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Central University of Tamil Nadu

(Established by an Act of Parliament, 2009)

Neelakudi Campus, Kangalancherry
Thiruvarur – 610 005, Tamil Nadu, India

DEPARTMENT OF MATERIALS SCIENCE
SCHOOL OF TECHNOLOGY

VISION

To evolve into a globally recognized department in the frontiers areas of Materials Science and Engineering

MISSION

1. To produce Materials Science graduates having professional excellence
2. To carry out quality research having social and industrial relevance
3. To provide technical support to budding entrepreneurs and existing industries.

Programme Specific Outcomes (PSO)

Name of the Programme	Outcomes
M.Tech Materials Science and Technology* (2016 onwards)	1. show consistent career growth in the field of materials science 2. become capable to design novel materials for sustainable technologies 3. develop new materials processes, improvise existing processes in accordance to industrial needs 4. shape themselves into successful entrepreneurs through commercializing the innovation in materials science 5. well-performing and globally recognized academic researchers/scientists in the field of materials science and technology
Ph.D. Materials Science (1002)	1. Become well versed in designing materials. 2. Show consistent career growth in the field of materials science 3. Create new materials processing, and improve current methods in line with the requirement of academics and industry 4. shape themselves into successful academic person 5. Globally recognized researchers/scientists in the field of materials science.

D. Graduate Attributes for
M.Tech Materials Science and Technology

1. Knowledge in the domain of materials science in sync with the current developments in research and academics
2. Communication Skills: Possess clarity in conveying ideas
3. Critical Thinking: Capacity to apply analytical thought in the designing of materials
4. Problem Solving: Participate in the research and development problems and apply the knowledge for self and societal growth
5. Forge cooperation and collaboration with materials scientists across the globe
7. Ethical and eco-friendly practices: Doing what is right for the environment and humanity
8. self-directed learning: developing self-sufficiency and self-discipline in professional development
9. creativity: the ability to create new materials, processes, methods, out-of-the-box materials solutions
10. Reasoning: ability to interpret and conclude from quantitative/qualitative data

Ph.D. Materials Science

1. Knowledge in the domain of materials science in sync with the current developments in research and academics
2. Communication Skills: Possess clarity in conveying ideas
3. Critical Thinking: Capacity to apply analytical thought in the designing of materials
4. Problem Solving: Participate in the research and development problems and apply the knowledge for self and societal growth
5. Forge cooperation and collaboration with materials scientists across the globe
7. Ethical and eco-friendly practices: Doing what is right for the environment and humanity

8. self-directed learning: developing self-sufficiency and self-discipline in professional development
9. creativity: the ability to create new materials, processes, methods, out-of-the-box materials solutions
10. Reasoning: the ability to interpret and conclude from quantitative/qualitative data

E. PSO to Mission Statement Mapping

(M.Tech)

M.Tech	PSO1	PSO2	PSO3	PSO4	PSO5
M1	3	3	2	2	1
M2	2	3	3	3	2
M3	3	3	3	3	3

(Ph.D)

Ph.D	PSO1	PSO2	PSO3	PSO4	PSO5
M1	3	2	2	3	2
M2	3	3	3	3	3
M3	3	2	3	3	2

F. Programme Outcomes (PO)

Name of the Programme	Outcomes

M.Tech Materials Science (2016-2019) Code: 1001	1. Understanding the interplay between the major aspects of materials science namely the composition, structure, processing, characterization, property, and performance 2. Hands-on training on interpretation, analysis, and reporting of research results in the field of materials science 3. Find innovative materials solutions to the existing challenges to humankind 4. Comprehension of scientific principles governing the field of materials science and technology 5. Equip students with a solid knowledge foundation for modern materials science and technology 6. Develop creative abilities and problem-solving and research fervor through the internship, mini, and major project courses

Ph.D. Materials Science (1002)	1. Understanding the importance of the major aspects of materials science namely the composition, structure, processing, characterization, property, and performance 2. Hands-on training on interpretation, analysis, and reporting of research results in the field of materials science 3. Find innovative materials solutions to the existing challenges to humankind 4. Capability to handle sophisticated instruments and analyze samples using them. 5. Interpretation of data and research problem-solving capability 6. Develop creative abilities and problem-solving and research fervor through the Ph.D. research work

*nomenclature change from M.Tech. Materials Science to M.Tech. Materials Science and Technology in 2021 through academic approval

G. PO to PSO Mapping

M.Tech

M.Tech	PO1	PO2	PO3	PO4	PO5	PO6
PSO1	3	3	3	2	3	3
PSO2	3	2	3	3	3	3
PSO3	3	2	3	3	3	3
PSO4	3	2	3	2	2	3
PSO5	3	3	3	3	3	3

Ph.D

Ph.D	PO1	PO2	PO3	PO4	PO5	PO6
PSO1	3	3	3	3	3	3
PSO2	3	3	3	2	3	2
PSO3	2	3	3	3	2	3
PSO4	3	3	2	3	3	3

PSO5	3	3	3	3	3	3

SEMESTER - I					
Course Code	**Course Name**	**L**	**T**	**P**	**Credits**
MST1911	Introduction to Materials Science	3	-	-	3

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	Level
CO 1	The students will be able to understand the fundamental concepts of materials science in the aspects of the structure of atoms, quantum states, bonding characteristics	Understand
CO 2	broad view of crystal structure classification, their types, close packing such fcc and hcp	Remember
CO 3	knowledge of semiconducting materials, classification into extrinsic and extrinsic to their application in microelectronic devices	Understand
CO 4	Understand the mechanical properties, stress-strain behavior including the optical properties and their applications as LASERS	Analyze
CO 5	Magnetic properties of materials, properties of materials, classification of magnetic materials	Analyze

b. Syllabus

Units	Content	Hrs.
I	Classification of Materials: Metals, Ceramics, Polymers, Composites, Advanced MaterialsMaterials of the future. Structure of atoms - Quantum States-Atomic bonding in SolidsImperfection in solids: Point defects, line defects, surface imperfection, grain boundaries, surface energy and equilibrium shapes of crystals- Importance of defects.	9

II	Fundamental concepts - Unit cells- Crystal systems- Crystallographic Points, Directions and Planes -Crystalline and non-crystalline materials: Single crystals- polycrystalline Materials Anisotropy-Noncrystalline solids - Metallic Crystal structures: FCC, BCC and HCP crystal structures, Atomic arrangements- Polymorphism and Allotropy.	9
III	Introduction to semiconducting materials - Bonding in Semiconductors -Classification of semiconductors: Carrier concentrations in intrinsic, extrinsic semiconductors- P-N junction: Application of voltage across a P-N Junction - Hall effect: Hall coefficients for intrinsic and extrinsic semiconductors - Hall Effect devices - Fermi level: Variation of conductivity, mobility with temperature- Insulators: Dielectric polarisation and mechanism- Dielectric properties.	9
IV	Types of mechanical properties- Factors affecting mechanical properties of metals -Elasticity and Plasticity of materials- Stress-strain behavior for metallic, ceramic, polymer materials ductile, low carbon steels and for different materials-Yield strength, tensile strength and modulus of elasticity-Hardness, toughness, Fatigue, creep and fracture-Optical properties: Light interaction with solids - absorption, refraction, diffraction, transmission, luminescence effects- Atomic, electronic interaction, Non-radiative transition, electro-optic materials, solid state LASERs.	9
V	Introduction -Classification of magnetism -Domain wall structure-Domain theory- Magnetic Hysteresis- Magnetic Anisotropy- High frequency application of ferrites -Types of magnetic materials: hard magnetic and soft magnetic materials, Superpara magnetic materials -Magneto-optic materials and their properties.	9

c. Mapping of Program Outcomes with Course Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	**3**	**1**	**3**	**3**	**3**	**3**
CO2	**3**	**1**	**3**	**3**	**3**	**3**
CO3	**3**	**1**	**3**	**3**	**3**	**3**
CO4	**3**	**1**	**3**	**3**	**3**	**3**
CO5	**3**	**1**	**3**	**3**	**3**	**3**

d. Evaluation Scheme

	CO1	CO2	CO3	CO4	CO5	Total
Internal	8	8	8	8	8	40
External	12	12	12	12	12	60
Total	**20**	**20**	**20**	**20**	**20**	**100**

e. Mapping Course Outcome with Internal Assessment (40 Marks)

	CO1	CO2	CO3	CO4	CO5
Assignments	2	2	2	2	2

Seminar	-	-	-	-	-
Test	6	6	6	6	6
Attendance	-	-	-	-	-
Total	8	8	8	8	8

f. Mapping Course Outcome with External Assessment (60 Marks)

Category	CO1	CO2	CO3	CO4	CO5
Part – A (Objective - 10 x 2 = 20 marks)	4	4	4	4	4
Part – B (Short Answer - 5 x 3 = 15 marks)	3	3	3	3	3
Part – C (Detailed answer- 5 x 5 = 25 marks)	5	5	5	5	5
Total	**12**	**12**	**12**	**12**	**12**

SEMESTER - I					
Course Code	**Course Name**	**L**	**T**	**P**	**Credits**
MST1912	Nanomaterials and Nanotechnology	3	-	-	3

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	Level
CO 1	The students will be able to understand the fundamental concepts of Nanoscience and Nanotechnology in the aspects of the size effects, quantum confinement effect and basic nanostructures.	Remember
CO 2	Broad view of chemical bonds and forces and interpret in-depth knowledge on surface energy.	Understand
CO 3	Knowledge of diffusion in nanostructures and their classification	Understand
CO 4	Understand the physicochemcal, optical, electrical and electronic properties and their comparsion.	Analyze
CO 5	Study of application of nanotechnology and check their use ir in various fields	Apply

b. Syllabus

Units	Content	Hrs.

I	Importance of size distribution and control -Effects of size on physio-chemical properties of nanomaterials - Size effects on surface area and aspect ratio- Quantum confinement effect- Size induced Metal Insulator Transition- Introduction to basic nanostructures - quantum dots, nanotubes, nanorods, nanowires, nanowells, nanofilms, nanocones, nanoribbons, nanoclusters, nanofoams, nanofibers, nanocrystals and carbon systems.	9
II	Introduction to chemical bonds and forces -Surface energy - Surface charge density- Chemical Potential and Surface curvature - Ostwald Ripening process - Stabilization against agglomeration -Electrostatic and Steric Stabilization- Interaction between two particles DVLO theory.	9
III	Diffusion in Nanostructures - Factors affecting diffusion - Surface, Volume and cross grain boundary diffusion - Growth controlled by diffusion - Diffusion kinetics - Kirkendall Effect- Classification of Nanomaterials- Nanoparticles by homogeneous nucleation and heterogeneous nucleation- VLS and SLS growth -Particle size, strain and grain size of nanomaterials.	9
IV	Introduction to Properties of nanomaterials, 1D, 2D and 3D quantum confinement, quantum effects on density of states, band gap energy, Brus-equation, Surface Plasmon Resonance, Role of size, Surface and Quantum confinement on properties of nanomaterials - Physicochemical, Optical, Electrical, Electronic, Magnetic, Thermodynamic, Mechanical, and Catalytic properties.	9
V	Application of Nanotechnology -Single Electron Transistor, Resonant Tunneling Diode, Quantum well and cascade lasers, Piezoelectric sensors, Energy storage devices -Molecular recognition and encapsulation, Multifunctional Organic/Inorganic materials for drug delivery applications- Chemical and Bio-Sensors.	9
	References: 1. W.Gaddand, D.Brenner, S.Lysherski and G.J.Infrate(Eds.), "Handbook of NanoSci, Eng. and Tech.", CRC Press, 2002. 2. T. Pradeep, "A Textbook of Nanoscience and Nanotechnology", Tata McGraw Hill Education, 2012. 3. C. P. Poole, Jr., F. J. Owens, "Introduction to Nanotechnology", Wiley, 2003. 4. B.Bhushan, "Springer Handbook of Nanotechnology", Springer-Verlag Berlin Heidelberg, 2004. 5. R. Kelsall, I.W. Hamley, and M. Geoghegan, "Nanoscale Science and Technology", John Wiley & Sons, 2005 6. G. Cao, "Nanostructures & Nanomaterials: Synthesis, Properties & Applications", Imperial College Press, 2004.	

c. Mapping of Program Outcomes with Course Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	3	3	3
CO2	3	3	2	3	3	3
CO3	3	3	2	3	3	3
CO4	3	3	3	2	3	3
CO5	3	2	3	3	3	3

d. Evaluation Scheme

	CO1	CO2	CO3	CO4	CO5	Total
Internal	8	8	8	8	8	40
External	12	12	12	12	12	60
Total	**20**	**20**	**20**	**20**	**20**	**100**

e. Mapping Course Outcome with Internal Assessment (40 Marks)

