Course Curriculum

(Course Structure and Syllabi)

For

Bachelor of Technology

In

Materials Science and Engineering

(Second Year Onwards)

Department of Materials Science and Engineering

National Institute of Technology Hamirpur Hamirpur– 177005 (India)

Curriculum for B Tech Programme

Course No.	Semester 3	Credits	Course Type
BS/Engg	Basic Sciences	3	Discipline core
	Engineering Courses	14	Discipline core
	Engineering Course (Lab)	2	Discipline core
Discipline Workshop	Basic Engineering Skills	1	Discipline core
Total		**20**	

Course No.	Semester 4	Credits	Course Type
	Engineering Course	13	Discipline core
	Engineering Course	3	Discipline Elective
	Engineering Course (Lab)	3	Discipline core
	LA/CA	1	Institute Elective
	Total	**20**	

Curriculum for B Tech Programme

Second Year													
3rd Semester							4th Semester						
SN	Code	Subject	L	T	P	C	SN	Code	Subject	L	T	P	C
1	MA-211	Numerical Methods and Computations	3			3	1	MS-221	Composite Materials	3			3
2	MS-211	Transport Phenomena	3	1		4	2	MS-222	Phase Transformation	3			3
3	MS-212	Materials Thermodynamics and Kinetics	3	1		4	3	MS-223	Materials Processing Techniques	3	1		4
4	MS-213	Introduction to Materials Science	3			3	4	MS-224	Heat Treatment	3			3
5	MS-214	Mechanical Behavior of Materials	3			3	5	MS-225	Material Processing Lab			2	1
6	MS-215	Transport Phenomena Lab			2	1	6	MS-226	Heat Treatment Lab			2	1
7	MS-216	Materials Science and Mechanical Testing Lab			2	1	7	MS-227	Composite Lab			2	1
8	MS-217	Metallographic Practices			2	1	8	MS-241/242/243	Discipline Elective (I)	3			3
							9	SA-201/202/203/204/205/206/207/208/209	LA/CA (NSS/NCC/Prayas etc)				1
		Total =				20			Total =				20

Curriculum for B Tech Programme

Discipline Elective-I

1. MS-241 Electronics, Magnetic and Optical Properties of Materials
2. MS-242 Biomaterials
3. MS-243 Mechanics of Solids

Curriculum for B Tech Programme

Course No.	Semester 5	Credits	Course Type
	Open Elective	3	Institute Electives
	Engineering Course	**12/10**	Discipline core
	Engineering Course	3	Discipline Elective
	Engineering Course (Lab)	2	Discipline core
	HSS Course (**Non Circuital branches)**	**0/2**	Institute Core
	Total	**20**	

Course No.	Semester 6	Credits	Course Type
	Engineering Course	**10/8**	Discipline Core
	Engineering Course	6	Discipline Elective
	Engineering Course	2	Stream Core
	Engineering Course (Lab)	2	Discipline Core
	HSS Course **(Circuital branches)**	**0/2**	Institute Core
	Total	**20**	

Third Year													
5th Semester							6th Semester						
S N	Code	Subject	L	T	P	C	SN	Code	Subject	L	T	P	C
1	MS-311	Iron and Steel Making	3	1		4	1	MS-321	Computational Materials Science	3			3
2	MS-312	Metal Working Science and Technology	3			3	2	MS-322	Polymer Science and Technology	3			3
3	MS-313	Characterization of Material	3			3	3	MS-323	Non-Ferrous Extractive Metallurgy	3	1		4
4	MS-314	Metal Working Lab			2	1	4	MS-324	Nano Materials Lab			2	1
5	MS-315	Material Characterization Lab			2	1	5	MS-325	Non-Destructive Testing and Computational Material Science Lab			2	1
6	MS-331/332/333	Discipline Elective (II)	3			3	6	MS-341/342/343	Discipline Elective (III)	3			3
7	MS-301/302/303/304	Open Elective	3			3	7	MS-361/362/363	Discipline Elective (IV)	3			3
8	HS-311	HSS Course (Non Circuital Branches)	2			2	8	MS-381/382	Stream Core- (I)	2			2
9													
		Total =				20			Total =				20

Discipline Elective (II)

1. MS-331 Corrosion Science and Engineering
2. MS-332 Magnetic Materials for Industry
3. MS-333 Energy Storage Devices and Fuel Cells

Discipline Elective (III)

1. MS-341 Nanomaterials and Applications
2. MS-342 Materials Selection and Design
3. MS-343 Surface Science and Engineering

Discipline Elective (IV)

1. MS-361 Failure Analysis of Materials
2. MS-362 Fuels Refractory and Furnaces
3. MS-363 Semiconductor Technology

Stream Core-I

1. MS-381 Non-Destructive Testing of Materials
2. Ms-382 Joining of Materials

Open Elective

1. MS-301 Nano-Materials and Applications.
2. MS-302 Materials for Renewable Energy
3. MS-303 Materials Characterization.
4. MS-304 Electronic and Optical Properties of Materials

Curriculum for B Tech Programme

Course No.	Semester 7	Credits	Course Type
	Engineering Course	9	Discipline Core
	Engineering Course	3	Discipline Elective
	Engineering Course	4	Stream Core
	Engineering Course (Lab)	2	Discipline Core
Vocational Training	Engineering Course	2	Discipline Core
	Total	**20**	

Course No.	Semester 8	Credits	Course Type
	UG Project*	12/12	Discipline elective
	Free Elective/Engineering Course/Open Elective Course (Courses available in other departments in the even semester)	**6**	Free Electives/Stream Elective (offered by Department/Institute Elective (Open Elective)
General Proficiency	Holistic Assessment	2	Institute Core
	Total	**20**	

* Students **opting for internship** will **complete the UG project** and the remaining credit requirements will be by fulfilled by opting **Free Elective Courses**

Fourth Year													
7th Semester							8th Semester						
SN	Code	Subject	L	T	P	C	SN	Code	Subject	L	T	P	C
1	MS-411	Ceramic Science and Engineering	3			3	1	MS-498	General Proficiency				2
2	MS-412	Tribology of Materials	3			3	2	MS-499	UG Project				12
3	MS-413	Thin Film Technology	3			3	3	MS-461/462/463	Stream Elective-I	3			3
4	MS-414	Ceramic Materials Lab			2	1	4	MS-481/482/483	Stream Elective-II	3			3
5	MS-415	Tribology Lab			2	1							
6	MS-416	Summer Training	2			2							
7	MS-451/452/453	Discipline Elective (V)	3			3							
8	MS-471/472	Stream Core- (II)	2			2							
9	MS-491/492	Stream Core – (III)	2			2							
		Total =				**20**			**Total =**				20

*The students should undergo vocational training during summer vacations after sixth semester

Discipline Elective (V)

1. MS-451 Smart Materials
2. MS-452 Electronic Ceramics
3. MS-453 Nanodevices

Stream Core-II

1. MS-471 Powder Metallurgy
2. MS-472 Phase Diagrams

Stream Core-III

1. MS-491 Light Metal & Alloys
2. MS-492 Structure of Materials

Stream Elective-I

1. MS-461 Advanced Functional Oxide Materials
2. MS-462 Advanced Materials Processing Technologies
3. MS-463 X-ray Techniques

Stream Elective-II

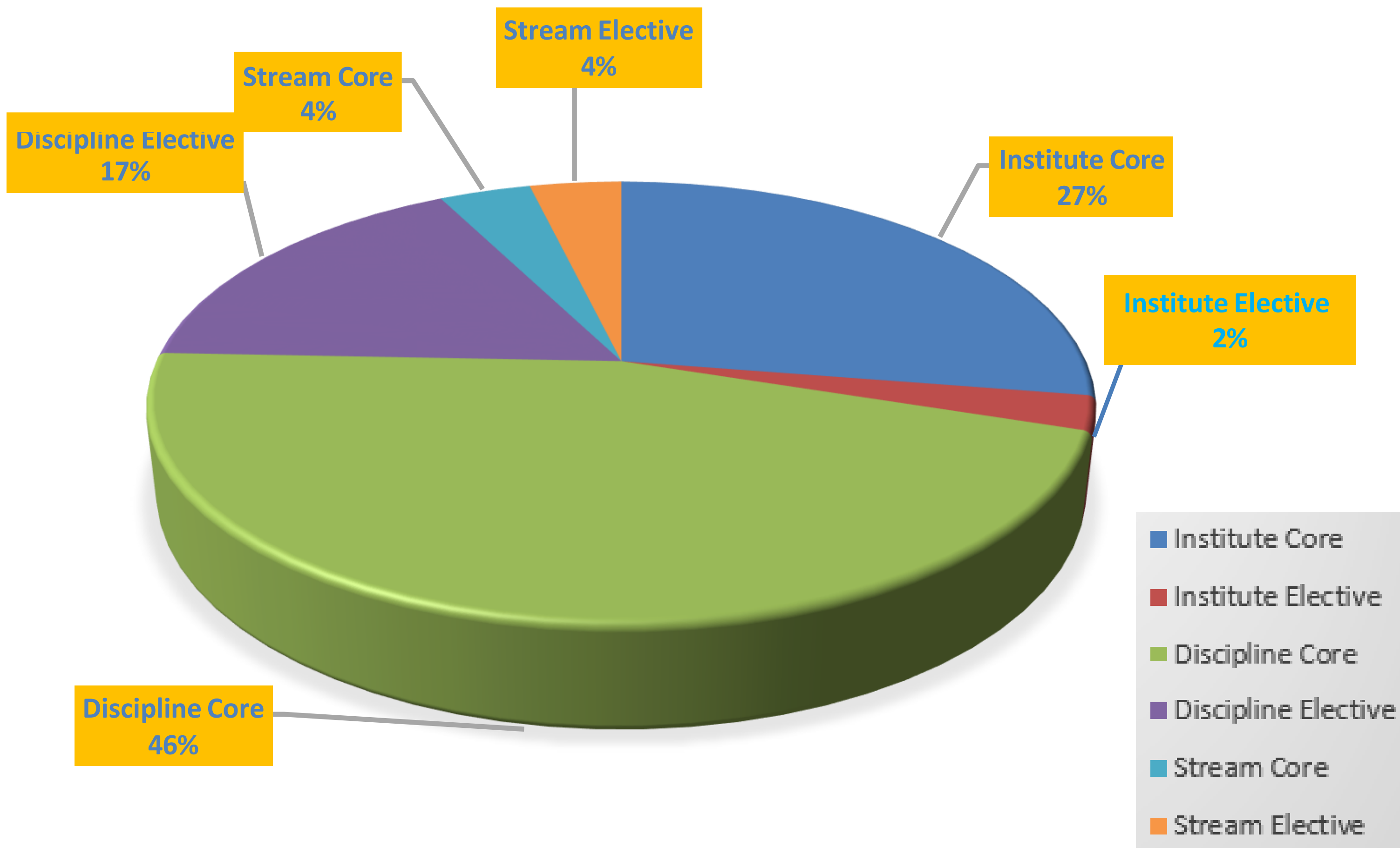
1. MS-481 High Temperature Materials
2. MS-482 Laser Materials Processing
3. MS-483 Spectroscopy

Types of Courses and credits in each Semester

	Semester								
Types of Courses	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**Total**
IC	20	20	0	0	2	0	0	2	44
IE	0	0	0	1	3	0	0	0-6*	4-10*
DC	0	0	20	16	12	12	13	0	73
DE	0	0	0	3	3	6	3	12	27
SC	0	0	0	0	0	2	4	0	6
SE	0	0	0	0	0	0	0	6*	0-6*
Total	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**160**
Total									**160**

* Students are free to choose any combination out of Free Electives, IE and SE for 6 credits

Share of Credits based on the Requirement of the Programme



Course Name: Numerical Methods and Computations
Course Code: MA-211
Course Type: Discipline Core

Contact Hours/Week: 03 **Course Credits: 03**

Course Objectives:

To increase the problem-solving skills of engineering students using powerful tools ofnumerical methods.
To enhance the capability of handling large system of equations that are common inengineering practice.
To learn to interpolate data useful in computer visulation.
To introduce the numerical methods for solving ordinary differential equations.

Unit No.	Course Content	Lectures
UNIT-01	**Numerical Solution of Linear Equations:** Errors: Definition and sources of errors, Relative and Percentage error, Round-off and Truncation errors. Linear Equations: Diagonally dominant systems, Jacobi and Gauss Seidel Iteration methods, Necessary and sufficient conditions for convergence of iteration methods.	8
UNIT-02	**Numerical Solution of Non-Linear Equations:** Non-Linear Equations: Bisection Method, Regula-Falsi Method, Newton-Raphson Method, Iteration method, Order of convergence.	4
UNIT-03	**Curve fitting:** Least square curve fitting: Linear, Reducible to linear, Quadratic,and Exponential fit. Evenly and unevenly spaced data points,	5
UNIT-04	**Interpolation:** Finite differences and difference operators, Lagrange's interpolation, Newton's forward, backward and, divided differenceinterpolation formulae.	5
UNIT-05	**Numerical Integration:** Newton-Cotes general formula: Trapezoidal rule, Simpson's-1/3rule, Simplson's-3/8 rule and their composite formulas, Errors in integration, Romberg integration method.	6
UNIT-06	**Numerical Solution of Ordinary Differential Equations:** Euler's method, Modified Euler's method, Runge- Kutta of second and fourth order method, Predictor corrector method: Adams-Bashforth-Moulton method of fourth order.	8

Course Outcomes

Upon successful completion of the course, the student will be able
CO1: Understand numerical techniques to find the roots of non-linear equations.CO2:
Understand difference operators and use of interpolation.
CO3: Understand numerical differentiation and integration and numerical solutions of ordinary differential equations.

Text Books: -

1. M. K. Jain, S. R. K. Iyengar and R. K. Jain, Numerical Methods for Scientific and Engineering Computation, New age International Publisher, India, 5th edition, 2007.
2. B. Bradie, A Friendly Introduction to Numerical Analysis, Pearson Education, India, 2007.
3. Richard L. Burden, J. Douglas Faires - Numerical Analysis, 9th Edition, Cengage India Private Limited (2010)

Reference Book:

4. K.E. Atkinson, W. Han, Elementary Numerical Analysis, 3rd Edition, Wiley, 2003.

Course Name: **Transport Phenomena**
Course Code: **MS-211**
Course Type: **Discipline Core**

Contact Hours/Week: **3L+1T** Course Credits: **4**

Course Objectives

- To understand basic concepts related to heat flow, fluid flow, mass transfer, in the context of metallurgical processes
- To become familiar with the mathematical treatment and equations related to transport phenomena; to comprehend the science behind process modelling

Unit Number	Course Content	Contact Hours
UNIT-01	**Introduction: Fluid Flow** - Viscosity – differential mass and momentum balances –overall momentum balance – mechanical energy balance – applications Fluid Mechanics: Newton's Law of Viscosity and mechanisms of momentum transfer; Newtonian& non- Newtonian fluids; Laminar and turbulent flows. Newton's second law of motion; Navier Stokes equation; typical boundary conditions in fluid flow problems; Dimensional analysis of equation of change. Engineering Bernoulli's equation and application. Compressible flow in conduits; Mixing and agitation.	**09**
UNIT-02	**Conduction Heat Transfer:** Steady state heat conduction - simple examples. Transient heat conduction - Systems with negligible internal resistance - Lumped heat analysis - Response time of a temperature- measuring instrument - System with negligible surface resistance- heat flow inan infinitely thin plate (Semi- infinite body) - System with finite surface and internal resistance - Chart solutions of transient heat conduction problems – Examples on Heat Treatment.	**09**
UNIT-03	**Convective Heat Transfer:** Forced and free convention - Boundary layer concept - velocity andthermal boundary layers (no derivation) - Simple problems - Flow over flat plate - laminar and turbulent boundary layers (no derivation) - Simple problems – Boundary layer development in acircular duct (no derivation) - Flow over cylinders and spheres-Simple problem- applications in metallurgical processes.	**06**
UNIT-04	**Radiation Heat Transfer:** Nature of thermal radiation, Concept of Black body, Emissive power – Gray body – Shape factor - Simple problems on Radiation heat transfer between surfaces. Introduction to Gas radiation. Selective examples from Met processes including thermal insulation in materials processing reactors, Melting, Quenching and Radiative losses at high temperature from furnaces and other reactors.	**06**
UNIT-05	**Mass Transfer:** Diffusion mass transfer. Simple problems using Fick's law of diffusion. Introduction to convective mass transfer-Introduction to computational fluid dynamics software. Molecular diffusion, Phenomenological description, mass diffusivity and its analogy with momentum and thermal diffusivity, temperature dependence of diffusion coefficient Diffusion insolids: generalized diffusion equation, the steady and transient, 1D solutions; Uphill diffusion; Kirkendal'seffect **Simultaneous Heat and Mass Transfer:** Elucidation through Gas carburizing process; Discussion on solidification phenomena (formation of gas bubbles during solidification), post combustion in steelmaking.	**06**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the principles of fluid flow, heat and mass transfer in metallurgical aspect.

CO2: Understand the science behind process modeling

CO3: Understand the various heat transfer in materials

Books and References

1. Transport Phenomena in Metallurgy by G. H Geiger and D. R Poirier; TMS Publication
2. Engineering in Process Metallurgy by R. Guthrie, Oxford Scientific Publications
3. Fundamentals of Momentum, Heat and Mass Transfer by Welty, Wicks, Wilson and Rorrer, Wiley
4. Basic Fluid Mechanics by C.P. Kothandaraman and R Rudramoorthy., New Age International Publishers
5. Fundamentals of Engineering Heat and Mass Transfer by Sachdeva, R C, New Age International Publishers

Course Name: **Materials Thermodynamics and Kinetics** Course Code: **MS-212** Course Type: **Discipline Core**		
Contact Hours/Week: **3L+1T**		Course Credits: **4**
Course Objectives • To introduces the fundamental concepts/theories on the thermodynamics of materials, from the basic concepts of enthalpy, entropy and free energy • To imparts the fundamental concepts relevant to the principle of thermodynamics • To enable the students to understand role of thermodynamics solutions for the Materials		
Unit Number	**Course Content**	**Contact Hours**
UNIT- 01	**Introduction and Basic Concepts:** Scope, application, importance in Metallurgical Engineering, state of system, thermodynamic equilibrium, Thermodynamic variables, properties of system	**06**
UNIT- 02	**First Law of Thermodynamics**: Internal Energy, Enthalpy, Heat Capacity, Cp & Cv, Hess Law, Kirchoff"s Law, Numerical Problems.	**06**
UNIT- 03	**Second Law of Thermodynamics:** Limitations of First Law, Various statements of 2nd law, Carnot theorem, Carnot cycle, Entropy, free energy, Gibbs Hemlholtz equations, Maxwell's relationships, Statistical concept of entropy, Numerical problems. **Third law of Thermodynamics:** Activity, fugacity & Equilibrium Constant, Chemical Potential and Numerical problems involving thermodynamic variables.	**06**
UNIT- 04	**Single Component Systems:** Clausis –Clapyron equations, Numerical Problems Phase Rule & Ellingham Diagrams: Temperature/free energy diagrams for Oxides, Sulphides & Halides.	**06**
UNIT- 05	**Solutions:** Partial Molar properties, Gibbs Duhem equation, Ideal-Non Ideal solutions, Raoult's Law, Henry law, Sievert's law, Regular solutions, Interaction parameter, Interaction coefficient and Numerical problems.	**06**
UNIT- 06	**Kinetics of Metallurgical Processes:** Basics, first, second, third, zero order reactions, collision theory, theory of Absolute Reaction rates, Activation Energy, Reduction of Oxide Ores, Kinetics of Roasting, Smelting, Numerical Problems.	**06**
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Understand the fundamental and basic principles of thermodynamics CO2: Lean to apply the basic principles and methods of thermodynamics in the study and the R&D of materials CO3: Understand the phase rules and the phase diagrams, as well as the application of the phase diagrams in the materials study. CO4: Cultivate the ability of discovering the potential of existing materials and of developing new materials.		
Books and References 1. Introduction to Metallurgical Thermodynamics by Gaskel, McGraw Hill. 2. Textbook of Materials and Metallurgical Thermodynamics by Ahindra Gohosh, PHI Learning. 3. Thermodynamics in Materials science by Robert DeHoff, CRC Press. 4. Chemical and Metallurgical Thermodynamicsby, Krishna Kant Prasad; Hem Shanker Ray; K. P. Abraham, New Age. 5. Problems in Metallurgical Thermodynamics and Kinetics by G S. Upadhyaya, R. K. Dube, Pergamon, Elsevier.		

Course Name: **Introduction to Materials Science**
Course Code: **MS-213**
Course Type: **Discipline Core**

Contact Hours/Week: **3L** | Course Credits: **3**

Course Objectives

- To impart knowledge about the structure of materials
- To introduce fundamental concepts relevant to phase diagrams, phase transformations and heat treatment of metals and alloys
- To enable the students to understand properties of engineering materials

Unit Number	Course Content	Contact Hours
UNIT- 01	**Introduction**: Why study materials science and engineering? Review of basic types of interatomic bonds, Classification of materials, Processing/structure/properties/ performance correlation	**03**
UNIT- 02	**Structure and Imperfections:** Lattices, Unit cells, Miller indices of directions and planes for cubic and hexagonal systems, Closepacking in solids, Common metallic structures, Voidsin close-packed structures, Polycrystalline materials, X-Ray diffraction for determination of crystal structures, **Solid state diffusion** – Ficks laws of diffusion, Diffusion mechanisms, Temperature dependendence of diffusivity, Defects in crystals - Point defects, Dislocations, Grain boundaries and Surfaces, Noncrystalline solids, Polymeric materials	**09**
UNIT- 03	**Phase Diagrams:** Phase rule, Solid solutions, Hume-Rothery rules, Intermediate phases and compounds, Unary and binary phase diagrams, Isomorphous and eutectic systems, Lever rule, Typical phase diagrams: Fe-C.	**03**
UNIT- 04	**Phase Transformations and Heat Treatment:** Classification of phase transformations, Liquid to solid transformation, Homogeneous and heterogeneous Nucleation, Kinetic considerations in solid state transformations, Microstructure and property changes in iron-carbon alloys, Precipitation and age hardening.	**09**
UNIT- 05	**Properties of Materials:** Mechanical Properties: Stress-strain response of metallic, ceramic and polymer materials, yield strength, tensile strength and modulus of elasticity, toughness, plastic deformation, fatigue, creep and fracture; **Electronic Properties**: Free electron theory, Fermi energy, density of states, elements of band theory, semiconductors, Hall effect, dielectric behaviour, piezo, ferro, pyroelectric materials; **Magnetic Properties:** Origin of magnetism in metallic and ceramic materials, paramagnetism, diamagnetism, ferro and ferrimagnetism; **Thermal Properties:** Specific heat, thermal conductivity and thermal expansion, thermoelectricity.	**12**

Course Outcomes

CO1: Classify various engineering materials and explain their structure and imperfections.
CO2: Draw some typical phase diagrams and discuss their distinctive features.
CO3: Explain Isothermal transformation and continuous cooling diagrams of steels
CO4: Describe various heat treatment processes

Books and References

1. Materials Science and Engineering, An Introduction by William D. Callister, Jr. and David G. Rethwisch, John Wiley and Sons, Inc.
2. Materials Science and Engineering by William F. Smith, McGraw Hill Education.
3. Modern Physical Metallurgy by R. E. Smallman, Butterwort-Heinemann.
4. Physical Metallurgy: Principles and Practice by V. Raghvan ,PHI Learning Private Ltd.

