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 – 177 005 (India)

Second Year													
3rd Semester							4th Semester						
SN	Code	Subject	L	T	P	Credits	SN	Code	Subject	L	T	P	Credits
1	HS-203	Organizational Behavior	3	0	0	3	1	MA-203	Engineering Mathematics-III	3	1	0	4
2	MS-211	Phase Transformations	3	1	0	4	2	MS-221	Heat Treatment	3	1	0	4
3	MS-212	Transport Phenomena	3	1	0	4	3	MS-222	Polymer Science and Technology	3	1	0	4
4	MS-213	Materials Thermodynamics and Kinetics	3	1	0	4	4	MS-223	Composite Materials	3	0	0	3
5	MS-214	Mechanical Behavior of Materials	3	1	0	4	5	ME-228	Materials Processing Techniques	3	1	0	4
6	MS-215	Materials Science Lab	0	0	2	1	6	MS-224	Heat Treatment and Phase Transformation Lab	0	0	2	1
7	MS-216	Transport Phenomena Lab	0	0	2	1	7	MS-225	Polymers and Composites Lab	0	0	2	1
8	MS-217	Mechanical Testing Lab	0	0	2	1	8	ME-229	Materials Processing Lab	0	0	2	1
		Total Hours = 25				22			Total Hours = 25				22

Third Year													
5th Semester							6th Semester						
SN	Code	Subject	L	T	P	Credits	SN	Code	Subject	L	T	P	Credits
1	MS-311	Characterization of Materials	3	1	0	4	1	MS-321	Non-Destructive Testing of Materials	3	1	0	4
2	MS-312	Ceramics Science and Engineering	3	1	0	4	2	MS-322	Tribology of Engineering Materials	3	1	0	4
3	MS-313	Iron and Steel Making	3	1	0	4	3	MS-323	Non-Ferrous Extractive Metallurgy	3	1	0	4
4	MS-314	Metal working Science & Technology	3	0	0	3	4	MS-324	Computational Materials Science	3	0	0	3
5	OET	Open Elective-I	3	0	0	3	5	OET	Open Elective-II	3	0	0	3
6	MS-315	Materials Characterization Lab	0	0	2	1	6	MS-325	Non-Destructive Testing and Computational Materials Science lab	0	0	2	1
7	MS-316	Ceramic Materials Lab	0	0	2	1	7	MS-326	Tribology Lab	0	0	2	1
8	MS-317	Metal Working Lab	0	0	2	1	8	MS-329	Seminar	0	0	2	1
		Total Hours = 24				21			Total Hours = 24				21

Fourth Year												
7th Semester							8th Semester					
SN	Code	Subject	L	T	P	Credits	SN	Code	Subject	L	T	P	Credits
1	MS-411	Thin Film Technology	3	0	0	3	1	HS-404	Engineering Economics and Accountancy	3	0	0	3
2	MS-412	Corrosion Science and Engineering	3	0	0	3	2	MS-421	Failure Analysis of Materials	3	0	0	3
3	DET	Professional Elective-I	3	0	0	3	3	DET	Professional Elective-III	3	0	0	3
4	DET	Professional Elective-II	3	0	0	3	4	DET	Professional Elective-IV	3	0	0	3
5	MS-418	Industrial Training Presentation	0	0	2	1	5	MS-428	General Proficiency	0	0	0	1
6	MS-419	Major Project (Stage-I)	0	0	12	6	6	MS-429	Major Project (Stage-II)	0	0	12	6
		Total Hours = 26				**19**			**Total Hours= 24**				**19**

Semester Wise Credits									
Semester	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**Total**
Credits	24	24	22	22	21	21	19	19	**172**
Hours/week	28	28	25	25	24	24	26	24	**204**

Professional Elective Courses

Professional Elective-I

MS-430	Spectroscopy
MS-431	Electronics and Magnetic Properties of Materials
MS-432	Fuels Refractory and Furnaces

Professional Elective-II

MS-450	Light Metal & Alloys
MS-451	Advanced Functional Oxide Materials
MS-452	X-ray Techniques

Professional Elective-III

MS-440	Materials Selection and Design
MS-441	Surface Science and Engineering
MS-442	Laser Materials Processing

Professional Elective-IV

MS-460	Nanomaterials and Applications
MS-461	Materials for Renewable Energy

Open Elective Courses

Open Elective-I

MS-370	Materials Characterization Techniques
MS-371	Materials for Renewable Energy

Open Elective-II

MS-380	Electronic and Optical Properties of Materials
MS-381	Nanomaterials and Nanotechnology

Course Name: **Organizational Behaviour**
Course Code: **HS-203**
Course Type: **Core**

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

Course Objectives

- To impart knowledge about the behavioural aspects related to professional organizations
- To introduce the fundamental concepts relevant to understanding of individual & group behavior in the organization
- To enable the students to understand the applied organizational themes like perception, motivation, interpersonal relationships, group dhynamics, leadership theories, role of power & politices in organizational context, conflict and negotiation, organizational diversity, dynamics of personality, attitude and job satisfaction, etc.

Unit Number	Course Content	Lectures
UNIT-01	**Organizational Behavior (OB):** Concept, nature, characteristics, conceptual foundations, determinants and importance, management functions, role & skills, disciplines that contribute to the field of OB, Challenges & Opportunities for OB, diversity in Organizations, attitudes & Job satisfaction.	**04L**
UNIT-02	**Perception**: Concept, nature, process, importance, management and behavioral applications of perception. Personality: concept, nature, types and theories of personality shaping. Learning; concept and theories of learning.	**08L**
UNIT-03	**Motivation:** concept, principles, theories-content, process & contemporary, Monetary and non-monetary motivation, applications of motivation. Leadership: Concept, functions, styles, and theories of leadership- trait, behavioural, and situational.	**06L**
UNIT-04	**Group and Interpersonal Relationship:** Analysis of Interpersonal Relationship, developing interpersonal relationship, Group Dynamic: Definition of Group, stages of Group Development, Punctuated Equilibrium Model, Group Structure, Group Decision Making, understanding work teams.	**05L**
UNIT-05	**Organizational Power and Politics:** concept of power, structure of power, classification of power, contrasting leadership & power, dependence a key to power, causes & consequences of political behaviour. Organizational conflict: view of conflict, conflict process, negotiation & bargaining strategies.	**06L**
UNIT-06	**Conflict and Negotiation:** conflict definition in conflict thought: Traditional view, the Human relation view, interactionist view. Functional versus dysfunctional conflict, conflict process. Negotiation Bargaining strategies, the negotiation process and issues in negotiation.	**07L**