	CO1	CO2	CO3	CO4	CO5
Assignments	1	1	1	1	1
Seminar	-	-	-	-	-
Test	6	6	6	6	6
Attendance	1	1	1	1	1
Total	8	8	8	8	8

f. Mapping Course Outcome with External Assessment (60 Marks)

Category	CO1	CO2	CO3	CO4	CO5
Part – A (Objective - 10 x 2 = 20 marks)	4	4	4	4	4
Part – B (Short Answer - 5 x 3 = 15 marks)	3	3	3	3	3
Part – C (Detailed answer- 5 x 5 = 25 marks)	5	5	5	5	5
Total	**12**	**12**	**12**	**12**	**12**

SEMESTER - I					
Course Code	**Course Name**	**L**	**T**	**P**	**Credits**
MST1914	Thermodynamics and kinetics of Materials	3	-	-	3

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	Level
CO 1	On completion of the course, students can explain the concepts of thermodynamics and kinetics and special emphasis on metallurgical thermodynamics.	Remember
CO 2	Students may understand the laws of thermodynamics and kinetics	Understand

CO 3	Students can apply the laws of thermochemistry to various types of materials.	Apply
CO 4	Students can solve the problems based on thermodynamics and kinetics.	Analyze
CO 5	Students can handle the day-to-day problems associated with thermodynamics and kinetics and provide solutions.	Skill

b. Syllabus

Units	**Content**	**Hrs.**
I	Thermodynamics and Kinetics - different approaches -emphasize metallurgical thermodynamics, transport phenomena, and applications. Laws of thermodynamics and related applications, the definition of thermodynamic terms, Heat capacity, Enthalpy, Hess's law, Kirchhoff's law and applications	9
II	Thermochemistry & its applications, Heat of formation, heat of combustion, Carnot's cycle, heat engine, Concepts of free energy, entropy and chemical equilibrium, criteria for spontaneity. Gibbs Helmholtz Equation, Maxwell's Relation, Transformation Formula, Ellingham - Richardson diagram and applications	9
III	Introduction to solutions, solution composition, partial molar quantities, the relationship between solution volume and partial molar volumes, thermodynamic properties of the ideal solution, Raoult's Law. Ideally dilute solution, thermodynamic properties of ideally dilute solution, and Henry's Law. Non-ideal solutions, fugacity, Arrhenius Equation (Ea), activity coefficients, equilibrium constant, Gibbs-Duhem relations.	9
IV	.Thermodynamic aspects of phase diagrams- phase rule, phase equilibrium, enthalpy and entropy of phase change, Clapeyron equation, binary ideal solutions and its free energy curves, Kroger-Vink defect notations, thermodynamic aspects of defect formation in metals and ceramics.	9
V	Principles of metallurgical kinetics, topochemical reaction, Mckewan model, Johnson - Mehl's equation, types of reaction, parabolic law, molecularity and order of the reaction, related applications in metallurgical processes. Transport phenomena, Mass transfer: properties of the mixture, diffusion flux, Fick's law, relation among molar fluxes, diffusivity. Heat transfer: conduction, convection, radiation.	9

	Tasks and Assignments: **References:** **1.Atkin's Physical Chemistry, by Peter Atkins and Julio De Paula, 8th Edition, Oxford Press, 2018.** **2. Physical Chemistry Through Problems, 2015, by Dogra S K, Publisher: New Age International Publisher.** **3. Physical Chemistry 6th Ed, by Ira N Levine, 2011,** **4. Gaskell, David R., Introduction to the thermodynamics of materials, 6th Ed, 2017, CRC press** **5. Mohanty, A. K., "Rate Processes in Metallurgy", Revised Ed, 2009, Prentice Hall of India (EEE).** **6. Problems in Metallurgical Thermodynamics and Kinetics: International Series on Materials Science and Technology (Materials Science & Technology Monographs), 2013, by G. S. Upadhyaya and R. K. Dube. Publisher: Pergamon.** **7. Kinetics of Materials 1st Edition by Robert W. Balluffi, Samuel M. Allen, W. Craig Carter, Publisher: Wiley-Interscience; 1 edition, 2005.** **8. Kinetics in Materials Science and Engineering 1st Edition, by Dennis W. Readey, 2017, Publisher: CRC Press.** **9. R. P. Rastogi, R. R. Misra, An Introduction to Chemical Thermodynamics, 6th edn., Vikas Pub. Pvt. Ltd. (2003).** **10. B. R. Puri, L. R. Sharma, M. S. Pathania, Elements of Physical chemistry, VishalPub. Co. Jalandhar.**	

c. Mapping of Program Outcomes with Course Outcomes

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	3	3	2	3	3
CO2	3	3	2	3	3	3
CO3	3	2	3	3	3	3
CO4	3	3	3	2	3	3
CO5	2	3	3	3	3	3

d. Evaluation Scheme

	CO1	**CO2**	**CO3**	**CO4**	**CO5**	**Total**
Internal	8	8	8	8	8	40
External	12	12	12	12	12	60
Total	**20**	**20**	**20**	**20**	**20**	**100**

e. Mapping Course Outcome with Internal Assessment (40 Marks)

	CO1	**CO2**	**CO3**	**CO4**	**CO5**

Assignments	1	1	1	1	1
Seminar	1	1	1	1	1
Test	5	5	5	5	5
Attendance	1	1	1	1	1
Total	8	8	8	8	8

f. Mapping Course Outcome with External Assessment (60 Marks)

Category	CO1	CO2	CO3	CO4	CO5
Part – A **(Short answer - 10 x 2 = 20 marks)**	4	4	4	4	4
Part – B **(Medium length Answer - 5 x 3 = 15 marks)**	3	3	3	3	3
Part – C **(Long Answer- 5 x 5 = 25 marks)**	5	5	5	5	5
Total	**12**	**12**	**12**	**12**	**12**

g. Rubric for Assignments

Sl. No.	Criteria	100%	75%	50%	25%	0%	Relation to COs
1	**Content** **50%**	Ideas are detailed, well developed, supported with specific evidence & facts and examples	Ideas are detailed, Developed and supported with evidence and facts mostly specific.	Ideas are presented but not particularly developed or supported;	Content is not sound	Not attended	CO1, CO2, CO3
2	**Organiza-tion** **50%**	Includes title, introduction, statement of the main idea with illustration and conclusion.	Includes title, introduction, statement of main idea and conclusion.	organizational tools are weak or missing	No organization	Not attended	CO3, CO4, CO5

SEMESTER - I					
Course Code	**Course Name**	**L**	**T**	**P**	**Credits**

MST1913	Synthesis and Characterization of Materials	3	-	-	3

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	Level
CO 1	The students are expected to understand basic principles of the synthesis methods involved in nanomaterials - limitations of synthesis methods	Understand
CO 2	Comprehensive understanding of bottom-up and top-down approach - specifically for certain materials	Analyze
CO 3	Advanced Fabrication methods for thin films with examples	Apply
CO 4	Sophisticated characterization instruments - fundamentals, principles and working mechanisms to be understood	Understand
CO 5	knowledge on various spectroscopic techniques required for sample characterization; thermal analysis and magnetic characterization techniques included	Remember

b. Syllabus

Units	Content	Hrs.
I	Synthesis of nanomaterials: Gold, Silver, different types of Nano oxides, TiO2, ZnO by using sol-gel method, Co-precipitation, Hydrothermal, Microwave, Solvothermaland bio synthesis methods, Nanotubes and Nanowires, Carbon nanotubes, Graphene preparation, powder syntheses, crystal growth techniques, zone refining, properties and applications.	9
II	Top down and bottom up synthesis- mechanical alloying, Mechanical ball-milling, Ion implantation, Inert gas condensation, Arc discharge, RF-plasma arc technique, Laser ablation, Template assisted synthesis, Clusters, Colloids, Zeolites, Porous silicon.	9
III	Deposition techniques: Chemical vapour deposition (CVD), Metal Organic chemical vapour deposition (MOCVD), Epitaxial growth techniques: Molecular beam epitaxy, Atomic layer deposition, Pulsed laser deposition, Pulsed electrochemical deposition, Magnetron sputtering, Spin coating, Introduction to Lithography techniques	9
IV	Principle, Theory, Working and Application; X-Ray Diffraction, Field Emission Scanning Electron Microscopy, High Resolution-Transmission Electron Microscopy, Atomic Force Microscopy, Scanning Tunnelling Microscopy.	9

V	Photoluminescence Spectroscopy, Raman Spectroscopy, X-Ray Photoelectron Spectroscopy (XPS), Thermal analysis – Differential Scanning Calorimetry (DSC) – Thermogravimetric Analysis (TGA) – Differential Thermal Analysis (DTA) – Dynamic Mechanical Analysis (DMA), Mechanical Testing- Nano Indentation -Vibrating Sample Magnetometer, Zeta Potential and Particle size measurement	9
	References: 1.S.P. Gaponenko, Optical Properties of semiconductor nanocrystals, Cambridge University Press, 1980. 2. W.Gaddand, D.Brenner, S.Lysherski and G.J.Infrate (Eds.), Handbook of NanoScience, Engg. and Technology, CRC Press, 2002. 3. K. Barriham, D.D. Vvedensky, Low dimensional semiconductor structures: fundamental and device applications, Cambridge University Press, 2001. 4. G. Cao, Nanostructures & Nanomaterials: Synthesis, Properties &Applications, Imperial College Press, 2004. 5. J. George, Preparation of Thin Films, Marcel Dekker, Inc., New York.2005. 6. B. D. Cullity, "Elements of X-ray Diffraction", 4th Edition, Addison Wiley,1978. 7. M. H. Loretto, "Electron Beam Analysis of Materials", Chapman and Hall,1984	

c. Mapping of Program Outcomes with Course Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	**3**	**2**	**2**	**3**	**3**	**2**
CO2	**3**	**2**	**2**	**3**	**3**	**2**
CO3	**3**	**2**	**2**	**2**	**3**	**2**
CO4	**3**	**2**	**2**	**2**	**3**	**2**
CO5	**3**	**2**	**3**	**2**	**3**	**2**

d. Evaluation Scheme

	CO1	CO2	CO3	CO4	CO5	Total
Internal	8	8	8	8	8	40
External	12	12	12	12	12	60
Total	**20**	**20**	**20**	**20**	**20**	**100**

e. Mapping Course Outcome with Internal Assessment (40 Marks)

	CO1	CO2	CO3	CO4	CO5
Assignments	2	2	2	2	2
Seminar	-	-	-	-	-
Test	6	6	6	6	6
Attendance	-	-	-	-	-
Total	8	8	8	8	8

f. Mapping Course Outcome with External Assessment (60 Marks)

Category	CO1	CO2	CO3	CO4	CO5
Part – A **(Objective - 10 x 2 = 20 marks)**	4	4	4	4	4

Part – B (Short Answer - 5 x 3 = 15 marks)	3	3	3	3	3
Part – C (Detailed answer- 5 x 5 = 25 marks)	5	5	5	5	5
Total	**12**	**12**	**12**	**12**	**12**

SEMESTER - I					
Course Code	**Course Name**	**L**	**T**	**P**	**Credits**
MST1915	Quantum Mechanics and ElectromagneticTheory	3	-	-	3

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	Level
CO 1	On completion of the course, the student will understand the need for quantum mechanics and limitations of classical dynamics	Understand
CO 2	the student will be able to define the postulates of quantum mechanics and representations	Remember
CO 3	solve one dimensional and three dimensional problems using quantum mechanical principles	Skill
CO 4	Understand Maxwell equations and the propagation of electromagnetic waves	Understand
CO 5	Solve propagation of electromagnetic waves across different mediums	Skill

b. Syllabus

Units	Content	Hrs.
I	Need for Quantum Mechanics -- Experimental Facts of Metals-specific heat capacity of metals - thermal conductivity - electrical conductivity -Widemann-Franz law -Drude model for metals - Hall Effect - Inadequacy of Classical Mechanics - Triumphs of Quantum mechanics -free electron theory -Explanation of Atomic structure - Superconductivity -Semiconductors – Magnetism	9

