TEACHING SCHEME AND COURSE CONTENTS

FOR

B.TECH

IN

MATERIALS SCIENCE AND ENGINEERING

CENTRE FOR MATERIALS SCIENCE AND ENGINEERING

NIT HAMIRPUR HP-177005

http://www.nith.ac.in/cmse/

Proposed Course Structure

FIRST YEAR

I Semester

SN	Code	Subject	L T P	Credits
1	MSS-111	Engineering Mathematics-I	3 1 0	3
2	MSS-112	Physics-I (Mechanics, Wave & Vibrations)	3 1 0	3
3	MSS-113	Chemistry-I (Physical Chemistry)	3 1 0	3
4	MSD-114	Computer Fundamentals & Programming	3 1 0	3
5	MSD-115	Mechanical Workshop	1 0 3	2
6	MSH-116	Engineering Economics & Management	3 1 0	3
7	MSH-119	Professional Ethics and Human Values	3 0 0	3
8	MSS-117	Physics-I Lab	0 0 3	1
9	MSD-118	Computer Fundamentals & Programming Lab.	0 0 3	1
		TOTAL	Hrs 33	22

II Semester

SN	Code	Subject	L T P	Credits
1	MSS-121	Engineering Mathematics-II	3 1 0	3
2	MSS-122	Physics-II (Electricity & Magnetism	3 1 0	3
3	MSS-123	Chemistry-II (Inorganic Chemistry)	3 1 0	3
4	MSD-124	Basic Electrical & Electronics Engineering	3 1 0	3
5	MSH-125	Communication Skills	3 1 0	3
6	MSD-126	Engineering Graphics	1 0 3	3
7	MSD-127	Basic Electrical & Electronics Engineering-Lab	0 0 3	1
8	MSS-128	Chemistry-I Lab	0 0 3	1
9	MSH-129	Communication Skills Lab	0 0 3	1
		TOTAL	Hrs 33	21

SECOND YEAR

III Semester

SN	Code	Subject	L T P	Credits
1	MSS-211	Engineering Mathematics-III	3 1 0	3
2	MSD-212	Basic Materials Science & Engineering	3 1 0	3
3	MSD-213	Polymer Science & Technology	3 1 0	3
4	MSD-214	Ceramic Science & Technology	3 1 0	3
5	MSD-215	Strength of Materials	3 1 0	3
6	MSD-216	Thermodynamics of Materials	3 1 0	3
7	MSD-217	Transport Phenomenon	3 1 0	3
8	MSD-218	Basic Materials Science Lab.	0 0 3	2
9	MSD-219	Strength of Materials Lab.	0 0 3	2
		TOTAL	Hrs 34	25

IV Semester

SN	Code	Subject	L T P	Credits
1	MSS-221	Numerical Analysis and Computational Methods	3 1 0	3
2	MSD-222	Material Processing Techniques	3 1 0	3
3	MSD-223	Iron and Steel Making	3 1 0	3
4	MSD-224	Mechanical Behavior of Materials	3 1 0	3
5	MSD-225	Basic Environmental Science	3 1 0	3
6	MSD-226	Physical Metallurgy	3 1 0	3
7	MSD-227	Material Processing Lab	0 0 3	2
8	MSD-228	Physical Metallurgy Lab.	0 0 3	2
9	MSS-229	Computational Methods Lab	0 0 3	2
		TOTAL	Hrs 33	24

THIRD YEAR

V Semester

SN	Code	Subject	L T P	Credits
1	MSD-311	Nanomaterials	3 1 0	3
2	MSD-312	Phase Transformation and Heat Treatment	3 1 0	3
3	MSD-313	Magnetic Materials for industry	3 1 0	3
4	MSD-314	Laser Material Processing	3 1 0	3
5	MSD-315	Materials Selection and Design	3 1 0	3
6	MSD-316	Materials for Specific Applications	3 1 0	3
7	MSO-317	Open Elective-I	3 1 0	3
8	MSD-318	Nanomaterials Lab.	0 0 3	2
9	MSD-319	Heat Treatment Lab.	0 0 3	2
		TOTAL	Hrs 34	25

VI Semester

SN	Code	Subject	L T P	Credits
1	MSD-321	Metal deformation Processing	3 1 0	3
2	MSD-322	Tribology of Engineering Processing	3 1 0	3
3	MSD-323	Electronic Materials for Industry	3 1 0	3
4	MSD-324	Failure Analysis	3 1 0	3
5	MSD-325	Material Characterization	3 1 0	3
6	MSD-326	Surface Engineering	3 1 0	3
7	MSO-327	Open Elective-II	3 1 0	3
8	MSD-328	Electronic Materials Lab.	0 0 3	2
9	MSD-329	Material Characterization Lab.	0 0 3	2
		TOTAL	Hrs 34	25

Fourth YEAR

VII Semester

SN	Code	Subject	L T P	Credits
1	MSD-411	Advanced Functional Oxide Materials	3 1 0	3
2	MSD-412	Semiconductor Devices and their Processing	3 1 0	3
3	MSE-413	Elective-I	3 1 0	3
4	MSE-414	Elective-II	3 1 0	3
5	MSD-415	Project-I	0 3 9	6
6	MSD-416	Industrial Training Viva**	0 0 0	3
7	MSD-417	Seminar-I	0 0 0	1
		TOTAL	Hrs 28	22

VIII Semester

SN	Code	Subject	L T P	Credits
1	MSD-421	Thin Film Technology	3 1 0	3
2	MSD-422	Composite Materials	3 1 0	3
3	MSE-423	Elective-III	3 1 0	3
4	MSE-424	Elective-IV	3 1 0	3
5	MSD-425	Project-II	0 3 9	6
6	MSD-426	General Proficiency	0 0 0	3
7	MSD-427	Seminar-II	0 0 0	1
		TOTAL	Hrs 28	22

**** Industrial training during summer vacation: 06-08 weeks duration**

Departmental Electives

Departmental Elective 1

SN	Code	Subject	L T P	Credits
1	MSE-413(a)	Light Metal & Alloys	3 1 0	3
2	MSE-413(b)	Electron Microscopy	3 1 0	3
3	MSE-413(c)	X-Ray Techniques	3 1 0	3

Departmental Elective 2

SN	Code	Subject	L T P	Credits
1	MSE-414(a)	Spectroscopy	3 1 0	3
2	MSE-414(b)	Computational Material Science	3 1 0	3
3	MSE-414(c)	Corrosion Engineering	3 1 0	3

Departmental Elective 3

SN	Code	Subject	L T P	Credits
1	MSE-423(a)	Nanodevices	3 1 0	3
2	MSE-423(b)	Electronic, and Optical Properties of Materials	3 1 0	3
3	MSE-423(c)	Non-Ferrous Metallurgy	3 1 0	3

Departmental Elective 4

SN	Code	Subject	L T P	Credits
1	MSE-424(a)	Materials for Green Energy	3 1 0	3
2	MSE-424(b)	Energy Storage Devices and Fuel Cells	3 1 0	3
3	MSE-424(c)	Electronic Ceramics	3 1 0	3

Summary

First Year:

07 Theory courses, **02** labs. courses in first semester and
06 theory courses, **03** labs. courses in second semester.

Second Year:

07 Theory courses,**02** labs. courses in third semester and
06 theory courses, **03** labs in fourth Semester.

Third Year:

06 Theory courses, **01** open elective course, **02**labs, courses in 5th semester and
06 Theory courses, **01** open elective course, **02** labs, courses, in 6th semester.

Fourth Year:

02Theory courses, **02** Departmental Electives courses, major project, Industrial training viva voce, and **01** Seminar in 7^{th} semester;
02Theory courses, **02** Departmental Electives courses, major project, General Proficiency and **01** Seminar in 8^{th} semester

Total number of electives = 14 (12 departmental electives and 02 open electives)

SUMMARY									
Semester	**Sem-1**	**Sem-2**	**Sem-3**	**Sem-4**	**Sem-5**	**Sem-6**	**Sem-7**	**Sem-8**	**Overall**
Credit	22	21	25	24	25	25	22	22	186
Hours/Week	33	33	34	33	34	34	28	28	257

[MSS-111] Engineering Mathematics I **3 Credits (3-1-0)**

Matrices: Matrices, Related matrices, Complex matrices (Hermitian and skew-Hermitian matrices, Unitary matrix), Solution of linear system of equations, Rank of a matrix, Gauss-Jordan method, Normal form of a matrix, Vectors, Linear dependence, Consistency of a linear system of equations, Rouche's theorem, System of linear homogeneous equations, Linear and orthogonal transformations, Characteristic equation, Eigen values, Eigen vectors, Properties of eigen values, Cayley-Hamilton theorem, Reduction to diagonal form, Quadratic form and their reduction to canonical form.