Course Outcomes

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

CO1: Identify the challenges of the present organization

CO2: Describe the organizational system

CO3: Apply the principles of organizational behavior to inculcate the habit of team work and which is essential for the organization

CO4: Assess the role of psychological and social principal in improvement of efficiency as well as quality of empoyee life

Books and References

1. Organizational Behavior by Robbins, S.P., Prentice Hall of India.
2. Organizational Behavior by Luthans F., McGraw-Hill.
3. Human Behavior at Work: Organizational Behavior by Davis K., Tata McGraw-Hill.

Course Name: **Phase Transformations**
Course Code: **MS-211**
Course Type: **Core**

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

Course Objectives

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

Unit Number	Course Content	Lectures
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.	**09L**
UNIT-02	**Thermodynamics of Phase Transformation:** Calculation of G_v for various transformations (polymorphic &solidification, precipitation, massive, eutectic & eutectoid), Nature of inter-phase interfaces and their energies, Fundamentals of diffusion, Flick's Laws	**06L**
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	**06L**
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.	**06L**
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.	**09L**

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 and phase properties
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

Course Name: **Transport Phenomena**
Course Code: **MS-212**
Course Type: **Core**

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

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	Lectures
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.	**09L**
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 in an infinitely thin plate (Semi-infinite body) - System with finite surface and internal resistance - Chart solutions of transient heat conduction problems – Examples on Heat Treatment.	**09L**
UNIT-03	**Convective Heat Transfer:** Forced and free convention - Boundary layer concept -velocity and thermal boundary layers (no derivation) - Simple problems - Flow over flat plate - laminar and turbulent boundary layers (no derivation) - Simple problems – Boundary layer development in a circular duct (no derivation) - Flow over cylinders and spheres-Simple problem- applications in metallurgical processes.	**06L**
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.	**06L**
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 in solids: generalized diffusion equation, the steady and transient, 1D solutions; Uphill diffusion; Kirkendal's effect **Simultaneous Heat and Mass Transfer:** Elucidation through Gas carburizing process; Discussion on solidification phenomena (formation of gas bubbles during solidification), post combustion in steelmaking.	**06L**

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-213**

Course Type: **Core**

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

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	Lectures
UNIT-01	**Introduction and Basic Concepts:** Scope, application, importance in Metallurgical Engineering, state of system, thermodynamic equilibrium, Thermodynamic variables, properties of system	**06L**
UNIT-02	**First Law of Thermodynamics**: Internal Energy, Enthalpy, Heat Capacity, Cp&Cv, Hess Law, Kirchoff"s Law, Numerical Problems.	**06L**
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**.**	**06L**
UNIT-04	**Single Component Systems:** Clausis –Clapyron equations, Numerical Problems **Phase Rule & Ellingham Diagrams:** Temperature/free energy diagrams for Oxides, Sulphides& Halides.	**06L**
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.	**06L**
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.	**06L**

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 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: **Mechanical Behaviour of Materials**
Course Code: **MS-214**
Course Type: **Core**

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

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	Lectures
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 dislocation stacking 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.	**12L**
UNIT-02	**Modes of Plastic Deformation:** Slip planes and slip directions, resolved shear stress, strain hardening and recovery of single crystals, Twinning, Grain boundary sliding and diffusional creep**.**	**03L**
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.	**03L**
UNIT-04	**Fracture**: Types of fracture- ductile fracture, brittle fracture; Theoretical fracture stress, Griffith theory, 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- surface treatment, compressive stresses.	**06L**
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.	**06L**
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.	**06L**

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: **Materials Science Lab**
Course Code: **MS-215**

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

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. To study the crystal structure, and crystal imperfections using models.
2. To measure the resistivity of the semiconductor crystal using four-probe method at different and determine its energy band-gap.
3. Realization of hysteresis curve of a magnetic material using an oscilloscope.
4. To determine the energy band gap of semiconductor using the p-n junction diode.
5. To determine the modulus of elasticity of metal/alloy by bending of beam method.
6. To study the Hall Effect in semiconductor and measure semiconductor parameters.
7. To study the resistivity variation of NaCl with temperature.
8. Determination of grain size for a given specimen, using optical microscope.
9. To study the temperature variation of dielectric constant and calculation of Curie temperature.
10. To obtain the CV and CD curve of a conductor, semiconductor and insulator sample.
11. To measure the corrosion potential and obtain tafel plot of mild and stainless steel.
12. Observation of a ferroelectric phase transition in potassium nitrate and measurement of its transition temperature

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 materials from their structures
CO2: Understand the science behind solidification mechanisms in materials
CO3: Understand the mechanism behind different transformations during heat treatments and alloy systems
CO4: Interpret the Microstructures of different metals, alloys using optical microscopy

Course Name:	**Transport Phenomena Lab**
Course Code:	**MS-216**
Contact Hours/Week: **2P**	Course Credits: **01**

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: **Mechanical Testing Lab**	
Course Code: **MS-217**	
Contact Hours/Week: **2P**	Course Credits: **01**

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. Determination of the tensile properties of different class of materials
2. Determine the Young's modulus of the given specimen by conducting torsion test
3. Determine the Young's modulus of the given specimen by conducting bending test
4. Principles of hardness testing comparison of different hardness techniques (Rockwell, Brinell, Vickers)
5. Jominy hardenability test to hardness as a function of quench rate and investigate the hardenability of steels
6. Effect of work hardening on tensile properties of metal
7. Demonstration of compressive mechanical testing of materials
8. Creep testing of lead-tin alloy wire under a fixed load
9. Visualization of slip and twinning in materials after deformation
10. Calculate fracture toughness of mild steel and cast iron and observation of their fracture surfaces
11. Calculation of fatigue life cycle of mild steel and plotting of S-N curve
12. Observation of fatigue failure surface under optical microscope and SEM

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: **Engineering Mathematics-III**
Course Code: **MA-203**
Course Type: **Core**

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

Course Objectives

- To introduce the fundamental concepts relevant to function of complex variable, numerical differentiation and integration and numerical solution of linear, non-linear and system of equations.
- To have the idea of evaluation of real integrals using complex variable.
- To understand the concept of approximating & interpolating polynomials and finding values of function at arbitrary point.
- To impart knowledge of various numerical technique to solve ODE.