II	Basics of Quantum Mechanics -De Broglie Hypothesis - Wave-Particle duality - Planck's constant - Concept of the Wave function- Principle of Superposition - Schrodinger Equation: time-dependent and time-independent - Probabilistic Interpretation - Expectation values - Dirac Ket/Bra Notation - Representation of physical observables as operators - Matrix representation of wave function /operators, quantum mechanical treatment of electrical, optical and thermal properties of materials.	9
III	One dimensional Particle inside a box - One Dimensional Barrier - Quantum Tunnelling concept through rectangular barrier problem - Link to the understanding of Scanning Tunnelling Microscopy - Harmonic Oscillator - Hydrogen Atom problem - Solutions leading to quantum numbers - Orbital Angular Momentum - Addition of angular momentum - Total Angular momentum - spin angular momentum.	9
IV	Gauss's law - Ampere's circuital law - Faraday's electromagnetic induction - the concept of displacement current - Maxwell's equations in free space, linear medium, and conducting medium - Wave equations obeyed by Electromagnetic (EM) waves - their solutions - Transverse nature of EM waves - Relation between E and B - Calculation of energy density, the intensity from Poynting vector, radiation pressure, momentum, etc for EM waves - Boundary conditions.	9
V	Propagation of EM waves from one medium to the other - Normal Incidence - Reflection and Transmission Coefficients- Oblique Incidence - Snell's law - Fresnel equations - Brewster's angle - Condition for total reflectance - Propagation of EM waves to a conducting medium - Concept of skin depth - conductors.	9
	References: 1. D.J. Griffiths, Introduction to Quantum Mechanics, Cambridge University Press, 3rd Ed 2. Nouredine Zetli, Quantum Mechanics: Concepts and Applications, Wiley India (2016) 3. Arthur Beiser, Concepts of Modern Physics, Tata Mc-Graw Hill (2003) 4. Ashcroft Mermin, Solid State Physics, Cengage Learning (2003) 5. Leon Van Dommelen, Quantum Mechanics for Engineers, e-copy available for free online (2012) 6. D.J. Griffiths, Introduction to Electrodynamics, Prentice Hall India Pvt Ltd 7. E.M. Purcell, Electricity and Magnetism: Berkley Series, Tata Mc.Graw Hall 8. Richard Feynman, The Feynman lectures of Physics, Addison– Wesley 9. Quantum Mechanics By H.A. Kramers -Dover Publications; Reprint edition (February 20, 2003) ISBN-10: 0486495337	

c. Mapping of Program Outcomes with Course Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	**1**	**1**	**1**	**3**	**3**	**2**

CO2	**1**	**2**	**1**	**3**	**3**	**2**
CO3	**1**	**3**	**1**	**3**	**3**	**3**
CO4	**1**	**2**	**1**	**3**	**3**	**2**
CO5	**1**	**3**	**1**	**3**	**3**	**3**

d. Evaluation Scheme

	CO1	CO2	CO3	CO4	CO5	Total
Internal	8	8	8	8	8	40
External	12	12	12	12	12	60
Total	**20**	**20**	**20**	**20**	**20**	**100**

e. Mapping Course Outcome with Internal Assessment (40 Marks)

	CO1	CO2	CO3	CO4	CO5
Assignments			5	-	5
Seminar	-	-	-	-	-
Test	6	6	6	6	6
Attendance	-	-	-	-	-
Total	6	6	11	6	11

f. Mapping Course Outcome with External Assessment (60 Marks)

Category	CO1	CO2	CO3	CO4	CO5
Part – A (Objective - 10 x 2 = 20 marks)	4	4	4	4	4
Part – B (Short Answer - 5 x 3 = 15 marks)	3	3	3	3	3
Part – C (Detailed answer- 5 x 5 = 25 marks)	5	5	5	5	5
Total	**12**	**12**	**12**	**12**	**12**

SEMESTER - I					
Course Code	**Course Name**	**L**	**T**	**P**	**Credits**
MST1916	SYNTHESIS AND CHARACTERIZATION OF MATERIALS LAB	-	-	6	3

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	Level
CO 1	On completion of the lab course, students will learn the method of material synthesis and their characterization technique	Understand
CO 2	Student will learn about various synthetic materials and their applications in science and technology	Remember
CO 3	Students will have hands-on training experience in chemical handling and materials synthesis by wet chemical method	Apply
CO 4	Students will learn how to analyze experimental data acquired by using various analytical characterization techniques, including XRD, UV-Vis, XPS, SEM, TEM, TGA and FTIR.	Analyze
CO 5	Students will be expertized in establishing structure-function correlations	Skill

b. Syllabus

Units	Experiment (Content)	Hrs.
I	Synthesis and Characterization of SILVER NANOPARTICLES	6
II	Synthesis and Characterization of Ag@Cu_2O Core-Shell Nanoparticle	6
III	Synthesis and Characterization of N-doped Carbon Quantum Dots (NCQDs)	6
IV	Synthesis and Characterization of Porous Organic Polymers by Wet Chemical Method	6
V	Synthesis and Characterization of ZnO and Ag doped ZnO thin films	6
VI	Synthesis and Characterization of Fe3O4	6

VII	Synthesis and Characterization of Co3O4 and CoO nanoparticles	6
VIII	Synthesis & Characterization of NiCoO2 and NiCo2O4 nanoparticles	6
	References: S. D. Solomon, et al, Synthesis and Study of Silver Nanoparticles Journal of Chemical Education, 2007, 84, 322-325. S.Paria, et al, Core/Shell Nanoparticles: Classes, Properties, Synthesis Mechanisms, Characterization, and Applications, Chem. Rev. 2012, 112, 2373–2433. S. Tao, et al, Microfluidic synthesis of Ag@Cu_2O core-shell nanoparticles with enhanced photocatalytic activity, Journal of Colloid and Interface Science, 2017, 486, 16–26. D. Bera, et al, Quantum Dots and Their Multimodal Applications: A Review, Materials 2010, 3, 2260-2345 R. Singh, et al, QPRTase modified N-doped carbon quantum dots: A fluorescent bioprobe for selective detection of neurotoxin quinolinic acid in human serum, Biosensors and Bioelectronics, 2018, 101, 103–109. X. Lai, et al, Hydrothermal synthesis and characterization of nitrogen-doped fluorescent carbon quantum dots from citric acid and urea, Ferroelectrics, 566:1, 116-123. O. M. Yaghi, et, al, Porous, Crystalline, Covalent Organic Frameworks, Science, 2005, 310, 1166. Kwan Su Kim et.al, Catalytic properties of Co3O4 nanoparticles for rechargeable Li/air batteries, Nano Research Letters, 2012,7,47.	

c. Mapping of Program Outcomes with Course Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	3

CO2	3	3	3	3	3	3
CO3	3	3	3	3	3	3
CO4	3	3	3	3	3	3
CO5	3	3	3	3	3	3

d. Evaluation Scheme

	CO1	CO2	CO3	CO4	CO5	Total
Practical	12	12	12	12	12	60
Laboratory Note Book	4	4	4	4	4	20
Attendance	2	2	2	2	2	10
Viva	2	2	2	2	2	10
Total	**20**	**20**	**20**	**20**	**20**	**100**

SEMESTER - II					
Course Code	**Course Name**	**L**	**T**	**P**	**Credits**
MST1921	Physical Metallurgy	3	-	-	3

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	Level

CO 1	The students will be able to understand the fundamental concepts of alloy formations, basic metallurgy concepts/rules.	Remember
CO 2	Broad view of Binary system, Iron-carbon diagram and classification of all steels.	Understand
CO 3	Understand all possible transformation and effect of alloying elements on TTT curves.	Understand
CO 4	Understand the concept of Pearlite, Austenite, and Martensite transformation and compare their kinetics and mechanism	Analyze
CO 5	Study of various heat treatment processes to use it for real time applications.	Apply

b. Syllabus

Units	Content	Hrs.
I	The impact of materials on progress- General classification of materials and classes of property - Materials tetrahedron- Metallurgy in Production Engineering-Solid Solutions and Alloys-Alloy Formation-Hume Rothery rules, Substitution and interstitial solid solutions with Example- Size effect - Super alloys - Phase equilibria and solubility limit - Components and phases- Effect of temperature and composition- Criteria for solid solubility.	9
II	Single Component system- Binary- Isomorphous- Eutectic phase diagram -Lever rule-Intermetallic compounds - Solidification of different types of solid solutions - Iron Carbon (Fe-C) diagram - Effect of alloying elements on Fe-C diagram. Ternary phase diagrams and Fe-Fe3C phase diagram- Classification of steels and their microstructures -applications.	9
III	Nucleation of spherical solid particle in a liquid and mechanism - Homogeneous and Heterogeneous nucleation and energy aspects - Hall Petch equation - Solid state transformation- Fraction of Transformation at constant rate of nucleation and growth - Possible transformations from Austenite-Time Temperature Transformation (TTT) curves, Continuous cooling transformation (CCT) curves- Effect of carbon, grain size and alloying elements on TTT curves.	9
IV	Pearlite Transformation: Mechanism, Diffusive theory, Displacive theory, upper and lower bainite, transformation rate, morphology, mechanism, Hull-Mehl Model and its kinetics of transformation, effects of alloying addition on pearlitic transformation-Austenite Transformation: formation of austenite, homogenization of austenite and its kinetics, austenite grain size, effect of grain size on mechanical properties -Martensitic transformation: kinetics and mechanism	9
V	Recovery, Recrystallization and grain growth, Annealing, Normalising, Hardening - Hardenability measurements: tempering, Martempering – Austempering - case hardening, precipitation hardening - Thermo mechanical treatments -Heat treatment furnaces - atmospheres - quenching media.	9

	References: 1. W.D. Callister, Jr. Materials Science & Engineering, John Wiley & Sons. 2. R.E. Reed Hill , Physical Metallurgy Principles, Affiliated East-West Press (2008) ISBN-10: 8176710458 ISBN-13: 978-8176710459 3. K.M. Harris, Physical Metallurgy, CBS; 1 edition (2005) ISBN-10: 9788123929194 ISBN-13: 978-8123929194	

c. Mapping of Program Outcomes with Course Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	**3**	**2**	**3**	**3**	**3**	**3**
CO2	**3**	**3**	**2**	**3**	**3**	**3**
CO3	**3**	**3**	**2**	**3**	**3**	**3**
CO4	**3**	**3**	**3**	**2**	**3**	**3**
CO5	**3**	**2**	**3**	**3**	**3**	**3**

d. Evaluation Scheme

	CO1	CO2	CO3	CO4	CO5	Total
Internal	8	8	8	8	8	40
External	12	12	12	12	12	60
Total	**20**	**20**	**20**	**20**	**20**	**100**

e. Mapping Course Outcome with Internal Assessment (40 Marks)

	CO1	CO2	CO3	CO4	CO5
Assignments	1	1	1	1	1
Seminar	-	-	-	-	-
Test	6	6	6	6	6
Attendance	1	1	1	1	1
Total	8	8	8	8	8

f. Mapping Course Outcome with External Assessment (60 Marks)

Category	CO1	CO2	CO3	CO4	CO5
Part – A **(Objective - 10 x 2 = 20 marks)**	4	4	4	4	4
Part – B **(Short Answer - 5 x 3 = 15 marks)**	3	3	3	3	3
Part – C **(Detailed answer- 5 x 5 = 25 marks)**	5	5	5	5	5
Total	**12**	**12**	**12**	**12**	**12**

SEMESTER - II					
Course Code	**Course Name**	**L**	**T**	**P**	**Credits**

MST1922	Ceramics and Composite materials	3	-	-	3

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	Level
CO 1	On successful completion of this course student can recognize the crystal structures, understand the classification of ceramic crystal structures -in-depth understanding on defects in ceramics, types, notations - frame defect reactions	Understand
CO 2	apart from understanding the parameters involved in ceramic processing and sintering, glass ceramics, introductory knowledge on additive manufacturing techniques	Analyze
CO 3	Knowledge applied to understand Ceramics with different electrical, magnetic, thermal properties apart from superconductors and glasses	Apply
CO 4	Classification of composites - formulation for fiber reinforced composites - solving problems related to composites	Understand
CO 5	Expanding the domain of composites to include carbon-carbon, polymer-based composites, ceramic-ceramic composites	Remember

b. Syllabus

Units	Content	Hrs.
I	Atomic structure and bonding - Crystal structures - Lattice/Basis - Coordination and radius ratio concept -Miller Indices - Point groups - space groups - symmetry operations - Ceramic crystal structures - Pauling rules -Types of Silicates- Defects in Ceramics - Kroger-wink notation - Defect reactions	9
II	Processing of Ceramics-SiC, SiN- Solid state sintering- liquid phase sintering -Nucleation, Densification, and Coarsening process - Grain Boundary Mobility - Porosity Evaluation - Annealing Process - Fabrication of Glasses - Glass ceramics-Alumino silicate, Borosilicate, Zinc silicate- chemical synthesis of ceramics-Additive manufacturing, extrusion techniques, replication technique-Applications.	9