Infinite Series: Convergence and divergence of infinite series, Geometric series test, Positive term series, p-series test, [Comparison test, D'Alembert's ratio test, Cauchy's root test (Radical test), Integral test, Raabe's test, Logarithmic test, Gauss's test] (without proofs), Alternating series and Leibnitz's rule, Power series, Radius and interval of convergence.

Differential Calculus: Indeterminate forms, Partial Differentiation and its geometrical interpretation, Homogeneous functions, Euler's theorem and its extension, Total differentials, Composite function, Jacobian, Taylor's and Maclaurin's infinite series, Errors and increments, Introduction to limits and Indeterminate forms, Maxima and minima of functions of two variables, Method of undetermined multipliers. Curve tracing.

Integral Calculus: Quadrature, Rectification, Surface and Volume of revolution for simple curves, Double integrals and their applications, Change of order of integration, Change of variables, Triple integrals and their applications, Change of variables.

Vector Calculus: Differentiation of vectors, Curves in space, Velocity and acceleration, Relative velocity and acceleration, Scalar and vector point functions, Vector operator del, gradient, divergence and curl with their physical interpretations, Formulae involving gradient, divergence and curl. Line, surface and volume integrals, Theorems of Green, Stokes and Gauss (without proofs) and their verifications and applications, Irrotational and Solenoidal fields.

Books and References*:*

1. Advanced Engineering Mathematics: by Erwin Kreyszig, John Wiley and Sons, NC, New York.
2. Advanced Engineering Mathematics: by R. K. Jain & S. R. K Iyengar, Narosa Pub. House.
3. Engineering Mathematics: Through Applications, Paras Ram, CBS Publishers
4. Advanced Engineering Mathematics: by C. R. Wylie & L. C. Barrett, McGraw Hill
5. Differential & Integral Calculus: by N. Piskunov, MIR Publications.

[MSS-112] Physics I (Mechanics, Waves and Vibrations) 3 Credits (3-1-0)

Motion of a particle and special theory of Relativity: Co-ordinate Systems and Motion of a Particle : Volume, velocity and acceleration in Cartesian and Spherical co-ordinate systems. Solid angle.Space Time Symmetry, Relationship of conservation laws and symmetries of space and time. Inertial frames of reference. Galilean transformation and Galilean invariance.Non-inertial frames, Coriolis force and its applications.Focault's pendulum.Concept of stationary universal frame of reference and search for ether. Michelson- Morley experiment, postulates of special theory of relativity. Lorentz transformations.Observer in relativity.Relativity of simultaneity. Effects of Relativity: Length contraction. Time dilation.Relativistic addition of velocities. Relativistic Doppler effect. Variation of mass with velocity and mass energy equivalence. Increase of mass in an inelastic collision, Relativistic momentum and energies. Transformation of momentum , energy. Minkowsky space

Free and Damped Vibrations: Simple harmonic motion, energy of a SHO. Compound pendulum, Electrical oscillations. Transverse vibrations of a mass on a string, composition of two perpendicular SHM of same period and of period ratio1 : 2. Anharmonic oscillations. Decay of free vibrations due to damping. Differential equation of motion, types of damping. Determination of damping co-efficient-logarithmic decrement, relaxation time and Q-Factor. Electromagnetic damping (Electrical oscillator**)**

Forced and Coupled Oscillator: Transient and steady behaviour of forced oscillator. Displacement and velocity variation with driving force frequency. Variation of phase with frequency. Power supplied to an oscillator and its variation with frequency. Q- value and band width. Q-value as an amplification. Stiffness coupled pendulums. Normal co-ordinates and normal modes of vibration.Inductance coupling of electrical oscillators.

Books and References*:*

1. Mechanics, Berkley Physics Course Vol. 1, 2nd edition.
2. The Feynman Lectures in Physics, Vol 1, R.P. Feynman, R.B. Lighton and M sands, Indian Reprint available with BI Publications, Bombay
3. Mechanics, DS Mathur, S Chand and Company
4. The Physics of Vibrations and Waves by H.J.Pain (English Language Book Society)/ John Wiley and Sons.
5. Fundamentals of Vibration and Waves, S.P.Puri, Low Cost Student Edition, Tata Mc-Graw Hill Company, New Delhi.
6. Waves, Berkeley Physics course Vol. III, Frank S. Crawford Jr., Mc-Graw Hill Book Company.
7. University Physics, Francis W Sears, Mark W. Zemanasky, Hugh D. Young, 6th Edition, Addison Wesley, Indian Student Edition Available with Narosa Publishing House, N. Delhi.
8. Vibrations and Waves, I.J. Main, Cambridge University Press.
9. Vibration and Waves, AP French, CBS Publishers.

[MSS-113] Chemistry I (Physical Chemistry) 3 Credits (3-1-0)

Reaction Dynamics*:* Order and molecularity of a reaction, rate laws in terms of the advancement of a reaction, differential and integrated form of rate expressions up to second order reactions, experimental methods of the determination of rate laws, kinetics of complex reactions (integrated rate expressions up to second order): (i) Opposing reactions (ii) parallel reactions and (iii) consecutive reactions and their differential rate equations (steady-state approximation in reaction mechanisms) (iv) chain reactions.

Temperature dependence of reaction rates; Arrhenius equation; activation energy. Collision theory and activated complex theory of reaction rates, Lindemann mechanism.

Solution Chemistry and Analysis*:* Principles of electro-chemical methods. Electrochemical reactions and types of electrochemical cells.Arrhenius theory and Debye-Huckel-Onsager theory for electrolytes. Transport numbers and their calculation. Nernst equation. Application of EMF and conductometric measurements in determining (i) free energy, enthalpy, entropy and kinetic parameters of reactions, (ii) equilibrium constants, and (iii) solubility limits of different salts. Commonly used electrode types and their functioning. Concentration cells with and without transference. Liquid junction potential; determination of activity coefficients and transference numbers.Detailed qualitative discussion of potentiometric/conductometric titrations (acid-base, redox, precipitation).

Books and References*:*

1. Barrow, G. M.; Physical Chemistry, Tata McGraw-Hill, 2007.
2. Castellan, G. W.; Physical Chemistry, Narosa, 2004.
3. Laidler, K. J.; Chemical Kinetics, Prentice Hall, 3rd Ed., 1997.
4. Bard, A. J.; Faulkner, L. R. Electrochemical Methods: Fundamentals and Applications, 2nd Ed., John Wiley and Sons, New York, 2002.
5. Koryta, J.; Dvorak, J.; Kavan, L. Priniciples of Electrochemistry, John Wiley and Sons; New York, 1993.

[MSS-121] Engineering Mathematics II **3 Credits (3-1-0)**

Fourier Series: Euler's formula, Conditions for a Fourier expansion, Functions having points of discontinuity, Change of interval, Odd and even periodic functions, Expansion of odd and even periodic functions, Half-range series, Typical wave-forms, Parseval's formula, Practical harmonic analysis.

Ordinary Differential Equations: Brief review of first order ordinary differential equations, Exact equations, Equations reducible to exact equations, Equations of the first order and higher degree, Clairaut's equation, Applications of differential equations of first order (Orthogonal trajectories). Linear differential equations with constant co-efficients, Complimentary functions and particular integral, Method of variation of parameters, Equations reducible to linear equations with constant co-efficients (Cauchy's and Legendre's linear equations), Simultaneous linear equations with constant co-efficients, Applications of linear differential equations in engineering.

Complex Numbers: 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.