Unit Number	Course Content	Lectures
UNIT-01	**Functions of Complex Variable** Applications of De Moivre's theorem, Exponential, Circular, Hyperbolic and Logarithmic functions of a complex variable, Inverse Hyperbolic functions, Real and imaginary parts of Circular and Hyperbolic functions, Summation of the series-'C+iS' method. Limit and derivative of complex functions, Cauchy-Riemann equations, Analytic functions and its applications, Complex integration, Cauchy's theorem, Cauchy's integral formula, Series of complex function, Taylor series, singularities and Laurent's series, Cauchy's residue theorem and its application for the evaluation of real definite integrals.	**12 L**
UNIT-02	**Interpolation** Least square curve fit and trigonometric approximations, Finite differences and difference operators, Newton's interpolation formulae, Gauss forward and backward formulae, Sterling and Bessel's formulae, Lagrange's interpolation.	**06L**
UNIT-03	**Numerical Integration** Integration by trapezoidal and Simpson's rules 1/3 and 3/8 rule, Romberg integration, and Gaussian quadrature rule, Numerical integration of function of two variables.	**05L**
UNIT-04	**Numerical Solution of Ordinary Differential Equations** Taylor series method, Picard's method, Euler's method, Modified Euler's method, Runge- Kutta method. Predictor corrector methods, Adam Bashforth and Milnes method, convergence criteria, Finite difference method.	**07L**
UNIT-05	**Numerical Solution of Linear and Non Linear Equations** Non Linear Equations: Bisection Method, Regula Falsi Method, Newton-Raphson Method, Iteration method. Linear Equations: Jacobi and Gauss Seidel Iteration methods, Relaxation method.	**06 L**

Course Outcomes

Upon successful completion of the course, the student will be able to:
CO1: Understand and analyze the concept of Numerical Solution of Linear and Non Linear Equations, Ordinary Differential Equations and Function of complex variable.
CO2: Identify an appropriate technique to solve the linear, non-linear equations, ordinary differential equations.
CO3: Formulate the problems on related topics and solve analytically.
CO4: Apply the concepts of linear, non-linear equations, differential equations and complex analysis in various engineering problems.
CO5: Demonstrate the concepts through examples and applications.

Books and References

1. Complex variables and Applications by R. V. Churchill, J. W. Brown & R. F. Verhey, McGraw Hill.
2. A first course in complex analysis with applications by Dennis G. Zill & P. D. Shanahan, Jones and Bartlett.
3. Numerical Methods for Scientific and Engineering Computation by M. K. Jain, S. R. K. Iyenger and R. K. Jain, New Age International Publishers, New Delhi
4. Numerical Methods for Engineers and Scientists (2nd Ed.) by J D Hoffman, CRC Press.
5. Numerical Analysis Mathematics and Scientific computing (3rd ed.) by D. Kincaid and W. Cheney, American Mathematical Society.

Course Name: **Heat Treatment**
Course Code: **MS-221**
Course Type: **Core**

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

Course Objectives

- The course will highlight a number of commercially significant applications where phase transformations due to heat treatment are important.
- To introduce fundamental concepts relevant to phase diagrams, phase transformations and heat treatment of metals and alloys
- To study the phase changes that occurs during both thermal and thermomechanical treatments.

Unit Number	Course Content	Lectures
UNIT-01	**Fundamentals:**Iron-carbon equilibrium diagram, Isothermal transformation diagrams, continuous cooling transformation diagram. Arsenisation and austenite grain size. Hardenability, its measurement and control.	**06L**
UNIT-03	**Principles of Heat Treatment of Metals:** Annealing, Normalizing, Hardenability, Hardening, Tempering, Harden ability, Mechanism of Heat removal during Quenching, Quenching media, Residual stresses and Quench Cracks, Martempering and Austempering, Purpose of alloying, Effect of alloying on Fe-Fe_3C Phase Diagram, Temperature Time Transformation (TTT) and Continuous Cooling Transformation(CCT) Plots	**06L**
UNIT-04	**Heat Treatment Processes:** Various methods of heat treatments surface hardening treatments, heat treatment of nonferrous alloys, heat treatment schedules/case studies of some important steels and special types of treatments viz. martempering, austempering and thermo-mechanical treatments and inter critical treatments. Heat treatment in reheating furnace and annealing furnace.	**06L**
UNIT-05	**Thermo-Mechanical Treatments:** High temperature treatment with low temperature tempering, Low temperature treatment with low temperature tempering; **Case Hardening of Steels:** Carburizing process for their process, advance and challenges. Flame hardening, Nitric process and challenges; **Hardenability of Steels:** Concept of critical diameter, joining-end quench test, effect of parameters viz: alloying elements, carbon content, austenic grain size, section size and quenching media	**09L**
UNIT-6	**Cast Iron and their Heat Treatment:** Grey, white, malleable, Heat treatment of non- ferrous materials, SG iron, Alloy cast irons**;** **Defects:** Defects in heat-treated materials and their prevention.	**09L**

Course Outcomes

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

CO1: Understand the effect of heat treatment on the microstructure of the materials.
CO2: Understand the role of phase transformations with respect to heat treatment on the development of microstructure.
CO3: Understand the properties of metallic materials.