Name: **Mechanical Behavior of Materials**
Course Code: **MS-214**
Course Type: **Discipline Core**

Contact Hours/Week: **3L** Course Credits: **3**

Course Objectives

- Explaining the theory of dislocations and different strengthening mechanisms of materials based on dislocation theory.
- How the dislocation motion results in the different types of fractures or failure in the materials

Unit Number	Course Content	Contact Hours
UNIT- 01	**Dislocation Theory:** Dislocation during growth of crystals; Theoretical and observed yield stress, geometry of dislocations. Burgers Vector, Right hand convention - Types of dislocations loops and motion out of crystals strain energy of mixed dislocation two hard particles; simple relationship for forces between dislocation vector notation of dislocation in crystal systems; combination of dislocationstacking fault energy; motion of extended dislocation; construction Frank dislocation; Cross slip; double jump; Geometrical characteristics of dislocation;Interaction of dislocations (simple cases); Motion of kinked and Jogged dislocation; Non conservation method Motion creation of vacancies, Frank Read source, Sessile dislocations Lomer-Cotrell, stair-rod; width of dislocation; Pile up of dislocation, solid solution strengthening anti-phase boundary; Yield unit; Luder bands.	**12**
UNIT- 02	**Modes of Plastic Deformation:** Slip planes and slip directions, resolved shear stress, strainhardening and recovery of single crystals, Twinning, Grain boundary sliding and diffusional creep.	**03**
UNIT- 03	**Strengthening Mechanisms:** Cold working and annealing: Recovery, Recrystallization and Grain Growth, dynamic recovery, strain/ work hardening, solute hardening or solid solution strengthening, precipitation hardening, dispersion hardening, grain refinement.	**03**
UNIT- 04	**Fracture:** Types of fracture- ductile fracture, brittle fracture; Theoretical fracture stress, Griffiththeory, Orowan Theory, Comparison with equation based on stress concentration Crack velocities; Dislocation model of crack nucleation Zener model, Cotrell-Hull model in BCC metals. Fracture toughness, ductile to brittle transition. Methods of protection against fracture- surfacetreatment, compressive stresses.	**06**
UNIT- 05	**Creep:** Generation and analysis of creep and creep-rupture data. Dislocation and diffusion mechanisms of creep. Grain boundary sliding and migration. Deformation mechanism maps. Effect of metallurgical and test variables on creep and fracture. Super plasticity. Parametric methods for prediction of long time properties. Creep fracture.	**06**
UNIT- 06	**Fatigue:** Stress cycles, Effect of mean stress on fatigue. High cycle and low cycle fatigue. Analysis of cyclic stress-strain data. Mechanisms of fatigue crack nucleation and propagation. Effect of metallurgical variables on fatigue. Corrosion fatigue. Fatigue fracture.	**06**

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1: Understand the yielding behavior and dislocation influence on plastic deformation.
CO2: Understand the various strengthening mechanisms and high temperature deformation
CO3: Understand testing methods like hardness, compression, and fatigue

Books and References

1. Mechanical Metallurgy by George E. Dieter, McGraw-Hill.
2. Mechanical Behavior of Materials by Krishan Chawla, Marc A. Meyers, Cambridge university press
3. Fundamentals of Materials Science and Engineering by William D. Callister, Jr., David G. Rethwisch, John Wiley & Sons.
4. Dislocations and Mechanical Behaviour of Materials by M.N Shetty, PHI Learning.
5. Mechanical Behaviour of Materials by H. Thomas. Courtney, Waveland Press.

Course Name: **Transport Phenomena Lab**
Course Code: **MS-215**
Course Type: **Discipline Core**

Contact Hours/Week: **2 P** Course Credits: **1**

Course Objectives

- To demonstrate the basic fundamentals of heat and mass transfer
- To demonstrate the fluid flow fundamentals applicable for materials processing

List of Experiments

1. Determination of Thermal Conductivity of a Metal Rod
2. Determination of Overall Heat Transfer Coefficient of a Composite plate
3. Determination of Heat Transfer Coefficient in a free Convection on a vertical tube
4. Determination of Heat Transfer Coefficient in a Forced Convention Flow through a Pipe
5. Determination of the heat conduction of metal powder (conductor)
6. Determination of the heat conduction of metal powder (insulator)
7. Determination of Steffan Boltzman Constant.
8. Calculation of Reynolds number of a laminar flow on a plate
9. Calculation of Reynolds number of a turbulent flow through a pipe
10. Determination of fluid flow inside a BOF steel making
11. Demonstration of Fick's first law and calculation of diffusivity constants
12. Demonstration of transient diffusion (Fick's second law)
    Note: The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Visualize the principals of heat transfer like conduction, convection.

CO2: Calculate the diffusivity of species in the solid solution.

CO3: Visualize fluid flow conditions under Iron and steel making furnaces

Course Name: **Materials Science and Mechanical Testing Lab** Course Code: **MS-216** Course Type: **Discipline Core**	
Contact Hours/Week: **2 P**	Course Credits: **1**

Course Objectives

- To develop the knowledge of basic experimental principals of material science and associated properties
- To study the microstructure and solidification defects in different materials.

List of Experiments

1. Investigating crystal structure and imperfections utilizing models.
2. Conducting resistivity measurements of semiconductor crystals via the four-probe method.
3. Exploring the Hall Effect in semiconductors and analyzing semiconductor parameters.
4. Evaluating the tensile properties of various material classes.
5. To determine the hardness number for a given metallic specimen by Brinell Test (HB).
6. To determine the Rockwell hardness number on B and C scales for a given metallic specimen.
7. To determine the hardness number for a given metallic specimen by Vickers hardness testing
8. To determine the impact energy/Impact strength of a given test specimen by Izod and Charpy impact tests.
9. Determining the fatigue life of materials using a Fatigue Tester.
10. Analyzing fractured surfaces using optical microscopy and Scanning Electron Microscopy (SEM).

Note: The concerned Course Coordinator will prepare the actual list of experiments/problems at the startof semester based on above generic list.

Course Outcomes

On successful completion of the course, the students will be able to identify
CO1: Identifying materials based on their structures
CO2: Evaluating the material's strength under tension and compression loading
CO3: Investigating the relationship between various types of loading and material hardness
CO4: Analyzing the fracture mode following tension and impact loading

Course Name: **Metallographic Practices**
Course Code: **MS-217**
Course Type: **Discipline Core**

Contact Hours/Week: **2P** Course Credits: **1**

Course Objectives

- To learn the principles of materials testing and characterization and to apply them for various engineering applications.
- To learn the characteristics of mechanical behaviour of materials

List of Experiments

1. To study the metallurgical microscope
2. To prepare the metallic sample for metallographic examination (3 turns)
3. To study the microstructure of various steel samples
4. To study the microstructure of various cast iron samples
5. To study the microstructure of modified and unmodified aluminium silicon alloys
6. To study the microstructure of various copper base alloys
7. To study the microstructure of Pb-base and Sn-base bearing alloys
8. To determine the grain size of given metallic sample by quantitative Metallography
9. Microstructural study using SEM – secondary and back scattered electron imaging
10. Chemical analysis using SEM – energy dispersive spectroscopy
11. Ductile and brittle fracture surface study using scanning electron microscope

Note: The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1: Know the different types of materials behavior under mechanical loading
CO2:Understand different types of materials failure under load
CO3:Know different mechanisms involved in loading

Course Name: **Composite Materials** Course Code: **MS-221** Course Type: **Discipline Core**		
Contact Hours/Week: **3 L**		Course Credits: **03**
Course Objectives • To impart knowledge of basics of composite materials and their importance • To study the various type of reinforcements/fibers and their properties • To obtain knowledge about different types of composite materials and their fabrication technique		
Unit Number	**Course Content**	**Contact Hours**
UNIT-01	**Introduction:** Classifications of Engineering Materials, Concept of composite materials, Matrix materials, Functions of a Matrix, Desired Properties of a Matrix, Polymer Matrix (Thermosets and Thermoplastics), Metal matrix, Ceramic matrix, Carbon Matrix, Glass Matrix etc.	**06**
UNIT-02	**Types of Matrix and Reinforcements:** Classification based on Matrix Materials: Organic Matrix Polymer matrix, Carbon matrix, Metal matrix, Ceramic matrix, Classification based on reinforcements. **Types of Fibres:** Glass fibers, Carbon fibers, Aramid fibers , Metal fibers, Alumina fibers, Boron Fibers, Silicon carbide fibers, Quartz and Silica fibers, Multiphase fibers, Whiskers, Flakes etc., **Mechanical properties of fibres:** Materials properties that can be improved by forming a composite materials and its engineering potential	**09**
UNIT-03	**Types of Composites:** Fiber Reinforced Composites, Fiber Reinforced Polymer (FRP) Composites, Laminar Composites, Particulate Composites, Comparison with Metals, Advantages & limitations of Composites	**06**
UNIT-04	**Fabrication of MMC:** Liquid Route; casting and infiltration techniques, Solid route powder metallurgy, diffusion bonding, roll bonding, High-Rate Consolidation Mechanical Alloying (MA), Gaseous and vapour route; Spray deposition, PVD, CVD In-situ processes; directional solidification, Chemical reaction **Fabrication of CMC:** Liquid Route; sol gel, slurry infiltration, Direct Metal Oxidation (DiMOx), Liquid Silicon Infiltration (LSI), Polymer Infiltration Pyrolysis (PIP), Solid route; powder metallurgy Gaseous and vapour route; Chemical Vapor Infiltration (CVI) **Fabrication of PMC:** Matched Die Mould (Closed mould); Compression Moulding, Cold Stamping, Press Moulding and Injection Moulding, Contact Mould (open mould); Vacuum Bag Moulding, Pressure Bag Moulding and Autoclave, Filament Winding, Pultrusion. **Manufacturing Techniques:** Tooling and Specialty materials, Release agents, Peel plies, releasefilms and fabrics, Bleeder and breather plies, bagging films.	**09**
UNIT-05	**Testing of Composites:** Mechanical testing of composites, Tensile testing, Compressive testing, Intra-laminar Shear testing, Inter-laminar Shear testing, Fracture testing.	**06**
Course Outcomes: Upon successful completion of the course, the students will be able to CO1: Understand the basic knowledge and the applications of composite materials. CO2: Understand the various types of reinforcements/fibers and their properties to make composite CO3: Understand the different methods of fabrication of composite materials. CO4: Understand the testing methods involved in composite materials		
Books and References: 1. Introduction to Composite Materials Design by Ever J. Barbero, CRC Press 2. Engineering Materials: Polymers, Ceramics and Composites by A.K Bhargava, Prentice Hall India. 3. Composite Materials Science and Engineering by K. K. Chawla, Springer-Verlag New York. 4. Composite Materials: Science and Applications by Deborah D. L. Chung, Springer 5. Fundamentals of Materials Science and Engineering by William D. Callister, Jr., David G. Rethwisch, John Wiley & Sons.		

Course Name: **Phase Transformations**
Course Code: **MS-222**
Course Type: **Discipline Core**

Contact Hours/Week: **3L** Course Credits: **3**

Course Objectives

- To develop an understanding of the basic principles of phase transformations and apply those principles to engineering applications
- To recognize the importance of the microstructures and physical properties of the materials so that a constructive materials selection process can be adopted

Unit Number	Course Content	Contact Hours
UNIT-01	**Fundamentals of Phase Transformation:** Alloy theory-terminal solid solutions and intermediate phases, Fe-C system, steel and iron microstructures with phase relations, Free energy-composition diagrams. Ideal and non-ideal behaviour of alloy systems.	**09**
UNIT-02	**Thermodynamics of Phase Transformation:** Calculation of Gv for various transformations (polymorphic &solidification, precipitation, massive, eutectic & eutectoid), Nature of inter-phase interfaces and their energies, Fundamentals of diffusion, Flick's Laws	**06**
UNIT-03	**Nucleation and Growth:** Homogenous and heterogeneous nucleation, Thermodynamic barrier for nucleation, nucleation rate, Structure and energy of interfaces. Strain energy and its effect on nucleation. Diffusion controlled and interface controlled growth mechanisms	**06**
UNIT-04	**Solidifications of Alloys:** Redistribution of solute during solidification, constitutional super cooling. Origin of cellular and dendritic structures, solidification at high undercooling, Rapid solidification, Zone refining, Growth of single crystals.	**06**
UNIT-05	**Solid State Transformations:** Kinetics of solid-state transformation, C-curve etc., Segregation precipitation reaction. Diffusional phase transformation process: Short-range diffusional and long-range diffusional process like polymorphic transformation, massive transformation, recrystallization, precipitation transformation, order disorder, eutectoid and spinoidal transformations.	**09**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Describe various types of phases and their transformation behaviour
CO2: Define and differentiate engineering materials of the basis of microstructure
CO3: Select proper processing technologies for synthesizing and fabricating different materials.
CO4: Analyze the microstructure of metallic materials using phase diagrams

Books and References

1. Phase Transformations in Materials by R. C. Sharma, CBS Publishers, New Delhi
2. Solid State Transformations by V. Raghavan, Prentice-Hall of India, New Delhi
3. Fundamentals of Materials Science and Engineering by William D. Callister, Jr., David G. Rethwisch, John Wiley & Sons
4. Phase transformations in metals and alloys; David A. Porter and K. E. Esterling, Chapman and Hall Publisher
5. Physical Metallurgy Principles, Reza Abbaschian, Robert E. Reed-Hill, Cengage Publisher

Materials Processing Techniques
Course Code: **MS-223**
Course Type: **Discipline Core**

Contact Hours/Week: **3L+1T** Course Credits: **4**

Course Objectives

- To provide knowledge of various casting process in manufacturing.
- To provide adequate knowledge of quality test methods conducted on welded and casted components.
- To provide knowledge of moulding, solidification, powder metallurgy and joining processes

Unit Number	Course Content	Contact Hours
UNIT-01	**Introduction:** Materials and Processes in manufacturing, Classification and Application of Metal Casting Processes. Foundry- Definition & classification. Patterns: Definition, classification, materials used for pattern, various pattern allowances and their importance. Ingredients and Properties of Green Sand; Function and Types of Cores; Preparation of sand molds: Molding machines- Jolt type, squeeze type and Sand slinger. Expendable Mold Casting: Removal Pattern- Green sand Mold Casting, Different types of casting moulds. Disposal Pattern- Investment (Lost Wax) Casting and Evaporative (Lost Foam) Casting.	**08**
UNIT-02	**Analysis and Design of Pouring System**: Cooling and Solidification in Green Sand Mold Metal Casting. Solidification: Definition, Nucleation and growth, Homogeneous and Heterogeneous Nucleation, Mechanism of Solidification of Pure Metals/ Alloys Casting. Concept of centre-line feeding resistance (CFR); Solidification time calculation in sand mold casting. Directional solidification-need and methods.	**05**
UNIT-03	**Metal mold and Metal casting**: Casting defects & Non Ferrous Foundry Practice: Solidification time calculation in metal mold casting with consideration of predominant interface resistance/constant surface temperature/predominant resistance in mold and solidified metal. Casting using metal molds (Permanent Mold Casting): Gravity die casting, pressure die casting, Vacuum Casting, slush casting, centrifugal casting, continuous casting squeeze casting, and Chilled Casting processes. Casting defects and their prevention methods; Inspection methods of castings.	**10**
UNIT-04	**Nonferrous foundry practice:** Aluminum castings – Advantages, limitations, melting of aluminum using lift-out type crucible furnace. Hardeners used- drossing, gas absorption and fluxing and flushing, grain refining, pouring temperature. Stir casting set up- procedure, uses, advantages and limitations	**06**
UNIT-05	**Machining Processes:** Mechanism and Mechanics of Cutting Machining: Chip Formation, Orthogonal and Oblique Cutting, Heat and Temperature in shear and friction plane. Materials and Life of Cutting Tool: Composition and Properties of Tool Materials, Tool Geometry, Turning and related operations, Shaping and Planning, Drilling and Related Operations, Milling and Gear Cutting, Broaching and Sawing, Economics of Cutting. Abrasive Grinding: Abrasive Finishing, Honing, Lapping, Polishing and Buffing. Electro-Discharge Machining (EDM), Ultrasonic Machining (USM) and Jet Machining Processes. Chemical Machining Processes. Material Additive Processes:	**12**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Describe the casting process, preparation of Green sand molds and Sweep.

CO2: Explain the Solidification process and Casting of Non-Ferrous Metals

CO3: Describe the quality assurance of components made of casting and joining process.

Books and References

1. Fundamentals of Modern Manufacturing: Materials Processes and Systems by M. P. Groover, John Wiley and Sons, New Delhi.
2. Manufacturing Science by Ghosh and Mallik, East West Press Pvt. Ltd., New
3. Manufacturing & Technology: Foundry Forming and Welding by P.N. Rao, Tata McGraw Hill
4. Powder Metallurgy: Science, Technology, and Materials by Anish Upadhyaya, Gopal Shankar Upadhyaya, CRC press.
5. Welding Processes and Technology by R.S. Parmar, Khanna Publishers, New Delhi

Course Name: **Heat Treatment**
Course Code: **MS-224**
Course Type: **Discipline Core**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To develop an understanding of the basic principles of phase transformations and apply those principles to engineering applications.
- To recognize the importance of the microstructures andphysical properties of the materials so that a constructive materials selection process can be adopted

Unit Number	Course Content	Contact Hours
UNIT-01	Introduction to Heat Treatment: Iron carbon equilibrium diagram, Isothermal transformation diagrams, continuous cooling transformation diagram, Austenisation and austenite grain size	**08**
UNIT-02	**Homogenization, Quenching and quenching media. Annealing**: Definition, Objectives, and Types, Full Annealing, Isothermal Annealing, Spheroidizing Annealing. Normalizing. Hardening: Definition, Objectives, and Types, Martensitic Hardening, Austempering, Martempering. Tempering: Definition, Objectives, and Types, Tempering of Martensite, Tempering of Bainite, Tempering of Austenite, Effect of Tempering on Mechanical Properties. Hardnenability, its measurements and control.	**08**
UNIT-03	**Case hardening treatments:** case carburizing and post carburizing heat treatment, nitriding, Carbonitriding, cyaniding. Surface hardening treatments: Induction hardening, flame hardening, laser hardening, and electron beam hardeningprocesses.	**05**
UNIT-04	**Heat treatment of non-ferrous alloys:** Re-crystallisation annealing of cold worked metals, age hardening. Temper designation for aluminum and magnesium alloys. Heat treatment of aluminum, copper, magnesium,, titanium and nickel alloys.	**06**
UNIT-05	**Cast Iron and their heat treatment:** Grey, white, malleable, SG Iron. Defects: Defects in heat treated materials and their prevention.	**03**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand and identify different type of heat treatment process
CO2: Explain the effect of heat treatment on the microstructure and mechanical properties of materials
CO3: Analyze the suitability of different heat treatment processes for specific materials and applications
CO4: Select the appropriate heat treatment process for a given material and application

Books and References

Phase Transformations in Materials by R. C. Sharma, CBS Publishers, New Delhi

1. Solid State Transformations by V. Raghavan, Prentice-Hall of India, New Delhi
2. Fundamentals of Materials Science and Engineering by William D. Callister, Jr., David G. Rethwisch, John Wiley & Sons
3. Phase transformations in metals and alloys; David A. Porter and K. E. Esterling, Chapman and Hall Publisher
4. Physical Metallurgy Principles, Reza Abbaschian, Robert E. Reed-Hill, Cengage Publisher

Name: **Materials Processing Lab**
Course Code: **MS-225**
Course Type: **Discipline Core**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives

- To know the basic concept of foundry lab, casting techniques and apply them for cast various engineering cast components.
- To know the concepts of materials joining technology and to apply them for the advanced manufacturing processing for various structural engineering applications.

List of Experiments

1. Study of Sieve Shaker and to estimate the grain fineness number for the given foundry sand.
2. To estimate the clay content in the sand using Clay Content Tester.
3. To estimate the moisture content in the green sand using Moisture Content Tester.
4. To estimate the permeability of the green sand using Permeability Tester.
5. To estimate compressive & shear strength of the green sand using Sand Strength Tester.
6. To determine the shatter index of the given sand using Shatter Index Tester.
7. To study the effect of compression pressure on the green density of green compact.
8. To study the effect of sintering temperature on the microstructure of green compact.
9. To study the effect of gas and arc welding processes on microstructure and hardness of given steel samples.
10. To study the effect of TIG and MIG welding processes on microstructure and hardness of given metallic samples.
11. Study of resistance welding and to make joints on the given sheets using spot and seem welding.
12. To study the effect of various parameters of soldering and brazing processes on strength of joint.

Note: The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1: Determine the properties of foundry sand.
CO2: Understand the foundry melting practice.
CO3: Develop basic welding skills in manual arc welding processes
CO4: Analyze the weldment microstructure.

Course Name: **Heat Treatment Lab**
Course Code: **MS-226**

Contact Hours/Week: **2P** Course Credits: 01

Course Objectives

- To develop the practical knowledge of heat treatment and phase transformation along with associated procedure of various engineering materials
- To study how different heat treatment and phase transformation process influences the microstructure and results in different mechanical behaviour.

List of Experiments

1. To study the microstructure, grain size and hardness of Annealed steel having ≤0.2%C and ≤0.4%C.
2. Annealing treatment of a cold worked steel and comparison of the annealed microstructure with the cold worked structure.
3. To study the microstructure, grain size and hardness of Normalized plain carbon steel having ≤0.2%C and ≤0.4%C and comparison of the microstructure with annealed structure.
4. Spheroidized annealing: To study the microstructure and hardness of Spheroidized plain carbon steel having ≤1.2%C steel.
5. To perform hardening and study the quenched structures of steel having ≤1.2%C – quenched in oil, water and brine solution.
6. To study the tempered structures of steel with low, medium and high temperature tempering. Compare the quenched and tempered structure.
7. To demonstrate nucleation process in water and other solvent media upon freezing.
8. Study of nucleation and growth in eutectoid steel (0.8% C).
9. To perform case carburizing of low carbon steel, measurement of hardness and observation of microstructure.
10. To study the effect of precipitation hardening treatment on Al-4% Cu alloy on Isothermal ageing.
11. To study the recrystallization behavior of pure metal (iron).
12. To study the effect of time and temperature on the grain size (grain growth) of pure Cu.
13. To demonstrate ductile to brittle phase transition in steels.