Functions of Complex Variable: Limit and derivative of complex functions, Cauchy-Riemann equations, Analytic functions and its applications, Geometrical representation of complex function, Conformal mapping and standard transformations, Complex integration, Cauchy's theorem, Cauchy's integral formula, Series of complex terms, Taylor's and Laurent's series, Cauchy's residue theorem and its application for the evaluation of real definite integrals.

Integral Transforms: Laplace Transforms of standard functions and their properties, Inverse Laplace Transforms, General Properties of inverse Laplace transforms and Convolution Theorem, Laplace Transforms of periodic functions, Bessel functions, Error function,Dirac-delta Function, Heaviside's Unit Function, Applications to linear simultaneous differential equations.

Books and References*:*

1. Advanced Engineering Mathematics: by Erwin Kreyszig, John Wiley and Sons, NC, New York.
2. Advanced Engineering Mathematics: by R. K. Jain & S. R. K Iyengar, Narosa Pub. House.
3. Engineering Mathematics: Through Applications, Paras Ram, CBS Publishers
4. Advanced Engineering Mathematics: by C. R. Wylie & L. C. Barrett, McGraw Hill.
5. Vector Calculus: by C. E. Weatherburn. John Wiley and Sons, NC, New York.
6. Complex variables and Applications: by R. V. Churchill, T. J. Brown & R. F. Verhey, McGraw Hill.
7. Differential Equations: by Shepley L. Ross, John Wiley & Sons, New York.

[MSS-122] Physics II (Electricity and Magnetism) 3 Credits (3-1-0)

Ideas of Vector Calculus: Scalar and vector fields, Differentiation of vector with respect to scalars, gradient, divergence, curl operations and their meaning. Idea of line, surface and volume integrals, Gauss, Stokes and Green's theorems, General orthogonal coordinates, expressions for gradient, div and curl in Cartesian, spherical and cylindrical co-ordinates (no derivation).

Electric Potential: Electric potential due to a dipole and quadrupole, long uniformly changed wire, charged disc. Electric potential energy. Curl of a vector field, stokes theorem (with proof) and its application to electrostatic field (Curl E = zero). Electric field as gradient of a scalar potential, calculation of electric field due to a point charge and a dipole from potential. Potential due to charge distribution and multiple moments. Method of Electrical images, Calculation of electric potential and field due to point charge placed near an infinite conducting sheet. Poisson and Laplace Equations (Derivation only).

Magnetic Field: Ampere circuital law and its applications, Hall Effect, Expression for Hall constant and its significance. Divergence and curl of magnetic field B. Vector potential: Definition of vector potential A.Definition of Surface current density and its use in calculation of change in magnetic field at a current sheet.

Electrostatic Fields in Dielectrics: Polarization of matter. Atomic and molecular dipoles, induced. Dipole moment and atomic polarizability. Electric susceptibility and polarization vector Capacity of a capacitor filled with Dielectrics. Dielectrics and Gauss's law Displacement vectorEstablishment of relation $\nabla D = \rho$ free . . Energy stored in a dielectric medium.

Magnetic Fields in Matter: Behavior of various substances in magnetic fields. Definition of M and H and their relation to free and bound currents.Magnetic permeability and susceptibility and their interrelation.Orbital motion of electrons and diamagnetism.Electron spin and paramagnetic.Ferromagnetism.Domain theory of ferromagnetism, magnetization curve, hysterics loss, ferrites.

Books and References*:*

1. Fundamentals of Electricity and Magnetism, Arthur F. Kip, International Student Edition, McGraw-Hill, Kogakusha Ltd.
2. Introduction to Electrodynamics, D.J. Griffth, 3rd Edition, Prentice Hall of India.
3. Electricity and Magnetism, Berkeley Physics course Vol. II, by E. M. Purcell, Mc-Graw Hill Book Company.
4. Electricity and Magnetism, M. L. Narchal, Panjab University Publication Bureau Chandigarh. 5. Electricity and Magnetism, A S Mahajan and A ARangwala, Tata Mc-Graw Hill Company.
5. Electricity and Magnetism, BrijLal and Subramanium, S Chand & Co.
6. Applied Mathematics for Engineers and Physicists by Pipes. 8. Mathematical methods for Physicists by G. Arfken

[MSS-123] Chemistry II (Inorganic Chemistry) 3 Credits (3-1-0)

Ionic Bonding*:* General characteristics of ionic bonding. Energy considerations in ionic bonding, lattice energy and solvation energy and their importance in the context of stability and solubility of ionic compounds.Statement of Born-Landé equation for calculation of lattice energy, Born Haber cycle and its applications, polarizing power and polarizability.Fajan's rules, ionic character in covalent compounds, bond moment, dipole moment and percentage ionic character.

Covalent bonding*:* VB Approach: Shapes of some inorganic molecules and ions on the basis of VSEPR and hybridization with suitable examples of linear, trigonal planar, square planar, tetrahedral, trigonalbipyramidal and octahedral arrangements.

Concept of resonance and resonating structures in various inorganic and organic compounds. MO Approach: Rules for the LCAO method, bonding and antibonding MOs and their characteristics for s-s, s-p and p-p combinations of atomic orbitals, nonbonding combination of orbitals, MO treatment of homonuclear diatomic molecules of 1st and 2nd periods.

Coordination Chemistry*:* Inner and outer orbital complexes of Cr, Fe, Co, Ni and Cu (coordination numbers 4 and 6). Structural and stereoisomerism in complexes with coordination numbers 4 and 6. Drawbacks of VBT.IUPAC system of nomenclature. Crystal Field Theory : Crystal field effect, octahedral symmetry. Crystal field stabilization energy (CFSE), Crystal field effects for weak and strong fields. Tetrahedral symmetry.Factors affecting the magnitude of D. Spectrochemical series.Comparison of CFSE for Oh and Td complexes, Tetragonal distortion of octahedral geometry.Jahn-Teller distortion, Square planar coordination.

Books and References*:*

1. Huheey, J. E.; Inorganic Chemistry, Prentice Hall, 1993.
2. Shriver, D. F. & Atkins, P. W.; Inorganic Chemistry, Oxford University Press.
3. Lee, J. D.; A new Concise Inorganic Chemistry, ELBS.
4. Cotton, F. A. & Wilkinson, G,; Advanced Inorganic Chemistry. Wiley-VCH, 1999.
5. Greenwood, N.N. &Earnshaw A.; Chemistry of the Elements, Butterworth-Heinemann,1997.

[MSS-211] Engineering Mathematics III **3 Credits (3-1-0)**

Partial Differential Equations: Formation and solutions of partial differential equations, Lagrange's linear equation of the first order, Non-linear equations, Charpit's method, Homogeneous linear equations with constant co-efficients, Non-homogeneous linear equations, Nonlinear equations of the second order (Monge's method), Method of separation of variables, Solution of wave equations, Heat flow equations, Laplace's equations and transmission line equations and their applications to engineering problems.

Special Functions: Series solutions about ordinary and singular point, Series solutions of Bessel's and Legendre's equations, Bessel's functions and Legendre's, polynomials, Modified Bessel's functions, Recurrence relations, generating functions and orthogonal properties, Equations reducible to Bessel's equation, Ber and Bei functions.

Integral Transforms: Definitions and Types of Integral Transforms, Application of Laplace transform to IVP and BVP, Periodic functions, Fourier transforms, Finite Fourier Sine and Cosine Transforms, Properties of Fourier Transforms, Applications of Integral Transforms to simple engineering problems. Hankel Transforms and its applications

Fundamental Concept of Probability: Mutually Exclusive , Independent events, Conditional probability, Tree diagram, Algebra of events, Multiplication rule, Baye's rule , Series and Parallel system, product law of reliability and unreliability.

Probability Distributions: Introduction to discrete and continuous Random variables, probability functions, probability density function, cumulative distribution function and their properties, two dimensional random variables, joint distribution of several random variables ,cumulative marginal and conditional distribution functions, Expected value. Bernoulli Trials, Binomial Distribution, Poisson and Normal Distribution, Expected value and variance of continuous and discrete random variables.