Books and References

1. Materials Science and Engineering by William F. Smith, Tata McGraw-Hill Education.
2. Physical Metallurgy: Principles and Practice by V. Raghvan, PHI Learning.
3. Phase Transformations in Metals and Alloys by David A. Porter, Kenneth E. Easterling, Mohamed Youssef AbdelraoufSherif, CRC Press.
4. Phase Transformation of Materials byR.C. Sharma, CBS Publishers & Distributors.
5. Heat Treatment: Principles and Techniques by T.V. Rajan, C.P. Sharma, Ashok Rajan, PHI Learning.

Course Name: **Polymer Science and Technology**
Course Code: **MS-222**
Course Type: **Core**

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

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	Lectures
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.	**09L**
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.	**06L**
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.	**06L**
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.	**09L**
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.	**06L**

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: **Composite Materials**

Course Code: **MS-223**

Course Type: **Core**

Contact Hours/Week: **3L** 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	Lectures
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.	**06L**
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	**09L**
UNIT-03	**Types of Composites:**: Fiber Reinforced Composites, Fiber Reinforced Polymer (FRP) Composites, Laminar Composites, Particulate Composites, Comparison with Metals, Advantages & limitations of Composites	**06L**
UNIT-04	**Fabrication Methods:** Processing of Composite Materials: Overall considerations, Autoclave curing, Other Manufacturing Processes like filament welding, compression moulding, resin-transplant method, pre-peg layer, Fibre-only performs, Combined Fiber-Matrix performs, Manufacturing Techniques: Tooling and Specialty materials, Release agents, Peel plies, release films and fabrics, Bleeder and breather plies, bagging films.	**09L**
UNIT-05	**Testing of Composites:** Mechanical testing of composites, Tensile testing, Compressive testing, Intra-laminar Shear testing, Inter-laminar Shear testing, Fracture testing.	**06L**

Course Outcomes

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

CO1: Understand the basic knowledge and the applications of the 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: **Materials Processing Techniques**

Course Code: **ME-228**

Course Type: **Core**

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

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	Lectures
UNIT-01	**Introduction and Basic Materials used in Foundry:** 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; Characterization and Testing of Green Sand; Function and Types of Cores; Core prints and Chaplets; Preparation of sand molds: Molding machines- Jolt type, squeeze type and Sand slinger. Expendable Mold Casting: Removal Pattern- Green sand Mold Casting, Dry Sand Mold Casting, Loam Sand Mold casting, CO_2 Sand Mold Casting, Vacuum Sand Mold casting, and Shell Mold Casting; Plaster Mold Casting and Ceramic Mold Casting; Disposal Pattern- Investment (Lost Wax) Casting and Evaporative (Lost Foam) Casting.	**08L**
UNIT-02	**Analysis and Design of Pouring System & Cooling and Solidification in Green Sand Mold Metal Casting:** Elements and Types of pouring systems; Mould filling characteristics: fluidity and turbulence; Analysis and Design of pouring system; Calculations for Mould filling time without/with inclusion of effect of different head losses. 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.	**06L**
UNIT-03	**Metal mold 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. 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.	**10 L**
UNIT-04	**Powder Metallurgy Processes**: Powder Production Methods -Chemical, Electrolytic, Atomization, Mechanical; Powder Characterization Methods -Chemical Composition and Structure, Particle Size and Surface Topography); Powder Compaction and Consolidation (Die Compaction, Warm Compaction, CIP and Roll Compaction, Powder Extrusion, Injection Moulding); Densification and Sizing; Impregnation and Infiltration; Sintering-Solid-State Sintering; Non-Isothermal Sintering; Liquid-State Sintering; Super Solidus Sintering; Activated Sintering; Pressure-Assisted Sintering. Advanced Powder Metallurgy-Isostatic pressing, Hot pressing and Spark sintering.	**06L**
UNIT-05	**Welding Process, Soldering and Brazing:** Definition, Principles, Classification, Application, Advantages & limitations of welding. Arc welding: Principle, Metal arc welding (MAW), Flux Shielded Metal Arc Welding, Inert Gas Welding, Submerged Arc Welding, and Atomic Hydrogen Welding. Special type of welding: Resistance welding principles, Seam welding, Butt welding, Spot welding and Projection welding. Friction welding, Explosive welding, Effect of carbon content on structure and properties of steel, Shrinkage in welds & Residual stresses, Concept of electrodes, filler rod and fluxes. Welding defects- Detection, causes & remedy. Soldering, brazing, gas welding: Soldering, Brazing, Gas Welding: Principle, oxy-Acetylene welding, oxy-hydrogen welding, air-acetylene welding,	**06L**

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, Shell, Investment and plaster molds.

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 and Phase Transformation Lab**
Course Code: **MS-224**

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 behaviours

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 importance 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: **Polymers and Composites Lab**
Course Code: **MS-225**

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. Demonstration of thermal properties of Thermosets and Thermoplasts
2. Processing of polyethylene beads by twin screw extruder machine
3. Synthesis of metal and ceramic matrix composites with polymeric filler materials
4. Synthesis of polymer matrix composites with polymeric fillers
5. Preparation of short fiber composites using injection moulding and extrusion techniques
6. Preparation of laminate composite and their surface characterization under AFM and SEM
7. Synthesis of cellulose based nanocomposite with agar matrix
8. Demonstration of solvent casting process for agar based biocomposites
9. Synthesis of hydroxyapetite based biocomposite for bone implant applications
10. Synthesis of clay based composite with agar and cellulose as filler material
11. Imaging of nanocompositefibres in SEM
12. Synthesis of Ytrria- Zirconia microcomposite for electronic applications

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: **Materials Processing Lab**
Course Code: **ME-229**

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: **Characterization of Materials**
Course Code: **MS-311**
Course Type: **Core**

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

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	Lectures
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.	**03L**
UNIT-02	**Surface Characterization Techniques**: 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.	**06L**
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).	**09L**
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.	**09L**
UNIT-05	**Fluorescence and Phosphorescence spectroscopy:** Basic principle, geometrical optics, construction, working principle and use of fluorescence spectrometers in materials analysis. X-ray Fluorescence (XRF). Electron Spin Resonance spectroscopy, Nuclear Magnetic Resonance.	**06L**
UNIT-06	**Thermal Characterization:** Differential Thermal analysis (DTA), Thermogravimetric analysis (TGA) and Differential Scanning Calorimetry (DSC) with suitable examples of glass and ceramic materials.	**03L**