Note: The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Define various heat treatment procedures for variety of engineering materials and their mportance in materials behavior.

CO2: Classify different heat-treated microstructure using microscope.

CO3: Provide the practical solution procedure for the betterment of the materials performance based heat treatment.

CO4: Develop comprehensive heat treatment procedure and process map for newly developed metals and alloys.

Course Name: **Composites Lab** Course Code: **MS-227**
Contact Hours/Week:**2P** Course Credits: **01**
Course Objectives • To gain understanding of synthesis and processing techniques for various class of polymers andcomposites • Introduction to physical and mechanical characterization techniques of polymers and composites alongwith their applications
List of Experiments 1. Fabrication of Metal Matrix Composites (MMCs) through Stir Casting. 2. Fabrication of laminate structures with Glass Fiber Reinforced Polymer Matrix Composites (PMCs). 3. Production of bio-composites utilizing the Hand-Lay-Up technique. 4. Fabrication of Polymer Matrix Composites (PMCs) employing the Solvent Casting Method. 5. Production of Metal Matrix Composites (MMCs) utilizing Powder Metallurgy Techniques. 6. Fabrication of Metal Matrix Composites (MMCs) employing Electrodeposition Methods. 7. Processing polyethylene beads using a twin-screw extruder machine. 8. Manufacturing short fiber composites through injection molding and extrusion processes. 9. Surface characterization of various composites using AFM and SEM. 10. Investigation of the degradation behavior of composites using Differential Scanning Calorimetry (DSC) Note: The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.
Course Outcomes: At the end of this course, the students would be able to: CO1: Understand the various composites synthesis process. CO2: Understand the principle of processing techniques for polymers and composite materials. CO3: Analyze the characterization results obtained from physical testing of various types of composites.

Course Name: **Electronics, Magnetic and Optical Properties of Materials**
Course Code: **MS-241**
Course Type: **Discipline Elective-I**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To undertake study and research in solid state engineering and electronic materials
- To understand the physics of device operations

Unit Number	Course Content	Contact Hours
UNIT-01	**Conductors:** Drude, Sommerfeild and quantum theories of electric conduction in metals, Maitthiessen rule of electrical conductivity, Energy Band Diagrams.	**06**
UNIT-02	**Semiconductors:** Band diagrams, direct and indirect band gap; Effective-mass of electron in conduction-band and that of hole in valence-band. Intrinsic semiconductors: Fermi-level; Density-of-states near the edges of conduction and valence-band; Intrinsic and Extrinsic-semiconductor	**06**
UNIT-03	**Dielectric materials:** Dielectric constants and polarization, linear dielectric materials, capacitors; Polarization mechanisms; Non-linear dielectrics, pyro-, piezo-, and ferro-electric properties, hysterisis and ferroelectric domains; Claussius-Mossoti relation,.	**06**
UNIT-04	**Magnetic Materials:** Orbital and spin - permanent magnetic moment of atoms, diamagnetism, paramagnetism, and Pauli-paramagnetism, Ferro, anti-ferro and ferri magnetism, Fe, Co and Ni and alloy additions, ferrites, magnetic hysteresis, Soft and Hard magnetic materials.	**09**
UNIT-05	**Optical Materials**: electron-hole recombination, solid state LEDs, lasers and IR detectors, bandgap engineering; Light interaction with materials transparency, translucency and opacity, refraction and refractive index, reflection, absorption and transmission.	**09**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the quantum mechanics of electron in crystals

CO2: Understand the basic electrical and magnetic properties of crystalline solids and amorphous materials.

Books and References

1. Physical Properties of Semiconductors by Charles M. Wolfe, Nick Holonyak and Gregory E. Stillman, Prentice Hall.
2. Solid State Physics by Neil W. Ashcroft and N. David Mermin, Sauders College, Philadelphia.
3. Introduction to Solid State Physics by CharlesKittel, John Wiley & Sons.
4. Electrical Properties of Materials by L. Solymar and D. Walsh, Oxford University Press.
5. Electronic Properties of Materials by R. E. Hummel, Springer.

Course Name: **Biomaterials**
Course Code: **MS-242**
Course Type: **Discipline Elective-I**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To study the importance and basic principles of Biomaterials
- To study the different types of corrosion Biomaterial

Unit Number	Course Content	Contact Hours
UNIT-01	**Introduction:** Introduction to materials at the interface with biological sciences, Social, Environmental & Ethical Issue	**6**
UNIT-02	**Response Based:** Bioinert/ Bioactive/ Bioresorbable Material Based: Bioceramic/ Biopolymer/ Biometallic **Application Based:** Structural (Bone replacement materials, dental biomaterials, cardiovascular biomaterials, total hip and knee replacement), Non structural (drug- delivery/ sensing/ surface modification).Concept of biocompatibility: Definition, Immune response, Testing (in vitro/ in vivo) Response Based: Bioinert/ Bioactive/ Bioresorbable Material Based:Bioceramic/ Biopolymer/ Biometallic	**8**
UNIT-03	**Biomimetics:** Introduction to structure and properties of proteins, biological cells and tissues Biological phenomenon on material surfaces Protein adsorption isotherms, - Kinetics of cell-material interaction Bacterial adhesion and kinetics of biofilm formation. Principles of various surface Characterization techniques: Atomic force microscopy, fluorescence microscopy, tensiometer (contact angle measurement), quartz crystal microbalance	**8**
UNIT-04	**Quantification of structure-property correlation -** Bioglass/ Glass-ceramics Macroporous scaffolds, Biodegradable polymers, Biocomposites. Thin films and coatings, Surface Engineering Micro-contact printing, Layer-by-layer assembly/ Functionalization Case Study **Self-assembly:** Thermodynamics and kinetics aspects, Drug-delivery/ Bio-responsive surfaces, Articulating joints, Dental restorative applications Cardiovascular patches/ heart valves	**12**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the basics of biomaterials.
CO2: Understand the basic design of biomaterials for specific scientific, industrial and medical applications
CO3: Understand the appropriate host response in a specific application.

Books and References

1. Buddy D. Ratner, Allan S. Hoffman, Frederick J. Schoen, Jack E.
2. Lemons. Biomaterials Science: An Introduction to Materials in Medicine, Academic Press, 2004, USA
3. J.B. Park and J.D. Bronzino. Biomaterials: Principles and Applications. CRC Press. 2002.ISBN: 0849314917

Course Name: **Mechanics of Solids** Course Code: **MS-243** Course Type: **Discipline Elective (I)**		
Contact Hours/Week: 3L		Course Credits: 03
Course Objectives 1. learn the fundamental concepts of stress, strain, and deformation of solids with applications to bars, beams, and columns. 2. Fundamentals of applying equilibrium, compatibility, and force deformation relationships to structural elements. 3. To draw Shear Force and Bending Moment Diagram for transverse loading.		
Unit Number	Course Content	Contract Hours
UNIT-01	Tension, compression and shear Types of external loads - self weight - internal stresses - normal and shear stresses - strain - Hooke‘s law - Poisson‘s ratio - relationship between elastic constants - stress strain diagrams - working stress - elongation of bars of constant and varying sections - statically indeterminate problems in tension and compression - assembly and thermal stresses - strain energy in tension, compression and shear..	**08**
UNIT-02	Analysis of stress and strain Stress on inclined planes for axial and biaxial stress fields - principal stresses - Mohr's circle of stress - principal stress problem as an eigenvalue problem - principal strains - strain rosette -thin cylinders (as an example to biaxial stresses)	**08**
UNIT-03	Bending moment and shear force: Types of beams - shear force and bending moment diagrams for simply supported, overhanging and cantilever beams - relationship between intensity of loading, shear force and bending moment. - stresses in laterally loaded symmetrical beams	**07**
UNIT-04	Theory of simple bending: limitations - bending stresses in beams of different cross sections - moment of resistance - beams of two materials - shearing stresses in bending - principal stresses in bending - strain energy in bending Torsion: Torsion of circular solid and hollow shafts - strain energy in shear and torsion – open and close coiled helical springs. Concept of shear flow and shear center.	**08**
UNIT-05	Deflection of beams: Differential equation of elastic curve - slope and deflection of beams by successive integration - Macaulay‘s method - moment area method - conjugate beam method - deflection due to shear.	**05**
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Analyze the behavior of the solid bodies subjected to various types of loading; CO2: Apply knowledge of materials and structural elements to the analysis of simple structures CO3: Undertake problem identification, formulation and solution using a range of analytical methods;		
Books and References 1. Gere, J.M., Mechanics of Materials, Thomson, Singapore, 2001. 2. Timoshenko, S.P., Young, D.H., Elements of Strength of Materials, East West Press, New Delhi, 2003. 3. Popov, E.P., Mechanics of Materials, Prentice Hall India, New Delhi, 2002. 4. Beer, F. P. and Johnston, E. R., Mechanics of Materials, Tata McGraw Hill, New Delhi, 2005 5. Nash, W.A., Strength of Materials, Schaum's Outline Series, McGraw Hill, New York, 1988		

Course Name: **Iron and Steel Making**
Course Code: **MS-311**
Course Type: **Discipline Core**

Contact Hours/Week: **3L+1T** Course Credits: **4**

Course Objectives

- To know the importance of the Iron and steel making and to apply them for the advancement of the production feasibilities in steel Industries to compete with the modern day manufacturing routes.
- To study the alternative routes of iron and steel making

Unit Number	Course Content	Contact Hours
UNIT-01	**Introduction:** Classification of furnaces; different kinds of furnaces; heat balance, energy conservation and energy audit; parts, construction and design aspects of blast furnace, ancillary equipment; blast furnace instrumentation.	**03**
UNIT-02	**Raw Materials and Burden Preparation:** Importance of the Iron and Steel making, Iron ore classification, Indian iron ores, limestone and coking coal deposits, problems associated with Indian raw materials, Iron ore beneficiation and agglomeration, Briquetting, sintering, Nodulising and pelletizing, testing of burden materials, burden distribution on blast furnace performance.	**03**
UNIT-03	**Principles and Processes of Iron Making:** Blast furnace parts, construction and design aspects, ancillary equipment for charging, preheating the blast, hot blast stoves,gas cleaning, Blast furnace operation, irregularities and remedies, Blast furnace instrumentation and control of furnace Compositional control of metal and slag in blast furnace, modern trends in blast furnace practice. Reduction of iron ores and oxides of iron by solid and gaseous reductions- thermodynamics and kinetics study of direct and indirect reduction, Gruner's theorem, blast furnace reactions. C-O and Fe- C-O equilibria, Rist diagrams, Ellingham diagram, materials and heat balance- Sponge Iron making.	**09**
UNIT-04	**Principles of Steel Making:** Development of steel making processes, physico-chemical principles and kinetic aspects of steelmaking, carbon boil, oxygen transport mechanism, desulphurisation, dephosphorisation, Slag Theories, slag-functions, composition, properties and theories, raw materials for steel making and plant layout	**06**
UNIT-05	**Steel Making Processes:** Open Hearth process- constructional features, process types, operation, modified Processes, Duplexing, pre-treatment of hot metal. Bessemer processes, Side Blown Converter, Top Blown processes-L.D, L.D.A.C., Bottom blown processes, combined blown processes, Rotating oxygen processes- Kaldo and Rotor, Modern trends in oxygen steel making processes-Electric Arc and Induction furnace-constructional features.	**06**
UNIT-06	**Steel Ladle Metallurgy:** Production practice for plain carbon steels, low alloy – stainless, tool and special steels, modern developments. Secondary steel making processes, continuous steel casting process Deoxidation and teeming practice. Principle, methods and their comparison, Killed, Rimmed and Capped steels, Degassing practices, ingot production, ingot defects and remedies. The advancement of the production feasibilities in steel Industries	**09**

Course Outcomes

Upon successful completion of the course, the students will be
CO1: Understand the Principles of extraction of ferrous metals
CO2: Understand the pyro-metallurgical process.
CO3: Understand the cleanliness of the steel during steel making.

Books and References

1. First Course in Iron and Steel Making by Dipak Mazumdar, Universities Press Publications.
2. Modern Iron Making by R.H.Tupkary, Khanna Publishers.
3. Principles of Blast Furnace Iron Making: Theory and Practice by A. K.Biswas, SBA Publications.
4. Manufacture of Iron and Steel by G. R. Bashforth, Chapman and Hall London.
5. Iron and Steel making: Theory and Practice by Ahindra Ghosh, Amit Chatterjee, PHI Publishers

Name: **Metal Working Science and Technology** Course Code: **MS-312** Course Type: **Discipline Core**	
Contact Hours/Week: **3**	Course Credits: **03**

Course Objectives

- To know the importance of different metal working processes in industrial manufacturing
- To understand the significance and inherent mechanics of metal working processes
- To understand the microstructural evolution during various metal working techniques

Unit Number	Course Content	Contact Hours
UNIT-01	**Introduction to metal working concepts:** Concept and classifications of metal working processes, mechanics of metal deformation, temperature and strain rate effects, instability andflowlocalization, concept of workability, microstructure and texture evolution, friction and lubrication, residual stress.	**06**
UNIT-02	**Rolling:** Introduction to rolling processes, Calculation of rolling load and power, variables affecting roll pressure, power and friction hill, theories of cold and hot rolling, different kinds of rolling mills roll pass design, defects in rolling. Forging: Closed-die and open-die forging, deformation zone, mechanics, forging equipment, die design and material selection, forging defects.	**09**
UNIT-03	**Extrusion:** Direct and indirect extrusion, impact extrusion, hydrostatic extrusion, equipment, extrusion variables, extrusion pressure. **Wire and Tube drawing:** Processes and equipment, hydrodynamic lubrication, draw stress, factors affecting draw stress and reduction.	**09**
UNIT-04	**Sheet metal working:** Different forming processes e.g. shearing, blanking, stamping, bending, deep drawing etc., formability, forming limit criteria, incremental sheet metal forming Non-conventional methods: Powder forging, superplastic forming, high energy rate forming,mushy-state forming.	**09**
UNIT-05	**Deformation of plastics and polymers:** Super-plasticity, formability, failures, friction, wear andlubrication	**03**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand classification and mechanics of metal working processes

CO2: Understand polymeric and powder forming processes

CO3: Understand the role of metal forming in industries

Books and References

1. Metal Working Science and Engineering by Edward M. Mielnik, McGraw Hill
2. Mechanical Working of Metals - Theory and Practice by J.N.Harris
3. Mechanical Metallurgy by G.E. Dieter, McGraw Hills Publications
4. Polymer Processing: Principles and Modeling by J.-F. Agassant, Carl Hanser Verlag GmbH & Company

Name: **Characterization of Materials** Course Code: **MS-313** Course Type: **Discipline Core**		
Contact Hours/Week: 3L		Course Credits: 3
Course Objectives • To introduce fundamental concepts relevant to materials analysis • To enable the students to understand properties of engineering materials and various advanced characterization methods		
Unit Number	**Course Content**	**Contact Hours**
UNIT-01	**X-ray Diffraction:** Diffraction under non-ideal conditions. Atomic scattering and Geometrical structure factors. Factors influencing the intensities of diffracted beams. Powder X-ray diffractometer. EXAFS and XANES. Applications of XRD in ceramic materials.	**03**
UNIT-02	**Microscopy:** Study of the morphology, aggregation, size and microstructure of ceramic materials using. Optical microscope, quantitative phase analysis. Principle of electron microscopy. Construction and operation of Transmission Electron. Microscope and Scanning Electron Microscope. Electron diffraction by crystalline solids; selected area diffraction.	**06**
UNIT-03	**AFM, SEM and XPS:** Atomic Force Microscope. Mechanism of image formation in SEM and its processing. Electron microprobe analysis (EDAX and WDS). Preparation of samples for electron microscopic studies. Electron spectroscopy for chemical analysis (ESCA/XPS).	**09**
UNIT-04	**Spectrophotometric analysis of materials:** Spectrophotometric analysis of materials: Basic laws of spectrophotometry and its application in micro analysis in UV/ Visible range, effect of reflectance factor on optical analysis, construction and working principle of spectrophotometer, importance of additive absorbance in multiple analysis of materials. Infrared spectrophotometry: General aspects of IR spectroscopy and its application in structural analysis of systems, sources of IR radiations, Optical systems and operation of Fourier transformed infrared (FTIR) spectrophotometer. Samples preparation, IR analysis and structural co-relations.	**09**
UNIT-05	**Fluorescence and Phosphorescence spectroscopy:** Basic principle, geometrical optics, construction, working principle and use of fluorescencespectrometers in materials analysis. X-ray Fluorescence (XRF). Electron Spin Resonance spectroscopy, Nuclear Magnetic Resonance.	**06**
UNIT-06	**Thermal Characterization:** Differential Thermal analysis (DTA) Thermogravimetric analysis (TGA) and Differential Scanning Calorimetry (DSC) with suitable examples of glass and ceramic materials.	**03**
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Understand common use of characterization techniques. CO2: Describe and analysis the various properties of materials. CO3: Understand principle of materials characterization technique		
Books and References 1. Materials Characterization Techniques by Sam Zhang, Lin Li and Ashok Kumar, CRC Press. 2. Materials Characterization: Introduction to Microscopic and Spectroscopic Methods by Yang Leng, Wiley & Sons. 3. Characterization of Materials by Elton N. Kaufmann, Wiley & Sons. 4. Springer Handbook of Crystal Growth by G. Dhanaraj, K. Byrappa, V. Prasad and M. Dudley, Springer-Verlag. 5. Physical Methods of Materials Characterization by Peter E.J. Flewitt and R.K. Wild, Taylor & Francis.		

Course Name: **Metal Working Lab** Course Code: **MS-314**	
Contact Hours/Week: **2P**	Course Credits: **01**

Course Objectives

- Demonstration of various metal working techniques.
- To practically calculate the process parameter involved in metal forming

List of Experiments

1. To prepare a sheet metal product (funnel) from mild steel sheet
2. To study and observe the plain and grooved rolling techniques
3. To study the elastic and plastic behavior of ferrous and non-ferrous metals during cold rolling
4. Characterize effect of forging on barreling and hardness
5. Measurements of strain, strain-rate and friction coefficient during cold forging
6. Effect of Severe Plastic Deformation on the Microstructure and properties (hardness)
7. Calculate strain and strain-rate for various chips and compare with strain and strain-rate imposed during rolling
8. Demonstration of extrusion of a metal rod
9. Demonstration of wire drawing process
10. To study and observe various swaging techniques

Note: The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Identify the suitable metal working technique

CO2: To design the process parameters

CO3: To analyze the mechanical properties based on microstructure obtained after processing

Course Name: **Materials Characterization Lab**
Course Code: **MS-315**
Course Type: **Discipline Core**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives

- To provide an insight into latest developments in materials characterization
- To provide an insight into selection of specific characterization for materials

List of Experiments

1. Optical microscopy (Different modes)
2. X-Ray Diffraction analysis
3. FTIR Spectroscopy Analysis
4. Raman Spectroscopy analysis
5. UV- Spectroscopy Analysis
6. Photo luminance Analysis
7. SEM analysis of polymer sample
8. SEM of metals and alloys
9. Demonstration of EDX spectroscopy
10. DSC/TGA analysis
11. Atomic force microscopy
12. Scratch and nanoindentation.

Note: The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1: Understand various materials characterization
CO2: Competent to know principles in different analysis of materials structure
CO3: Competent to comment on selection of specific characterization for materials to be used for particular application

Course Name: **Corrosion Science and Engineering**
Course Code: **MS-331**
Course Type: **Discipline Elective (II)**

Contact Hours/Week: **3** Course Credits: **03**

Course Objectives

- To study the importance of corrosion
- To study the basic principles of electrochemistry and aqueous corrosion processes
- To study the different types of corrosion

Unit Number	Course Content	Contact Hours
UNIT-01	**Introduction**: Introduction to Corrosion: Examples of corrosion, Economic and Technical significance of Corrosion, Chemical and Electrochemical reactions, Electrochemical and thermodynamic principles, Nernst equation and electrode potentialsof metals, Electro motive force, EMF and galvanic series, merits and demerits; origin of Pourbaix diagram and its importance to iron, aluminum and magnesium metals. Electrochemical Equilibrium, Electrode kinetics, Evans diagram, Polarization and types of polarization. Mixed potential theory. Passivity; Effect of oxides, solution velocity and galvanic coupling.	**12**
UNIT-02	**Types of Corrosion:** Uniform pitting, Intergranular, Stress corrosion. Corrosion fatigue. Erosion corrosion, Crevice corrosion, Hydrogen embrittlement, dezincification. Atmospheric, pitting, dealloying, stress corrosion cracking, intergranular corrosion, corrosion fatigue, fretting corrosion and high temperature oxidation; causes and remedialmeasures. Purpose of testing, laboratory, semi-plant and field tests, Susceptibility tests for intergranular corrosion, stress corrosion cracking.	**06**
UNIT-03	**Methods of Testing**: Purpose of corrosion testing - Classification - Susceptibility tests for intergranular corrosion- Stress corrosion test. Salt spray test humidity and porosity tests, accelerated weathering tests. ASTM standards for corrosion testing and tests for assessment of wear. Sequential procedure for laboratory and on-site corrosion investigations, corrosion auditing and corrosion map of India. Practical knowledgeabout corrosion and its application in engineering field. Their causes and remedial measures.	**06**
UNIT-04	**Corrosion Behaviour of Industrial Metals and Alloys**: Steels, Stainless steels, Copperand Copper alloys, Nickel and Nickel alloy, Aluminium and Aluminium alloys, Titaniumand Titanium alloys etc. Corrosion failure of ceramic materials- Corrosion degradation of concrete. Environmental degradation and corrosion of polymer materials.	**06**
UNIT-05	**Corrosion Prevention:** Selection of proper materials, Design rules and its modifications, Alloying additions, Environmental conditioning, Cathodic and anodic protection, Organic and inorganic coating, Surface engineering. Metallic and non- metallic coatings,mechanical and chemical methods and various corrosion inhibitors and passivator.	**06**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Elucidate the principles of corrosion and its prevention to the students.
CO2: Understand the importance of the corrosion of engineering materials. CO3:
Understand the various corrosion behaviors of materials and its protection.

