation at room temperature are the main focus of the study. A brief study of relaxation type and its relationship with free volume is also enlightened.