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 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: **Ceramics Science and Engineering**

Course Code: **MS-312**

Course Type: **Core**

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

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	Lectures
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, spinel and fluorite structures - examples. Co-ordination number and ionic radius ratio, Pauling's Rules, packing fraction, critical radius ratio and density.	**09L**
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	**09L**
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. Powder 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.	**06L**
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 diffusion of solutes – crystalline glasses – enamels – photosensitive and photo-chromic glasses ; Blowing, pressing, drawing, rolling and casting - Pilkington process for float glass.	**06L**
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	**06L**

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: **Iron and Steel Making**
Course Code: **MS-313**
Course Type: **Core**

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

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	Lectures
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.	**03L**
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.	**03L**
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.	**09L**
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	**06L**
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.	**06L**
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	**09L**

Course Outcomes

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

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

Course Name: **Metal Working Science and Technology**
Course Code: **MS-314**
Course Type: **Core**

Contact Hours/Week: **3L** 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	Lectures
UNIT-01	**Introduction to metal working concepts:** Concept and cclassifications of metal working processes, mechanics of metal deformation, temperature and strain rate effects, instability and flow localization, concept of workability, microstructure and texture evolution, friction and lubrication, residual stress.	**06L**
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.	**09L**
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.	**09L**
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.	**09L**
UNIT-05	**Deformation of plastics and polymers:** Super-plasticity, formability, failures, friction, wear and lubrication.	**03L**

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

Course Name:	**Materials Characterization Lab**
Course Code:	**MS-315**
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 techniques
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: **Ceramic Materials Lab**
Course Code: **MS-316**

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.

Ceramic powder preparation and compaction:

5. Micron and nano alumina
6. Silica Gel and precipitated Silica
7. Magnesioalumino hydrate (MAH) and MgAl2O4 Spinel
8. Calculation of density before and after compaction of ceramic powders

Characterization of Ceramic powder:

9. Tap density, DTA / TGA / DTGA, IR, Particle Size Analysis
10. Determination of Alkali resistance of glass
11. Determination of alkalinity of glass
12. Determination of Chemical durability of different types of glasses

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: 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: **Metal Working Lab**
Course Code: **MS-317**

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 metal working technique suited to a particular application
CO2: To design the process parameters involved in a particular technique
CO3: To analyze the mechanical properties based on microstructure obtained after processing

Course Name: **Non-Destructive Testing of Materials**
Course Code: **MS- 321**
Course Type: **Core**

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

Course Objectives

- To impart the importance of non-destructive testing in assuring quality control inengineering 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	Lectures
UNIT-01	**Introduction:** Non-destructive testing and its comparison with destructive testing, role of NDT in quality control.	**06L**
UNIT-02	**Liquid penetrant inspection:** its principles, equipment, advantages, limitations and applications.	**06L**
UNIT-03	**Magnetic particle inspection:** its principles, equipment, advantages, limitations and applications. **Ultrasonic inspection:** its principles, equipment, advantages, limitations and applications.	**06L**
UNIT-04	**Eddy current inspection:** its principles, equipment, advantages, limitations and applications. **X-ray radiography**: its principles, equipment, advantages, limitations and applications.	**09L**
UNIT-05	**Quality control:** Statistical quality control, control charts, control chart attribute and variables and acceptance sampling; Quality assurance and ISO 9000:2000	**09L**

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: **Tribology of Engineering Materials**
Course Code: **MS-322**
Course Type: **Core**

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

Course Objectives

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

Unit Number	Course Content	Lectures
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	**09L**
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	**06L**
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	**06L**
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	**09L**
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.	**06L**

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: **Non-Ferrous Extractive Metallurgy**
Course Code: **MS-323**
Course Type: **Core**

Contact Hours/Week: **3L +1T** 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	Lectures
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.	**03L**
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	**03L**
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 insitu, 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.	**12L**
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 electrowinning.	**09L**
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 UO_2. Other important metals such as nickel and magnesium, major non-ferrous metal production in India Carbon-in pulp process.	**09L**

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: **Computational Materials Science**

Course Code: **MS-324**

Course Type: **Core**

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

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	Lectures
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	**06L**
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	**03L**
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,	**09L**
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, hyperdynamics **Generalized Continuum Models of Microstructure:** Cosserat continua, Micromorphic continua, Nonlocal and gradient-dependent models, Stochastic models of heterogeneous microstructure	**09L**
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	**09L**

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: **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: **Tribology Lab**
Course Code: **MS-326**

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 realised.

List of Experiments

1. To perform the wear test of various materials using **Reciprocating Tribometer**: Pure Metal, Composite /Alloy,Ceramic and Polymer
2. Analysis and comparison of the wear Properties of different Materials (in reciprocating motion) : Coefficient of Friction, Wear volume, Wear Rate
3. Study of the Wear mechanism of various samples using **Scanning Electron Microscopy**
4. To perform the wear test of various materials using **Pin on Disc Tribometer**: Pure Metal, Composite /Alloy, Ceramic and Polymer
5. Analysis and comparison of the wear Properties of different Materials(in rotational motion) : Coefficient of Friction, Wear volume, Wear Rate
6. Study of the Wear mechanism of various samples using **Scanning Electron Microscopy.**
7. To study the wear and friction properties of oils and greases using **Four Ball Tester.**
8. To study the effect test parameter (Speed, temperature, and lubrication) on the wear behavior of metallic system.
9. To study the erosion (wear) of material using the **Air Jet Erosion Tester**.
10. To study the erosion (wear) of material using the **Slurry Erosion Tester.**
11. To study the abrasive wear properties of the metallic system using **Dry Abrasion Tester**.
12. To study the surface profiling of the wear surfaces using **Atomic force Microscopy** (AFM).