Books and References

1. Corrosion Engineering by M.G. Fontana & N.D Greens, McGraw Hill Publishing Company.
2. Corrosion & Corrosion control by H.H. Uhlig, John Wiley & Sons.
3. Physical Chemistry by Daniels and Alberty, John Wiley & Sons Inc.
4. An Introduction to Metallic Corrosion & its Prevention by Raj Narayan, Oxford & IBH Publishing Co.
5. Corrosion of Metals: Physicochemical Principles and Current Problems by Helmut Kaesche, Springer

Course Name: **Magnetic Materials for Industry** Course Code: **MS-332** Course Type: **Discipline Elective-II**		
Contact Hours/Week: **3L**		Course Credits: **03**
Course Objectives • To study the basics and origin of magnetism in condensed matter • To study the different types of Magnetic materials used by industries		
Unit Number	**Course Content**	**Contact Hours**
UNIT-01	**Types of Magnetic Materials and Their Characteristic Features:** Magneticunits: Magnetic moments: Dia, para,ferro, antiferro, ferrimagnetism, hard and soft magnets, etc. **Magnetic Domains and Hysteresis Loops:** Domain theory, Domain growthand domain wall rotation, Stability of domain structure, Susceptibility and coercivity calculations.	**6**
UNIT-02	**Magnetic Anisotropy**: Magnetic anisotropy and exchange energies Origin of magnetic anisotropy and its application: Effect of inclusions, internal stress, magnetostriction and preferred orientation on magnetization, demagnetizationeffects, magneto-static, magnetoelastic energy. single domain magnets, superparamagnetism, easy and hard axis surface magnetism	**8**
UNIT-03	**Magnetism interactions:** Magnetic behaviour-exchange interaction and magnetic domains exchange energy **Magnetism In Different Materials:** Magnetism in elements, alloys and compounds, thin films, multilayer, amorphous and nanocrystalline materials, Hard and soft magnetic materials. Textured magnetic materials.	**8**
UNIT-04	**Applications of magnetic Materials**: a) **Magnetic storage:** Overview of magnetic recording, reading and play back theories; magnetic materials as reading head and storage media; technological aspects of high density storage media. b) **Magnetoresistance:** Various types of magnetoresistance; Giant and colossal magnetoresistance materials and their applications. Various techniques of magnetic recording and recovery. c) **Spintronics**: Spintronic devices and their applications in fast, reliable, non-volatile and miniaturized electronic circuits	**12**
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Understand the origin of magnetism. CO2: Understand the basic design of magnetic materials for specific scientific and industrial applications.		
Books and References 1. Charles Kittel Introduction To Solid State Physics 2nd Edition 2005 2. B. D. Cullity, Introduction to Magnetic Materials, Addison-Wesley Publications, California, London, 1972 3. J. P. Jakubovics, Magnetism and Magnetic Materials, Institute of Materials, London, 1994 4. D. Jiles, Introduction to Magnetism and Magnetic Materials, Chapman & Hall, 1991 5. S.Blundell, Magnetism in Condensed Matter ,Oxford Master Series in Condensed Matter hysics,2001		

Course Name: **Energy Storage Devices and Fuel Cells**
Course Code: **MS-333**
Course Type: **Discipline Elective-I**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To study the different energy storage devices
- To study the basic operations of storage devices

Unit Number	Course Content	Contact Hours
UNIT-01	**Battery Characteristics:** Voltage, current, capacity, electricity storage density, power, discharge rate, cycle life, energy efficiency, shelf life **Primary batteries**: The chemistry, fabrication, performance aspects, packing and rating of zinc-carbon, magnesium, alkaline, manganous dioxide, mercuric oxide, silver oxide batteries, zinc/air and lithium button cells- solid electrolyte cells	**6**
UNIT-02	**Secondary Batteries:** The chemistry, fabrication and performance aspects and rating of lead acid and valveregulated (sealed) lead acid, nickel-cadmium, nickel-zinc, lithium and lithium ion batteries -Rechargeable zinc alkaline battery. Reserve batteries: Zinc-silver oxide, lithium anode cell,thermal batteries. Batteries for electric vehicles: Metal/air, zinc-bromine, sodium-beta alumina and lithium/iron sulphide batteries. (outline only) Photogalvanic cells. Battery specifications for cars, heart pacemakers, computer standby supplies etc.	**8**
UNIT-03	**Fuel Cells:** Introduction – relevance, importance and classification of fuel cells. Background theory -thermodynamic aspects of electrochemistry-energy conversion and its efficiency – factors affecting the efficiency, electrode kinetics of electrochemical energy conversion.	**8**
UNIT-04	**Types of Fuel Cells:** Description, working principle, components, applications and environmental aspects of thefollowing types of fuel cells: alkaline fuel cells, phosphoric acid, solid oxide, molten carbonate,direct methanol fuel cells. Proton Exchange Membrane fuel cells - basic aspects – workingand high temperature operation – recent development in technology. **Hydrogen as Fuel, Solar Cell and Environment:** Sources of hydrogen and preparation – clean up and storage – use as fuel in cells.Energy conversion devices, photovoltaic and photo electrochemical cells – photo biochemicalconversion cell. Future prospects-renewable energy and efficiency of renewable fuels – economy of hydrogen energy – life cycle assessment of fuel cell systems.	**12**

Course Outcomes

C01: Upon successful completion of the course, students will have the understanding of the mechanisms of operation of storage devices
CO2: How these devices can provide the alternate energy sources to conventional one.

Books and References

1. AuliceScibiohM.andViswanathan B, "Fuel Cells – principles and applications', University Press (India), 2006
2. Pletcher D and Walsh C, "Industrial Electrochemistry", Blackie Academic and Professional, 1993
3. Christopher M A Brett, "Electrochemistry – Principles, Methods and Applications", Oxford University,2004.
4. Newman J S and Thomas -Alyea K.E. "Electrochemical systems" (3rd ed) Wiley, Hoboken, NJ 2004.
5. Hoogers G (Ed), "Fuel cell handbook" CRC, Boca Raton, FL 2003
6. Lindon David, "Handbook of Batteries", McGraw Hill, 2002.

Course Name: **Nanomaterials and Applications** Course Code: **MS-301** Course Type: **Open Elective**		
Contact Hours/Week: **3L**		Course Credits:**03**
Course Objectives • To provides an introduction to Nanomaterials and Applications • To provide an introduction to synthesis of nanomaterials • To provide an understanding on various process involved in nanomaterials synthesis		
Unit Number	**Course Content**	**Contact Hours**
UNIT-01	**Introduction to Nanotechnology**– Importance of size distribution and control-Effects of size on physiochemical properties of nanomaterials–Size effects on surface area and aspect ratios –Size induced Metal Insulator Transition-Introduction to basic nanostructures	**09**
UNIT-02	**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, Diffusionin Nanostructures	**06**
UNIT-03	**Top down and bottom up synthesis**-mechanical alloying, Mechanical ball milling, Ion implantation, Inert gas condensation, Arcdischarge, RF-plasma arc technique, Laser ablation, Template assisted synthesis.Self-assembly, self-assembled monolayers (SAMs).	**06**
UNIT-04	**Synthesis of nanomaterials:** Gold, Silver, different types of Nano oxides, TiO2, ZnOby using sol-gel method, Carbon nanotubes, Graphene preparation, properties and applications, vapors deposition: Epitaxial growth techniques: Molecular beam epitaxy, Atomic layer deposition, Pulsed laser deposition, Magnetron sputtering, Spin coating, Micro lithography Etching process: Dryetching, Wetetching.	**09**
UNIT-05	**Properties of nanomaterials**: 1D, 2D and 3D quantum confinement, quantum effects on density of states, band gap energy, Brus equation, surfaceplasmon resonance, role of size, surface and quantum confinement on properties of nanomaterials – physicochemical, optical, luminescence, electrical electronic, magnetic, thermodynamic, mechanical, and catalytic properties. Application of Nanotechnology	**06**
Course Outcomes Upon successful completion of the course, the students will be able to CO1: List and generally explain the nanotechnology CO2: Describe the process of synthesis of nanomaterials CO3: List and describe the primary application of technology		
Books and References 1. Handbook of Nanoscience, Engg. and Technology by W. Gaddand, D. Brenner, S. Lysherski and G. J. Infrate, CRC Press. 2. A Textbook of Nanoscience and Nanotechnology by T. Pradeep, Tata McGraw Hill Education 3. Introduction to Nano Technology by C. P. Poole, Jr. , F. J. Owens, Wiley. 4. Springer Handbook of Nanotechnology by B. Bhushan, Springer- Verlag Berlin Heidelberg. 5. Nanoscale Science and Technology by R. Kelsall, I. W. Hamley, and M. Geoghegan, John Wiley & Sons.		

Course Name: **Materials for Renewable Energy**
Course Code: **MS-302**
Course Type: **Open Elective**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To provides an introduction to energy systems and renewable energy resources, with a scientific examination of the energy field and an emphasis on alternate energy sources and their technology and application
- To emphasized the Energy conservation methods

Unit Number	Course Content	Contact Hours
UNIT-01	**Nuclear Metallurgy:** Structures and properties of materials with special relevance for nuclear power generation: uranium and other actinides, beryllium, zirconium, rare-earth elements, graphite. The materials of nuclear fuels and nuclear fuel element fabrication. Reprocessing of nuclear fuel elements. Nuclear Power Plant and Their Materials: Nuclearreactor, pressurized reactor, breeder reactor. Materials for fuel, control rods, coolant, moderator, shielding	**09**
UNIT-02	Effects of Radiation on Materials Properties: Effects of X-rays on creep, fatigue, tensile, and other properties of metals, alloys, ceramics, polymers, rubbers etc. Effects on electrical, Electronic and magnetic behavior of materials, Effects on crystal structure, grain size etc.	**09**
UNIT-03	Materials in Fuel cells and Solar Cells: Electrocatalyst materials for low temperature fuel cells, Conductive membranes for low-temperature fuel cells, Materials for high temperature fuel cells, silicon, quantum dots for solar energy, nanomaterials for solar thermal energy and photovoltaic	**06**
UNIT-04	Materials in Thermal Power Generation: Superalloys, steels, ceramics, TBC, hydrogen membrane materials, sensor and sensor materials, biomass, coal, fly ash, etc Materials in Hydro Power Generation Materials for power plant components, steel, stainless steel, ceramics, etc.	**06**
UNIT-05	Energy storage: Artificial photosynthesis/solartofuels, CO2 separation and utilization, Safer nuclear waste disposal, biofuels production, biological fuel cell technologies, reduction of energy, Use in manufacturing processes, Improved grid technologies, sustainable energy economic.	**06**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: List and generally explain the main sources of energy and their primary applications in the India, and the world

CO2: Describe the challenges and problems associated with the use of various energy sources
CO3: List and describe the primary renewable energy resources and technologies.

Books and References

1. Introduction to Nuclear Science by J .C. Bryan, CRC Press.
2. Nuclear Reactor Materials and Applications by B. M. Ma, Van Nostr and Reinhold Company.
3. Nuclear Reactor Materials by C.O. Smith, Addison-Wesley Publishing Company.
4. Structural Materials in Nuclear Power Systems by J.T.A. Roberts, Plenum Press.
5. Handbook of Fuel Cells by Wolf Vielstich, Arnold Lamm, Hubert A. Gasteiger, and Harumi Yokokawa, John Wiley and Sons, Inc.

Course Name: **Materials Characterization**
Course Code: **MS-303**
Course Type: **Open Elective**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart knowledge about the materials characterization
- To introduce fundamental concepts relevant to materials analysis
- To enable the students to understand properties of engineering materials and various advanced characterization methods

Unit Number	Course Content	Contact Hours
UNIT-01	**Optical Microscopy**: Optical microscope- Basic principles and components, Different examination modes (Bright field illumination, Oblique illumination, Dark field illumination, Phase contrast, Polarized light, Hot stage, Interference techniques), Stereomicroscopy, Photo microscopy, Colour metallography, Specimen preparation, Applications.	**06**
UNIT-02	**Electron Microscopy:** Interaction of electrons with solids, Scanning electron microscopy Transmission electron microscopy and specimen preparation techniques, Scanning transmission electron microscopy, Energy dispersive spectroscopy, Wave length dispersive spectroscopy.	**06**
UNIT-03	**Diffraction Methods:** Fundamental crystallography, Generation and detectionof X-rays, Diffraction of X-rays, X-ray diffraction techniques, Electron diffraction.	**06**
UNIT-04	**Thermal characterization:** Thermo gravimetric analysis (TGA), Differential thermal analysis (DTA), Differential scanning Calorimetry (DSC), Dynamic mechanical analysis (DMA), Thermomechanical analysis (TMA) and Dynamic mechanical thermal analysis (DMTA), Basic theory, Instrumentation and applications	**06**
UNIT-05	**Surface Analysis:** Atomic force microscopy, scanning tunneling microscopy, X-ray photoelectron spectroscopy.	**06**
UNIT-06	**Spectroscopy:** Atomic absorption spectroscopy, UV/Visible spectroscopy, Fourier transform infrared spectroscopy, Raman spectroscopy.	**06**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand common use of characterization technique
CO2: Describe and analysis the various properties of material
CO3: Understand principle of materials characterization technique

Books and References

1. Materials Characterization Techniques by Sam Zhang, Lin Li and Ashok Kumar, CRC Press.
2. Materials Characterization: Introduction to Microscopic and Spectroscopic Methods by Yang Leng, Wiley & Sons.
3. Characterization of Materials by Elton N. Kaufmann, Wiley & Sons.
4. Growth of Single Crystals by R. A. Laudise, Prentic eHall.
5. Springer Handbook of Crystal Growth by G.Dhanaraj, K. Byrappa, V. Prasad and M. Dudley, Springer-Verlag.

Course Name: **Electronic and Optical Properties of Materials** Course Code: **MS-304** Course Type: **Open Elective**		
Contact Hours/Week: 3L		Course Credits: 03
Course Objectives To introduce the fundamentals of electronic materials, their properties and examples. To expose the properties and applications of functional materials in modern technology. To familiarize the students with various concepts related to electronic and optical properties and their exploitation to develop the useful materials based on the structure, chemistry and the processing techniques.		
Unit Number	Course Content	Contract Hours
UNIT-01	**Introduction**: Review of quantum mechanical concepts, In adequacies of free electron theory, Electron in metals-consequences of interaction with lattice, Brillouin zones and nearly free electron model.	**06**
UNIT-02	**Electrical properties of metals & alloys**: Classical theories of conductivity, Quantum mechanical theory of conductivity, Experimental results & their interpretations: metals, alloys, ordering & phase stability. Electrical resistivity: Electrical resistivity of metals, Alloys, Multiphase solids And Mattheissen rule.	**09**
UNIT-03	**Semiconducting Materials**: Semiconductor band diagrams, direct and indirect bandgap, applications of semiconductors; intrinsic and extrinsic semiconductors, and mobility measurements;	**06**
UNIT-04	**Dielectric and Insulating Materials**: Review of polarization, Clausius Mosotti equation, Mechanisms of polarization, Dielectric permittivity and loss (in brief), Dielectric break down in materials, High K dielectric, Non-linear dielectrics: Ferroelectric, Piezoelectric pyroelectric phenomena	**09**
UNIT-05	**Optical Materials**: electron-hole recombination, bandgap engineering; Light interaction with materials transparency, translucency and opacity, refraction and refractive index, reflection, absorption and transmission	**06**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Learn the basics of materials used in present electronic industry.
CO2: Explain the behavior of conductivity of metals and classifications of semiconductor materials
CO3: Explain the importance of optical properties.

Books and References

1. Physics of Semiconductor Devices by S.M. Sze, Wiley.
2. Semiconductor Opto-electronic Devices by P. Bhattacharya, PHI.
3. Optoelectronics by Wilson Hawkes, PHI.
4. The Science and Engineering of Microelectronics Fabrication by
5. S. Campbell, Oxford. Electronic Properties of Materials by
   Hummel, Springer

Course Name: **Computational Materials Science**
Course Code: **MS-321**
Course Type: **Discipline Core**

Contact Hours/Week: **3L + 1T** Course Credits: **04**

Course Objectives

- To understand the role of computational techniques in solving problems in materials science
- To impart knowledge of various kind of multiscale modelling techniques used in material science

Unit Number	Course Content	Contact Hours
UNIT-01	**Basics of computational materials science:** Atomistic theory of matter, Statistical mechanics of materials (equilibrium and non-equilibrium systems and ensembles, Stochastic processes and stochastic modeling),Coarse graining methods, Continuum models of materials and microstructures	**06**
UNIT-02	**Multiscale Simulation Methods:** Molecular Dynamics, equilibrium and kinetic Monte Carlo simulation, mesoscopic methods such as Dislocation Dynamics and the Phase Field method, and continuum-level modeling of materials behavior in Finite Element simulations	**03**
UNIT-03	**Numerical Methods for Atomistic Modeling I:** General theory of atomistic simulations, Advanced methods for the generation of atomistic samples, MD integration algorithms for different thermodynamic ensembles (NVE,NVT,NPT), Energy minimization algorithms and structure optimization, Introduction to Density Functional Theory, Determination of defect properties, Atomic interaction potentials, including EAM, BOP and Tight-Binding Methods, Advanced analysis and visualization methods for atomistic samples,	**09**
UNIT-04	**Numerical Methods for Atomistic Modeling II:** Monte Carlo and kinetic Monte Carlo methods, Modeling thermally activated events: transition state theory, nudged elastic band calculations, hyper-dynamics **Generalized Continuum Models of Microstructure:** Cosserat continua, Micro-morphic continua, Nonlocal and gradient-dependent models, Stochastic models of heterogeneous microstructure	**09**
UNIT-05	**Dislocation Theory and Simulation:** Foundations of dislocation theory (stress and strain fields, dislocation energetics and interactions),Dislocation-based modeling of plastic deformation processes, Discrete and continuous simulation approaches	**09**

Course Outcomes:

Upon successful completion of the course, the students will be able to

CO1: Identify the simulation techniques for solving a particular problem in material science

CO2: Perform basic atomistic and microstructure level simulations

CO3: Apply finite element method for solving stress-strain, heat and mass transfer problems in material science

CO4: Study and model the role of dislocations and other material defects

Books and References:

1. Introduction to Computational Materials Science: Fundamentals to Applications, Richard LeSar, Cambridge University Press
2. Computational Materials Science: An Introduction, June Gunn Lee, CRC press
3. Computational Materials Science: From Ab Initio to Monte Carlo Methods, Kaoru Ohno, Keivan Esfarjani, and Yoshiyuki Kawazoe, Springer
4. Density Functional Theory: A Practical Introduction by David Sholl and Janice A. Steckel, Wiley
5. Computational Materials Engineering: Achieving High Accuracy and Efficiency in Metals Processing Simulations by Maciej Pietrzyk, Lukasz Madej, Lukasz Rauch, Danuta Szeliga, Butterworth-Heinemann Publisher

Course Name: **Polymer Science and Technology** Course Code: **MS-322** Course Type: **Discipline Core**		
Contact Hours/Week: **3 L**		Course Credits: **03**
Course Objectives • To provide in-depth structure-property-processing co-relation for polymeric materials. • To understand the different behaviour of polymers; Thermal, Optical, Mechanical and Chemical. • To understand the properties of different special kind of polymers; conducting, magnetic, and biodegradable.		
Unit Number	**Course Content**	**Contact Hours**
UNIT-01	**Introduction:** Types of polymeric materials and their structures, Classification of polymerization reactions, Step growth and chain growth polymerization. Inter and intra molecular reactions. Average molecular weight concept. General theory of chain growth polymerization. Copolymerization; Crystalline and amorphous polymers, conducting polymers introduction, classification, preparation and properties.	**09**
UNIT-02	**Polymers**: Polymerization, Degree of polymerization, Structural features, Thermoplastic and thermosetting polymers, Mechanical properties, Thermal properties. Strengthening mechanism,Fibres. Special purpose plastics. Glass transition temperature and its importance.	**06**
UNIT-03	**Plastics, Rubbers and Fibres of Commercial Importance:** Additives: Plasticisers, fillers, Stabilisers, lubricants, Retarders, Inhibitors etc., Tensile properties of polymers, Impact strength, Softening point, Heat distortion temperature, Melt flow index, Mouldability. General applications of polymers, polymer blends, polymers for biomedical applications.	**06**
UNIT-04	**Processing of Polymers:** Flow properties of polymers, Extrusion, Injection and blow moulding. Calendaring, Vacuum & pressure forming and warm forging. Casting of fibres and filaments, Assembly by adhesion.	**09**
UNIT-05	**Properties in Service Environments:** Effects of vapours and solvents on polymeric materials. Oxidation and thermal degradation of polymers. Solubility, permeability, radiation damage and chemical resistance of polymers.	**06**
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Classify different types of polymers CO2: Understanding the properties of different types of polymers CO3: Designing and processing new types of polymers and composites.		
Books and References 1. Fundamentals of Polymer Engineering by Ram, Arie, Springer. 2. Textbook of Polymer Science by Fred W. Billmeyer, Wiley. 3. Polymer Science by V.R. Gowariker, N.V. Viswanathan and J. Sreedhar, Wiley. 4. Fundamentals of Materials Science and Engineering by William D. Callister, Jr., David G. Rethwisch, John Wiley & Sons. 5. Physical Metallurgy, Principles and Practice by V. Raghavan, PHI Publisher		

Course Name: **Non-Ferrous Extractive Metallurgy** Course Code: **MS-323** Course Type: **Discipline Core**		
Contact Hours/Week: **3 L+1 T**		Course Credits: **04**
Course Objectives To elucidate the concepts of production of some of common non-ferrous metals by conventional routes To bring about the challenges associated with production of metals in an energy efficient and environment friendly manner		
Unit Number	**Course Content**	**Contact Hours**
UNIT-01	**Introduction**: General principles of extraction of metals from oxides and sulphides; Mineral resources of non – ferrous metals in India; their production, consumption and demand; Future of non–ferrous metal industries in India.	03
UNIT-02	**Principles of Mineral Processing**: Introduction to minerals, ores and their resources, Ore preparation: Comminution: Crushing and grinding, sizing of comminuted particles, Concentration techniques: Gravity concentration, Magnetic and electrostatic separation, Froth floatation	03
UNIT-03	**Pyro-metallurgical Process**: Role of Ellingham diagrams in Extraction of metals, Calcination, Roasting, Reduction and matte smelting using blast furnace and electric arc furnace, Flash smelting, converting, principals of metallothermic reduction. Refining, distillation and vacuum refining. **Hydrometallurgical Process**: leaching methods such as in situ, heap and percolation leaching, pressure leaching and bacterial leaching, Mechanical and pneumatic vats. Solution purification methods such as chemical, ion exchange and solvent extraction, cementation. **Electrometallurgical Process**: Faraday's laws; Review of properties of aqueous electrolytes, ionic mobilities, transport number and conductivity in electrolytes, Electrode potential, polarization, gas and metal over voltage, E.M.F. of cells. Elementary idea of electro deposition, electro winning and electro refining.	12
UNIT-04	**Aluminium**: Bayer process, its chemistry and practice. Hall-Heroult process: carbon anodes, theoretical principles, factors influencing the process, current and energy efficiencies. **Copper**: Roasting, matte smelting, converting, fire-refining and electro-refining,Ausmelt/Isasmelt process, Hydrometallurgy of copper. Zinc: Pyrometallurgy, sinter-roasting and Imperial smelting process. Hydrometallurgical extraction: roasting, leaching and electro winning.	09
UNIT-05	**Lead**: Blast furnace smelting, refining of lead bullion Titanium: Up-gradation of ilmenite and Kroll process Gold and Silver: Cyanidation process. **Uranium**: Acid and alkali processes for digestion of uranium ores. Production of reactor grade **Uranium and UO2.** Other important metals such as nickel and magnesium, major non-ferrous metal production in India Carbon-in pulp process.	09
Course Outcomes: Upon successful completion of the course, the students will be able to CO1: Understanding the principles of extraction of non-ferrous metals CO2: Understanding of pyro-metallurgical, hydrometallurgical, electrometallurgical process CO3: Understand various process of materials extraction and mineral processing		
Books and References: 1. Principles of Extractive Metallurgy by T. Rosenquist, Mcgraw Hill. 2. Unit Processes of Extractive Metallurgy by R. D. Pehike, American Elsevier. 3. Aluminium Smelter Technology by K. Grjortheim and B.J. Welch, Aluminium-Verlag. 4. Extractive Metallurgy of Copper by A.K. Biswas and W.G. Davenport, Pergamon. 5. Extraction of Non-Ferrous Metals by H.S. Ray, R. Sridhar and K.P. Abraham,		

Affiliated East – West Press.