Books and References*:*

1. Advanced Engineering Mathematics: by Erwin Kreyszig . John Wiley and Sons, NC, New York.
2. Engineering Mathematics: Through Applications, Paras Ram, CBS Publishers
3. Partial Differential Equation for Engineers and Scientists: by J.N. Sharma and Kehar Singh
4. Narosa Publishing House, New Delhi/ Alpha Science Int. Ltd, UK.
5. Engineering Mathematics, Babu Ram, Pearson
6. Advanced Engineering Mathematics: by R. K. Jain & S. R. K Iyengar, Narosa Pub. House.
7. Elements of Partial Differential Equations: by Ian N. Sneddon, McGraw-Hill, Singapore.
8. Differential Equations: by Shepley L. Ross, John Wiley & Sons, New York.
9. Advanced Engineering Mathematics by Chandrika Prasad.
10. Higher Engg. Mathematics, B. V. Ramana TMH

[MSD-212] Basic Materials Science and Engineering 3 Credits (3-1-0)

Crystal bondings– Ionic bond, covalent bond, molecular bond, hydrogen bond, metallic bond & Van der waals bond.

Crystalline and noncrystalline materials – Crystal structure, space lattice, unit cell, crystal systems, atomic packing factor, Co-ordination numbers,crystal structure for metallic elements,Crystal directions &Planes, miller indices, stacking sequence in HCP & FCC.

Defects in crystalline Materials: Point, line, surface and volume defects

Basic characterization techniques: (X-rays and optical microscopy).

Phase Diagram: Phase diagrams, diffusion and phase transformation.

Mechanical properties: stress strain curves, elastic modulus, plastic deformation, slip, dislocation motion, critical resolved shear stress, strengthening mechanisms. Introduction tofatigue and creep properties of materials.

Electrical and magnetic properties of materials: Distinction between conductors, semiconductors and insulators, Brief summary of Free electron theory and Band Theory, Dielectric Materials with a brief introduction to ferroelectrics, Magnetic materials.

Books and References*:*

1. Fundamentals of Materials Science and Engineering, 5th Edition, W D Callister Jr., John Wiley and sons, 2001.
2. Essentials of Materials for Science and Engineering by Donald R. Askeland and Pradeep P. Phule, 2004.
3. The Science and Engineering of Materials, Donald R. Askeland (Chapman & Hall)
4. Materials Science and Engineering, V. Raghvan

[MSD-213] Polymer Science & Technology **3 Credits (3-1-0)**

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.

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.

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 ofpolymers, polymer blends, polymers for biomedical applications.

Processing of Polymers: Flow properties of polymers, Extrusion, Injection and blow moulding. Calendaring, Vacuum & pressure forming and warm forging. Casting of fibers and filaments. Assembly by adhesion.

Properties in Service Environments : Effects of vapours andsolvents on polymeric materials. Oxidation and thermal degradation of polymers.Solubility,permeability, radiation damage and chemical resistance of polymers.

Books and References:

1. Textbook of Polymer Science - Billmeyer F, Wiley Interscience, 1994
2. Principles of Polymer Chemistry P.J. Flory, Cornell University Press.
3. Polymers: Chemistry and Physics of Modern Materials, J.M.G. Cowie, Blackie Academic andProfessional.
4. Principles of Polymerization, G. Odion, John Wiley publishers.
5. Polymer Science, V.R. Gowariker, N.V. Viswanathan and J. Sreedhar, Wiley-Eastern.

[MSD-214] Ceramics Science & Technology **3 Credits (3-1-0)**

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.

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.

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, cermets

Glasses: Types of glasses - structure, properties and applications of various types of glasses. SilicateGlass ceramics- heat flow and precipitation from glasses – growth controlled by diffusion of solutes – crystalline glasses – enamels – photosensitive and photochromic glasses ; Blowing, pressing, drawing, rolling and casting - Pilkington process for float glass.

Property Evaluation: Rupture strength; fracture Toughness, Elastic Constants, Hardness, Creep, Thermal PropertyCoefficient of thermal expansion, Electronic Property, Measurement of electro-optic properties Weibull Statistics of Strength Data for Fine Ceramics

Books and References:

1. Introduction to Ceramics W.D. Kingery, H.K. Bowen, D.R. Ulhmann
2. Introduction to Ceramics, W. D. Kingry (Jhon-Wiley)
3. Introduction to Ceramics, M. N. Rahman

[MSD-215] Strength of Materials **3 Credits (3-1-0)**

Stress, Strain and Deformation of Solids: Rigid bodies and deformable solids – Tension, Compression and Shear Stresses –Deformation of simple and compound bars – Thermal stresses – Elastic constants –Volumertric strains – Stresses on inclined planes – principal stresses and principal planes– Mohr's circle of stress.

Transverse Loading on Beams and Stresses in Beam: Beams – types transverse loading on beams – Shear force and bending moment in beams –Cantilevers – Simply supported beams and over – hanging beams. Theory of simple bending– bending stress distribution – Load carrying capacity – Proportioning of sections – Flitchedbeams – Shear stress distribution.

Torsion: Torsion formulation stresses and deformation in circular and hollows shafts – Stepped shafts– Deflection in shafts fixed at the both ends – Stresses in helical springs – Deflection of helicalsprings, carriage springs.

Deflection of Beams: Double Integration method – Macaulay's method – Area moment Theorems for computationof slopes and deflections in beams - Conjugate beam and strain energy – Maxwell's reciprocaltheorems.

Thin Cylinders, Spheres and Thick Cylinders: Stresses in thin cylindrical shell due to internal pressure circumferential and longitudinalstresses and deformation in thin cylinders – spherical shells subjected to internal pressure –Deformation in spherical shells – Lame's theory – Application of theories of failure.

Books and References:

1. Hibbeler, R.C., Mechanics of Materials, Pearson Education, Low Price Edition, 2007
2. Ferdinand P. Been, Russell Johnson, J.r. and John J. Dewole Mechanics of Materials, Tata Mcgraw Hill publishing 'co. Ltd., New Delhi.2007
3. Bansal, R.K., Strength of Materials, Laxmi Publications (P) Ltd., 2007
4. Jindal U.C., Strength of Materials, Asian Books Pvt. Ltd., New Delhi, 2007.

[MSD-216] Thermodynamics of Materials **3 Credits (3-1-0)**

Introduction and Basic Concepts: Scope, application, importance in Metallurgical Engineering, state of system, thermodynamic equilibrium, properties of system.

First Law of Thermodynamics: Internal Energy, Enthalpy, Heat Capacity, Cp&Cv, Hess Law, Kirchoff's Law, Numerical Problems.

Second Law of Thermodynamics: Limitations of First Law, Various statements of 2nd law, Carnot theorem, Carnot cycle, Entropy, free energy, Gibbs Helholtz equations, Maxwell's relationships, Statistical concept of entropy, Numerical problems.

Third law of Thermodynamics

Thermodynamic Variables: Activity, fugacity & Equilibrium Constant, Chemical Potential and Numerical problems involving thermodynamic variables

Single Component Systems: Clausis –Clapyron equations, Numerical Problems

Phase Rule & Ellingham Diagrams: Temperature/free energy diagrams for Oxides, Sulphides& Halides.

Solutions: Partial Molar properties, Gibbs Duhem equation, Ideal-Non Ideal solutions, Raoult's Law, Henry law, Sieverts law, Regular solutions, Interaction parameter, Interaction coefficient and Numerical problems.

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.

Books and References:

1. Gaskel, Introduction to Metallurgical Thermodynamics, Mcgraw Hill, 2004
2. Textbook of Materials and Metallurgical Thermodynamics, A. Ghosh (PHI)
3. DeHoff R T, Thermodynamics in Materials science, McGrawhill, Newyork 1993.
4. Prasad, Krishna Kant, Ray, H. S. and Abraham, K. P., "Chemical and MetallurgicalThermodynamics", New Age International, 2006
5. Upadhyaya, G. S. and Dube, R. K., "Problems in Metallurgical Thermodynamics andKinetics", Pergamon Press, London, 1977.

[MSD-217] Transport Phenomena **3 Credits (3-1-0)**

Fluid Mechanics: Properties of fluids such as density, viscosity and specific weight. Fluid statics - Pressure at apoint - Pressure variations in horizontal and vertical directions - Concept of gauge and absolutepressure. Use of manometer for pressure measurements. Introduction to Hydrostatic Forces.

Energy Balance in Fluid Flow: Types of flow - continuity equation - Application to one dimensional problems. Derivation of Bernoulli's equation and Euler's equation.