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 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: **Thin Film Technology**
Course Code: **MS-411**
Course Type: **Core**

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

Course Objectives

- To learn the concepts for 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	Lectures
UNIT-01	**Physics of Thin Films:** Introduction and overview- Basic Physics, Chemistry and Materials Science, Solid State Physics- Ideal solids and crystal structure, Defects in solids, Bonds and Electrons, Thermodynamics and Phase Diagrams. Kinetics and Diffusion, Nucleation and Growth, Film Formation, Growth modes and Zone modelth.	**09L**
UNIT-02	**Film Deposition Methods:** Vacuum and Kinetic Theory of Gasses, Physical methods of films Deposition: Evaporation – thermal, e-beam, Sputter Deposition - DC, MF,RF, Microwave, pulsed laser, Ion-Beam, Arc Deposition – Cathodic, Anodic, Molecular Beam Epitaxy, Chemical methods of Film deposition: Deposition of Inorganic Films From Solutions, Chemical Vapor Deposition -Electrolysis, Anodization, Spray pyrolysis, polymerization, Other techniques: Langmuir Blodgett, Self-Arrangement, Monolayer and Spin Coating.	**09L**
UNIT-03	**Properties of Thin Films**: Optical properties, electrical properties, magnetic properties, mechanical properties.	**06L**
UNIT-04	**Thin Film Characterization:** Imaging Techniques, Structural Techniques, Chemical Techniques, Optical Techniques, Electrical / Magnetic Techniques, Mechanical Techniques	**06L**
UNIT-05	**Applications for Thin Film of Advanced Materials:** Transparent conducting coating, Optical coating, Sensors, Superconductivity, Giant and colossal magnetoresistance, Super hard coatings, Ferro-electronic effect.	**06L**

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 toconduct microstructural and chemical analysis.
CO3: Select appropriate deposition method and materials for an engineeringapplication.

Books and References

1. Thin Film Deposition: Principles and Practice by Donald L. Smith, McGraw-Hill, Singapore.
2. Plasma Techniques for Film Deposition by Konuma Mitsuharu, Alpha Science.
3. An Introduction to Physics and Technology of Thin Films by Alfred Wagendristel, Yuming Wang, Singapore: World Scientific.
4. Thin Film Processes by John L Vossen, Academic Press, New York.
5. Thin Film Physics by O.S. Heavens, London: Methuen.

Course Name: **Corrosion Science and Engineering**
Course Code: **MS-412**
Course Type: **Core**

Contact Hours/Week: **3L** 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	Lectures
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 potentials of 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.	**12L**
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 remedial measures. Purpose of testing, laboratory, semi-plant and field tests, Susceptibility tests for intergranular corrosion, stress corrosion cracking.	**06L**
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 knowledge about corrosion and its application in engineering field. Their causes and remedial measures.	**06L**
UNIT-04	**Corrosion Behaviour of Industrial Metals and Alloys:** Steels, Stainless steels, Copper and Copper alloys, Nickel and Nickel alloy, Aluminium and Aluminium alloys, Titanium and Titanium alloys etc. Corrosion failure of ceramic materials- Corrosion degradation of concrete. Environmental degradation and corrosion of polymer materials.	**06L**
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.	**06L**

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: **Engineering Economics and Accountancy**
Course Code: **HS-404**
Course Type: **Core**

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

Course Objectives

- To impart knowledge about the Economics and its applicability to the Engineers
- To introduce the fundamental concepts of economics
- To enable the students to understand the factors that causes the changes in economic conditions of the entrepreneur

Unit Number	Course Content	Lectures
UNIT-01	**Introduction to Engineering Economics:** Definitions, Nature, Scope and application; Difference between Micro Economics and Macro Economics; Theory of Demand & Supply: Meaning, Determinants, Law of Demand, Elasticity of demand, Demand Forecasting, Law of Supply, Equilibrium between Demand & Supply.	**06L**
UNIT-02	**Production and Cost**: Production functions, Isoquant, Least Cost combination, Laws of Returns to Scale. Economics and Diseconomies of Scale of production, Cost and Cost curves, Revenue and Revenue curve, Break even analysis.	**06L**
UNIT-03	**Costing and Appraisal:** Cost elements, Economic cost, Accounting cost, Standard cost, Actual cost, Overhead cost, Cost control, Criteria of project appraisal, Social cost benefit analysis	**05L**
UNIT-04	**Markets**: Meaning, Types of Markets, Characteristics (Perfect Competition, Monopoly, Monopolistic Competition, Oligopoly) Price and Output Determination; Product Differentiation; Selling Costs; Excess Capacity.	**05L**
UNIT-05	**Money**: Meaning, Functions, Types; Monetary Policy- Meaning, Objectives, Tools; Fiscal Policy:-Meaning, Objectives, Tools. **Banking:** Meaning, Types, Functions, Central Bank: its Functions, concepts CRR, Bank Rate, Repo Rate, Reverse Repo Rate, SLR.	**04L**
UNIT-06	**Depeciation:** Meaning of depreciation, causes, object of providing depreciation, factors affecting depreciation, Methods of Depreciation: Straight line method, Diminishing balance method, Annuity method and Sinking Fund method	**04L**
UNIT-07	**Financial Accounting:** Double entry system (concept only), Rules of Double entry system, Journal(Sub-division of Journal) , Ledger, Trial Balance Preparation of final accounts-Trading Account. Profit and Loss account, Balance Sheet.	**06L**

Course Outcomes

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

CO1: Identify the challenges of the economy as entrepreneur/manufacturer as well as consumer
CO2: Describe the economic system at the micro and macro level
CO3: Apply principles of economics and accountancy in the professional, personal and societal life
CO4: Assess the role of engineering economics and accounting in attaining economic efficiency