Course Name: **Nano-Materials Lab**
Course Code: **MS-324**
Course Type: **Discipline Core**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives

- To gain understanding of synthesis and processing techniques for various class of polymers and composites
- Introduction to physical and mechanical characterization techniques of polymers and composites along with their applications

List of Experiments

1. To synthesize nanoparticles of gold and silver
2. To synthesize CdS nanoparticles.
3. Synthesis of ZnO nanoparticles.
4. Synthesis of TiO2 nanoparticles.
5. Synthesis of Fe2O3 nanoparticles
6. Imaging of nanocomposite fibres in SEM
7. Calculate the crystallite size of nanoparticles using XRD technique
8. Calculate the crystallite size of nanoparticles using Zeta-Sizer
9. FTIR studies of prepared nanoparticles.
10. Optical studies of prepared nanoparticles using UV-Visible spectroscopy
11. Raman studies of prepared nanoparticles
12. Morphological studies of nanoparticles by SEM analysis

Note: The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.

Course Outcomes

At the end of this course, the students would be able to:
CO1: Understand the various polymers and composites synthesis process
CO2: Understand the principle of processing techniques for polymers and composite materials
CO3: Analyze the characterization results obtained from physical testing of polymers and composites

Course Name: **Non-Destructive Testing and Computational Materials Science Lab**
Course Code: **MS-325**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives:
- To provide an insight into the various types of materials testing and computational techniques in materials science
- To provide demonstration of non-destructive testing and computational analysis of materials

List of Experiments:
1. Visualization of surface cracks under optical microscope
2. Magnetic particle inspection test.
3. Dye penetration test.
4. Testing of welded joints.
5. Eddy current inspection of cracks.
6. Ultrasonic testing technique.
7. Simulation of Iron-carbon binary phase diagram.
8. Calculation of free energy of reduction of Fe_2O_3 (Hematite) by coke and carbon-monoxide present inside blast furnace reactor.
9. Demonstration of 3D crystal structures of engineering ceramics like Al_2O_3 , SiO_2 , TiO_2 by crystal maker software.
10. Analysis of X-Ray and TEM diffraction patterns by crystal maker software.
11. Calculation of CCT and TTT diagrams for phase transformation in mild steel by J-Mat-Pro.
12. Modeling of steel turbulence inside a steel making LD converter furnace by Fluent/Gambit.

Note: The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.

Course Outcomes:
Upon successful completion of the course, the students will be able to
CO1: Perform destructive and non-destructive testing of a component
CO2: Compute simulated X-Ray and diffraction pattern of a given material
CO3: Visualize complex 3D crystals via software

Course Name:	**Nanomaterials and Applications**
Course Code:	**MS-441**
Course Type:	**Discipline Elective-III**

Contact Hours/Week: **3L** Course Credits: **3**

Course Objectives

- To impart knowledge about the nanomaterials and nanotechnology
- To introduce fundamental concepts relevant to nanomaterials for specific application
- To enable the students to understand properties of engineering nanomaterials

Unit Number	Course Content	Contact Hours
UNIT-01	**Introduction to Nanotechnology –** Importance of size distribution and control -Effects of size on physiochemical properties of nanomaterials – Size effects on surface area and aspect ratios – 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	**06**
UNIT-02	**Introduction to chemical bonds and forces -**Surface energy – Surface charge densityChemical Potential and Surface curvature – Ostwald Ripening process – Stabilization against agglomeration -Electrostatic and Steric Stabilization– Interaction between two particles DVLO theory	**03**
UNIT-03	**Diffusion in Nanostructures –** Factors affecting diffusion - Surface, Volume and cross grain boundary diffusion – Growth controlled by diffusion – Diffusion kinetics – Kirkendall EffectClassification of Nanoparticles – Zero, One, Two andThree dimensional nanostructuresNanoparticles by homogeneous nucleation and heterogeneous nucleation- VLS and SLS growth - particle size, strain and grain size of nanomaterials.	**09**
UNIT-04	**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, luminescence, electrical electronic, magnetic, thermodynamic, mechanical, and catalytic properties.	**09**
UNIT-05	**Application of Nanotechnology –**Single Electron Transistor, Resonant Tunnelling 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	**09**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand common use nanomaterials, its chemical structure, properties and morphology.
CO2: Describe general structure and function of nanomaterials.
CO3: Understand and account for methods for categorization of nanomaterials.
CO4: Explain the application of nanomaterials in various fields

Books and References

1. Handbook of Nanoscience, Engg. And Technology by W. Gaddand, D .Brenner, S.Lysherski and G.J.Infrate, CRC Press.
2. A Textbook of Nanoscience and Nanotechnology by T. Pradeep, Tata McGraw Hill Education.
3. Introduction to Nano Technology by C. P. Poole, Jr., F. J. Owens, Wiley.
4. Springer Handbook of Nanotechnology by B. Bhushan, Springer-Verlag Berlin Heidelberg.
5. Nanoscale Science and Technology by R. Kelsall, I.W. Hamley, and M. Geoghegan, John Wiley & Sons.

Name: **Materials Selection and Design**
Course Code: **MS-342**
Course Type: **Discipline Elective-III**

Contact Hours/Week: **3** Course Credits: **03**

Course Objectives

- To understand different service condition for a component and properties required.
- To introduce fundamental concepts of selective properties for a selection
- To critical understanding of design and properties

Unit Number	Course Content	Contact Hours
UNIT-01	**Materials Selection in Design:** General criteria for selection, performance characteristics of materials, materials selection process, design process and materials selection, economics of materials, recycling and materials selection.	**06**
UNIT-02	**Materials Properties and Design:** Role of Crystal Structure. Stress – Strain diagram, Design for strength, Rigidity. Effect of static strength, stiffness, fracture toughness, Design for yielding and fracture toughness fatigue, creep andwear resistance, brittle fracture, fatigue failure, corrosion resistance. **Designing with plastics:** brittle materials .Design examples with shaft design, spring design and C-frames	**09**
UNIT-03	**Manufacturing Considerations in Design:** Surface finish, Texture, Dimensional tolerances in fitting, interchange ability selective assembly, and geometric tolerance.	**06**
UNIT-04	**Types of design:** Design tools and materials data Design under static loading, variable loading, and eccentric loading – stress concentration. Design examples with shaft design, spring design and C-frames, Materials and shape – microscopic and microstructural shape factors – limit to shape efficiency Comparison of structural sections and materials indices – case studies.	**09**
UNIT-05	**Materials Selection methods:** Ashby Method, Case Studies, Multiple Constraints in materials selection, Multiple Objectives, Role of Materials in Shaping the Product Character.	**06**

Course Outcomes:

Upon successful completion of the course, the students will be able to
CO1: Classify various engineering materials and explain their structure and imperfections
CO2: Draw some typical application of different materials with their distinctive features
CO3: Explain different service condition of a part and basic required properties
CO4: Describe various selection criteria for a newly designed component

Books and References:

1. Materials Selection in Mechanical Design by M.F. Ashby, Elsevier Publishers, Oxford.
2. Selection of Engineering Materials by Gladius Lewis, Prentice Hall Inc., New Jersey, USA.
3. Selection and Use of Engineering Materials by J. A Charles, Butterworths, London, UK.
4. Materials Selection and Design by Maleque, Md Abdul, Salit, Mohd Sapuan, Springer
5. Engineering Materials: Properties and Selection by Budinski, Kenneth G, Prentice Hall India Learning Private Limited

Course Name: **Surface Science and Engineering** Course Code: **MS-343** Course Type: **Discipline Elective-III**		
Contact Hours/Week: **3L**		Course Credits: **03**
Course Objectives • To analyze the various concepts of surface engineering and comprehend the design difficulties • To assess the surface testing methods and comprehend the degradation properties		
Unit Number	**Course Content**	**Contact Hours**
UNIT-01	**Introduction of tribology:** surface degradation, wear and corrosion, types of wear, adhesive,abrasive, oxidative, corrosive, erosive and fretting wear, roles of friction and lubrication overview of different forms of corrosion	**06**
UNIT-02	**Chemical and electrochemical polishing:** significance, specific examples, chemical conversion coatings, phosphating, chromating, chemical coloring, anodizing of aluminum alloys, thermochemical processes -industrial practices	**03**
UNIT-03	**Surface Treatment**: Alloy plating, electro composite plating, properties of electro deposits, electro less composite plating; application areas, properties.	**09**
UNIT-04	**Definitions and concepts:** physical vapor deposition (PVD), evaporation, sputtering, ion plating, plasma nitriding, process capabilities, chemical vapor deposition (CVD), metal organic CVD, plasma assisted CVD.	**09**
UNIT-05	**Thermal spraying:** techniques, advanced spraying techniques - plasma surfacing, detonation gun and high velocity oxy-fuel processes, **Laser Processing**: Laser surface alloying, laser cladding, specific industrial applications, tests for assessmentof wear and corrosion.	**09**
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Define different forms of processing techniques of surface engineering materials CO2: Know the types of Pre-treatment methods to be given to surface engineering[CO3: Select the Type of Deposition & Spraying technique with respect to application CO4: Study of surface degradation of materials		
Books and References 1. Surface Modification Technologies - An Engineer's guide by T.S. Sudarshan, Marcel Dekker, New York. 2. Electroplating and Other Surface Treatments - A Practical Guide by C. .D .Varghese, TMH. 3. Introduction to Surface Engineering by P. A. Dearnley, Cambridge University Press 4. Advanced Techniques for Surface Engineering by W. Gissler, H.A. Jehn, Springer. 5. Introduction to Surface and Thin Film Processes by John A. Venables, Cambridge University Press.		

Course Name: **Failure Analysis of Materials** Course Code: **MS-361** Course Type: **Discipline Elective-IV**		
Contact Hours/Week: **3L**		Course Credits: **03**
Course Objectives • To know the importance of the failure analysis of real life problems using various testing and characterization techniques • To know the root cause of failure of engineering materials		
Unit Number	**Course Content**	**Contact Hours**
UNIT-01	**Introduction to Failure analysis and Prevention:** Concepts, root causes analysis, primary root causes, design deficiencies, materials defects, manufacturing/installation defects, categories of failure, failure prevention, Failure analysis methodology, tools and techniques of failure analysis, failure data retrieval, procedural steps for investigation of a failure for failure analysis; types of failure and techniques for failure analysis.	**06**
UNIT-02	**Type of Stresses**: Elastic stress distributions for simple shapes, Thermal residual stresses, Metallurgical residual stresses, Mechanical residual stresses, Chemical effects on residual stresses.	**06**
UNIT-03	**Mode of Fractures:** Brittle fracture, Brittle fracture of normally ductile steels, Characteristics of Brittle fracture, Microstructures aspect of brittle fracture, Combined fracture modes, Ductile fracture, Characteristics of ductile fracture, Microstructures aspects of ductile fracture, Fatigue fracture, Types of fatigue fracture, Stages of fatigue fracture, Microscopic and macroscopic characteristics of fatigue fracture.	**09**
UNIT-04	**Different Type of Failures:** Wear failure, Abrasive and adhesive wear, Fretting wear, Wear failures-fatigue, Corrosion failure, Life cycle of a metal, Basic nature of corrosion, Forms of corrosion (Galvanic corrosion, Uniform corrosion, Crevice corrosion, Stress-corrosion cracking), Corrosion fatigue, Hydrogen embrittlement in alloys, Elevated-temperature failure, Creep, Elevated-temperature fatigue, Thermal fatigue, Metallurgical instabilities, Environmentally induced failure, Cooling methods.	**09**
UNIT-05	**Tools and Techniques in Failure Analysis:** Visual examination, Basic principles of liquid penetrant testing and Magnetic particle testing. Radiography - basic principle, electromagnetic radiation sources, radiographic imaging, inspection techniques, applications, limitations and safety. General Practices, Photography, X-rays, metallographic techniques, Fractography. Examples of component failures in metals, Ceramics, polymers and plastics. Case studies of failure analysis: Introduction to quality management, Inspection, inspection by sampling.	**06**
Course Outcomes: Upon successful completion of the course, the students will be able to CO1: Understand general failure analysis procedures CO2: Learn fundamental sources of failures CO3: Investigate the materials failure's background or history of a sample to determine why a particular failure occurred.		
Books and References: 1. Deformation and Fracture Mechanics of Engineering Materials by R.W.Hertz berg, John Wiley sons. 2. Fundamentals of Fracture Mechanics by J.F.Knott., Butterworth London. 3. Fracture Mechanics by H.L.Evalds and R.J.H.Warnhil, Edward Arnold Ltd. 4. Deformation and Fracture Mechanics of Engineering Materials by R.W.Hertzberg, John Wiley & Sons. 5. Metallurgy of Failure Analysis by A.K.Das, TMH.		

Course Name: **Fuels Refractory and Furnaces** Course Code: **MS-362** Course Type: **Discipline Elective-IV**		
Contact Hours/Week:**3L**		Course Credits: **03**
Course Objectives • The main aim of the course is to give detailed information about operations of industrial furnaces • To understand the role of refractories in furnace, fabrication and characterization of refractories		
Unit Number	**Course Content**	**Contact Hours**
UNIT-01	**Metallurgical coke**: manufacture, specifications, testing and properties; Coking and Non-coking coals; Characterization of coal properties (caking and swelling indices, calorific value , proximate and ultimate analysis, etc); Coal carbonization and effects of different parameters; Properties of coke, char and graphite; Fuel combustion and the effects of different factors; Combustion calculations; Alternative source of energy(viz. ferro coke, formed coke, charcoal, solar, wind, tidal, etc.) and their suitability for metallurgical and power industries. Fuel for Sponge Iron and thermal power Plants	**09**
UNIT-02	**Liquid fuels their properties:** Testing and metallurgical applications. Gaseous fuels, their properties, testing and metallurgical application, manufacture of producer gas and water gas. Coke Oven Gas, Blast Furnace Gas and natural Gas. Factors affecting the choice of fuels.	**06**
UNIT-03	**Acid, basic and neutral refractories:** composition and properties; Methods of production of fire clay, silica, magnesite, chrome- magnesite, dolomite and insulation bricks; special refractories; Testing of Refractories, Factors deciding the choice of refractory for a particular furnace and its parts.	**06**
UNIT-04	**Metallurgical furnaces:** classification and uses. Thermal performance and Heat losses in Furnaces. Furnace efficiency and heat balance computation, Sankey Diagrams, Flame characteristics in combustion. Variable affecting heat utilization in flame furnaces. Burner Designs and selection. Radiant tubes & their uses. Bouyancy movement of gases; types of drafts and draft control. Large pressure drop conditions, uses of high pressure blowers and compressed air blast. Flow through tuyeres/lances. Jet movement of gases and patterns flow. Radiant heat transfer in gases and flames. Calculation of transient condition of heating of charge by HeislerCharts.	**09**
UNIT-05	**Heat recovery aspects:** Waste Heat Utilization methods, Recuperator and Regenerator calculations, types of Recuperators and Regenerators and Checker brick work. Vacuum production in furnaces. Ingot heating soaking pits. Continuous Pusher type furnaces, walking beam furnaces, Roller Hearth furnaces; Bell type furnaces and other heat treatment furnaces. Direct –arc melting furnaces, salt bath furnaces.	**06**
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Identify the refractory properties required for efficient operations of furnaces CO2: Understand the role of refractories in furnace CO3: Understand various industrial fabrication and characterization of refractories		
Books and References 1. Metallurgical Furnaces by Krivadin and Markov, Central Books Ltd. 2. Refractories by A. Rashid Chesti, Prentice- Hall of India Private Ltd. 3. Elements of Fuels, Refractories and Furnaces by O.P. Gupta, Khanna Publication. 4. Fuels& Refractories, Macmillan by J. D. Gilchrist, Elsevier Science. 5. Refractory Material Selection for Steelmaking by Thomas Vert, Wiley		

Course Name: **Semiconductor Technology**
Course Code: **MS-363**
Course Type: **Discipline Elective-IV**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To study the different materials required for semiconductor industry
- To study the fabrication and processing of device.

Unit Number	Course Content	Contact Hours
UNIT-01	**Physics and Properties of Semiconductors materials:** crystal structure, energy bands, Fermi level, carrier concentration at thermal equilibrium, carrier transport phenomena, Hall Effect, recombination mechanism, optical and thermal phenomenon.	**6**
UNIT-02	**Device Processing Technology:** oxidation, diffusion, ion-implantation, deposition, lithography, etching and interconnect. p-n Junction: depletion region, diffusion, generation-recombination, current-voltage characteristics, junction breakdown, charge storage and transient behavior.	**8**
UNIT-03	**Metal-Semiconductor Contacts:** equilibrium, idealized metal semiconductor junctions, ohmic contacts, Solar energy-definitions, its intensity distribution, variation and spectrum, thermodynamics of solar energy spectrum, mechanism of heat losses, efficiency, photo thermal conversion materials and their preparation and characterization	**8**
UNIT-04	**Design of material for solar applications:** collectors, selective surface, composite semiconductors, solar reflectors and concentrators, thermo-electric conversion, chalcogenide and alloy semiconductors, criteria for material selection, spectral response, efficiency. **Types of Photovoltaic (PV) cells;** p-n homo and hetero junction, First, Second and Third Generation PV devices**.**	**12**

Course Outcomes

Upon successful completion of the course,
C01: students will have the understanding various steps required for device fabrication
CO2: Students will be able to work in semiconductor industry

Books and References

1. Simon M. Sze, Semiconductor Devices: Physics and Technology, 2nd Edition, John Wiley and Sons
2. S. Campbell, The Science and Engineering of Microelectronics Fabrication, Oxford, 1996
3. D. Nag Chaudary, Principle of Microelectronics Technology, Wheeler Publishing.

Name: **Non-Destructive Testing of Materials**
Course Code: **MS- 381**
Course Type: **Stream Core-I**

Contact Hours/Week: **2L** Course Credits: **02**

Course Objectives

- To impart the importance of non-destructive testing in assuring quality control in engineering components.
- To understand the basic principles of various NDT methods, fundamentals, discontinuities, importance of NDT, applications, limitations of NDT methods and techniques and codes, standards and specifications related to non-destructive testing technology.

Unit Number	Course Content	Contact Hours
UNIT-01	**Introduction:** Non-destructive testing and its comparison with destructive testing, role of NDT in quality control.	**06**
UNIT-02	**Liquid penetrant inspection:** its principles, equipment, advantages, limitations applications.	**06**
UNIT-03	**Magnetic particle inspection:** its principles, equipment, advantages, limitations applications. **Ultrasonic inspection:** its principles, equipment, advantages, limitations and applications.	**06**
UNIT-04	**Eddy current inspection:** its principles, equipment, advantages, limitations and applications. **X-ray radiography:** its principles, equipment, advantages, limitations and applications.	**09**
UNIT-05	**Quality control:** Statistical quality control, control charts, control chart attribute and variables and acceptance sampling; Quality assurance and ISO 9000:2000	**09**

Course Outcomes:

Upon successful completion of the course, the students will be able to

CO1: Identify the types of equipment used for each Non-Destructive and Destructive Examination.

CO2: Explain the purpose of the Equipment, Application, and standard techniques required for major NDT Testing

CO3: Have the knowledge and essential skills to identify strengths and weaknesses in materials used in fabrication

Books and References:

1. Practical Non-Destructive Testing by Baldev Raj, T. Jayakumar, M. Thavasimuthu, Woodhead Publishing Limited
2. Handbook of Magnetic Particle Testing by K.C. Srivastava, Oscar Publications.
3. Statistical Quality Control by E.L. Grant and R.S. Larenwork, Tata McGraw-Hill
4. Non-Destructive Testing by B. Hull, Springer.
5. Non-Destructive Test and Evaluation of Materials by J Prasad, C. G. Krishnadas Nair, McGraw Hill Education

Course Name: **Joining of Materials**
Course Code: **MS-382**
Course Type: **Stream Core-I**

Contact Hours/Week: 2L — Course Credits: 02

Course Objectives
To impart the knowledge of joining different metallic and non-metallicmaterials

Unit Number	Course Content	Contract Hours
UNIT-01	**Thermal and mechanical effects of joining**: Isotherm and thermalcycle, fusion and solidification, heat affected zone, microstructure, fastening, riveting, clinching, distortion and residual stresses in different joints	**05**
UNIT-02	**Joining of ferrous and non ferrous metals**: Plain carbon structuralsteels, high strength low alloy steels, alloy steels, cast iron, stainless steels, aluminium alloys, copper alloys, titanium alloys, nickel alloys, characterization, defects and remedial measures	**09**
UNIT-03	**Joining of non metallic materials**: Structural polymers, structural ceramics, composites, defects and remedial measures **Joining of dissimilar materials**: Structural steel-stainless steel, aluminium-copper, metal-polymer, metal-ceramic, microstructure,defects and remedial measures	**06**
UNIT-04	**Quality assessment of joint**: Inspection, mechanical testing, non-destructive testing, standards and codes for joint testing and qualification of joints	**04**

Course Outcomes
Upon successful completion of the course, the students will be able to
CO1: Learn the basics of joining materials.
CO2: Thermal and mechanical effects of joining.
CO3: Learn the quality assessment of joints.