Internal and External Flow: Classification of flow - Reynolds number - Laminar flow between parallel plates and circularpipes - Simple problems.

Pressure in Fluid Flow: Head loss due to friction -Darcy - Weisbach equation - flow through pipes - use of Moody diagram - Minor losses - Simple problems.

Conduction Heat Transfer: Steady state heat conduction - simple examples. Transient heat conduction - Systems withnegligible internal resistance - Lumped heat analysis - Response time of a temperature measuring instrument - System with negligible surface resistance- heat flow in an infinitely thinplate (Semi infinite body) - System with finite surface and internal resistance - Chart solutionsof transient heat conduction problems – Examples on Heat Treatment

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 boundarylayers (no derivation) - Simple problems – Boundary layer development in a circular duct (noderivation) - Flow over cylinders and spheres-Simple problem- applications in metallurgicalprocesses.

Radiation Heat Transfer: Nature of thermal radiation, Concept of Black body, Emissive power – Gray body – Shapefactor - Simple problems on Radiation heat transfer between surfaces. Introduction to Gas radiation.

Mass Transfer: Diffusion mass transfer. Simple problems using Fick's law of diffusion.Introduction to convective mass transfer-Introduction to computational fluid dynamicssoftware.

Books and References:

1. Transport Phenomena in Materials Processing/Geiger & Poirier/ John Wiley & Sons.
2. Kothandaraman C.P. and Rudramoorthy, R., "Basic Fluid Mechanics", New Age International Publishers, Chennai 1998,
3. Sachdeva, R C," Fundamentals of Engineering Heat and Mass Transfer", New AgeInternational Publishers, New Delhi, 1996.
4. Byron Bird R, W E Shawart, "Transport Phenomena", John-Wiley & Sons Inc,1994.

[MSD-218] Basic Materials Science Laboratory 2 Credit (0-0-3)

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 and determine vacancy migration and vacancy formation energy.
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 determine the percentage of moisture in a given sample of Rock/Charcoal/Soil/Seeds, using Infra-Red moisture balance method as well as crucible method.

[MSD-219] Strength of Materials Laboratory **2 Credit (0-0-3)**

1. To perform tensile test in ductile and brittle materials and to draw stress-strain curve and to determine various mechanical properties
2. Ball milling and pellet pressing.
3. To study the Impact testing machine and perform the Impact tests (Izod&Charpy).
4. To perform shear test on different materials and determine ultimate shear strength.
5. To perform any one hardness test (Rockwell, Brinell&Vicker's test) and determine hardness of materials.
6. To perform torsion test and to determine various mechanical properties.
7. To perform bending test on beam (wooden or any other material) and to determine the Young's modulus and Modulus of rupture.
8. Determination of Bucking loads of long columns with different end conditions
9. To draw shear Force, Bending Moment Diagrams for a simply Supported Beam under point and distributed Loads.
10. To prepare the composite specimen and then test on ultimate tensile machine.

[MSS-221] Numerical Analysis & Computational Methods 3 Credits (3-1-0)

Programming Fundamentals & Techniques: Steps in program development, algorithm, flowchart, psuedocode, evolution and classification of programming languages, Basics of mathematical programming languages such as FORTRAN, MATLAB, C, C++ etc.

Numerical Computations and Errors Analysis : Introduction, Numbers and their accuracy, Floating point arithmetic, errors in numbers, Computational methods for error estimation, General error formulae-approximation of a function, series approximations and error propagation in computation.

Algebraic and Transcendental Equations: Revision of some basic concepts on polynomial equations, Bisection method, iterative method, Regula-falsi method, Newton-Raphson method, Secant method, Generalized Newton's method for multiple roots, solution of non-linear simultaneous equations and finding complex roots by Newton-Raphson method.

System of Simultaneous Algebraic Equations: Solution of system of algebraic linear equations-Gauss elimination method, Jacobi's method and Gauss-Seidal method, Eigen values and eigen vectors-Power method, Jacobi's method and Householder method.

Interpolation and Function Approximations: Least square curve fit and trigonometric approximations, Approximations by trigonometric polynomials and quality of approximations, Finite differences and difference operators, Newtons interpolation formulae, Gauss forward and backward formulae, Sterling, Bessel's and Evertte's formulae, Interpolation with unevenly spaced data points-Lagrange's interpolation.

Numerical Differentiation and Integration: Numerical differentiation, errors in numerical differentiation, Maximum and minimum values of a tabulated function, Numerical integration- Trapezoidal, Simpson's 1/3 and 3/8 rules, Boole's and Weddle's rules, Romberg integration- recursive formulae, Evaluation of double integrals by Trapezoidal and Simpson's rules.

Ordinary Differential Equations: Taylor's series method, Picard's method, Euler's method, Modified Euler's method, Runge- Kutta methods of 2^{nd} and 4th order, Adams- Moltan and Miline methods, Solution of simultaneous and higher order equations. Finite Difference Method to solve ordinary differential equation.

Applications of Programming and Numerical methods to solve various problems related to material science engineering.

Books and References*:*

1. Numerical Methods for Engineers and Scientists :J.N. Sharma, Narosa Publishers
2. Numerical Analysis : F. B. Hildbrand
3. Numerical Method for Engineers and Scientists : Jain, lyngar and R. K. Jain, Narosa
4. Introductory Methods of Numerical Analysis :S.S. Sastry, PHI
5. Programming with C : Byron GottFried
6. An Introduction to Programming and Numerical Methods in MATLAB: Otto & Denier
7. Numerical Analysis using MATLAB, Rizwan Butt, Infinity Science Press.
8. Numerical Methods, Srimanta Pal, Oxford.

[MSD-222] Material Processing Techniques **3 Credits (3-1-0)**

Solidification from Liquid and Vapor Phase; Basics of heat flow: plane front solidification of single phase and poly phase alloys, dendritic solidification, cellular solidification; Nucleation and growth, Homogeneous and heterogeneous nucleation, Interface stability, Development of micro structure, Faceted and nonfaceted structure, Super cooling, Equilibrium phase diagrams, Eutectic and peritectic solidifications and their microstructures

Casting Processes: Application and advantages of metal casting processes and classification of foundries. Types of patterns, patterns materials patterns allowances, and color codification. Mould and Core making: Ingredients: sand, clay, binders, and moisture, characterization of moulding sand, general requirement, and sand conditioning. Classification of moulding methods based on technique used viz., green sand, dry sand, CO2 process, shell moulding etc. and machine moulding, floor and pit moulding. Feeder and Riser Design in Casting; Fluidity; Shrinkage; Defects in different casting techniques such as: Sand casting, investment casting, pressure die casting and others.

Powder processing: Production of metallic, Ceramic and composite powders, Recent developments in powder production, Mechanical alloying, Development of nanostructures and composite materials via powder processing route, Powder Compaction and Consolidation; Cold Isotactic Pressing. Sintering and full density processing; Solid-State Sintering; Liquid phase sintering; Pressure-Assisted Sintering.

Metals Joining Processes: Welding processes- gas, arc, resistance and plasma welding, welding consumables: flux, gas, electrode, fillet weld, butt weld, weld thermal cycle, weld testing, microstructure, and weld properties. Scope of micro joining, resistance-spot, laser welding, ultrasonic welding, micro-plasma welding, Metallurgical principles involved in welding of carbon, alloy steels and important nonferrous alloys such as aluminum and magnesium. Welding defects and their remedies: micro-structural features of Heat Affected Zone (HAZ) and their effect on mechanical properties.

Books and References:

1. M.C. Flemmings, Solidification Processing, McGraw-Hill College, 1974.
2. Chalmner, B., Principles of Solidification, Wiley (1977)
3. W. Kurz and D.J. Fisher, Fundamentals of Solidification, CRC Press, 1998.
4. . Degarmo, E.P., Black, J.T. Kosher R.A, Materials and Processing in Manufacturing, PHI (1986).
5. R.M. German, Powder Metallurgy Science, 2008.
6. A. Upadhyaya, G.S. Upadhyaya, Powder Muetallurgy: Science Technology and Materials, 2011

[MSE-223] Iron and Steel Making **3 Credits (3-1-0)**

Raw Materials and Burden Preparation: 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.