III	Properties of ceramics - Dielectrics/Ferroelectrics - Pyroelectrics - Piezoelectric ceramics - Magnetoceramics- Ferrites - Hexaferrites - Superparamagnetism- High Tc Superconductors YBCO and BSCCO systems - Magnetoresistance (GMR, CMR, etc.) - Conducting Ceramics - Thermal properties of ceramics - Thermal expansion - Thermal stresses -Thermal Creep - Mechanical properties of ceramics - strength - toughness - correlation to microstructure.	9
IV	Introduction to Composites - Classification of Composites - Connectivity in composites - Geometry of reinforcement - Particle reinforced composites - Fiber reinforced composites - Influence of Fiber orientation, diameter, length and concentration - Elastic Modulus under transverse and longitudinal loading - Properties of Fibers- Structural composites - laminar, Sandwich	9
V	Classification depending on matrix-Organic Matrix composites - Metal matrix Composites - Ceramic Matrix composites - Transformation Toughening - Carbon Carbon Composites - Natural composites - Wood- Nanocomposites-Application of composites.	9
	References: Introduction to Materials Science and Engineering - William J Callister, Wiley, 2014 2. Ceramics Materials – Science and Engineering - Iker Morris, Larson & Keller, 2014 3. Magnetoelectric Composites- Mirza Bichurin, CRC Press, 2019 4. Composite Materials for Industry, Electronics and Environment-O.V. Mukbaniani, 2019 5. Introduction to Ceramics- W.D. Kingrey, Wiley, 2012. 6. Ceramic Processing and Sintering – M.N. Rahman, CRC Press, 2013 7. Composite Materials: Processing, Applications, and Characterizations- Kamal K.Kar Springer, 2017 8. Composite Materials: Engineering and Science - F.L. Mathews, Springer, 1994	

c. Mapping of Program Outcomes with Course Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	**3**	**2**	**3**	**3**	**3**	**3**
CO2	**3**	**2**	**3**	**3**	**3**	**3**
CO3	**3**	**2**	**3**	**2**	**3**	**2**
CO4	**3**	**2**	**3**	**2**	**3**	**2**
CO5	**3**	**2**	**3**	**2**	**3**	**2**

d. Evaluation Scheme

	CO1	CO2	CO3	CO4	CO5	Total
Internal	8	8	8	8	8	40
External	12	12	12	12	12	60
Total	**20**	**20**	**20**	**20**	**20**	**100**

e. Mapping Course Outcome with Internal Assessment (40 Marks)

	CO1	CO2	CO3	CO4	CO5
Assignments			5	-	5
Seminar	-	-	-	-	-

Test	6	6	6	6	6
Attendance	-	-	-	-	-
Total	6	6	11	6	11

f. Mapping Course Outcome with External Assessment (60 Marks)

Category	CO1	CO2	CO3	CO4	CO5
Part – A **(Objective - 10 x 2 = 20 marks)**	4	4	4	4	4
Part – B **(Short Answer - 5 x 3 = 15 marks)**	3	3	3	3	3
Part – C **(Detailed answer- 5 x 5 = 25 marks)**	5	5	5	5	5
Total	**12**	**12**	**12**	**12**	**12**

SEMESTER - II					
Course Code	**Course Name**	**L**	**T**	**P**	**Credits**
MST1923	POLYMERS AND BIOMATERIALS	3	-	-	3

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	Level
CO 1	On completion of the course, students can explain the concepts of polymers and biomaterials and special emphasis on petrochemical products.	Remember
CO 2	Students may understand the structure property relationship of polymers and biomaterials	Understand
CO 3	Students can apply the design principle to various types of materials.	Apply
CO 4	Students can solve the problems based on polymers and biomaterials	Analyze
CO 5	Students can handle the day-to-day problems associated with polymers and biomaterials and provide solutions.	Skill

b. Syllabus

Units	Content	Hrs.

I	Introduction to Natural and Synthetic Polymers, Developments in Polymeric Materials, Basic concepts of Oligomers & Polymers: Functionality and Degree of Polymerization.Molecular weight and its distribution - End group analysis, Osmometry, Light scattering, ultracentrifugation, gel permeation chromatography, viscosity.	9
II	Polymerization techniques - Step-growth polymerization, Carother's equation, Functionality, Cross Linking, polymer manufacturing, Chain growth polymerization, Free radical polymerization, states of polymers, transition temperatures such as Glass Transition (Tg), Crystallisation temperature (Tc), Melting Temperature (Tm), solubility parameters, solution properties- Structure-Property relationship.	9
III	Natural Polymers: Chemical & Physical structure, properties, source, important chemical modifications. Chemical and Physical structure, properties of Carbohydrates, Protein, Nucleic acids. Applications of polymers such as proteins, cellulose, lignin, starch, resin, shellac, latex, vegetable oils and gums.	9
IV	Synthetic polymers: Manufacturing of various fractions of crude petroleum important for polymer industry for raw Materials such as ethylene, propylene, butadiene, vinyl chloride, vinylidene dichloride, styrene, acrylic monomers like acrylic acid, acrylonitrile, methacrylic acid, methacrylates, acrylamide. Solvents such as alcohols, toluene, xylene, acetone, ketones, terpenes, chloromethanes. Evaluation of raw materials and reactants for synthesis & manufacturing of polymers. Polyacids such as phthalic acid, terephthalic acid, isomers and anhydrides. Phenols, polyols and their modifications, Isocyanates, Amino Compounds, Petroleum based materials.	9
V	Introduction to biomaterials for biomedical applications, Chemical structure and property of biomaterials, Degradation of biomaterials. Polymeric biomaterials: Hydrogel, bio-conjugation techniques. Biomaterials for drug delivery application (small molecules, gene and protein). Biocompatibility, biomaterials implantation, evaluation of biomaterials, nano-biomaterials, biomaterials for imaging and diagnosis, Cell-Biomaterials interaction, biomaterial and scaffold for tissue engineering, 3D printing, Electro spinning.	9

	Tasks and Assignments: **References:** **1. Billmeyer F, 'Textbook of Polymer Science', 3 ed. Wiley Interscience, 2007** **2. Principles of Polymer Science, Bahadur and Sastry, Narosa Publishing House 2002.** **3. Polymer Science , Gowarikar, New Age International Publisher, 2015.** **4. Textbook of Polymer Science and Engg, Anilkumar and R. K. Gupta, CRC Press; 3 edition, 2018.** **5. Fundamentals of Polymer Science: An introductory text, 2nd Ed. P. Painter and M. Colman, Technomic publishing Co Inc,1998.** **6. Polymer Chemistry: An Introduction, 3rd Ed. Malcolm P. Stevens, Oxford University Press, Inc, 1998.** **7. Principles of Polymer Systems, Rodriguez, CRC Press; 6 edition, 2014.** **8. Biomaterials : An Introduction, by Park, Joon, Lakes, R. S. Publisher: Springer, 2007.** **9. Polymer Science and Technology by J. R. Fried, Pearson Prentice Hall; 3 edition, 2014.** **10. Carraher's Polymer Chemistry, Ninth Edition, 2013 by Charles E. Carraher Jr**	

c. Mapping of Program Outcomes with Course Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	3	3	3
CO2	3	3	3	3	2	3
CO3	3	3	3	3	3	2
CO4	3	3	3	2	3	3
CO5	3	2	3	3	3	3

d. Evaluation Scheme

	CO1	CO2	CO3	CO4	CO5	Total
Internal	8	8	8	8	8	40
External	12	12	12	12	12	60
Total	**20**	**20**	**20**	**20**	**20**	**100**

e. Mapping Course Outcome with Internal Assessment (40 Marks)

	CO1	CO2	CO3	CO4	CO5
Assignments	1	1	1	1	1
Seminar	1	1	1	1	1

Test	5	5	5	5	5
Attendance	1	1	1	1	1
Total	8	8	8	8	8

f. Mapping Course Outcome with External Assessment (60 Marks)

Category	CO1	CO2	CO3	CO4	CO5
Part – A **(Short answer - 10 x 2 = 20 marks)**	4	4	4	4	4
Part – B **(Medium length Answer - 5 x 3 = 15 marks)**	3	3	3	3	3
Part – C **(Long Answer- 5 x 5 = 25 marks)**	5	5	5	5	5
Total	**12**	**12**	**12**	**12**	**12**

g. Rubric for Assignments

Sl. No.	Criteria	100%	75%	50%	25%	0%	Relation to COs
1	**Content** **50%**	Ideas are detailed, well developed, supported with specific evidence & facts and examples	Ideas are detailed, Developed and supported with evidence and facts mostly specific.	Ideas are presented but not particularly developed or supported;	Content is not sound	Not attended	CO1, CO2, CO3
2	**Organiza -tion** **50%**	Includes title, introduction, statement of the main idea with illustration and conclusion.	Includes title, introduction, statement of main idea and conclusion.	organizational tools are weak or missing	No organization	Not attended	CO3, CO4, CO5

SEMESTER - II					
Course Code	**Course Name**	**L**	**T**	**P**	**Credits**
MST1924	Computational Techniques for Materials Science	2	-	2	3

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	Level
CO 1	Understanding the need computational modelling in the field of materials science and types of calculation methods could be utilized	Understand
CO 2	Student will understand fundamental theory behind different computational methods	Understand
CO 3	Apply computational method to understand structure-function correlation of materials	Apply
CO 4	Students will be able to address practical issues problems, prediction of property of the materials and analyse to feedback to initial computational design	Analyze
CO 5	Student can be expertized in computational design, predict and propose new solutions	Skill

b. Syllabus

Units	Content	Hrs.

I	Introduction to Computational Materials Science, Multi-scale Simulation of Materials at different Length and Time scales - Atomistic, Nanoscopic, Microscopic, Mesoscopic, Macroscopic, and Structural Scales, Computational Perspective of Materials - Crystal Structures, Physical, Chemical, Mechanical and Thermal Properties, Material Processing and Device Performance Modelling, Software Packages and Online Web Tools for Computational Materials Science, Advantages-Disadvantages and Application of Computational Materials Science.	9
II	Electronic Structure Calculations of Materials, Fundamental Concepts of Quantum Mechanics - Schrödinger Wave Equation, Particle in a Box, Hydrogen Atom, Hartee-Fock Theory, Slater Approximation, Born-Oppenheimer Approximation, Self-Consistent Approach, First Principles Method, Density Functional Theory (DFT), Thomas-Fermi-Dirac Approximations- Hohenberg-Kohn Theorems, Kohn-Sham Equations, Exchange Correlation Functional, Local Density Approximation (LDA), Generalized-Gradient Approximation (GGA), Ab Initio Method, Force Fields and Molecular Dynamics (MD), Molecular Statistics (MS), Monte Carlo (MC) Simulation, Density of States (DOS), Fermi energy, Band Gap Energy, Brillouin Zone, Computational Tools for Electronic Structure Calculations.	9
III	Computational Thermodynamics and Phase Equilibria of Materials, Basic Concepts - Calculation of Thermodynamic Properties, Heat Capacity, Enthalpy, Entropy, Gibbs Energy, Thermal Vacancies, Solution Phases-Phase Rule, Binary and Ternary Phase Diagrams, Modelling of Solution Phases using Standard Redlich Kister Model, and Geometry Models - Kohler, Muggianu, Toop Models, Modelling of Compound Phases using Sublattice Model, Gibbs Free Energy Minimization and Phase Equilibria Calculations (CAL)- Phase Diagrams (CALPHAD) approach, Software tools and online resources for calculating thermodynamics and phase equilibria of materials.	9
IV	Finite Element Analysis (FEA) of materials, Introduction to Mathematical Concepts - Matrices, Vectors, Tensors, Linear Algebra, Differential Equations, Computational Models - Classical and Numerical Methods, FEA Method, Discretizations- 1D, 2D and 3D finite elements with Examples, Procedure of FEA, Stiffness Matrix - Truss and Beam Elements, Plane stress, Plain strain, axis symmetric analysis, 3D analysis, Modelling of Elastic Properties of Materials using FEA Method, Limitations and Application, Computer tools for FEA method, computational fluid dynamics.	9

V	Integrated Computational Materials Engineering (ICME), Material Genome Initiative, Computational Design of Materials, Design of Experiments (DOE) - Analysis of Variance (ANOVA), Linear Regression Method, Artificial Intelligence - Machine Learning or Artificial Neural Networks (ANN), Materials Informatics, Materials Data Management, Software Codes and Online Web links for ICME, Future Scope of ICME.	9

Tasks and Assignments:

References:

1. D. Raabe, "Computational Materials Science", Wiley VCH Verlag GmbH, 1998.

2. Z. X. Guo (Ed), "Multiscale Materials Modelling: Fundamental and Applications", Woodhead Publishing Limited, Cambridge, 2007.