Books and References

1. Mittal K.L. and Pizzi A., Adhesion Promotion Techniques,
2. Parmer R.S., Welding Engineering and Technology, Khanna.
3. Koichi M., Analysis of Welded Structures, Pergamon Press.
4. Larry J., Welding Principles and Applications, 4th Ed., Delmar Publishers

Course Name**: Ceramic Science and Engineering** Course Code**: MS-411** Course Type: **Discipline Core**		
Contact Hours/Week: **3**		Course Credits: **03**
Course Objectives • To understand the fundamentals (structure, properties and processing) of ceramic materials • To appreciate its advantages and limitations of various ceramic materials • To apply those fundamentals for selecting and developing ceramic materials for different engineering applications		
Unit Number	**Course Content**	**Contact Hours**
UNIT-01	**Introduction**: Review of bonding types in ceramics, calculation of percentage ionic Character Types of ceramics, Ceramic crystal structures: Sodium chloride, cesium chloride, alumina, spine and fluorite structures examples. Co-ordination number and ionic radius ratio, Pauling's Rules, packing fraction, critical radius ratio and density.	**09**
UNIT-02	**Properties and Applications of Engineering Ceramics:** Ceramics for mechanical functions: Abrasives properties and applications SiC, Cubic Boron Nitride (CBN) properties and applications. Ceramics for electrical and insulating functions Barium Titanate and its modifications insulating porcelains properties and applications. Ceramics for magnetic functions - Normal and inverse spinel structure Zinc, Nickel, Manganese and Iron ferrites structure properties and applications Ceramics for thermal functions: Refractories - Desirable characteristics - applications - Ceramics for nuclear applications	**09**
UNIT-03	**Preparation and Forming of Ceramics:** Preparation of Alumina, Zirconia, Silicon carbide Silicon Nitrides, Boron Nitride, Brief description of slip and slurry casting - applications. Powde processing equipment and 70 process details of hot pressing, Hot Isostatic Pressing and Cold Isostatic Pressing**.** Liquid Phase sintering. Shock wave compaction, reaction-sintering, cermet.	**06**
UNIT-04	**Glasses: Types of glasses** - structure, properties and applications of various types of glasses Silicate Glass ceramics- heat flow and precipitation from glasses – growth controlled by diffusior of solutes – crystalline glasses – enamels – photosensitive and photo-chromic glasses ; Blowing, pressing, drawing, rolling and casting - Pilkington process for float glass.	**06**
UNIT-05	**Property Evaluation:** Rupture strength; fracture Toughness, Elastic Constants, Hardness, Creep, Thermal Property, Coefficient of thermal expansion, Electronic Property, Measurement of electro-optic properties Weibull Statistics of Strength Data for Fine Ceramics	**06**
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Know the structure and properties of different ceramic materials CO2: Understand the phase diagrams and comprehend the phase transformations in ceramic materials CO3: Understand the testing methods for evaluating the mechanical properties of ceramic materials CO4: Understand the electrical, magnetic and optical properties of important ceramic systems		
Books and References 1. Introduction to Ceramics by W.D.Kingery, H.K.Bowen, D.R.Ulhmen, John Wiley. 2. Physical Ceramics for Engineers by Van Vlack, H.Lawrence, Addison-Wesley Educational Publishers. 3. Modern ceramic engineering: Properties, processing and use in design by Richerson, W.David, M.Dekker. 4. Elements of Ceramics by F. H. Norton, Addison-Wesley. 5. Fundamentals of Materials Science and Engineering by William D. Callister, Jr., David G. Rethwisch, John Wiley & Sons.		

Course Name: **Tribology of Materials**
Course Code: **MS-412**
Course Type: **Discipline Core**

Contact Hours/Week: **3** Course Credits: **03**

Course Objectives

- The impart knowledge on friction and methods to minimize wear of engineering components
- To enable the students to understand the wear behavior on coatings materials

Unit Number	Course Content	Contact Hours
UNIT-01	**Surface properties and surfaces in contact**: Nature of metallic surface, surface geometry measurement of surface topography, quantifying surface roughness, contact between surfaces; Friction, the laws of friction, measurement of friction, origin of friction, theories of friction adhesion theory, extension of the adhesion theory	**09**
UNIT-02	**Wear**: Types of wear, adhesive wear, Archard's law, abrasive wear, erosion wear, factors affecting corrosive wear, wear map, various wear testing methods- pin on disc, pin on drum, slurry wear, air jet and water jet erosion as per ASTM standards	**06**
UNIT-03	**Tribological properties of solid materials:** Hardness, strength, ductility and work hardening rate, effect of crystal structure, effect of microstructure, mutual solubility of rubbing pairs and effect of temperature	**06**
UNIT-04	**Surface treatments to reduce wear**: Surface treatments with or without change of composition, surface coating- welding, flame, spraying, plasma spraying, electroplating and electroless coating, chemical vapor deposition (CVD) and physical vapour deposition (PVD), super hard coatings	**09**
UNIT-05	**Surfaces and Friction**: Topography of Engineering surfaces- Contact between surfaces - Sources of sliding Friction– Adhesion-Ploughing- Energy dissipation mechanisms Friction Characteristics of metals – Friction of non-metals. Friction of lamellar solids – friction of Ceramic materials and polymers – Rolling Friction – Source of Rolling Friction – Stick slip motion –Measurement of Friction.	**06**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Apply the basic theories of friction and wear to predictions about the frictional behavior encountered sliding interfaces.

CO2: Characterize features of rough surface

CO3: Interpret the latest research on new topics in tribology

Books and References

1. Tribology – Friction and Wear of Engineering Materials by Ian M Hutchings, Edward Arnold.
2. Tribology – Principles and Design Applications by R.D. Arnold, P.B. Davies, J. Hallingand T.L. Whomes, Springer Verlag.
3. Introduction to Tribology by B. Bhushan, John Wiley.
4. Principles and Applications of Tribology by B. Bhushan, John Wiley.
5. Engineering Tribology by G. Stachowiak and A.W. Batchelor, Elsevier Butterworth-Heinemann.

Course Name: **Thin Film Technology**
Course Code: **MS-413**
Course Type: **Discipline Core**

Contact Hours/Week: **3** Course Credits: **03**

Course Objectives

- To learn the concepts of thin film coating starting from source materials to transportation and depositions.
- To learn the related methods and technology for deposition of thin films
- To learn the physics and techniques to analyze and characterize thin film in terms of its optical, electrical, magnetic and mechanical properties

Unit Number	Course Content	Contact Hours
UNIT-01	**Vacuum components and systems:** Need for vacuum, ways to achieve vacuum, measurement of vacuum dry and vapour pumps, concept of different gauges: Bayet- Albert gauge, Pirani, Penning pressure control and measurement gauge, conductance and other system design considerations principle of different vacuum pumps: roots pump, rotary, diffusion, turbo molecular pump, cryogenic- pump, ion pump, effect of the substrate on the film growth, in-situ and ex-situ substrate cleaning techniques.	**09**
UNIT-02	**Environment for thin film deposition:** Deposition parameters and their effects on film growth formation of thin films (sticking coefficient, formation of thermodynamically stablecluster – theory of nucleation) capillarity theory. Growth modes: zone model for sputtering and evaporation, Island growth, Volmer weber Layer growth, Van Vawler Megrue, Stranski – Krans Favour mode Microstructure in thin films, adhesion Film contamination, thin filmdefects, cosine law of deposition conformal coverage and line of sight deposition.	**09**
UNIT-03	**Methods of thin film deposition**: Deposition of inorganic film from solutions, chemical vapor deposition – Electrolysis, anodization, spray pyrolysis, polymerization, Langmuir- Blodgett, self- assembly, monolayers and spin coating method. Theory of evaporation and physical vapor deposition techniques: Evaporation and effusion, Hertz-Knudsen equation, Knudsen cell, directionality of evaporating molecules, vapour pressure and sublimation. Thermal, resistive, and e-beam evaporation Laser ablation, Flash and Cathodic arc deposition, Electrical discharges used in thin film deposition: Sputtering, Glow discharge sputtering Magnetron sputtering, Ion beam sputtering, Ion plating pulsed LASER deposition	**06**
UNIT-04	**Electrodeposition, molecular beam epitaxial and laser pyrolysis**: Chemical vapor deposition techniques, advantages and disadvantages of CVD over PVD techniques, reactiontypes, boundarie and flow, metal-organic CVD (MOCVD), plasma enhanced CVD (PECVD), thermally activated CVD, Spray pyrolysis.	**06**
UNIT-05	**Thin film characterization**: In-situ characterization of film deposition process, Film thickness measurements, XRD, AFM, Electron diffraction techniques (LEED and RHEED) Electron spectroscopy for chemical analysis. Thin film properties and applications Transparent conductive coatings, optical coatings, super-hard coatings, superconductivity, giant and colossal magnetoresistance, Ferro electronics, LED, solid oxide fuel cells, solar cells.	**06**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the general principles and techniques of thin film deposition.

CO2: Choose the right tools to perform thin film thickness measurement and to conduct microstructural and chemical analysis.

CO3: Select appropriate deposition method and materials for an engineering application.

Books and References

1. Materials Science of Thin Films: Milton Ohring.
2. Thin Film Phenomenon by K. L. Chopra, McGraw-Hill
3. Methods of Experimental Physics, by G. L. Weissler and R.W. Carlson "Vacuum Physics and Technology"
4. A User's Guide to vacuum Technology by J. F. O'Hanlon, John Wiley, and Sons
5. Vacuum Physics and Techniques by T. A. Delchar, Chapman, and Hall.

Course Name: **Ceramic Materials Lab**

Course Code: **MS-414**

Contact Hours/Week: **2P** Course Credits: **01**

Course Objectives

- Demonstration of ceramic synthesis and characterization principles
- Characterization ceramic properties

List of Experiments

1. Determination of percentage Moisture content of clay.
2. Determination of % Grit content of clay.
3. Determination of Water of Plasticity of Clays.
4. Determination of Atterberg's Plasticity of clays.
5. Ceramic powder preparation and compaction:
6. Micron and nano alumina
7. Silica Gel and precipitated Silica
8. Magnesioalumino hydrate (MAH) and MgAl2O4 Spinel
9. Calculation of density before and after compaction of ceramic powders
10. Characterization of Ceramic powder:
11. Tap density, DTA / TGA / DTGA, IR, Particle Size Analysis
12. Determination of Alkali resistance of glass
13. Determination of alkalinity of glass
14. Determination of Chemical durability of different types of glasses

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Calculate the physical properties of clay and clay based composites

CO2: Synthesize various types of ceramic and their composites

CO3: Perform characterization of glass and other ceramic types

Course Name: **Tribology Lab** Course Code: **MS-415**
Contact Hours/Week: **2P** Course Credits: **01**
Course Objectives To evaluate the wear property of a material so as to determine whether the material is adequate for a specific wear application. To evaluate the potential of using a certain surface engineering technology to reduce wear for a specific application To investigate the effect of treatment conditions (processing parameters) on the wear performance, so that optimised surface treatment conditions can be realized.
List of Experiments To perform the wear test of various materials using Reciprocating Tribometer: Pure Metal, Composite /Alloy,Ceramic and Polymer. Analysis and comparison of the wear Properties of different Materials (in reciprocating motion): Coefficient of Friction, Wear volume, Wear Rate Study of the Wear mechanism of various samples using Scanning Electron Microscopy To perform the wear test of various materials using Pin on Disc Tribometer: Pure Metal, Composite /Alloy, Ceramic and Polymer Analysis and comparison of the wear Properties of different Materials (in rotational motion) : Coefficient of Friction, Wear volume, Wear Rate Study of the Wear mechanism of various samples using Scanning Electron Microscopy. To study the wear and friction properties of oils and greases using Four Ball Tester. To study the effect test parameter (Speed, temperature, and lubrication) on the wear behavior of metallic system. To study the erosion (wear) of material using the Air Jet Erosion Tester. To study the erosion (wear) of material using the Slurry Erosion Tester. - To study the abrasive wear properties of the metallic system using Dry Abrasion Tester. To study the surface profiling of the wear surfaces using Atomic force Microscopy (AFM).
smart Upon successful completion of the course, the students will be able to CO1: Understand the effect of the various service conditions on the wear behavior of the different materials CO2: Understand the various wear mechanism involved in a specific wear application CO3: Understand the parameters for controlling the wear of the materials in specific wear application

Course Name: **Smart Materials** Course Code: **MS-451** Course Type: **Discipline Elective-V**		
Contact Hours/Week: **3L**		Course Credits: **3**
Course Objectives • To get familiar with the different families of smart materials • To understatnd the importance of material structure in tailoring smart properties, • To understand the mechancism, design and applicaiton of materials. • Provide appreciation to utilize smart materials in context of smart engineering structure		
Unit Number	**Course Content**	**Contact Hours**
UNIT-01	Overview of Smart Materials: Introduction to smart materials, Classification of smart materials, Importance of material structure, Modification of material structures, Stimuli for reversible shape and structural transformation, Single crystals vs Polycrystalline systems, Fundamental principle of piezoelectricty, Introduction to electronic materials and electro- active Materials, Chemically and optical activated materials.	05
UNIT-02	Ceramic Based Smart Materials: Perovskite structure, Piezoelectric and electrostrictive ceramics, Ferroelectric ceramics senosrs for ultrasonic testing, Overview of synthesis rote of smart ceramics, Role of crystal size and morphology. Polymeric Smart Materials: Overview of polymer materials, Electroconductive polymers, Polymers in Bio-medical sensing, Self-healing materials, Nanoparticles, Porous particles, Thermo-responsive polymers, Overview of thin film based smart materials.	09
UNIT-03	Shape Memory Alloys (SMA): Shape memory alloys, Microstructural mechanisms, Range of SMA, phases and crystal structure, High temperature SMA, Magnetic SMA, Giant magnetostrictive material. Magnetic Materials: Principles of Magnetostriction, Rare earth magnetostrictive materials, Giant Magnetostriction and Magneto-resistance effect, Electro-rheological fluids, Magneto Rhelological fluids, Usage in smart drug delivery systems.	08
UNIT-04	Sensing, Actuation and Smart Composites: Piezeoelctric sensors and actuators, Fibre Optics, Application of smart sensors and actuators for Structural Health Monitoring (SHM), Vibration control using smart materials, Review of composites, Different types of composites, Flexible ceramic composites, Composite based on smart materials, Smart composites based on structrual materials.	08
UNIT-05	Emerging and Advance Applications of Smart Materials: Waster Energy Harvesting using smart Materials, Introduction to cantilever beam based harvesting Technique, Self-healing smart mateirals, Smart Materials in Flexible Electronics, Smart materials as wearable devices in healthcare, Smart textile, Advances in Structural Health Monitoring, Smart materials in drug delivery, Application in forensic science, Use of smart materials in day to day life.	06
Course Outcomes Upon successful completion of the course, the students will be able to CO5: Understand the fundamental aspects of intelligent/smart materials CO6: Understand the role of structure and stimuli for the smart response. CO7: Understand the methodology of newer materials development towards specific applications CO8: Think and develop solutions to the problems by using smart materials.		
Books and References 1. Gandi, M.V. and Thompson, B.S., “Smart Materials and Structures,” Chapman & Hall, UK, 1992, 2. Culshaw, B.,“Smart Structures and Materials,” Artech House, Inc., Norwood, USA, 1996. 3. Schwartz M. (Ed.) (2009) Smart Materials, CRC Press, Taylor and Francis Group 4. Hou X. (Ed.) (2016), Design, Fabrication, Properties and Applications of Smart and Advanced Materials, CRCPress) 5. Elhajjar et al. (Eds.) (2014) Smart Composites Mechanics and Design, LLC, Taylor and Francis Group		

Course Name: **Electronic Ceramics** Course Code: **MS-452** Course Type: **Discipline Elective-V**		
Contact Hours/Week: **3L**		Course Credits: **03**
Course Objectives • To study the advanced ceramics properties and their applications • To study the different types of ceramics materials used by industries for different industries		
Unit Number	**Course Content**	**Contact Hours**
UNIT-01	Introduction: Atomic structure including ionic and covalent bonding, Ceramic crystal structures, Clay structures, and amorphous materials. Atomic defects including intrinsic and extrinsic point defects, Kroger-Vink notation. Synthesis and Microstructure Development: Microstructure development in equilibrium and nonequilibrium phases, Solid- state sintering, densification vs. coarsening processes, Grain boundary mobility, Porosity evolution (stability/entrapment), Liquid phase sintering, constrained sintering, Ceramic coatings and their deposition.	8
UNIT-02	Electrical Properties: Conductors: electrodes, varistors, thermistors, Insulators and Dielectrics: polarization, charge displacement, dielectric strength, dielectric constant and loss, equivalent circuits, Ferroelectricity, Piezoelectrics, Pyroelectrics, actuators and sensors. Classification of superionic solids-Alumina and oxide based superionic conductors and their applications in fuel cells and batteries.	8
UNIT-03	Magnetic Properties: Spinel, normal and inverse, Weiss domains, ferrites, soft and hard, super-exchange, garnets, permeability, microstructure-property relations, dia, para, ferro and ferrimagnetic materials, chemical substitutions, device performance and applications.	8
UNIT-04	Thermal and Mechanical Properties: Heat capacity, Thermal conductivity, Thermal expansion, Creep and thermal stresses. Mechanical properties: Strength, Toughness and micro structural design. Multiferroic and Spintronic Materials and Their Applications: Single phase and composite multiferroic material, BiFeO3, RMnO3, Magnetoelectric coupling.	12
Course Outcomes C01: Upon successful completion of the course, students will have the understanding of the mechanisms responsible for unique properties of ceramics materials CO2: Tthe requirement of advanced ceramics for different industrial requirements		
Books and References 1. Electro ceramics: Materials, Properties and Applications/A. J. Moulson and J. M. Herbert/John Wiley & Sons 2003 2. Ceramic Science and Technology/W. D. Kingery, H. K. Bowen and D. R. Uhlman/John Wiley and Sons, Singapore. 1991 3. Ceramic Processing and Sintering, 2nd Ed/M. N. Rahaman/CRC Press. 2003 4. R. C. Buchanan, Ceramic Materials for Electronics, Marcel Dekker, 1986 5. F. F. Y. Wang, Ceramic Fabrication Processes, Academic Press, 1976.		

Course Name: **Nanodevices**
Course Code: **MS-453**
Course Type: **Discipline Elective-V**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To study about the nano scale level devices
- To study the basic principal of operation of nano devices

Unit Number	Course Content	Contact Hours
UNIT-01	Introduction: MEMs/NEMs, Electronic Transport in Nanostructures, Semiconductor devices to Single electron Transistors, Micro fluidics and their Applications, Materials for Microfluidic devices, active and smart passive Micro fluidics devices, Lab-on-a-chip for Biochemical analysis.	8
UNIT-02	Micro/Nanofabrication Techniques: Stamping techniques for Micro and Nanofabrication, Material aspects of MEMS and NEMS. Packaging and characterization of sensors; Packaging& Reliability. Method of packaging.	8
UNIT-03	Micro and Nano-sensors: Fundamentals of sensors, Temperature Sensors, Smoke Sensors, Sensors for aerospace and defense, Accelerometer, Pressure Sensor, Night Vision System, Nano tweezers, nano-cutting tools, Integration of sensor with actuators and electronic circuitry.	8
UNIT-04	Molecular Devices: Molecular-scale elements, Molecules that emulate conventional electronic circuit elements, Logic circuits using molecular diodes, Semiconductor nanocrystals, Directed self-assembly of molecular circuits, Properties of DNA and its potential applications in molecular electronics, possible self-assembled molecular-scale circuits of the future.	12

Course Outcomes

Upon successful completion of the course,
C01: Students will have the understanding of the mechanisms of operation of nano devices
CO2: How these devices are fabricated.
CO3: How the working principals of these nanodevices is different from conventional one

Books and References

1. Sensors: Micro &Nanosensors, Sensor Market trends (Part 1&2) - H. Meixner.
2. Nanoscience& Technology: Novel structure and phenomena - Ping Sheng
3. Enabling Technology for MEMS and nano devices - Balles, Brand, Fedder, Hierold.
4. Optimal Synthesis Methods for MEMS - G. K. Ananthasuresh.
5. MEMS & MOEMS Technology and Applications - P. RaiChoudhury.
6. Poole Jr., C.P., Owens, F.J. Introduction to Nanotechnology , Wiley (2003).

Course Name: **Powder Metallurgy**
Course Code: **MS-471**
Course Type: **Stream Core-II**

Contact Hours/Week: **3** Course Credits: **03**

Course Objectives

- To introduce the concepts of powder metallurgy with special reference to recent development of powder metallurgy products
- To understand the powder characterization techniques.

Unit Number	Course Content	Contact Hours
UNIT-01	**Introduction:** Scope, limitations in making components, application of powder metallurgy **Powder production:** Production methods like physical, chemical, mechanical methods; Single fluid atomization like rotating electrode atomization, roller atomization, rotating disc atomization; Two fluid atomization like gas atomization water atomization, oil atomization etc. Reduction methods, carbonyl process, hydride-de hydride process, electrolytic method	**06**
UNIT-02	**Powder characterization:** Particle size and Size distribution using sieving sedimentation method, Andreasen pipette method, size distribution functions like normal distribution, log-normal distribution, Rosin-Rammler distribution, particle shape, shape factors, specific surface area of powder, flow rate, tap density, apparent density, compressibility, pyrophoricity, explosivity, toxicity of powder	**08**
UNIT-03	**Powder compaction:** Slip casting, slurry casting, Die compaction, isostatic pressing, single level and multi-level part compaction, repressing, plane strain compression, powder forging, powder roll compaction, powder extrusion	**08**
UNIT-04	**Sintering:** Theory of sintering, sintering practice, furnaces and atmosphere control activated sintering techniques, after sintering treatments; industrial sintering practice for various and non-ferrous products	**06**
UNIT-05	**Application of powder metallurgy:** Self-lubricating bearing, magnetic materials tungsten carbide tool bits, bearing materials, dispersion strengthen materials for high temperature applications and manufacture of diamond based cutting tools, Development of friction material through P/M route: Clutch plate, and brake pads for airplanes	**06**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: To understand various powder production methods

CO2: To characterize powders using various techniques.

CO3: To utilize the powder metallurgy in various applications.

Books and References

1 Masuda H., Powder Technology Handbook, Taylor & Francis 2006
2 German R.M., A to Z of Powder Metallurgy, Elsevier 2005
3 Sands R.L. and Shakespeare C.R., Powder Metallurgy Practice and Applications, Newness Publication 1970
4 Powder Metal Technologies and Applications, Metals Handbook, Vol. 7, 9th 1989 edition, ASM
5 Hirschhorn J.S., Introduction to Powder Metallurgy, APMI 1975 6 Upadhyaya G.S., Powder Metallurgy Technology, Cambridge Press 1996

Course Name: **Phase Diagrams**
Course Code: **MS-472**
Course Type: **Stream Core (II)**

Contact Hours/Week: 2L — Course Credits: 02

Course Objectives
To impart the knowledge of formation of phase diagrams and understanding of phase diagrams.