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, material and heat balance- Sponge Iron making.

Principles of Steel Making: Development of steel making processes, physico-chemical principles and kinetic aspects of steelmaking, carbon boil, oxygen transport mechanism, desulphurisation, dephosphorisation, SlagTheories, slag-functions, composition, properties and theories, raw materials for steel making and plant layout

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.

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.

Books and References

1. Tupkary, R. H., "Modern Iron Making", 4th edition, Khanna Publishers, New Delhi.
2. Tupkary, R. H., "Modern Steel Making", 4th Edition, Khanna Publications, New Delhi.
3. Biswas, A. K., "Principles of blast furnace iron making: theory and practice", SBA Publications, Kolkata, 1994.
4. Bashforth, G. R., "Manufacture of Iron and Steel", Vol. I, Chapman and Hall London, 1964.
5. Bashforth, G. R., "Manufacture of Iron and Steel", Vol.2, 3rd Edition, Chapman & Hall, London, 4. 1964

[MSD-224] Mechanical Behavior of Materials **3 Credits (3-1-0)**

Concepts of Stress and Types of Stress: Concepts of Stress and types of Stresses, Concepts of Strain and types of Strain, Units of stress and other quantities.

Elastic, Anelastic and Viscoelastic Behavior: Elastic behaviour: Atomic model of elastic behaviour, The modulus as a design parameter, Rubber like elasticity. Anelastic behavior: Relaxation Processes. Viscoelastic behaviour: spring dashpot models.

Stress and Strain Relationships for Elastic Behaviour: Description of stress at a point, state of stress in two dimensions, state of stress in three dimensions, Description of strain at a point, Hydrostatic component of stress, Elastic Stress – Strain relations, Calculation of Stresses from Elastic Strains, Strain Energy, Anisotropy of Elastic behaviour, Stress Concentration

Plasticity of Materials: The Flow Curve, True Stress and True Strain, Yielding and plastic flow, Dislocations the basis for yield.

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.

Micro-Plasticity of Crystals: Slip planes and slip directions, resolved shear stress, strain hardening and recovery of single crystals, Twinning, Grain boundary sliding and diffusional creep.

Plastic Deformation: Grain boundaries, Strain hardening, strain aging, The tensile stress strain curve: temperature dependence, strain rate, strain rate and temperature, Creep.

Cold Worked Structure: Recovery, Recrystallization and Grain Growth.

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.

Fracture: Types of fracture- ductile fracture, brittle fracture; Theoretical fracture stress, Griffith theory, Orowan Theory, Comparison with equation based on stress concentration Crack velocities; Inglis equation; 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.

Books and References:

1. The structure and properties of materials, volume III, Mechanical Behaviour/H.E Hayden, William G Moffatt, John Wulff /Willey Eastern Ltd. 1986.
2. Mechanical Metallurgy/G.E Dieter adapted by David Bacon/ McGraw-Hill Book Company 1988.
3. Dislocations and mechanical behavior of materials/ M.N.Shetty/ PHI Learning Pvt. Ltd. 2013
4. Mechanical Behavior of Materials/ Marc André Meyers, Krishan Kumar Chawla/Cambridge University Press 2009.

[MSD-226] Physical Metallurgy **3 Credits (3-1-0)**

Structure of Metals and Alloys: Nature of metallic bonding, crystal structure of metals-Miller indices, Miller-Bravais indices, structure of alloys-Types of solid solutions, Hume Rothery Rules.

Imperfections in Crystals: Point imperfections, Dislocations, High angle boundaries, Interaction between crystal imperfections.

Equilibrium Diagrams: The Phase rule, Isomorphous systems, Lever rule, Coring, Eutectic system, Eutectoid, Peritectic, Peritectoid, Monotectic and Syntectic reactions, Micro structural changes during cooling-slow and non-equilibrium cooling, Study of Fe-Fe3C, Cu-Zn, Al-Si Binary diagrams, Numerical problems.

Solidification in Metals: Energetics of solidification, Nucleation and Growth, Homogeneous Nucleation, Heterogeneous Nucleation, Growth of solid, Smooth or Stable interface growth, Temperature inversion in pure metals-Dendritic growth in pure metals, Constitutional Supercooling, Dendritic Growth in Alloys, Freezing of Ingots, Segregation, Porosity.

Diffusion in Solids: Diffusion mechanisms, Fick's laws and their applications in various Metallurgical phenomena, Kirkendall effect, Numerical problems.

Engineering Alloys: Ferrous Alloys and Nonferrous Alloys.

Books and References:

1. Physical Metallurgy Principles. Reza Abbaschian, Lara Abbaschian and Robert Reed-Hill, Cengage Learning India, 2013.
2. Fundamentals of Materials Science and Engineering, 5th Edition, W D Callister Jr., John Wiley and sons, 2001.
3. S. H. Avner, Introduction to Physical Metallurgy, McGraw Hill, 1987.

[MSD-227] Material Processing Laboratory **2 Credit (0-0-3)**

1. Preparation of green sand mould.
2. To estimate AFS grain fineness number for dry silica sand.
3. To estimate the clay content in the sand.
4. To estimate the moisture content in the green sand.
5. To estimate the permeability of the green sand.
6. To estimate hardness, compressive, shear and tensile strength for core sand.
7. To estimate refractoriness of the sand.
8. To study the effect of gas and arc welding processes on microstructure and hardness of given steel samples
9. To study the effect of various parameters of soldering and brazing processes on strength of joint.
10. To study the effect of TIG and MIG welding processes on microstructure and hardness of given metallic samples.

[MSD-228] Physical Metallurgy Laboratory 2 Credit (0-0-3)

1. To study design, principle and application of basic tools of wide use to a Metallurgist such as metallurgical microscope, hardness tester, image analyzer.
2. To study design, principle and application of furnace and thermocouple
3. To study design, principle and application of scanning electron microscope.
4. Introduction of metallographic sample preparation.
5. To study and compare the difference between solidification behavior of pure metal and an alloy.
6. Qualitative and Quantitative metallographic analysis and establishing correlation with phase diagram of the given alloy system:
    a. Recognition of the phase and state of material from the microstructure.
    b. Finding out the weight % of carbon in ferrous alloys from the microstructure w.r.t Hypo-, Hyper- phases and their morphologies.
7. Alloy Development:
    a. To study the effect on microstructure and mechanical property.
    b. To study the solidification defects such as segregation, porosity etc.
8. To observe the line defects in given samples
9. To observe the surface defects in given samples.
10. To observe the volume defects –metallographic observation of dislocations, grain boundaries, twin boundaries, inclusions and precipitates in given samples.

[MSS-229] Computational Methods Laboratory **2 Credit (0-0-3)**

To develop computer program for following methods using MATLAB/FORTRAN/C/C++

1. Numerical Solution of Algebraic/Trans dental equations by Bisection and False position method.
2. Numerical Solution of Algebraic/Trans dental equations by Newton Raphson method.
3. Numerical solution of linear system of equations by direct methods(Cramer's rule, Elimination methods)
4. Numerical solution of linear system of equations by iterative methods(Jacobi and Gauss Seidal method)
5. Numerical Integration: Trapezoidal rule, simpson's rule, double integration
6. Interpolation: Forward, Backward and central interpolation
7. Numerical differentiation using finite difference approximation.

[MSD-311] Nanomaterials **3 Credits (3-1-0)**

Introduction to Nanomaterials: Amorphous, Crystalline, microcrystalline, quasicrystalline and nanocrystalline materials- historical development of nanomaterials – Nanomaterials classification (Gleiter's Classification), Bottom up and Top Down approach, Properties of Nanomaterials, Quantum Confinement, Density of State, Zero dimension, one dimension and two dimensional nanostructures

Physical Methods: Inert gas condensation, Arc discharge, RF-plasma, Plasma arc technique, Ion sputtering, Laser ablation, Laser pyrolysis, Ball Milling, Molecular beam epitaxy, Chemical vapor deposition method and other variants, Electrodeposition.