3. Z. H. Barber, "Introduction to Materials Modelling", Maney Publishing, 2005.

4. D. Frenkel and B. Smith, "Understanding Molecular Simulations", Academic Press, 2002.

5. E. B. Tadmor, "Modeling Materials Continuum, Atomistic and Multiscale Techniques", Cambridge University Press, 2012.

6. E. Kaxiras, "Atomic and Electronic Structure of Solids", Cambridge University Press, 2003.

7. R. Aris, "Mathematical Modelling Techniques", Dover: New York, 1994.

8. S. Yip (Editor), "Handbook of Materials Modeling", Springer: Dordrecht, 2005.

9. M. Law and W. D. Kelton, "Simulation Modeling and Analysis" 3rd Ed., Tata McGraw-Hill:New Delhi, 2007.

10. Y. K. Rao, "Stoichiometry and Thermodynamics Computations in Metallurgical Processes", Cambridge University Press, 1985.

11. K. M. Hangos and I. T. Cameron, "Process Modeling and Model Analysis", Academic Press: London, 2001.

12. T.R. Chandrupatla and A. D. Belegundu, "Introduction to Finite Elements in Engineering", 2nd Ed., Prentice-Hall, 1997.

13. Douglas C. Montgomery, "Design and analysis of experiments", 5th Ed., John Wiley and Sons, 2001.

14. B. Yegnanarayana, "Artificial Neural Networks", Prentice-Hall of India, 1999.

c. Mapping of Program Outcomes with Course Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	2	3	3
CO2	3	3	2	3	3	3
CO3	3	2	3	3	3	3
CO4	3	3	3	2	3	3
CO5	2	3	3	3	3	3

d. Evaluation Scheme

	CO1	CO2	CO3	CO4	CO5	Total
Internal	8	8	8	8	8	40
External	12	12	12	12	12	60
Total	**20**	**20**	**20**	**20**	**20**	**100**

e. Mapping Course Outcome with Internal Assessment (40 Marks)

	CO1	CO2	CO3	CO4	CO5
Assignments	1	1	1	1	1

Practical	0	2	2	2	2
Test	6	4	4	4	4
Attendance	1	1	1	1	1
Total	8	8	8	8	8

f. Mapping Course Outcome with External Assessment (60 Marks)

Category	CO1	CO2	CO3	CO4	CO5
Part – A **(Short answer - 10 x 2 = 20 marks)**	4	4	4	4	4
Part – B **(Medium length Answer - 5 x 3 = 15 marks)**	3	3	3	3	3
Part – C **(Long Answer- 5 x 5 = 25 marks)**	5	5	5	5	5
Total	**12**	**12**	**12**	**12**	**12**

SEMESTER - II					
Course Code	**Course Name**	**L**	**T**	**P**	**Credits**
MST19E22	Powder metallurgy	3	-	-	3

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	Level
CO 1	the student will be able to understand the basics of powder metallurgy	Remember
CO 2	the student should be able to identify particle size, shape distribution, powder characteristics	Understand

CO 3	the student should grasp the metal powder production methods	Understand
CO 4	the student can understand the powder compaction methods - different types of compaction	Understand
CO 5	the student should be able to employ different sintering methods and able to make different products	Apply

b. Syllabus

Units	**Content**	**Hrs.**
I	Historical and modern developments in Powder Metallurgy. Advantages, limitations and applications of Powder Metallurgy. Basic Steps for Powder Metallurgy.	9
II	Characteristics of metal powder Chemical composition, Particle size, shape and size distribution, Characteristics of powder mass such as apparent density, tap density, flow rate, friction index. Properties of green compacts and sintered compacts.	9
III	Metal powder production methods Atomization, Reduction from oxide, Electrolysis, Crushing, Milling, Condensation of metal vapour, Hydride and carbonyl processes, Mechanical Alloying, New developments. Powder conditioning, fundamentals of powder compaction, density distribution in green compacts, compressibility, green Strength, pyrophorocity and toxicity.	9
IV	Powder Compaction Methods Basic aspects, types of compaction presses, compaction tooling and role of lubricants, Single and double die compaction, isostatic pressing, hot pressing.Powder Forming Powder rolling, powder forging, powder extrusion and explosive forming technique.	9
V	Sintering Definition, stages, effect of variables, sintering atmospheres and furnaces, Mechanism, liquid-phase sintering, Secondary operations. Sintered Products Study of sintered bearings, cutting tools, metallic filters, friction and antifriction parts and electrical contact materials. Defects in Powder metallurgy processed materials and their processing to minimize defects : Friction stir processing etc.	9
	References 1. Introduction to Powder Metallurgy, A. K. Sinha, Dhanpatrai Publication 2. Powder Metallurgy: Science, Technology, and Materials, Anish Upadhyaya, Gopal Shankar Upadhyaya, CRC Press 3. Powder Metallurgy: Science, Technology and Applications, P. C. Angelo, R. Subramanian 4. Powder Metallurgy, W.D.Jones 5. Principles of Powder Metallurgy, T.Shukerman 6. Handbook of Powder Metallurgy :- H.H.Hausner 7. Powder Metallurgy, ASM Handbook, Vol-VII.	

c. Mapping of Program Outcomes with Course Outcomes

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	**3**	**2**	**3**	**3**	**3**	**2**
CO2	**3**	**2**	**3**	**3**	**3**	**2**
CO3	**3**	**2**	**3**	**3**	**3**	**2**
CO4	**3**	**2**	**3**	**3**	**3**	**2**

CO5	**3**	**2**	**3**	**3**	**3**	**3**

d. Evaluation Scheme

	CO1	CO2	CO3	CO4	CO5	Total
Internal	8	8	8	8	8	40
External	12	12	12	12	12	60
Total	**20**	**20**	**20**	**20**	**20**	**100**

e. Mapping Course Outcome with Internal Assessment (40 Marks)

	CO1	CO2	CO3	CO4	CO5
Assignments	2	2	2	2	2
Seminar	-	-	-	-	-
Test	6	6	6	6	6
Attendance	-	-	-	-	-
Total	8	8	8	8	8

f. Mapping Course Outcome with External Assessment (60 Marks)

Category	CO1	CO2	CO3	CO4	CO5
Part – A (Objective - 10 x 2 = 20 marks)	4	4	4	4	4
Part – B (Short Answer - 5 x 3 = 15 marks)	3	3	3	3	3
Part – C (Detailed answer- 5 x 5 = 25 marks)	5	5	5	5	5
Total	**12**	**12**	**12**	**12**	**12**

SEMESTER - II					
Course Code	**Course Name**	**L**	**T**	**P**	**Credits**
MSN15E1	**THIN FILM SCIENCE TECHNOLOGY**	3	-	-	3

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	Level
CO 1	To familiarize with the preparation of thin films	Remember
CO 2	To understand the kinetics of thin films	Understand
CO 3	To apply the knowledge of characterization techniques required to study thin films	Apply
CO 4	To analyze the techniques required to study the various properties of thin films	Analyze

CO 5	Applications where the thin films are required and implemented.	Skill

b. Syllabus

Units	Content	Hrs.
I	Kinetics aspects of vacuum in the gas chamber, classifications in vacuum ranges, thin film epitaxy, types of epitaxy, different growth techniques, liquid phase epitaxy, vapor phase epitaxy, molecular beam epitaxy, metal organic vapor phase epitaxy, sputtering (RF and DC), pulsed laser deposition, thickness measurement, microbalance technique, photometry, ellipsometry, and interferometry	9
II	Nucleation and kinetics, critical nucleation parameters, spherical and non-spherical (cap, disc and cubic-shaped), Growth kinetics: Kinetics of binary alloys (GaAs and InP), Ternary ($Al_{1-x}Ga_xAs$). quaternary semiconductors, derivation of growth rate and composition expressions	9
III	X-ray diffraction, photoluminescence, UV-Vis-IR spectrophotometer, Atomic force microscope, Scanning Electron microscope, Hall effect, Vibrating sample magnetometer, Secondary Ion Mass spectrometry, X-ray photoemission spectrometer	9
IV	Dielectric properties, determination of dielectric properties, optical properties, determination of optical constants, mechanical properties, determination of mechanical properties of thin films, magnetic and superconducting properties	9
V	LED, Laser and solar cell, Microelectromechanical systems (MEMS), thin film capacitor, ferromagnetic thin films: data storage, GMR sensors, fabrication and characterization of thin film transistors and FET (quantum dots)	9
	References 1. Goswami A, Thin film fundamentals, New Age International Limited, New Delhi(1996) 2. Aicha Eishabini Riad et al, Thin film technology hand book, Mc-Graw Hill professional publishers (1997) 3. Krishna Seshan, Hand book of Thin film deposition, William Andrew publishers (2012) 4. Donald smith, Thin film deposition: principles and practice, Mc-Graw Hill professional publishers (1995)	

c. Mapping of Program Outcomes with Course Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	2	3	3	2
CO2	3	2	2	3	3	2
CO3	3	2	2	2	3	2
CO4	3	2	2	2	3	2
CO5	3	2	2	2	3	1

d. Evaluation Scheme

	CO1	CO2	CO3	CO4	CO5	Total
Internal	8	8	8	8	8	40
External	12	12	12	12	12	60
Total	**20**	**20**	**20**	**20**	**20**	**100**

e. Mapping Course Outcome with Internal Assessment (40 Marks)

	CO1	CO2	CO3	CO4	CO5
Assignments	2	2	2	2	2
Seminar	-	-	-	-	-
Test	6	6	6	6	6
Attendance	-	-	-	-	-
Total	8	8	8	8	8

f. Mapping Course Outcome with External Assessment (60 Marks)

Category	CO1	CO2	CO3	CO4	CO5
Part – A **(Short answer - 10 x 2 = 20 marks)**	4	4	4	4	4
Part – B **(Medium length Answer - 5 x 3 = 15 marks)**	3	3	3	3	3
Part – C **(Long Answer- 5 x 5 = 25 marks)**	5	5	5	5	5
Total	**12**	**12**	**12**	**12**	**12**

SEMESTER - II					
Course Code	**Course Name**	**L**	**T**	**P**	**Credits**
MST19E21	Nanoscale Fabrication and Techniques	3	-	-	3

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	Level
CO 1	The students will be able to understand the fundamental concepts of concepts in bulk, 2D, 1D and 0D materials – Properties of matter change at nanoscale- Top-down and Bottom up fabrication concepts.	Remember
CO 2	Broad view of lithography and clean room concepts	Understand
CO 3	Understand all possible top-down nanoscale fabrication methods	Understand

CO 4	Understand all possible bottom-up nanoscale fabrication methods	Understand
CO 5	Study of Focused ion beam fabrication techniques to use it in making nanostructures.	Apply

(Number of CO's are not fixed)

a1. Tabular Column for action verbs

General Objectives	Specific Objectives
Remember - retrieval of Information	List, Name, Define, Identify, Recall, Recognize, Tabulate, State, Repeat
Understand – demonstration of comprehension	Translate, Interpret, Extrapolate, Define in your own words, Differentiate, Cite example, Relate, Classify, Restate, Summarize, Locate
Apply – applying knowledge in a new context	Employ, Illustrate, Use, Solve
Analyze – supporting assertions using evidence, identifying causes	Compare, Contrate, Criticize, Examine, Question, Test, Distinguish
Evaluate – coming to a judgement on the value of information	Predict, Select, Appraise, Find out,
Create – combining knowledge to come to new conclusions	Assemble, Construct, Develop, Formulate, Propose, Organize, Hypothesize
Skill	Arrange for the experiment, Experiment, Demonstrate, Verify the Hypothesis, Draw, Articulate

b. Syllabus

Units	Content	Hrs.
I	Introduction to Nanotechnology: Nanotechnology concepts in bulk, 2D, 1D and 0D materials – Properties of matter change at nanoscale-Surface to volume ratio-quantum confinement effect – Origin of the properties- Size dependent properties -Top-down and Bottom up fabrication concepts- Examples of nanostructures.	9
II	Introduction to Lithography: Clean room concepts and protocols - Photolithography process - Optical lithography – Various light sources – Resists: positive and negative photoresists and their comparison in terms of various parameters – Lift-off process- Applications and limitations.	9
III	Nanoscale Fabrication Top down Techniques: Scanning probe lithography –soft lithography – Nano contact printing – Nanoimprint lithography or E-beam lithography – Nano sphere lithography – Colloidal lithography –Applications and limitations.	9