Unit Number	Course Content	Contract Hours
UNIT-01	**Phase equilibria in single component system** Phase equilibria in one-component systems: variation of Gibbs free energy with temperature and pressure, Clausius-Clapeyron equation, P-T diagram	**08**
UNIT-03	**Free energy composition diagram:** Phase rules Phase rules and its applications, Lever Rule, Fundamentals of Free energy-composition diagram for binary systems. Examples of common binary Free energy-composition diagrams: Eutectic, Eutectoid, Peritectic etc.	**09**
UNIT-04	**Phase diagrams** Study of some common phase diagrams, such as Fe-C, Cu-Zn, Al-Cu, FeO-SiO2 and evolution of equilibrium microstructure on cooling.	**07**

Course Outcomes
Upon successful completion of the course, the students will be able to
CO1: Learn the basics of Phase equilibria.
CO2: Understand the application of phase diagrams.

Books and References

1. Phase Equilibria in Materials: S.P.Gupta
2. Phase Transformation: Porter and Easterling.
3. Introduction to Thermodynamics of Materials: David R. Gaskell 3. Physical Chemistry of Metals: L.Darken and R.W.Gury

Course Name: **Light Metals and Alloys** Course Code: **MS-491** Course Type: **Stream Core-III**		
Contact Hours/Week: **3 L**		Course Credits: **03**
Course Objectives • To deal with the physical metallurgy, of Aluminum Magnesium and Zinc alloys in detail • To deal with the physical metallurgy, of Titanium, Beryllium and Zirconium alloys in detail		
Unit Number	**Course Content**	**Contact Hours**
UNIT-01	**Aluminium Alloys:** Classification, Properties and physical metallurgy of Al-Cu alloys, Al-Mg alloys, Al-Zn alloys, Al-Mn alloys and Al-Si alloys Aluminum alloys: Ternary phase diagrams, Al-Cu-Mg alloys, Al-Si-Mg alloys and Al-Zn-Mg alloys.	**09**
UNIT-02	**Magnesium Alloys:** Precipitation hardening in Magnesium Base alloys, Mg-Al-Zn alloys, Corrosion resistance of Mg-alloys. Zinc-base alloys: Classification, properties and applications.	**09**
UNIT-03	**Commercially Pure Titanium:** Properties, applications, Interstitial solid solutions of Titanium, Strengthening mechanisms of Titanium alloys.	**06**
UNIT-04	**Titanium Alloys:** Alpha Ti alloys, Beta Ti-alloys, Alpha plus Beta Ti alloys, Ti-6Al-4V, Ti-8Al-1Mo- 1V, Ti-13V11Cr-3Al alloys.	**06**
UNIT-05	**Beryllium alloys:** Classification properties and applications Zirconium alloys: Classification, properties and applications.	**06**
Course Outcomes Upon successful completion of the course, the students will be able to CO1: To attain sound knowledge on microstructures, properties, and applications of several nonferrous alloys CO2: To design light alloys for specific metallurgical applications.		
Books and References 1. Heat Treatment, Structure and Properties of Non-Ferrous alloys by Charlie Brooks, ASM Metals Park, Ohio. 2. Light Alloys: Metallurgy of the Light Metals by I. J. Polmear, E.Arnold, Metal Park, Ohio American Society for Metals. 3. Introduction to Physical Metallurgy by S.H. Avner, Published by Tata McGraw Hill. 4. Engineering Physical Metallurgy by Y. Lakhtin, CBS Publishers and Distributors. 5. Metallurgical Abstracts on Light Metals and Alloys by Keikinzoku Shogakukai, Light Metal Educational Foundation.		

Course Name: **Structure of Materials** Course Code: **MS-592** Course Type: **Stream Core-III**		
Contact Hours/Week: 2L		Course Credits: 02
Course Objectives the knowledge of arrangement of materials' internal components – determines virtually everything about a material: its properties, its potential applications, and its performance within those applications.		
Unit Number	Course Content	Contract Hours
UNIT-01	**Introduction** Electronic structure of Materials Bond types- structural descriptors of bonded materials.	**02**
UNIT-02	Crystallography of 2D: Translational symmetry, reflection and glide symmetry, Rotational symmetry: Proper rotation axes. Quasicrystals: aperiodic tiling patterns; Icosahedral, structures Plane point groups: combination of reflections and rotations Five distinct plane lattices and 17 plane groups International convention for plane groups Crystallography of 3D: Inversion, rotoinversion, rotoreflection, screw axis. Stereographic projection fundamentals Basis for the 32 crystallographic point groups International notations and conventions for representation of point groups Space lattices: Bravais lattices and crystal system Space groups: Derivation and international table for crystallography Important crystal structures like Rocksalt, fluorite, zinc blende, antifluorite, perovskite etc.	**12**
UNIT-03	**Non-crystalline state.** Generic descriptors: short-range order, glass transition, pair-distribution Function, Hard sphere model Liquid crystalline state - Structural classes, Concept of isotropic and anisotropic liquid crystals,	**05**
UNIT-04	**Microstructures** Structural hierarchies: Nano-, micro-, meso-, macro structures Discussion with illustrative examples Deformation structures. Transformation microstructures: solidification, solid solid, composite structures Fundamentals of stereology and application to microstructural analysis	**05**
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Learn the basics of Phase equilibria. CO2: Understand the application of phase diagrams.		
Books and References 1. Phase Equilibria in Materials: S.P.Gupta 2. Phase Transformation: Porter and Easterling. 3. Introduction to Thermodynamics of Materials: David R. Gaskell 3. Physical Chemistry of Metals: L.Darken and R.W.Gury		

Course Name: **Advanced Functional Oxide Materials**
Course Code: **MS-461**
Course Type: **Stream Elective-I**

Contact Hours/Week:3 Course Credits: **03**

Course Objectives

- To impart the importance of advanced functional oxide materials in various fields
- To impart the importance of magnetic oxide materials, spintronics in field of materials science

Unit Number	Course Content	Contact Hours
UNIT-01	**High–Tc Superconductors:** Cuppurate Materials, Magnetic and Electrical properties flux pinning and flux dynamics. Application in superconducting magnets, micro strip resonators and filters Colossal magnets resistance (CMR) materials: Introduction to perovskite materials, electrical and magnetic sensors, read- write heads	**03**
UNIT-02	**Magnetic oxide materials:** Ferromagnetic oxide materials, Ferrites materials Applications of Ferrites Ferroelectric and Dielectric Materials: origin of dielectrics, ferroelectrics, and piezoelectric, pyroelectric properties. Application of these materials	**06**
UNIT-03	**Spintronics:** Wide band gap semiconductor, dielectric magnetic semiconductor, half-metallic materials. Basic mechanism of spin polarization and application of Spintronics device.	**09**
UNIT-04	**Multiferroic Materials:** Origin of magnetic ordering in the oxide materials, origin of ferroic in electric odide ordering in oxide materials.Coupling of magnetic and electric dipole ordering. Possible materials and their engineering for multiferroic properties. Their future application	**09**
UNIT-05	**Nano Composite of oxide materials:** The synthetization of nano oxide materials. Composite of nano oxide with different host materials.	**09**

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1:Understand and explain the superconductors
CO2:Understand the concepts of spintronic
CO3:Understand the multiferroic Materials

Books and References

1. Magnetism and Magnetic Materials, Institute of Materials by J.P. Jakubovics, Maney Publishing.
2. High Temperature Superconductivity by J. W. Lynn, Springer- Verlag
3. Characterization of Nanophase Materials by Z.L Wang, Wiley- VCH.
4. The Science and Engineering of Microelectronics Fabrication by S. Compbell, Oxford University Press.
5. Functional Oxides by Bruce, O’Hare, Walton, Wiley

Course Name: **Advanced Materials Processing Technologies**
Course Code: **MS-462**
Course Type: **Stream Elective I**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To impart knowledge about Advanced Materials Processing Technologies
- To introduce fundamental concepts relevant to Advanced Materials Processing Technologies
- To enable the students to understand the importance applications of Advanced Materials Processing Technologies

Unit Number	Course Content	Contact Hours
UNIT-01	**Continuous Casting:** Introduction to continuous casting, Different components in continuous casting, liquid metal, solidification, thermomechanical processing, Products of Continuous Casting: Billets, Slab, Bloom and subsequent rolling and finishing.	**09**
UNIT-02	**Severe Plastic Deformation:** Equal channel angular Pressing, Accumulative roll bonding, high pressure torsion, twist extrusion, corrugated pressing, multi-axial forging.	**09**
UNIT-03	**Thermomechanical Processing:** Hot rolling, hot extrusion, hot forging. Inter-critical annealing. Thermomechanical proceesing of materials by Gleeble	**09**
UNIT-04	**3-D Printing:** Introduction to 3D printing, Product design, different materials used in 3D printing. 3D printing in metallurgy, research and development 3D printing in medical, other applications of 3D printing.	**09**

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1: Understand different Advanced Materials Processing Technologies
CO2: Describe and analysis the various material processing Techniques
CO3: Understand principle of advanced materials processing technique

Books and References

1. 3D Printing, Technology Applications and selection by Rafiq Noorani, CRC press.
2. Continuous Casting, by Michael Vynnycky, MDPI AG.
3. Metal Casting: Principles And Practice 2nd Edition 2020, by T V Ramana Rao, New age International (P) Ltd Publishers
4. Thermo-mechanical Processing of Metallic Metarials: Volume 11 by B. Verlinden, J Driver, I. Samajdar, R. D Doherty, Elsevier Science Ltd

Course Name: **X-Ray Techniques** Course Code: **MS- 463** Course Type: **Stream Elective-I**		
Contact Hours/Week: 3L		Course Credits: **03**
Course Objectives To understand concept of symmetries and crystal structures To understand the material properties based on its solid state structure To practically visualize and perform the lattice parameter calculation of crystals		
Unit Number	**Course Content**	**Contact Hours**
UNIT-01	**Introduction:** Continuous and Characteristic Radiation, X-ray generation, X-ray Diffraction: Crystallography basics, reciprocal lattice, absorption edges, Bragg's law, Diffraction methods – Laue, rotating crystal and powder methods. Stereographic projection. Intensity of diffracted beams –structure factor calculations and other factors. Cameras- Laue, Debye-Scherer cameras, Seeman-Bohlin focusing cameras.	**09**
UNIT-02	**Analysis of X-Ray Diffraction**: Line broadening, particle size, crystallite size, Precise parameter measurement, Phase identification, phase quantification, Phase diagram determination X-ray diffraction application in the determination of crystal structure, lattice parameter, residual stress – quantitative phase estimation, ASTM catalogue of Materials identification.	**09**
UNIT-03	**X-ray Fluorescence Spectroscopy:** Moseley's law, Compton scattering, Energy Dispersive XRF (EDXRF), Wave Dispersive XRF (WDXRF)	**06**
UNIT-04	**X-ray Absorption Spectroscopy**: Synchrotron as X-ray Source, X-rays Absorption, Absorption Edge and its Position, XAFS, XANES, EXAFS, NEXAFS, SEXAFS	**06**
UNIT-05	**X-ray Photo-Electron Spectroscopy:** Photo-Electric Effect, XPS Spectra, Orbital Splitting, Spin-Orbital Splitting, Total Angular Momentum, Surface Charging, Energy Analyzer, X-ray Induced Auger emission, Depth Profiling.	**06**
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Define concepts such as lattice, point and space groups CO2: Be familiar with Bragg's law and explain its relation to crystal structure CO3: Identify and describe diffraction methods CO4: Interpret and assign X-ray and electron diffraction patterns		
Books and References 1. The Basics of crystallography and Diffraction by C. Hammond, Oxford University 2. Press. X-ray crystallography by B. D. Cullity, Addison-Wesley Publishing Company, Inc. 3. Modern Metallographic Techniques and their Applications by V. A. Phillips, Wiley Eastern. 4. Modern Techniques in Metallography by D. G. Brandon, Von Nostrand Inc. NJ, USA. 5. Tools and Techniques in Physical Metallurgy by F. Weinberg Volume I & II, Marcel and Decker.		

Name: **High Temperature Materials**
Course Code: **MS-481**
Course Type: **Stream Elective-II**

Contact Hours/Week: **3** Course Credits: **03**

Course Objectives

- To impart knowledge on requirements for materials for high temperature use and the behavior of materials at high temperatures.
- To impart knowledge of material failure and their protection at high temperature

Unit Number	Course Content	Contact Hours
UNIT-01	**Introduction:** Need for high temperature materials, historical development of high temperature materials, equipment for material testing at high temperatures, requirements of high temperature materials (mechanical properties and preferred microstructure, environmental resistance, erosion and wear).	**03**
UNIT-02	**Principles for high temperature strengthening**: Metallic materials (solid solution strengthening, precipitation strengthening, dispersion strengthening grain size and grain boundary effects) Ceramic materials (phase control, defect tolerance, thermal shock resistance) composite materials.	**09**
UNIT-03	**Creep and stress rupture:** Creep test, stress rupture test, structural changes during creep mechanism of creep deformation, fracture at elevated temperatures. **Creep:** fatigue interaction: Modes of high temperature fracture and fatigue fracture, creep- fatigue interaction (creep accelerated by fatigue), fatigue-creep interaction (fatigue accelerated by creep), micro-mechanism of damage, fracture criterion for creep fatigue, creep-fatigue failure mapping, creep-fatigue testing, influence of environment.	**06**
UNIT-04	**Materials for high temperature:** Metals / alloys, superalloys, steels, titanium and its alloys, ceramics (Alumina, Zirconia, Silicon carbide, Silicon nitride, Glass ceramics) composites (Metal matrix composites, ceramic matrix composites) carbon – carbon composites.	**09**
UNIT-05	**Coatings for protection against high temperature corrosion and erosion:** Corrosion / oxidation resistant coatings (metallic, ceramic, rare and reactive metal reinforced coatings), high temperature erosion and wear, thermal barrier coats. **Case studies**: Applications in industry, aerospace, defense and nuclear industry.	**09**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1:Understand the importance of materials designed for high temperature

CO2:Understand the mechanism leading to their failure at high temperature

CO3:Understand the selection criteria of choosing materials for high temperature applications

Books and References

1. Meetham, G. W., Van de Voorde, M. H., “Materials for High Temperature Engineering Applications (Engineering Materials)”, 1st 2000 Ed., Springer.
2. Chan R. W., “High temperature structural materials”, Chapman & Hall. 1996
3. Reed R. C., “The Super-alloys: Fundamentals and Applications”, Cambridge University Press. 2008
4. Birks, N., Meier, G. H., and Pettit, F. S., “Introduction to the High Temperature Oxidation of Metals”, Cambridge University Press. 2009
5. Bose, S., “High Temperature Coatings”, ButterworthHeinemann. 2007

Course Name: **Laser Materials Processing** Course Code: **MS-482** Course Type: **Stream Elective-II**		
Contact Hours/Week: **3**		Course Credits: **03**

Course Objectives

- To understand the physics of laser
- To introduce fundamental concepts of laser materials interaction and the capability of laser
- To critical understanding of Laser in various manufacturing process of engineering materials

Unit Number	Course Content	Contact Hours
Unit 1	**Introduction**: Concept of laser, basic mechanisms in lasers; Properties of laser; Types of laser, gas, liquid and solid state lasers; Pulsed and CW lasers	**06**
Unit 2	**Laser-Materials Interaction**: Interaction of laser with metals, ceramics, polymers, composites and other materials; Laser heating fundamentals Laser Forming: Process principle, analysis and applications of Laser forming processes such as Bending and Deep drawing.	**09**
Unit 3	**Laser Machining**: One, two and three dimensional laser machining; Process principle, analysis and applications of laser Drilling, Cutting, Turning, and Milling processes Laser assisted machining (LAM) **Laser Welding**: Principles, Significance of laser welding variables; Laser welding of various materials including steel, aluminium and its alloys and titanium and its alloys	**09**
Unit 4	**Laser Heat Treatment:** One dimensional thermal heating and cooling of metals; Mechanisms of hardening in steel and cast irons Lasers in Surface Engineering Applications: Laser glazing; Laser alloying; Microstructural considerations in laser rapid heating process	**06**
Unit 5	**Laser Rapid prototyping:** Selective laser Sintering (SLS), 3D Printing, Beam Deposition (Laser Engineered Net Shaping (LENS)	**06**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Draw typical LASER process and physics behind them.

CO2: To classify the selective laser for a selective process for various engineering materials

CO3: Explain uses of laser process of different manufacturing process in industries

CO4: Describe Laser as a rapid prototyping and welding process

Books and References

1. Laser Materials Processing by W. M. Steen, Springer.
2. Laser Materials Processing by M. Bass, North Holland Publishing Co., Amsterdam.
3. Laser Machining- Theory and Practice by G. Chryssolouris, Springer Verlog, New York Inc.
4. Industrial Lasers and Their Applications by J. T. Luxon, and D. E. Parker, Prentice-Hall, Englewood Cliffs, NJ.
5. Laser Processing of Materials by Schaaf, Peter (Ed.), Springer

Course Name: **Spectroscopy**
Course Code: **MS-483**
Course Type: **Stream Elective-II**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

To solve problems related to the structure, purity and concentration of chemicals.
To study molecular interactions by choosing suitable spectroscopic methods and interpreting corresponding data.

Unit Number	Course Content	Contact Hours
UNIT-01	**Introduction to Spectral Methods**: Molecular and atomic spectroscopy- interaction of electromagnetic radiation with matter-Energy levels in atoms andmolecules – Absorption techniques and emission techniques: fluorescence, phosphorescence and chemo luminescence – Beer-Lambert law; qualitative andquantitative analyses – limitations – visible absorption spectroscopy.	**03**
UNIT-02	**UV-Visible Spectroscopy**: Electromagnetic Spectrum, Laws of Absorption of Light, Deviation from Beer-Lambert's Law, Mie Theory, Instrumentation Infrared Spectroscopy: The Born-Oppenheimer approximation, the types of molecular motion, electronic transition, energy of electronic transition, selection rules, the Franck- Condon principle, classification of electronic transition, classical description of molecular rotation, rotational spectra, determination of the bond length from rotational constants, vibrational stretching and vibrational satellites, Stark effect, selection rules, rotational spectra of polyatomic molecules, classical description of molecular vibrations, the classical harmonic oscillator, vibrational selection rules, bonddissociation energies, isotopic shift, FTIR, Instrumentation	**09**
UNIT-03	**Raman Spectroscopy**: Description of Raman scattering, Rayleigh scattering, Stokes and anti- Stokes scattering, polarizability of the molecules, Placzek theory, rotational Raman spectra, vibrational Raman spectra, Raman spectra of polyatomic molecules, Instrumentation	**06**
UNIT-04	**Emission Spectroscopy**: Ffluorescence and phosphorescence, deactivation processes – internal conversion, de-excitation process, non-radiative and radiativetransitions, characteristic of fluorescence emission, Stokes shift, fluorophores, quantum yield of a fluorescent process, phosphorescence, intersystem crossing, Jablonski diagram. **Photoelectron spectroscopy**: The photoelectric effect, UV photoelectron spectroscopy UPES, X- ray photoelectron spectroscopy XPES, electron bindingenergy, ESCA, Auger electron spectroscopy, Instrumentation.	**09**
UNIT-05	**Spectra in magnetic field –NMR**: The Stern-Gerlach's experiment, nuclear spinangular momentum, the magnetic moment of a nucleus, the nuclei in a magnetic field, the Larmor frequency, the chemical shift, electronic shielding of nuclei, the chemical shift scale, the spin-spin coupling, the spin-spin coupling constant, spin-spin splitting, molecular structure from NMR spectra,Instrumentation	**09**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: To apply formalisms based on molecular symmetry to predict spectroscopic properties.

CO2: To analyze and interpret spectroscopic data collected by the methods discussed in the course.

CO3: To solve problems related to the structure, purity and concentration of chemicals and to study molecular interaction

Books and References

1. Spectroscopy of Organic Compounds by P.S.Kalsi, New Age International Publishers.Organi
2. Spectroscopy by William Kemp, Palgrave Publishers.
3. Analytical Chemistry by G.D Christian, John Wiley Press.
4. Principles of Instrumental Analysis by D.A. Skoog, F.J. Holler and S.R. Crouch, Thomas
5. Brookes/Cole.Mass Spectrometry by Gross, Jürgen, Springer

Degree with Minor in Materials Science and Engineering

Course No.	Semester V	Credits	Course Type
MS-310	Introduction to Materials Science	3	Discipline Core
Course No.	**Semester VI**	**Credits**	**Course Type**
MS-320	Mechanical Behavior of Materials	3	Discipline Core
Course No.	**Semester VII**	**Credits**	**Course Type**
MS-410	Heat Treatment	3	Discipline Core
Course No.	**Semester VIII**	**Credits**	**Course Type**
MS-420	Characterization of Materials	3	Discipline Core

Course Name: **Introduction to Materials Science**
Course Code: **MS-310**
Course Type: **Discipline Core**

Contact Hours/Week: **3L** Course Credits: **3**

Course Objectives

- To impart knowledge about the structure of materials
- To introduce fundamental concepts relevant to phase diagrams, phase transformations and heat treatment of metals and alloys
- To enable the students to understand properties of engineering materials

Unit Number	Course Content	Contact Hours
UNIT- 01	**Introduction**: Why study materials science and engineering? Review of basic types of interatomic bonds, Classification of materials, Processing/structure/properties/ performance correlation	**03**
UNIT- 02	**Structure and Imperfections:** Lattices, Unit cells, Miller indices of directions and planes for cubic and hexagonal systems, Closepacking in solids, Common metallic structures, Voidsin close-packed structures, Polycrystalline materials, X-Ray diffraction for determination of crystal structures, **Solid state diffusion** – Ficks laws of diffusion, Diffusion mechanisms, Temperature dependendence of diffusivity, Defects in crystals - Point defects, Dislocations, Grain boundaries and Surfaces, Noncrystalline solids, Polymeric materials	**09**
UNIT- 03	**Phase Diagrams:** Phase rule, Solid solutions, Hume-Rothery rules, Intermediate phases and compounds, Unary and binary phase diagrams, Isomorphous and eutectic systems, Lever rule, Typical phase diagrams: Fe-C.	**03**
UNIT- 04	**Phase Transformations and Heat Treatment:** Classification of phase transformations, Liquid to solid transformation, Homogeneous and heterogeneous Nucleation, Kinetic considerations in solid state transformations, Microstructure and property changes in iron-carbon alloys, Precipitation and age hardening.	**09**
UNIT- 05	**Properties of Materials:** Mechanical Properties: Stress-strain response of metallic, ceramic and polymer materials, yield strength, tensile strength and modulus of elasticity, toughness, plastic deformation, fatigue, creep and fracture; **Electronic Properties**: Free electron theory, Fermi energy, density of states, elements of band theory, semiconductors, Hall effect, dielectric behaviour, piezo, ferro, pyroelectric materials; **Magnetic Properties:** Origin of magnetism in metallic and ceramic materials, paramagnetism, diamagnetism, ferro and ferrimagnetism; **Thermal Properties:** Specific heat, thermal conductivity and thermal expansion, thermoelectricity.	**12**

Course Outcomes

CO1: Classify various engineering materials and explain their structure and imperfections.
CO2: Draw some typical phase diagrams and discuss their distinctive features.
CO3: Explain Isothermal transformation and continuous cooling diagrams of steels
CO4: Describe various heat treatment processes

Books and References

1. Materials Science and Engineering, An Introduction by William D. Callister, Jr. and David G. Rethwisch, John Wiley and Sons, Inc.
2. Materials Science and Engineering by William F. Smith, McGraw Hill Education.
3. Modern Physical Metallurgy by R. E. Smallman, Butterwort-Heinemann.
4. Physical Metallurgy: Principles and Practice by V. Raghvan ,PHI Learning Private Ltd.