Chemical Methods: Metal nanocrystals by reduction, Solvothermal synthesis, Photochemical synthesis, Electrochemical synthesis, Nanocrystals of semiconductors and other materials by arrested precipitation, Thermolysis routes, Sonochemical routes, , Liquid-liquid interface, Hybrid methods, Solvated metal atom dispersion, Post-synthetic size-selective processing. Sol-gel, Micelles and microemulsions, Cluster compounds.

Biological Methods of Synthesis: Use of bacteria, fungi, Actinomycetes for nanoparticle synthesis, Magnetotactic bacteria for natural synthesis of magnetic nanoparticles; Mechanism of formation; Viruses as components for the formation of nanostructured materials; Synthesis process and application, Role of plants in nanoparticle synthesis

Lithographic Techniques : AFM based nanolithography and nanomanipulation, E beam lithography, Ion beam lithography, oxidation and metallization. Mask and its application. Deep UV lithography, X-ray based lithography.

Groups of Carbon: Fullerenes, Carbon Nanotubes, Types of Carbon Nanotubes, Functionalization of Carbon nanotubes, Properties and Synthesis of Carbon nanotubes.

Thin Films: Electro plating, Electroless plating, Langmuir-Blodget films, Thermal growth, Chemical vapour deposition, sputtering deposition, molecular beam epitaxy atomistic nucleation process, cluster coalescence and deposition, grain structure of films and coatings, amorphous thin films.

Books and References:

1. Carl C. Koch (ed.), NANOSTRUCTURED MATERIALS, Processing, Properties and Potential Applications, NOYES PUBLICATIONS, Norwich, New York, U.S.A.
2. Bhusan, Bharat (Ed), "Springer Handbook of Nanotechnology", 2nd edition, 2007
3. Mark Ratner and Daniel Ratner, "Nano Technology", Pearson Education, New Delhi, 2003.
4. Charles P. Poole Jr., Frank J. Ownes, 'Introduction to Nanotechnology", Wiley Interscience, 2003.
5. G. Wilde, "Nanostructured Materials', Elsevier, 2008.
6. Bamberg, D., Grundman, M. and Ledentsov, N.N., "Quantum Dot Heterostructures", Wiley, 1999.
7. G Timp (ed), "Nanotechnology", AIP press/Springer, 1999.

[MSD-312] Phase Transformation and Heat Treatment 3 Credits (3-1-0)

Introduction: Phase transformations: An overview, concepts of surface and interface energy.
Diffusion: Concept of diffusion, Fick's laws of diffusion, Kirkendell effect
Solidification: Theory of Nucleation, Homogeneous and Heterogeneous Nucleation, Nucleation Kinetics, Growth Kinetics, Different types of Diffusion Growth. Nucleation and Grain size, Super Cooling, Directional Solidifications, and Segregations.
Iron -Cementite Phase Diagram: Phase Transformation in Steel on heating and cooling, Austenitic Grain Growth on heating, Determination of Grain Size, Isothermal Transformation Diagrams, Perlite, Bainite and Martensitic Transformations, Transformation of Austenite on Continuous Cooling.
Principles of Heat Treatment of Metals: Annealing, Normalizing, Hardenability, Hardening, Tempering, Hardenability, Mechanism of Heat removal during Quenching, Quenching media, Residual stresses and Quench Cracks, Martempering and Austempering, Purpose of alloying, Effect of alloying on Fe-Fe3C Phase Diagram, Temperature Time Transformation (TTT) and Continuous Cooling Transformation(CCT) Plots
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
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.
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.

Books and References:

1. Phase Transformations in Metals and Alloys/D.A. Porter ,K.E. Easterling, Mohamed Sherif/ CRC Press; 4th Indian Reprint 2009
2. Heat treatment of Steels/ Vijendra Singh/ Standard Publishers Distributors 2009.
3. Phase Transformation of Materials/ R.C. Sharma/ CBS Publishers 2002.
4. Heat Treatment: Principles and Techniques/ T.V. Sharma, C.P. Sharma, Ashok Rajan/PHI 2011
5. Principles of Heat Treatment of Steel / George Krauss /American Society for Metals 1980.

[MSD-313] Magnetic Materials for Industry **3 Credits (3-1-0)**

Types of Magnetic Materials and Their Characteristic Features: Magnetic units: Magnetic moments: Dia, para,ferro, antiferro, ferrimagnetism etc.

Magnetic Domains and Hysteresis Loops: Domain theory, Domain growth and domain wall rotation, Stability of domain structure, Susceptibility and coercivity calculations.

Magnetic Anisotropy: Magnetic anisotropy and exchange energies Origin of magnetic anisotropy and its application: Effect of inclusions, internal stress, magnetostriction and preferred orientation on magnetization, demagnetization effects, magneto-static, magnetoelastic energy.

Magnetism In Different Materials: Magnetism in elements, alloys and compounds, thin films, multilayer, amorphous and nanocrystalline materials, Hard and soft magnetic materials. Textured magnetic materials.

Applications of magnetic Materials:

a) **Magnetic storage:** Overview of magnetic recording, reading and play back theories; magnetic materials as reading head and storage media; technological aspects of high density storage media.
b) **Magnetoresistance:** Various types of magnetoresistance; Giant and colossal magnetoresistance materials and their applications. Various techniques of magnetic recording and recovery.
c) **Spintronics**: Spintronic devices and their applications in fast, reliable, non-volatile and miniaturized electronic circuits

Books and References:

1. Charles Kittel Introduction To Solid State Physics 2nd Edition 2005
2. B. D. Cullity, Introduction to Magnetic Materials, Addison-Wesley Publications, California, London, 1972
3. J. P. Jakubovics, Magnetism and Magnetic Materials, Institute of Materials, London, 1994
4. D. Jiles, Introduction to Magnetism and Magnetic Materials, Chapman & Hall, 1991
5. S.Blundell, Magnetism in Condensed Matter ,Oxford Master Series in Condensed Matter hysics,2001

[MSD-314] Laser Material Processing **3 Credits (3-1-0)**

Introduction: Concept of laser, basic mechanisms in lasers; Properties of laser; Types of laser, gas, liquid and solid state lasers; Pulsed and CW lasers

Laser-Material 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.

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

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

Books and References:

1. Steen W. M., Laser Material Processing, Springer
2. Bass, M., "Laser Materials Processing", North Holland Publishing Co., Amsterdam
3. Chryssolouris, G., "Laser Machining- Theory and Practice", Springer Verlog, NYork Inc.
4. Luxon, J. T. and Parker, D. E., Industrial Lasers and Their Applications", Prentice-Hall, Englewood Cliffs, NJ.

[MSD-315] Materials Selection and Design **3 Credits (3-1-0)**

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.

Material 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

Manufacturing Considerations in Design: Surface finish, Texture, Dimensional tolerances in fitting, interchangeability selective assembly, and geometric tolerance.

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 materialindices – case studies.

Material Selection using Ashby Method, Case Studies, Multiple Constraints in material selection, Multiple Objectives, Role of Materials in Shaping the Product Character.

Books and References:

1. M.F. Ashby, "Materials Selection in Mechanical Design' – Third edition, Elsevier publishers, Oxford, 2005.
2. Gladius Lewis, "Selection of Engineering Materials", Prentice Hall Inc, New Jersey, USA, 1995.
3. Charles.J.A. and Crane,F.A.A., "Selection and Use of Engineering Materials", Butterworths, London, UK, 1989

[MSD-316] Materials for Specific Applications 3 Credits (3-1-0)

Engineering Materials and their Properties: Classes of engineering materials - the evolution of engineering materials, Definition of materials properties, Displaying material properties using materials selection charts, Forces for change in materials selection and design, Materials and the environment-selection of materials for automotive, aerospace, Biomaterials, Smart Materials Nuclear Materials and Defence applications

Automotive materials: Selection strategy for selection of materials for automotive component manufacturing

a) Materials selection for IC engines: Piston, piston rings, cylinder, Engine block, Connecting rod, Crank shaft, Fly wheels, Gear box, Gears, Splines, Clutches.
b) Materials selection for bearings, leaf springs, chasis & frames, Bumper, shock absorbers, windscreens, panels, brake shoes, Disc, wheels, differentials , damping and antifriction fluids, Tyres and tubes.
c) Materials for electronic devices meant for engine control, ABS, Steering, Suspension, Sensors, anticollision, Anti-fog, Head lamps.