IV	Nanoscale Fabrication Bottom up Techniques: Plasma Arcing-Chemical vapour deposition (CVD)-Dip pen nanolithography-Molecular beam epitaxy (MBE)-Sol gel process for making nanostructured surfaces- functionalized silica glass surfaces- Molecular self-assembly-DNA nanotechnology- Nanocoating by Langmuir Blodgett (LB) film method.- Self assembly- Applications.	9
V	Focused ion beam (FIB) fabrication: Steps involved in FIB process-Nanostructures in FIB fabrication – Lab-on-a-chip (LOC) fabrication - Applications and Limitations.	9
	References: **1.** John F. Mongillo, *Nanotechnology 101*, Publisher: Science 101, ISSN 1931-3950, ISBN–13: 978–0–313–33880–9 2. Cui Z, Nanofabrication: Principles, Capabilities and Limits, Springer 2008 3. Campbell, The Science and Engineering of Microelectronic Fabrication, 2nd Edition, Oxford University Press, (2001).	

c. Mapping of Program Outcomes with Course Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	**3**	**2**	**3**	**3**	**3**	**3**
CO2	**3**	**3**	**2**	**3**	**3**	**3**
CO3	**3**	**3**	**2**	**3**	**3**	**3**
CO4	**3**	**3**	**3**	**2**	**3**	**3**
CO5	**3**	**2**	**3**	**3**	**3**	**3**

d. Evaluation Scheme

	CO1	CO2	CO3	CO4	CO5	Total
Internal	8	8	8	8	8	40
External	12	12	12	12	12	60
Total	**20**	**20**	**20**	**20**	**20**	**100**

e. Mapping Course Outcome with Internal Assessment (40 Marks)

	CO1	CO2	CO3	CO4	CO5
Assignments	1	1	1	1	1
Seminar	-	-	-	-	-
Test	6	6	6	6	6
Attendance	1	1	1	1	1
Total	8	8	8	8	8

f. Mapping Course Outcome with External Assessment (60 Marks)

Category	CO1	CO2	CO3	CO4	CO5
Part – A **(Objective - 10 x 2 = 20 marks)**	4	4	4	4	4
Part – B **(Short Answer - 5 x 3 = 15 marks)**	3	3	3	3	3
Part – C **(Detailed answer- 5 x 5 = 25 marks)**	5	5	5	5	5
Total	**12**	**12**	**12**	**12**	**12**

SEMESTER - II					
Course Code	**Course Name**	**L**	**T**	**P**	**Credits**
MST19E24	**Advanced Crystal growth**	3	-	-	3

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	Level
CO 1	The student should be able to understand the fundamentals of nucleation theory, theoretical models governing nucleations like homogeneous and heterogeneous.	Understand
CO 2	The student will be able to gain the skill of growing single crystals utilizing Czochralski, Stepanov and Liquid Encapsulated Czochralski techniques	skill
CO 3	Students can understand the Bridgman technique and the factors that govern crystal growth, Also will learn about different melt growth methods.	Apply
CO 4	The student will get a wider knowledge of the solution growth process including slow cooling methods, high temperature solution growth methods etc.	skill
CO 5	The student will get to know about vapor growth techniques including chemical and physical vapor deposition processes, criteria governing growth of single crystals in chemical vapor transport etc.	Remember

b. Syllabus

Units	Content	Hrs.

I	Unit I - Nucleation theory: Introduction – Nucleation – Theories of Nucleation – Classical theory of Nucleation – Gibbs Thomson equation for vapour – Modified Thomson's equation for melt – Gibbs-Thomson equation for solution – Energy of formation of a nucleus – Spherical nucleus – Cylindrical nucleus – Heterogeneous nucleation – Cap-shaped nucleus – Disc-shaped nucleus.	9
II	Unit – II – Czochralski technique Czochralski and Related methods: Introduction – The basic crystal pulling methods – Czochralski growth – Kyropoulos growth – Dendrite methods – The Stepanov method – Edgedefined film-fed growth – Relevant theory – Aspects to be considered – Fluids flow crucibles – heat flow – Refined Process – liquid encapsulated Czochralski technique.	9
III	Unit – III – The Bridgman technique and other melt growth processes The Bridgman and Related methods: Introduction – The basic process – Relevant theory – Crucibles – Thermal considerations. Other melt growth processes: Introduction – The Verneuil process – Floating-zone process – Arc fusion growth – Skull melting – Thin film methods: molten-phase epitaxy.	9
IV	Unit – IV – Solution growth Low-temperature solution growth: Introduction – Solvents and solutions – Slow cooling process – solvent evaporation process – Temperature-difference process – The use of electrolytic process. High-temperature solution growth: Introduction – Solvents and solutions – Slow cooling methods – Temperature-difference methods – High-pressure methods – Solvent evaporation methods – Electrolytic process – Liquid-phase epitaxy	9
V	Unit – V – Vapour Growth Techniques Vapour Growth – Physical Vapour Deposition – Chemical Vapour Deposition –Advantages of CVD – Disadvantages of CVD – Chemical Vapour Transport – Definition of Chemical vapour transport reactions – Fundamentals of chemical vapour transport – Criteria for the choice of transport reaction – Specifications of the technique – Transported materials and transporting agents – A Temperature variation method for the growth of large crystals by chemical vapour	9
	References 1. J. C. Brice, Crystal Growth Processes, John Wiley and Sons, New York, 1986. 2. P. SanthanaRagavan and P. Ramasamy, Crystal Growth Processes and Methods (KRU Publications, Kumbakonam, 2001. 3. K. Sangwal, Elementary Crystal Growth (Edited), SAAN Publishers, Lublin, 1994 4. Govindhan Dhanaraj, Kullaiah Byrappa, Vishwanath Prasad, Michael Dudley (Eds.), Hand book of Crystal Growth Springer Heidelberg Dordrecht London New York, 2010.	

c. Mapping of Program Outcomes with Course Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	2
CO2	3	3	3	2	3	3
CO3	3	3	2	3	3	3
CO4	3	3	3	3	2	3
CO5	3	3	3	3	2	3

d. Evaluation Scheme

	CO1	CO2	CO3	CO4	CO5	Total
Internal	8	8	8	8	8	40
External	12	12	12	12	12	60
Total	**20**	**20**	**20**	**20**	**20**	**100**

e. Mapping Course Outcome with Internal Assessment (40 Marks)

	CO1	CO2	CO3	CO4	CO5
Assignments	2	2	2	2	2
Seminar					
Test	6	6	6	6	6
Attendance	-	-	-	-	-
Total	8	8	8	8	8

f. Mapping Course Outcome with External Assessment (60 Marks)

Category	CO1	CO2	CO3	CO4	CO5
Part – A (Short answer - 10 x 2 = 20 marks)	4	4	4	4	4
Part – B (Medium length Answer - 5 x 3 = 15 marks)	3	3	3	3	3
Part – C (Long Answer- 5 x 5 = 25 marks)	5	5	5	5	5
Total	**12**	**12**	**12**	**12**	**12**

SEMESTER - II					
Course Code	**Course Name**	**L**	**T**	**P**	**Credits**

MST1927	PROPERTIES OF MATERIALS LAB	-	-	6	3

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	Level
CO 1	On completion of the lab course, students can explain the concepts of the properties of different materials.	Remember
CO 2	Students may understand the structure property relationship of various class of materials	Understand
CO 3	Students can apply the basic knowledge in thermal, optical, electrical, magnetic, diffraction spectroscopic, and electrochemical techniques.	Apply
CO 4	The students will gain experience on (a) operation of instruments (DSC, Four Probe apparatus, Hall effect setup, UV-Vis, Fluorescence, XRD, electrochemical instrument) for materials property measurement.	Analyze
CO 5	Acquire raw experimental data, post-processing and analysis of the data, calculation and plotting of materials property data using Origin software, and essential laboratory safety and instrument handling/operation procedures etc. .	Skill

b. Syllabus

Units	Experiment (Content)	Hrs.
I	Measurement of Thermal Properties of PMMA using Differential Scanning Calorimetry	9
II	Determination of Energy Band Gap of Germanium using Four Probe Resistivity Method	9
III	Calculation of Hall Voltage, Carrier Concentration and Mobility of Ge using Hall Effect Setup	9
IV	Determination of Corrosion Rate of Metal/Alloy sample using Electrochemical Setup	9

V	Determination of Unknown Concentration of KMnO4 from UV-Vis Spectroscopy	9
VI	Phase Analysis of Hydroxy Apatite using X-ray diffraction method	9
VII	UV-Visible study of Photocatalyst mediated Degradation of Dye	9
VIII	Measurement of Emission Peak Wavelength of CdS nanoparticles using Fluorescence Spectroscopy	9
IX	Electroplating of an Cu Electrode with Zn Metal using Electrochemical Setup	9
X	Calculation of Specific Capacitance of Metal Conductor using Electrochemical Setup	9
	Tasks and Assignments: **References:**	

c. Mapping of Program Outcomes with Course Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	3	3	3
CO2	3	2	3	3	3	3
CO3	3	3	2	3	3	3
CO4	3	3	2	3	3	3
CO5	3	2	3	3	3	3

(If the correlation between mission statement and program specific outcome is high 3 is assigned, for moderate 2, for low 1, and for 0 are assigned)

d. Evaluation Scheme

	CO1	CO2	CO3	CO4	CO5	Total
Practical	15	15	15	15	15	75
Viva	5	5	5	5	5	25
Total	**20**	**20**	**20**	**20**	**20**	**100**

SEMESTER - III					
Course Code	**Course Name**	**L**	**T**	**P**	**Credits**
MST1932	**Clean energy technology**	3	-	-	3

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	Level
CO 1	Describe the fundamentals and main characteristics of clean energy sources and their differences compared to fossil fuels.	Remember
CO 2	Explain the technological basis for harnessing clean energy sources	Understand
CO 3	Recognize the effects that current energy systems based on fossil fuels have on the environment and society	Remember
CO 4	Discuss how to utilize local energy resources (renewable and non-renewable) to achieve the sustainable energy system	Analyze
CO 5	get a road map for design of materials for sustainable energy generation and harvesting methods	Skill

b. Syllabus

Units	Content	Hrs.
I	Global Energy Needs -Current energy status of India - Energy production from different sources - Hydrothermal - Geothermal - Solar - Renewable/Non-Renewable sources - Environmental impact - Necessity of energy materials.	9
II	Materials for Thermal Power Generation - Environmental Impact of thermal power plantsImproving Efficiency of thermal power plants - Materials challenges in high temperature and pressure of steam-Thermal Barrier Coating (TBC) over turbines - Materials Compositions for TBC -Yttria stabilized Zirconia and perovskite-based compositions.	9
III	Batteries - Types of Batteries- battery mechanism - Electrochemical reactions: Corrosion, oxidation, and prevention- Open circuit voltage - theoretical capacity - theoretical specific energy calculations - Irreversible losses in battery -Testing of a Battery - Lithium Primary Battery – Secondary Rechargeable Batteries - Lead Acid Battery - Ni-Cd Battery - Li-ion Battery - Recent developments in Batteries - Industrial Testing and Standard procedures for Battery - Fabrication Techniques.	9
IV	Fuel Cells, Components of Fuel Cells - types of Fuel Cells - the difference between batteries and fuel cells - working of fuel cell - theoretical efficiency - various factors affecting efficiency - calculation of the consumption of gases - high temperature - intermediate and low-temperature fuel cells - Materials for Solid Oxide Fuel cells -materials for Polymer Electrolyte Fuel Cells - Automobile and stationary power applications.	9