Books and References

1. Principles of Micro Economics by Mceachern & Kaur, Cengage Publication.
2. Managerial Economics by Craig Peterson & W Cris Lewis, PHI Publication.
3. Modern Microeconomics by A. Koutsoyiannis, Macmillan.
4. Managerial Economics Theory and Applications by D. M.Mithani. Himalaya Publication House.
5. Fundamental of Managerial Economics Mark Hirschey, South Western Educational Publishing.
6. Engineering Economics by Degramo, Prentice Hall.
7. Financial Accounting–A Managerial Perspective by R. Narayanaswamy, PHI.
8. Introduction to Accounting by J.R. Edwards & Marriot, Sage Publication.
9. Cost Accounting by Jawahar Lal, Tata McGraw Hill.
10. Project Planning Analysis, Selection, Implementation and Review by Prasanna Chandra, Tata McGraw Hill

Course Name: **Failure Analysis of Materials**
Course Code: **MS-421**
Course Type: **Core**

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	Lectures
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.	**06L**
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.	**06L**
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.	**09L**
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.	**09L**
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.	**06L**

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: **Spectroscopy**
Course Code: **MS-430**
Course Type: **Professional Elective-I**

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	Lectures
UNIT-01	**Introduction to Spectral Methods:** Molecular and atomic spectroscopy-interaction of electromagnetic radiation with matter-Energy levels in atoms and molecules – Absorption techniques and emission techniques: fluorescence, phosphorescence and chemo luminescence – Beer-Lambert law; qualitative and quantitative analyses – limitations – visible absorption spectroscopy.	**03L**
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, bond dissociation energies, isotopic shift, FTIR, Instrumentation	**09L**
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	**06L**
UNIT-04	**Emission Spectroscopy**: Ffluorescence and phosphorescence, deactivation processes – internal conversion, de-excitation process, non-radiative and radiative transitions, 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 binding energy, ESCA, Auger electron spectroscopy, Instrumentation.	**09L**
UNIT-05	**Spectra in magnetic field –NMR**: The Stern-Gerlach's experiment, nuclear spin angular 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	**09L**

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.
2. Organic 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 Brookes/Cole.
5. Mass Spectrometry by Gross, Jürgen, Springer

Course Name: **Electronics and Magnetic Properties of Materials**

Course Code: **MS-431**

Course Type: **Professional 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	Lectures
UNIT-01	**Conductors:** Drude, Sommerfeld and quantum theories of electric conduction in metals, Maitthiessen rule of electrical conductivity, Energy Band Diagrams.	**06L**
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	**06L**
UNIT-03	**Ionic conductors:** Ionic conduction – review of defect equilibrium and diffusion mechanisms; Theory of ionic conduction, conduction in glasses; Effect of stoichiometric and extrinsic defects on conduction.	**06L**
UNIT-04	**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, dielectric dispersion and losses Applications in sensors, actuators and memory devices.	**09L**
UNIT-05	**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,Magnetic behaviour-exchange interaction and magnetic domains exchange energy, magnetocrystalline energy, magnetorestriction;hard and soft magnets, single domain magnets,superparamagnetism, easy and hard axis surface magnetism, **Applications**: Spintronics and memory devices, Superconductors, Multiferroic materials	**09L**

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.

CO3: 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: **Fuels Refractory and Furnaces**
Course Code: **MS-432**
Course Type: **Professional Elective-I**

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	Lectures
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	**09L**
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.	**06L**
UNIT-03	Acid, basic and neutral refractories, their 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.	**06L**
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.	**09L**
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.	**06L**

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: **Light Metals and Alloys**
Course Code: **MS-450**
Course Type: **Professional Elective-II**

Contact Hours/Week:**3L** 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	Lectures
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 Aluminium alloys: Ternary phase diagrams, Al-Cu-Mg alloys, Al-Si-Mg alloys and Al-Zn-Mg alloys.	**09L**
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.	**09L**
UNIT-03	**Commercially Pure Titanium:** Properties, applications, Interstitial solid solutions of Titanium, Strengthening mechanisms of Titanium alloys.	**06L**
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.	**06L**
UNIT-05	**Beryllium alloys:** Classification properties and applications Zirconium alloys: Classification, properties and applications.	**06L**

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: **Advanced Functional Oxide Materials** Course Code: **MS-451** Course Type: **Professional Elective-II**		
Contact Hours/Week:**3L**		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**	**Lectures**
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	**03L**
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	**06L**
UNIT-03	**Spintronics**: Wide band gap semiconductor, dielectric magnetic semiconductor, half-metallic materials. Basic mechanism of spin polarization and application of Spintronics device.	**09L**
UNIT-04	**MultiferroicMaterials**: 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	**09L**
UNIT-05	**Nano Composite of oxide materials**: The synthetization of nano oxide materials. Composite of nano oxide with different host materials.	**09L**
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: **X-Ray Techniques**
Course Code: **MS- 452**
Course Type: **Professional Elective-II**

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	Lectures
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.	**09L**
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.	**09L**
UNIT-03	**X-ray Fluorescence Spectroscopy**: Moseley's law, Compton scattering, Energy Dispersive XRF (EDXRF), Wave Dispersive XRF (WDXRF)	**06L**
UNIT-04	**X-ray Absorption Spectroscopy:** Synchrotron as X-ray Source, X-rays Absorption, Absorption Edge and its Position, XAFS, XANES, EXAFS, NEXAFS, SEXAFS	**06L**
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.	**06L**

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 Press.
2. 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.