Name:	**Mechanical Behavior of Materials**
Course Code:	**MS-320**
Course Type:	**Discipline Core**

Contact Hours/Week: **3L** Course Credits: **3**

Course Objectives

- Explaining the theory of dislocations and different strengthening mechanisms of materials based ondislocation theory.
- How the dislocation motion results in the different types of fractures or failure in the materials

Unit Number	Course Content	Contact Hours
UNIT- 01	**Dislocation Theory:** Dislocation during growth of crystals; Theoretical and observedyield stress, geometry of dislocations. Burgers Vector, Right hand convention - Typesof dislocations loops and motion out of crystals strain energy of mixed dislocation two hard particles; simple relationship for forces between dislocation vector notation of dislocation in crystal systems; combination of dislocationstacking fault energy; motion of extended dislocation; construction Frank dislocation; Cross slip; double jump; Geometrical characteristics of dislocation;Interaction of dislocations (simple cases); Motion of kinked and Jogged dislocation; Non conservation method Motion creation of vacancies, Frank Read source, Sessile dislocations Lomer-Cotrell, stair- rod; width of dislocation; Pile up of dislocation, solid solution strengthening anti-phase boundary; Yield unit; Luder bands.	**12**
UNIT- 02	**Modes of Plastic Deformation:** Slip planes and slip directions, resolved shear stress, strainhardening and recovery of single crystals, Twinning, Grain boundary sliding and diffusional creep.	**03**
UNIT- 03	**Strengthening Mechanisms:** Cold working and annealing: Recovery, Recrystallization and Grain Growth, dynamic recovery, strain/ work hardening, solute hardening or solid solution strengthening, precipitation hardening,dispersion hardening, grain refinement.	**03**
UNIT- 04	**Fracture:** Types of fracture- ductile fracture, brittle fracture; Theoretical fracture stress, Griffiththeory, Orowan Theory, Comparison with equation based on stress concentration Crack velocities; Dislocation model of crack nucleation Zener model, Cotrell-Hull model in BCC metals. Fracture toughness, ductile to brittle transition. Methods of protection against fracture- surfacetreatment, compressive stresses.	**06**
UNIT- 05	**Creep:** Generation and analysis of creep and creep-rupture data. Dislocation and diffusion mechanisms of creep. Grain boundary sliding and migration. Deformation mechanism maps. Effect of metallurgical and test variables on creep and fracture. Super plasticity. Parametric methods for prediction of long time properties. Creep fracture.	**06**
UNIT- 06	**Fatigue:** Stress cycles, Effect of mean stress on fatigue. High cycle and low cyclefatigue. Analysis of cyclic stress-strain data. Mechanisms of fatigue crack nucleation and propagation. Effect of metallurgical variables on fatigue. Corrosionfatigue. Fatigue fracture.	**06**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the yielding behavior and dislocation influence on plastic deformation. CO2: Understand the various strengthening mechanisms and high temperature deformationCO3: Understand testing methods like hardness, compression, and fatigue

Books and References

1. Mechanical Metallurgy by George E. Dieter, McGraw-Hill.
2. Mechanical Behavior of Materials by Krishan Chawla, Marc A. Meyers, Cambridge university press
3. Fundamentals of Materials Science and Engineering by William D. Callister, Jr., David G. Rethwisch,John Wiley & Sons.
4. Dislocations and Mechanical Behaviour of Materials by M.N Shetty, PHI Learning.
5. Mechanical Behaviour of Materials by H. Thomas. Courtney, Waveland Press.

Course Name: **Heat Treatment**
Course Code: **MS-410**
Course Type: **Discipline Core**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To develop an understanding of the basic principles of phase transformations and apply those principles to engineering applications.
- To recognize the importance of the microstructures andphysical properties of the materials so that a constructive materials selection process can be adopted

Unit Number	Course Content	Contact Hours
UNIT-01	Introduction to Heat Treatment: Iron carbon equilibrium diagram, Isothermal transformation diagrams, continuous cooling transformation diagram, Austenisation and austenite grain size	**08**
UNIT-02	**Homogenization, Quenching and quenching media. Annealing**: Definition, Objectives, and Types, Full Annealing, Isothermal Annealing, Spheroidizing Annealing. Normalizing. Hardening: Definition, Objectives, and Types, Martensitic Hardening, Austempering, Martempering. Tempering: Definition, Objectives, and Types, Tempering of Martensite, Tempering of Bainite, Tempering of Austenite, Effect of Tempering on Mechanical Properties. Hardnenability, its measurements and control.	**08**
UNIT-03	**Case hardening treatments:** case carburizing and post carburizing heat treatment, nitriding, Carbonitriding, cyaniding. Surface hardening treatments: Induction hardening, flame hardening, laser hardening, and electron beam hardeningprocesses.	**05**
UNIT-04	**Heat treatment of non-ferrous alloys:** Re-crystallisation annealing of cold worked metals, age hardening. Temper designation for aluminum and magnesium alloys. Heat treatment of aluminum, copper, magnesium,, titanium and nickel alloys.	**06**
UNIT-05	**Cast Iron and their heat treatment:** Grey, white, malleable, SG Iron. Defects: Defects in heat treated materials and their prevention.	**03**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand and identify different type of heat treatment process
CO2: Explain the effect of heat treatment on the microstructure and mechanical properties of materials
CO3: Analyze the suitability of different heat treatment processes for specific materials and applications
CO4: Select the appropriate heat treatment process for a given material and application

Books and References

Phase Transformations in Materials by R. C. Sharma, CBS Publishers, New Delhi

1. Solid State Transformations by V. Raghavan, Prentice-Hall of India, New Delhi
2. Fundamentals of Materials Science and Engineering by William D. Callister, Jr., David G. Rethwisch, John Wiley & Sons
3. Phase transformations in metals and alloys; David A. Porter and K. E. Esterling, Chapman and Hall Publisher
4. Physical Metallurgy Principles, Reza Abbaschian, Robert E. Reed-Hill, Cengage Publisher

Name: **Characterization of Materials** Course Code: **MS-420** Course Type: **Discipline Core**		
Contact Hours/Week: 3L		Course Credits: 3
Course Objectives • To introduce fundamental concepts relevant to materials analysis • To enable the students to understand properties of engineering materials and various advanced characterization methods		
Unit Number	**Course Content**	**Contact Hours**
UNIT-01	**X-ray Diffraction:** Diffraction under non-ideal conditions. Atomic scattering and Geometrical structure factors. Factors influencing the intensities of diffracted beams. Powder X-ray diffractometer. EXAFS and XANES. Applications of XRD in ceramic materials.	**03**
UNIT-02	**Microscopy:** Study of the morphology, aggregation, size and microstructure of ceramic materials using. Optical microscope, quantitative phase analysis. Principle of electron microscopy. Construction and operation of Transmission Electron. Microscope and Scanning Electron Microscope. Electron diffraction by crystalline solids; selected area diffraction.	**06**
UNIT-03	**AFM, SEM and XPS:** Atomic Force Microscope. Mechanism of image formation in SEM and its processing. Electron microprobe analysis (EDAX and WDS). Preparation of samples for electron microscopic studies. Electron spectroscopy for chemical analysis (ESCA/XPS).	**09**
UNIT-04	**Spectrophotometric analysis of materials:** Spectrophotometric analysis of materials: Basic laws of spectrophotometry and its application in micro analysis in UV/ Visible range, effect of reflectance factor on optical analysis, construction and working principle of spectrophotometer, importance of additive absorbance in multiple analysis of materials. Infrared spectrophotometry: General aspects of IR spectroscopy and its application in structural analysis of systems, sources of IR radiations, Optical systems and operation of Fourier transformed infrared (FTIR) spectrophotometer. Samples preparation, IR analysis and structural co-relations.	**09**
UNIT-05	**Fluorescence and Phosphorescence spectroscopy:** Basic principle, geometrical optics, construction, working principle and use of fluorescencespectrometers in materials analysis. X-ray Fluorescence (XRF). Electron Spin Resonance spectroscopy, Nuclear Magnetic Resonance.	**06**
UNIT-06	**Thermal Characterization:** Differential Thermal analysis (DTA) Thermogravimetric analysis (TGA) and Differential Scanning Calorimetry (DSC) with suitable examples of glass and ceramic materials.	**03**
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Understand common use of characterization techniques. CO2: Describe and analysis the various properties of materials. CO3: Understand principle of materials characterization technique		
Books and References 1. Materials Characterization Techniques by Sam Zhang, Lin Li and Ashok Kumar, CRC Press. 2. Materials Characterization: Introduction to Microscopic and Spectroscopic Methods by Yang Leng, Wiley & Sons. 3. Characterization of Materials by Elton N. Kaufmann, Wiley & Sons. 4. Springer Handbook of Crystal Growth by G. Dhanaraj, K. Byrappa, V. Prasad and M. Dudley, Springer-Verlag. 5. Physical Methods of Materials Characterization by Peter E.J. Flewitt and R.K. Wild, Taylor & Francis.		

Degree with Minor in Electronic Materials

Course No.	**Semester V**	**Credits**	**Course Type**
MS-310	Introduction to Materials Science	3	Discipline Core
Course No.	**Semester VI**	**Credits**	**Course Type**
MS-320	Electronics, Magnetic and Optical Properties of Materials	**3**	**Discipline Elective-I**
Course No.	**Semester VII**	**Credits**	**Course Type**
MS-410	Thin Film Technology	3	Discipline Core
Course No.	**Semester VIII**	**Credits**	**Course Type**
MS-420	Characterization of Materials	3	Discipline Core

Course Name: **Introduction to Materials Science**
Course Code: **MS-310**
Course Type: **Discipline Core**

Contact Hours/Week: **3L** Course Credits: **3**

Course Objectives

- To impart knowledge about the structure of materials
- To introduce fundamental concepts relevant to phase diagrams, phase transformations and heat treatment of metals and alloys
- To enable the students to understand properties of engineering materials

Unit Number	Course Content	Contact Hours
UNIT- 01	**Introduction**: Why study materials science and engineering? Review of basic types of interatomic bonds, Classification of materials, Processing/structure/properties/ performance correlation	**03**
UNIT- 02	**Structure and Imperfections:** Lattices, Unit cells, Miller indices of directions and planes for cubic and hexagonal systems, Closepacking in solids, Common metallic structures, Voidsin close-packed structures, Polycrystalline materials, X-Ray diffraction for determination of crystal structures, **Solid state diffusion** – Ficks laws of diffusion, Diffusion mechanisms, Temperature dependendence of diffusivity, Defects in crystals - Point defects, Dislocations, Grain boundaries and Surfaces, Noncrystalline solids, Polymeric materials	**09**
UNIT- 03	**Phase Diagrams:** Phase rule, Solid solutions, Hume-Rothery rules, Intermediate phases and compounds, Unary and binary phase diagrams, Isomorphous and eutectic systems, Lever rule, Typical phase diagrams: Fe-C.	**03**
UNIT- 04	**Phase Transformations and Heat Treatment:** Classification of phase transformations, Liquid to solid transformation, Homogeneous and heterogeneous Nucleation, Kinetic considerations in solid state transformations, Microstructure and property changes in iron-carbon alloys, Precipitation and age hardening.	**09**
UNIT- 05	**Properties of Materials:** Mechanical Properties: Stress-strain response of metallic, ceramic and polymer materials, yield strength, tensile strength and modulus of elasticity, toughness, plastic deformation, fatigue, creep and fracture; **Electronic Properties**: Free electron theory, Fermi energy, density of states, elements of band theory, semiconductors, Hall effect, dielectric behaviour, piezo, ferro, pyroelectric materials; **Magnetic Properties:** Origin of magnetism in metallic and ceramic materials, paramagnetism, diamagnetism, ferro and ferrimagnetism; **Thermal Properties:** Specific heat, thermal conductivity and thermal expansion, thermoelectricity.	**12**

Course Outcomes

CO1: Classify various engineering materials and explain their structure and imperfections.
CO2: Draw some typical phase diagrams and discuss their distinctive features.
CO3: Explain Isothermal transformation and continuous cooling diagrams of steels
CO4: Describe various heat treatment processes

Books and References

1. Materials Science and Engineering, An Introduction by William D. Callister, Jr. and David G. Rethwisch, John Wiley and Sons, Inc.
2. Materials Science and Engineering by William F. Smith, McGraw Hill Education.
3. Modern Physical Metallurgy by R. E. Smallman, Butterwort-Heinemann.
4. Physical Metallurgy: Principles and Practice by V. Raghvan ,PHI Learning Private Ltd.

Course Name: **Electronics, Magnetic and Optical Properties of Materials**
Course Code: **MS-320**
Course Type: **Discipline Elective-I**

Contact Hours/Week: **3L** Course Credits: **03**

Course Objectives

- To undertake study and research in solid state engineering and electronic materials
- To understand the physics of device operations

Unit Number	Course Content	Contact Hours
UNIT-01	**Conductors:** Drude, Sommerfeild and quantum theories of electric conduction in metals, Maitthiessen rule of electrical conductivity, Energy Band Diagrams.	**06**
UNIT-02	**Semiconductors:** Band diagrams, direct and indirect band gap; Effective-mass of electron in conduction-band and that of hole in valence-band. Intrinsic semiconductors: Fermi-level; Density-of-states near the edges of conduction and valence-band; Intrinsic and Extrinsic-semiconductor	**06**
UNIT-03	**Dielectric materials:** Dielectric constants and polarization, linear dielectric materials, capacitors; Polarization mechanisms; Non-linear dielectrics, pyro-, piezo-, and ferro-electric properties, hysterisis and ferroelectric domains; Claussius-Mossoti relation,.	**06**
UNIT-04	**Magnetic Materials:** Orbital and spin - permanent magnetic moment of atoms, diamagnetism, paramagnetism, and Pauli-paramagnetism, Ferro, anti-ferro and ferri magnetism, Fe, Co and Ni and alloy additions, ferrites, magnetic hysteresis, Soft and Hard magnetic materials.	**09**
UNIT-05	**Optical Materials**: electron-hole recombination, solid state LEDs, lasers and IR detectors, bandgap engineering; Light interaction with materials transparency, translucency and opacity, refraction and refractive index, reflection, absorption and transmission.	**09**

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1: Understand the quantum mechanics of electron in crystals
CO2: Understand the basic electrical and magnetic properties of crystalline solids and amorphous materials.

Books and References

1. Physical Properties of Semiconductors by Charles M. Wolfe, Nick Holonyak and Gregory E. Stillman, Prentice Hall.
2. Solid State Physics by Neil W. Ashcroft and N. David Mermin, Sauders College, Philadelphia.
3. Introduction to Solid State Physics by CharlesKittel, John Wiley & Sons.
4. Electrical Properties of Materials by L. Solymar and D. Walsh, Oxford University Press.
5. Electronic Properties of Materials by R. E. Hummel, Springer.

Course Name: **Thin Film Technology**
Course Code: **MS-410**
Course Type: **Discipline Core**

Contact Hours/Week: **3** Course Credits: **03**

Course Objectives

- To learn the concepts of thin film coating starting from source materials to transportation and depositions.
- To learn the related methods and technology for deposition of thin films
- To learn the physics and techniques to analyze and characterize thin film in terms of its optical, electrical,magnetic and m mechanical properties

Unit Number	Course Content	Contact Hours
UNIT-01	**Vacuum components and systems:** Need for vacuum, ways to achieve vacuum, measurement of vacuum, dry and vapour pumps, concept of different gauges: Bayet- Albertgauge, Pirani, Penning, pressure control and measurement gauge, conductance and other system design considerations, principle of different vacuum pumps: roots pump, rotary, diffusion, turbo molecular pump, cryogenic-pump, ion pump, effect of the substrate on the film growth, in-situ and ex-situ substrate cleaning techniques.	**09**
UNIT-02	**Environment for thin film deposition:** Deposition parameters and their effects on film growth, formation of thin films (sticking coefficient, formation of thermodynamically stablecluster – theory of nucleation), capillarity theory. Growth modes: zone model for sputteringand evaporation, Island growth, Volmer weber, Layer growth, Van Vawler Megrue, Stranski – Krans Favour mode. Microstructure in thin films, adhesion, Film contamination, thin filmdefects, cosine law of deposition, conformal coverage and line of sight deposition.	**09**
UNIT-03	**Methods of thin film deposition**: Deposition of inorganic film from solutions, chemical vapor deposition – Electrolysis, anodization, spray pyrolysis, polymerization, Langmuir- Blodgett, self-assembly, monolayers and spin coating method. Theory of evaporation and physical vapor deposition techniques: Evaporation and effusion, Hertz-Knudsen equation, Knudsen cell, directionality of evaporating molecules, vapour pressure and sublimation. Thermal, resistive, and e-beam evaporation, Laser ablation, Flash and Cathodic arc deposition, Electrical discharges used in thin film deposition: Sputtering, Glow discharge sputtering, Magnetron sputtering, Ion beam sputtering, Ion plating, pulsed LASER deposition	**06**
UNIT-04	**Electrodeposition, molecular beam epitaxial and laser pyrolysis**: Chemical vapor deposition techniques, advantages and disadvantages of CVD over PVD techniques, reactiontypes, boundaries and flow, metal-organic CVD (MOCVD), plasma enhanced CVD (PECVD), thermally activated CVD, Spray pyrolysis.	**06**
UNIT-05	**Thin film characterization**: In-situ characterization of film deposition process, Filmthickness measurements, XRD, AFM, Electron diffraction techniques (LEED and RHEED)Electron spectroscopy for chemical analysis. Thin film properties and applications Transparent conductive coatings, optical coatings, super-hard coatings, superconductivity, giant and colossal magnetoresistance, Ferro electronics, LED, solid oxide fuel cells, solar cells.	**06**

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the general principles and techniques of thin film deposition.

CO2: Choose the right tools to perform thin film thickness measurement and to conduct microstructural andchemical analysis.

CO3: Select appropriate deposition method and materials for an engineering application.

Books and References

1. Materials Science of Thin Films: Milton Ohring.
2. Thin Film Phenomenon by K. L. Chopra, McGraw-Hill
3. Methods of Experimental Physics (Vol 14) by G. L. Weissler and R.W. Carlson "Vacuum Physics and Technology"
4. A User's Guide to vacuum Technology by J. F. O'Hanlon, John Wiley, and Sons
5. Vacuum Physics and Techniques by T. A. Delchar, Chapman, and Hall.

Name: **Characterization of Materials** Course Code: **MS-420** Course Type: **Discipline Core**		
Contact Hours/Week: 3L		Course Credits: 3
Course Objectives • To introduce fundamental concepts relevant to materials analysis • To enable the students to understand properties of engineering materials and various advanced characterization methods		
Unit Number	**Course Content**	**Contact Hours**
UNIT-01	**X-ray Diffraction:** Diffraction under non-ideal conditions. Atomic scattering and Geometrical structure factors. Factors influencing the intensities of diffracted beams. Powder X-ray diffractometer. EXAFS and XANES. Applications of XRD in ceramic materials.	**03**
UNIT-02	**Microscopy:** Study of the morphology, aggregation, size and microstructure of ceramic materials using. Optical microscope, quantitative phase analysis. Principle of electron microscopy. Construction and operation of Transmission Electron. Microscope and Scanning Electron Microscope. Electron diffraction by crystalline solids; selected area diffraction.	**06**
UNIT-03	**AFM, SEM and XPS:** Atomic Force Microscope. Mechanism of image formation in SEM and its processing. Electron microprobe analysis (EDAX and WDS). Preparation of samples for electron microscopic studies. Electron spectroscopy for chemical analysis (ESCA/XPS).	**09**
UNIT-04	**Spectrophotometric analysis of materials:** Spectrophotometric analysis of materials: Basic laws of spectrophotometry and its application in micro analysis in UV/ Visible range, effect of reflectance factor on optical analysis, construction and working principle of spectrophotometer, importance of additive absorbance in multiple analysis of materials. Infrared spectrophotometry: General aspects of IR spectroscopy and its application in structural analysis of systems, sources of IR radiations, Optical systems and operation of Fourier transformed infrared (FTIR) spectrophotometer. Samples preparation, IR analysis and structural co-relations.	**09**
UNIT-05	**Fluorescence and Phosphorescence spectroscopy:** Basic principle, geometrical optics, construction, working principle and use of fluorescencespectrometers in materials analysis. X-ray Fluorescence (XRF). Electron Spin Resonance spectroscopy, Nuclear Magnetic Resonance.	**06**
UNIT-06	**Thermal Characterization:** Differential Thermal analysis (DTA) Thermogravimetric analysis (TGA) and Differential Scanning Calorimetry (DSC) with suitable examples of glass and ceramic materials.	**03**
Course Outcomes Upon successful completion of the course, the students will be able to CO1: Understand common use of characterization techniques. CO2: Describe and analysis the various properties of materials. CO3: Understand principle of materials characterization technique		
Books and References 1. Materials Characterization Techniques by Sam Zhang, Lin Li and Ashok Kumar, CRC Press. 2. Materials Characterization: Introduction to Microscopic and Spectroscopic Methods by Yang Leng, Wiley & Sons. 3. Characterization of Materials by Elton N. Kaufmann, Wiley & Sons. 4. Springer Handbook of Crystal Growth by G. Dhanaraj, K. Byrappa, V. Prasad and M. Dudley, Springer-Verlag. 5. Physical Methods of Materials Characterization by Peter E.J. Flewitt and R.K. Wild, Taylor & Francis.		