V	Ragone Plot - Supercapacitors - Non-Faradaic/Faradaic - Hybrid type - role of carbon materials in Supercapacitors- Photovoltaics -the principle of photovoltaic cell - Material challenges - perovskites as absorbers - Harvesting of waste heat by thermoelectric materials - Properties of materials to be used for thermoelectric applications.	9
	References 1. Series of Articles on "Materials Research Bulletin" 37 (2012) - Thermal Barrier coatings for efficient gas turbine engines 2. Linden D and Reddy Thomas B., Handbook of Batteries, Mc-Graw Hill (2001) 3. A.J.Bard and L.R. Faulkner, Electrochemical Methods: Fundaments and Applications, Wiley 2nd Edition (2000) 4. James Larminie and A. Dicks, Fuel Cells Explained, Wiley 2nd edition (2003) 5. Fuel Cell Handbook by EG&G Technical Services (2004) (e-copy available) 6. Sossina M. Haile, Materials for Fuel Cells, Materials Today (March 2003) 7. Allan J. Jacobson, Materials for solid oxide Fuel Cells, Chemistry of Materials 22, 660 (2010) 8. Green, M. A. Solar Cells: Operating Principles, Technology, and System Applications. Prentice Hall (1981) 9. Bell, Lon E. "Cooling, Heating, Generating Power, and Recovering Waste Heat with Thermoelectric Systems." Science 321 (September 12, 2008): 1457-1461	

c. Mapping of Program Outcomes with Course Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	3	2	2	3
CO2	2	2	3	2	2	3
CO3	2	2	3	2	2	3
CO4	2	2	3	2	2	3
CO5	2	2	3	3	2	3

d. Evaluation Scheme

	CO1	CO2	CO3	CO4	CO5	Total
Internal	8	8	8	8	8	40
External	12	12	12	12	12	60
Total	**20**	**20**	**20**	**20**	**20**	**100**

e. Mapping Course Outcome with Internal Assessment (40 Marks)

	CO1	CO2	CO3	CO4	CO5
Assignments	2	2	2	2	2
Seminar	-	-	-	-	-
Test	6	6	6	6	6
Attendance	-	-	-	-	-
Total	8	8	8	8	8

f. Mapping Course Outcome with External Assessment (60 Marks)

Category	CO1	CO2	CO3	CO4	CO5
Part – A (Short answer - 10 x 2 = 20 marks)	4	4	4	4	4
Part – B (Medium length Answer - 5 x 3 = 15 marks)	3	3	3	3	3
Part – C (Long Answer- 5 x 5 = 25 marks)	5	5	5	5	5
Total	**12**	**12**	**12**	**12**	**12**

SEMESTER - III					
Course Code	**Course Name**	**L**	**T**	**P**	**Credits**
MST1931	Corrosion Science and Engineering	3	-	-	3

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	Level
CO 1	Understanding basic concept of electrochemistry and its effect on materials and introduction and importance of study corrosion science and engineering	Understand

CO 2	Understanding different electrochemical cell and prediction of corrosion	Apply
CO 3	Different types of corrosions and mechanism	Remember
CO 4	Identify reason for corrosion and testing methods	Analyze
CO 5	Corrosion protection and environmental effect	Skill

b. Syllabus

Units	**Content**	**Hrs.**
I	Basic concepts: Definition and importance, Electrochemical nature and forms of corrosion and its prevention in various industries- The direct and indirect effects of corrosion. Electrochemical thermodynamics and kinetics: Electrode potentials, Potential-pH (Pourbiax) diagrams, Reference electrodes and experimental measurements, Faraday's laws, Instrumentation and experimental procedure.	9
II	Galvanic and concentration cell corrosion: Basic concepts, Experimental measurements, and determination of rates of galvanic corrosion, Concentration cells. Corrosion measurement through polarization techniques: Tafel extrapolation plots, Polarization resistance method, Commercial corrosion probes, Other methods of determining polarization curves.	9
III	: Passivity: Basic concepts of passivity, Properties of passive films, Experimental measurement, Applications of potentiostatic Anodic Polarization, Anodic protection. Pitting and crevice corrosion: Mechanisms of pitting and crevice corrosion, Secondary forms of crevice corrosion, Localized pitting, Metallurgical features and corrosion: Inter-granular corrosion, Weldment corrosion, De-alloying and dezincification.	9

IV	Environmental induced cracking: Stress corrosion cracking, Corrosion fatigue cracking, Hydrogen induced cracking, Methods of prevention and testing, Erosion, Fretting and Wear. Environmental factors and corrosion: Corrosion in water and aqueous solutions, Corrosion in sulphur bearing solutions, Micro-biologically induced corrosion, Corrosion in acidic and alkaline process streams.	9
V	Atmospheric and elevated temperature corrosion: Atmospheric corrosion and its prevention, Oxidation at elevated temperatures, Alloying, Oxidizing environments. Prevention and control of corrosion: Cathodic protection, Coatings and inhibitors, Material selection and design.	9
	Tasks and Assignments: **References:** **A. Text Books:** **1.** Fontana, M.G., Corrosion Engineering, Tata McGraw-Hill (2008). 3rd Ed. (seventh reprint) 2. Jones, D.A., Principles and Prevention of Corrosion, Prentice-Hall (1996) 3. Uhlig H.H, “Corrosion and its control”, Willey, 1985. **B. Reference books:** 1. Pierre R. Roberge, Corrosion engineering: principles and practice, McGraw-Hill (2008). 2. Pierre R. Roberge, Handbook of corrosion engineering, McGraw-Hill (2012). 2nded. 3. Sastri, V.S., Ghali, E. and Elboujdaini, M., Corrosion prevention and protection: Practical solutions, John Wiley and Sons (2007). 4. Pludek, “Design and corrosion prevention”, McMillan, 1978. 5. Raj Narain, “Introduction to metal corrosion”, Oxford IBH, 1983.	

c. Mapping of Program Outcomes with Course Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	3	3	3
CO2	3	3	2	3	3	3
CO3	3	2	3	3	2	3
CO4	3	3	3	2	3	3
CO5	2	3	2	3	3	3

d. Evaluation Scheme

	CO1	CO2	CO3	CO4	CO5	Total
Internal	8	8	8	8	8	40
External	12	12	12	12	12	60
Total	**20**	**20**	**20**	**20**	**20**	**100**

e. Mapping Course Outcome with Internal Assessment (40 Marks)

	CO1	CO2	CO3	CO4	CO5
Assignments	1	1	1	1	1

Test	6	6	6	6	6
Attendance	1	1	1	1	1
Total	8	8	8	8	8

f. Mapping Course Outcome with External Assessment (60 Marks)

Category	CO1	CO2	CO3	CO4	CO5
Part – A **(Short answer - 10 x 2 = 20 marks)**	4	4	4	4	4
Part – B **(Medium length Answer - 5 x 3 = 15 marks)**	3	3	3	3	3
Part – C **(Long Answer- 5 x 5 = 25 marks)**	5	5	5	5	5
Total	**12**	**12**	**12**	**12**	**12**

SEMESTER - III					
Course Code	**Course Name**	**L**	**T**	**P**	**Credits**
MST19E31	**SMART MATERIALS AND STRUCTURES**	3	-	-	3

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	Level

CO 1	On completion of the course, students can explain the concepts of smart materials and special emphasis on supramolecular polymers..	Remember
CO 2	Students may understand the structure property relationship of smart materials	Understand
CO 3	Students can apply the design principle to various types of smat structures.	Apply
CO 4	Students can analyze tasks based on smart materials and its design	Analyze
CO 5	Students can handle the day-to-day problems associated with smart materials and provide solutions.	Skill

b. Syllabus

Units	Content	Hrs.
I	Introduction to Smart materials and Structures. Definition and examples of intermolecular forces present in supramolecular materials. Superhydrophobic, superhydrophilic, superoliophobic, superoliophilic surfaces. Smart surfaces with hierarchical micro and nano structures for special and switchable wettability. Self-cleaning coatings, Lotus effect, butterfly effect, Gecko leg and water strider leg structure for special wettability. Design of new materials with stimuli responsive surfaces.	9
II	Self-assembly processes in organic materials. Definition, design and synthetic strategies of Catenanes, rotaxanes, pseudorotaxanes. Main supramolecular forces involved in such assemblies. Self-assembly processes in metal-containing compounds. Self-assembly of metal nanoparticles (via H-bonding and electrostatic forces). Application of coordination bonds in the preparation of large supramolecular assembled materials such as Cages, macrocycles and catenanes.	9
III	Polymeric materials and grids. Nano-capsules and containers. Discussion of main synthetic strategies for their preparation. Examples of each type. Potential uses of such assemblies as nano-reactors and for transport (e.g. drug-delivery).	9
IV	Molecular switches and machines. Use of supramolecular forces to assemble components that respond (on-off) to external stimuli. Molecular-shuttles, Molecular-abacus and Molecular-muscles, Molecular-elevator. Assembling such components into surfaces for molecular electronics. Supramolecular interaction of polymeric materials in the solid state. Self-assembled monolayers. Molecularly imprinted polymers.	9
V	Soft smart hybrid materials based on Carbon nanotubes, Graphene oxide, graphene, fullerene, organogels, hydrogels, ionic liquid gels. Preparation, characterization and application of these hybrid materials using various spectroscopic and microscopic techniques.	9

Tasks and Assignments:
References:

1) Supramolecular chemistry : fundamentals and applications : advanced textbook, Publisher: Heidelberg : Springer, 2006

2) Supramolecular Chemistry –Fundamentals and Applications, Katsuhiko Ariga and Toyoki Kunitake, Springer, 2006, ISBN-10 3-540-01298-2 Springer Berlin Heidelberg New York

ISBN-13 978-3-540-01298-6 Springer Berlin Heidelberg New York, 2006, DOI: 10.1007/b84082

3) Advanced Textbook Lehn, J.-M. (1995) Supramolecular Chemistry. Wiley-VCH. ISBN 978-3-527-29311-7.

4) Jerry L. Atwood, Jonathan W. Steed (2, eds.) (2017) Supramolecular Chemistry: From Molecules to Nanomaterials. Wiley. ISBN 978-0-470-74640-0

5) Supramolecular Soft Matter: Applications in Materials and Organic Electronics: Interaction of carbon nanotubes and small molecules. Publisher: John Wiley & Sons, Inc. 2011, 381-406. Print ISBN: 9780470559741 Online ISBN: 9781118095331.

S. Srinivasan, A. Ajayaghosh.

Learning materials:

1) Beauty in Chemistry, Artistry in the Creation of New Molecules, Editor-Luigi Fabbrizzi, The Mechanical Bond: A Work of Art, by Carson J. Bruns and J. Fraser Stoddart, Publisher Springer, Berlin, Heidelberg, 2012.

2) Balzani, V.; Gómez-López, M.; Stoddart, J. F. (1998). "Molecular Machines". Accounts of Chemical Research. 31 (7): 405–414. doi:10.1021/ar970340y

E-materials:

1) Lehn, J. M. (1990). "Perspectives in Supramolecular Chemistry—From Molecular Recognition towards Molecular Information Processing and Self-Organization". Angewandte Chemie International Edition in English. 29 (11): 1304–1319. doi:10.1002/anie.199013041.

2) Ikeda, T.; Stoddart, J. F. (2008). "Electrochromic materials using mechanically interlocked molecules". Science and Technology of Advanced Materials. 9: 014104., doi:10.1088/1468-6996/9/1/014104.