Course Name: **Materials Selection and Design**
Course Code: **MS-440**
Course Type: **Professional Elective-III**

Contact Hours/Week: **3L** 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	Lectures
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.	**06L**
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 and wear resistance, brittle fracture, fatigue failure, corrosion resistance. Designing with plastics, brittle materials .Design examples with shaft design, spring design and C-frames	**09L**
UNIT-03	**Manufacturing Considerations in Design:** Surface finish, Texture, Dimensional tolerances in fitting, interchange ability selective assembly, and geometric tolerance.	**06L**
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.	**09L**
UNIT-05	**Materials Selection** using Ashby Method, Case Studies, Multiple Constraints in materials selection, Multiple Objectives, Role of Materials in Shaping the Product Character.	**06L**

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-441**

Course Type: **Professional Elective III**

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

Course Objectives

- To analyse 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	Lectures
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 lubricationoverview of different forms of corrosion	**06L**
UNIT-02	Chemical and electrochemical polishing, significance, specific examples, chemical conversion coatings, phosphating, chromating, chemical colouring, anodizing of aluminium alloys, thermochemical processes -industrial practices	**03L**
UNIT-03	Surface pre-treatment, deposition of copper, zinc, nickel and chromium - principles andpractices, alloy plating, electro composite plating, properties of electro deposits, electroless composite plating; application areas, properties.	**09L**
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.	**09L**
UNIT-05	Thermal spraying, techniques, advanced spraying techniques - plasma surfacing, detonation gun and high velocity oxy-fuel processes, laser surface alloying, laser cladding, specific industrial applications, tests for assessment of wear and corrosion.	**09L**

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: **Laser Materials Processing**
Course Code: **MS-442**
Course Type: **Professional Elective-III**

Contact Hours/Week: **3L** 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	Lectures
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	**06L**
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.	**09L**
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	**09L**
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	**06L**
Unit 5	**Laser Rapid prototyping:** Selective laser Sintering (SLS), 3D Printing, Beam Deposition (Laser Engineered Net Shaping (LENS)	**06L**

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: **Nanomaterials and Applications**		
Course Code: **MS-460**		
Course Type: **Professional Elective-IV**		
Contact Hours/Week: **3L**		Course Credits: **03**
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**	**Lectures**
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	**06L**
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	**03L**
UNIT-03	**Diffusion in Nanostructures** – Factors affecting diffusion - Surface, Volume and cross grain boundary diffusion – Growth controlled by diffusion – Diffusion kinetics – Kirkendall Effect-Classification of Nanoparticles – Zero, One, Two andThree dimensional nanostructures-Nanoparticles by homogeneous nucleation and heterogeneous nucleation- VLS and SLS growth - particle size, strain and grain size of nanomaterials.	**09L**
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.	**09L**
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	**09L**
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.		

Course Name: **Materials for Renewable Energy**

Course Code: **MS- 461**

Course Type: **Professional Elective-IV**

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	Lectures
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: Nuclear reactor, pressurised reactor, breeder reactor. Materials for fuel, control rods, coolant, moderator, shielding	**09L**
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 behaviour of materials, Effects on crystal structure, grain size etc.	**09L**
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	**06L**
UNIT-04	Materials in Thermal Power Generation Super-alloys, 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.	**06L**
UNIT-05	**Energy storage**: Artificial photosynthesis/solar to fuels, 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.	**06L**

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. Fundamentals of Radiation Materials Science by G.S. Was, Springer.
3. Nuclear Reactor Materials and Applications by B.M. Ma, Van Nostrand Reinhold Company.
4. Nuclear Reactor Materials by C.O. Smith, Addison-Wesley Publishing Company.
5. Structural Materials in Nuclear Power Systems by J. T. A. Roberts, Plenum Press.

Course Name: **Materials Characterization Techniques**
Course Code: **MS-370**
Course Type: **Open Elective-I**

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	Lectures
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, Photomicroscopy, Colour metallography, Specimen preparation, Applications.	**06L**
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, Wavelength dispersive spectroscopy.	**06L**
UNIT-03	**Diffraction Methods:** Fundamental crystallography, Generation and detection of X-rays, Diffraction of X-rays, X-ray diffraction techniques, Electron diffraction.	**06L**
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	**06L**
UNIT-05	**Surface Analysis:** Atomic force microscopy, scanning tunneling microscopy, X-ray photoelectron spectroscopy.	**06L**
UNIT-06	**Spectroscopy:** Atomic absorption spectroscopy, UV/Visible spectroscopy, Fourier transform infrared spectroscopy, Raman spectroscopy.	**06L**

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 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. Growth of Single Crystals by R.A. Laudise, Prentice Hall.
5. Springer Handbook of Crystal Growth by G. Dhanaraj, K. Byrappa, V. Prasad and M. Dudley, Springer-Verlag.

Course Name: **Materials for Renewable Energy**

Course Code: **MS-371**

Course Type: **Open Elective-I**

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	Lectures
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: Nuclear reactor, pressurised reactor, breeder reactor. Materials for fuel, control rods, coolant, moderator, shielding	**09L**
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 behaviour of materials, Effects on crystal structure, grain size etc.	**09L**
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	**06L**
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.	**06L**
UNIT-05	**Energy storage**: Artificial photosynthesis/solar to fuels, CO_2 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.	**06L**

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 Nostrand 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: **Electronic and Optical Properties of Materials**

Course Code: **MS-380**

Course Type: **Open Elective-II**

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 theirexploitation to develop the useful materials based on the structure, chemistry and the processingtechniques.

Unit Number	Course Content	Lectures
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.	**06L**
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.	**09L**
UNIT-03	**Semiconducting Materials:** Semiconductor band diagrams, direct and indirect bandgap, applications of semiconductors; intrinsic and extrinsic semiconductors, and mobility measurements;	**06L**
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	**09L**
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	**06L**

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 S. Campbell, Oxford.
5. Electronic Properties of Materials by Hummel, Springer

Course Name: **Nanomaterials and Nanotechnology**

Course Code: **MS-381**

Course Type: **Open Elective-II**

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

Course Objectives

- To provides an introduction to Nanomaterials and Nanotechnology
- To provide an introduction to synthesis of nanomaterials
- To provide an understanding on various process involved in nanomaterials synthesis

Unit Number	Course Content	Lectures
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	**09L**
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, Diffusion in Nanostructures	**06L**
UNIT-03	**Top down and bottom up synthesis-** mechanical alloying, Mechanical ball milling, Ion implantation, Inert gas condensation, Arc discharge, RF-plasma arc technique, Laser ablation, Template assisted synthesis. Self-assembly, self-assembled monolayers (SAMs).	**06L**
UNIT-04	**Synthesis of nanomaterials:** Gold, Silver, different types of Nano oxides, TiO2, ZnO by 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: Dry etching, Wet etching.	**09L**
UNIT-05	**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. Application of Nanotechnology	**06L**

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 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.