3)http://www.oxkstu.ru/download/Ariga_K_Supramolecular_Chemistry_-_Fundamentals_and_Applications.pdf

c. Mapping of Program Outcomes with Course Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	2
CO2	3	3	3	2	3	3
CO3	3	3	2	3	3	3
CO4	3	3	3	3	2	3
CO5	3	2	3	3	2	3

d. Evaluation Scheme

	CO1	CO2	CO3	CO4	CO5	Total
Internal	8	8	8	8	8	40
External	12	12	12	12	12	60
Total	**20**	**20**	**20**	**20**	**20**	**100**

e. Mapping Course Outcome with Internal Assessment (40 Marks)

	CO1	CO2	CO3	CO4	CO5
Assignments	1	1	1	1	1
Seminar	1	1	1	1	1
Test	5	5	5	5	5
Attendance	1	1	1	1	1
Total	8	8	8	8	8

f. Mapping Course Outcome with External Assessment (60 Marks)

Category	CO1	CO2	CO3	CO4	CO5
Part – A **(Short answer - 10 x 2 = 20 marks)**	4	4	4	4	4
Part – B **(Medium length Answer - 5 x 3 = 15 marks)**	3	3	3	3	3
Part – C **(Long Answer- 5 x 5 = 25 marks)**	5	5	5	5	5
Total	**12**	**12**	**12**	**12**	**12**

g. Rubric for Assignments

Sl. No.	Criteria	100%	75%	50%	25%	0%	Relation to COs
1	**Content** **50%**	Ideas are detailed, well developed, supported with specific evidence & facts and examples	Ideas are detailed, Developed and supported with evidence and facts mostly specific.	Ideas are presented but not particularly developed or supported;	Content is not sound	Not attended	CO1, CO2, CO3
2	**Organiza-tion** **50%**	Includes title, introduction, statement of the main idea with illustration and conclusion.	Includes title, introduction, statement of main idea and conclusion.	organizational tools are weak or missing	No organization	Not attended	CO3, CO4, CO5

SEMESTER - III					
Course Code	**Course Name**	**L**	**T**	**P**	**Credits**
MST19E32	**Crystallography and Materials design**	3	-	-	3

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	**Level**
CO 1	to understand how the structure and bonding is related to the materials and materials' properties	Remember
CO 2	Get the fundamental principle of XRD generation, diffraction, Bragg's law, Concept of Reciprocal space, recording of powder pattern for various materials	Analyze

CO 3	the skill of determining space groups, point groups, overall crystal structure from existing knowledge through refinement methods	Skill
CO 4	Hands-on training on refinement of XRD data on FULLPROF platform	skill
CO 5	Get introduced to advanced structural characterization techniques such as Neutron diffraction, Synchrotron methods, EXAFS etc.	Remember

b. Syllabus

Units	Content	Hrs.
I	Overview, materials and material properties, roles of structure and bonding, history of crystallography, symmetry, symmetry operators, translation, rotation, combination of symmetry operations, screw axes and glide planes, point groups,space groups, unit cell	9
II	X-ray Generation, Diffraction, Convolution theorem and Fourier Transformation, Bragg's law, Miller indices, Geometry of diffraction, Reciprocal space, Ewald's construction, structure factor of atoms, determination of structure factor, electron density, recording of powder-diffraction patterns of materials	9
III	Laue groups, space group determination, systematic absences, referring crystallographic database (ICSD and OCD), structure refinement, lattice parameter refinement (lebail and Pauli's method), displacement parameters, isotropic, anisotropic, least squares approach to refinement, Rietveld method, R-factors, 3-D visualization of crystal structure	9
IV	Introduction to FULLPROF software, Understanding the essential variables, Hands on training to structural refinement of powder X-ray diffraction pattern, Strengths and limitations of various structural refinement software	9
V	Crystal structure and property correlation for selective oxide and chalcogenide systems, Electron diffraction, Neutron diffraction, EXAFS technique to determine the crystal structure	9

	References 1. Christopher Hammond, Basics of crystallography and diffraction, Oxford University press, 2001. 2. M.A. Wahab, Essentials of Crystallography, Narosa Publishers 2014 3. International tables for crystallography, published by International union of crystallography, Volumes I 4. Giacovazza, Fundamentals of Crystallography, Oxford University Press 2011 5. Newnham, Properties of Materials, Oxford University Press 2004 6. FULLPROF manual, document available at https://www.ill.eu/fileadmin/users.../Introduction_to_FullProf_Suite_JRC.pdf 7. John N. Lalena, David A. Cleary, Principle of inorganic materials design, John Wiley, 2005 **Additional reading:** 1. Ladd, Symmetry of crystals and molecules, Oxford University Press, 2014 2. Lulek, Symmetry and structural properties of condensed matter, Elsevier 2000	

c. Mapping of Program Outcomes with Course Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	3	2	3	2
CO2	3	2	3	2	3	2
CO3	3	2	3	2	3	2
CO4	3	2	3	2	3	2
CO5	3	2	3	3	3	2

d. Evaluation Scheme

	CO1	CO2	CO3	CO4	CO5	Total
Internal	8	8	8	8	8	40
External	12	12	12	12	12	60
Total	**20**	**20**	**20**	**20**	**20**	**100**

e. Mapping Course Outcome with Internal Assessment (40 Marks)

	CO1	CO2	CO3	CO4	CO5
Assignments	2	2	2	2	2
Seminar	-	-	-	-	-
Test	6	6	6	6	6
Attendance	-	-	-	-	-
Total	8	8	8	8	8

f. Mapping Course Outcome with External Assessment (60 Marks)

Category	CO1	CO2	CO3	CO4	CO5
Part – A (Short answer - 10 x 2 = 20 marks)	4	4	4	4	4
Part – B (Medium length Answer - 5 x 3 = 15 marks)	3	3	3	3	3
Part – C (Long Answer- 5 x 5 = 25 marks)	5	5	5	5	5
Total	**12**	**12**	**12**	**12**	**12**

Category	CO1	CO2	CO3	CO4	CO5
Part – A **(Short answer - 10 x 2 = 20 marks)**	**4**	**4**	**4**	**4**	**4**
Part – B **(Medium length Answer - 5 x 3 = 15 marks)**	**3**	**3**	**3**	**3**	**3**
Part – C **(Long Answer- 5 x 5 = 25 marks)**	**5**	**5**	**5**	**5**	**5**
Total	**12**	**12**	**12**	**12**	**12**

SEMESTER - III					
Course Code	**Course Name**	**L**	**T**	**P**	**Credits**
MST1935	Material Testing Lab	-	-	6	3

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	**Level**
CO 1	On completion of the lab course, students can understand the various material testing methods	Understand
CO 2	Students may remember the non-destructive testing (NDT) methods	Remember
CO 3	Students can apply the basic knowledge in microscopic analysis (Optical, SEM, etc)	Apply
CO 4	The students will gain experience on electrochemical (corrosion tests) measurement.	Analyze
CO 5	Acquire basic laboratory safety procedures, operation of instruments etc.	Skill

b. Syllabus

Units	**Experiment (Content)**	**Hrs.**
I	Determination of Hardness of a Material using Brinell Hardness Tester	9
II	Determination of Hardness of a Material using Rockwell Hardness Tester	9
III	Determination of Hardness of a Material using Vickers Hardness Tester	9
IV	Determination of Microhardness of a Material using Microhardness Hardness Tester	9
V	Determination of Impact Strength of a Material using Charpy Impact Tester	9
VI	Determination of Tensile Strength of a Material using Tensometer Tester	9
VII	Determination of Mechanical Properties of a Material using Universal Testing Machine	9
VIII	Preparation and Microstructure Analysis of a Material using Optical Microscope	9
IX	Examination of Defects in a sample using Non-destructive Testing Method	9
X	Determination of Corrosion Rate of a Metal using Electrochemical Method	9

	Tasks and Assignments: **References:**	

c. Mapping of Program Outcomes with Course Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	3	3	3
CO2	3	2	3	3	3	3
CO3	3	3	2	3	3	3
CO4	3	3	2	3	3	3
CO5	3	2	3	3	3	3

(If the correlation between mission statement and program specific outcome is high 3 is assigned, for moderate 2, for low 1, and for 0 are assigned)

d. Evaluation Scheme

	CO1	CO2	CO3	CO4	CO5	Total
Practical	15	15	15	15	15	75
Viva	5	5	5	5	5	25
Total	**20**	**20**	**20**	**20**	**20**	**100**

SEMESTER - III					
Course Code	**Course Name**	**L**	**T**	**P**	**Credits**
MST19E33	Porous Materials	3	-	-	3

a. Course Outcome (CO)

On the successful completion of the course, the student will be able to

(Course outcomes are specific for a particular course. CO should be specific, measurable, achievable, realistic, and time-bound)

	Course Outcome	Level
CO 1	Student know about various type of porous materials, classifications and definition	Remember
CO 2	Understanding fundamental theory behind adsorption processes	Understand
CO 3	Student will learn about inorganic porous materials and their applications	Apply
CO 4	Student will learn about inorganic-organic hybrid porous materials and their applications	Analyze
CO 5	Student will learn about organic porous materials and their applications. Finally they will be able to come with the conclusion that which materials are suitable and better for practical application.	Create

b. Syllabus

Units	Content	Hrs.
I	Definition of porous materials, natural porous materials, living porosity, clay minerals, artificial porous solids, classifications of porous materials, micro-, meso- and macro-porous materials, amorphous and crystalline porous solids, characterization methods, applications.	9
II	Concept of surface area, method of porosity measurement, chemisorption and physisorption, theory of adsorption: reversible monolayer adsorption – Langmuir adsorption isotherm, multilayer adsorption – BET (Brunauer, Emmet, Teller) model, BET surface area calculation, multipoint BET analysis, capillary condensation, types of adsorption, IUPAC classification, hysteresis, pore size distributions, adsorption kinetics, heterogeneous catalysis.	9
III	Inorganic porous materials; zeolites: synthesis, characterization, structure, functions and applications – water purification, molecular sieves, gas sorption, catalysis; porous silica: synthetic methods, silica gels, silica surfaces, MCM-41 and MCM-48, structure, stability, adsorption, heterogeneous catalysis, drug delivery; porous carbon: activated carbon, different synthetic methods, carbonization, stability, pre- and post-synthetic modification, nanocarbons, applications – pollutants removal, catalysis, energy related.	9
IV	Inorganic-organic hybrid porous materials; Periodic MesoporousOrganosilicas (PMOs): different synthetic methods, characterization, stability, post synthetic modification, applications – catalysis, adsorbent, chromatography; Metal Organic Frameworks (MOFs): nomenclature, design and synthesis, pre- and post-synthetic modification, characterization, stability, functionalization and applications – gas sorption and separation, catalysis, luminescent and sensors, CO2 capture, water purification, bio-related application, energy storage and energy conversion.	9
V	Organic porous materials; amorphous and crystalline porous organic solids, Polymers of Intrinsic Microporosity (PIMs), Porous Organic Polymers (POPs), Covalent Organic Frameworks (COFs), Conjugated Microporous Polymers (CMPs), Covalent Triazine Frameworks (CTFs), Porous Aromatic Frameworks (PAFs), porous organic cages, design principle, topology, diversities, different synthetic methods and challenges, pre- and post-synthetic modification, characterization, stability, porosity, applications - gas adsorption and separation, semiconduction and photoconduction, heterogeneous catalysis, luminescent and sensors, pollutant removal, CO2 capture, bio-related application, energy storage and energy conversion.	9
	Tasks and Assignments: **References:** 1. P. Van Der Voort, K. Leus, E. De Canck, Introduction to Porous Materials, 1st Ed., 2019, John Wiley & Sons Ltd., ISBN: 978-1-119-42660-8. 2. D. W. Bruce, D. O'Hare, R. I. Walton, Porous Materials, 2011, John Wiley & Sons, Ltd., ISBN: 978-0-470-99749-9. 3. E. A. Boucher, Porous Materials: Structure, Properties and Capillary Phenomena, Journal of Materials Science, 1976, 11, 1734-1750. 4. A. G. Slater, A. I. Cooper, Function-led Design of New Porous Materials, Science, 2015, 348, aaa8075. 5. L. R. MacGillivray, Metal-Organic Frameworks: Design and Application,	

	2010, John Wiley & Sons, Ltd., ISBN: 978-0-470-19556-7. 6. H.-C. Zhou, J. R. Long, O. M. Yaghi,Introduction to Metal–Organic Frameworks, Chemical Reviews, 2012, 112, 673–674. 7. S. Das, P. Heasman, T. Ben, S. Qiu, Porous Organic Materials: Strategic Design and Structure−Function Correlation, Chemical Reviews, 2017, 117, 1515−1563. 8. K. Geng, T. He, R. Liu, S. Dalapati, K. T. Tan, Z. Li, S. Tao, Y. Gong, Q. Jiang, D. Jiang, Covalent Organic Frameworks: Design, Synthesis, and Functions, Chemical Reviews, 2020, DOI: 10.1021/acs.chemrev.9b00550.	

c. Mapping of Program Outcomes with Course Outcomes

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	3	3	3
CO2	3	3	3	3	3	3
CO3	3	3	3	3	3	3
CO4	3	3	3	2	3	3
CO5	3	3	3	3	3	3

d. Evaluation Scheme

	CO1	CO2	CO3	CO4	CO5	Total
Internal	8	8	8	8	8	40
External	12	12	12	12	12	60
Total	**20**	**20**	**20**	**20**	**20**	**100**

e. Mapping Course Outcome with Internal Assessment (40 Marks)

	CO1	CO2	CO3	CO4	CO5
Assignments	1	1	1	1	1
Test	6	6	6	6	6
Attendance	1	1	1	1	1
Total	8	8	8	8	8

f. Mapping Course Outcome with External Assessment (60 Marks)

Category	CO1	CO2	CO3	CO4	CO5
Part – A **(Short answer - 10 x 2 = 20 marks)**	4	4	4	4	4
Part – B	3	3	3	3	3

(Medium length Answer - 5 x 3 = 15 marks)					
Part – C **(Long Answer- 5 x 5 = 25 marks)**	5	5	5	5	5
Total	**12**	**12**	**12**	**12**	**12**