Aerospace materials: Requirements of space and aerospace materials, land base and aerospace materials, Identification of components of aero planes, space vehicles and missiles, materials

usage in each sections and criticality of the components and their materials selection,gas turbine and aero engines, Creep, fatigue and corrosion, Ni and Co based superalloys, Special steels, Titanium alloys, Intermetallics, ceramics and their composites,New High strength material.

Biomaterials Properties of Materials, Materials in Medical Applications, Stainless steel alloys,Cobalt based alloys, titanium based alloys, polymers, Bioresorbable and Bio erodible materials, bioceramics, porous ceramics, bioactive glasses, calcium phosphates,collagen, thin films, grafts and coatings, biological functional materials Latex products.

.**Smart materials**: Smart materials and their properties, Piezoelectric, magneto structure, Shape memory materials, Electro Rheological fluids, Optical fibers, actuation, sensing and control augmentation, distributed/discrete sensing and actuation, methods of analyses, finite elements, applications: Vibration suppression, shape control, sizing and optimization.

Nuclear Materials: Structure of the nucleus; binding energy; fission reactions; neutron cross sections; moderation of neutrons; multiplication factor; diffusion, slowing down theories and criticality concept; fusion reactions. General feature of nuclear reactors; classification of nuclear reactors based on applications and fuel, moderator configuration; materials for nuclear reactors viz., fuels, moderators, control rods, coolants, reflector sand structural materials. Fabrication of fuel and cladding materials. Reactor minerals; occurrence in India; Properties of uranium, uranium dioxide, uranium carbide, uranium nitride fuels, dispersion type fuels, plutonium and thorium type fuels. Uranium: Chemistry of leaching, production of concentrate, refining of concentrate, production of UO2, production of nuclear grade uranium metal, refining of uranium, fuel fabrication. Production of enriched uranium; processing of the spent fuel and extraction of Pu. Thorium: Sources of Th, Treatment of monazite, methods of producing thorium metal, refining, production in India. Zirconium: Sources, treatment of zircon, methods for separation of Hf from Zr, reduction of Zr compound to metal, production of Zr metal powder, production in India. Beryllium: Sources, treatment of beryl, reduction of

beryllium compounds, refining. Radiation units; radiation protection standards; radiation effects in solids; radiation hazards and shielding; uses of radioactive isotopes; disposal of radioactive wastes. Nuclear power reactors in India.

Books and References:

1. Gladius Lewis, “Selection of Engineering Materials”, Prentice Hall Inc. New Jersey USA, 1995.
2. Charles J A and Crane. F A. A., “Selection and Use of Engineering Materials”, 3rd Edition, Butterworths, London UK, 1996.
3. George F. Titterton: Aircraft Materials and Processes, Himalayan Books, New Delhi, 1998.
4. L.C. Merrite, "Basic principles of Nuclear science and Reactors" Wiley Eastern 1977.
5. Sujata V., Bhat., “Biomaterials”, Narosa Publication House, New Delhi, 2002
6. M. V. Gandhi and B. S. Thompson, “Smart Materials and Structures”, Chapman and Hall, London, First Edition, 1992.

[MSD-318] Nanomaterials Laboratory **2 Credit (0-0-3)**

1. Synthesis of oxide nanoparticles by precipitation technique, also calculate the crystallite size using XRD technique
2. Chemical synthesis of Ag nanoparticles; UV-Visible absorption of the colloidal sol; Mie formalism; Estimation of size by curve fitting
3. Synthesis of Nano-ferrite particles by precipitation method, also calculate the crystallite size using XRD technique
4. Chemical synthesis of CdS nanoparticles; Optical absorption spectra; Band gap estimation from the band edge.
5. Study the annealing effects on the physical size and properties of nano-particles.
6. Mechanical ball milling technique to oxide ceramics preparation: crystallite size measurement by XRD
7. Sol-gel spin coating route to make nanothin films and measure the surface roughness measurement by AFM.
8. Study the particle size distribution using Scanning Electron Microscopy and also find average the grain size.
9. Synthesis of nanorods and confirmation of nanorods formation by SEM analysis.
10. Calculate the lattice parameters and diameter of nanorods using XRD technique

[MSD-319] Heat Treatment Laboratory **2 Credit (0-0-3)**

1. Annealing treatment of a cold worked steel and comparison of the annealed microstructure with the cold worked structure
2. Normalizing treatment of steel and comparison of the microstructure with annealed structure.
3. To perform hardening and study the quenched structures of steel – quenched in oil, water and brine solution
4. To study the quenched and tempered structures of steel –
    (a) low temperature tempering.
    (b) medium temperature tempering.
    (c) high temperature tempering.
5. Compare the quenched and tempered structure.
6. To perform cold working followed by recrystallization and studies the recrystallization behaviour of metal (iron/ copper).
7. To study the effect of time and temperature on grain size of a metal (iron/ copper).
8. To study the nucleation rate and growth rate of pearlite in eutectoid steel.
9. Determination of hardenability of steels using Jominy End Quench Test.
10. Study the effect of quenching media on hardening of steel.
11. Pack carburizing of 0.2% carbon steel and to measure the diffusion coefficient of carbon in steel.

[MSD-321] Metal Deformation Processing **3 Credits (3-1-0)**

Fundamentals of Metal Forming: Classification of forming process- Mechanics of metal working, Flow stress determination, Effect of temperature, strain rate and metallurgical structure on metal working, Friction and lubrication. Deformation zone geometry, Workability, Residual stresses.

Forging: Hot, Cold and Warm Forging – types of presses and hammers. Classification, Open die forging and closed die forging, die design, forging in plane strain, calculation of forging loads, use of software for analysis - forging defects – causes and remedies, residual stresses in forging.

Rolling: Classification of rolling processes, types of rolling mills, hot and cold rolling, rolling of bars and shapes, forces and geometrical relationship in rolling, analysis of rolling load, torque and power, rolling mill control, rolling defects- causes and remedies.

Extrusion: Direct and indirect extrusion, variables affecting extrusion, deformation pattern, equipments, port – hole extrusion die, hydrostatic extrusion, defects and remedies, simple analysis of extrusion ,tube extrusion and production of seamless pipe and tube.

Drawing: Drawing of road, wires and tubes.

Sheet Metal Forming and Other Processes: Forming methods – Shearing, Fine and Adiabatic blanking, bending, stretch forming, deep drawing, defects in formed part, sheet metal formability, forming limit diagram. High velocity forming, Comparison with conventional forming, Explosive forming, Electro hydraulic, Electro Magnetic forming.

Books and References:

1. Dieter.G.E., "Mechanical Metallurgy", McGraw – Hill Co., SI Edition, 1995.
2. Surender Kumar, "Technology of Metal Forming Processes", PHI, New Delhi, 2008
3. Mechanical Working of Metals: Theory and Practice / Pergamon / John Noel Harris 1983
4. DeGarmo's Materials and Processes in Manufacturing/ J. T. Black (Author), Ronald A. Kohser/ Wiley 2011

[MSD-322] Tribology of Engineering Processing **3 Credits (3-1-0)**

Introduction to Tribology: Introduction to tribology and Factors influencing Tribological phenomena, Properties of materials relevant to friction and wear

Surfaces, Friction and Wear: Engineering surfaces: Surface characterization, Contact of engineering surfaces: Hertzian and nonhertzian contact, Contact pressure and deformation in non-conformal contacts. Causes of friction,Stick-slip friction behavior and friction instability, sliding and rolling friction, frictional heating and temperature rise, Friction measurement techniques. Wear and wear types, Mechanisms of wear, Wear of metals and non-metals. Wear models - asperity contact, constant and variable wear rate, geometrical influence in wear models, wear damage. Wear in various mechanical components, wear measurement and controlling techniques.

Lubricants and their physical properties: Types of additives, extreme pressure lubricants, recycling of used oils and oil conservation, oil emulsion, Selection of Lubricants, Hydrodynamic lubrication: Reynolds Equation, Infinite bearing, short bearing Elastohydrodynamic Lubrication: Principle and application, pressure - viscosity term in Reynold,,s equation, Hertz theory, Ertel-Grubin Equation. Gas lubrication: Introduction, merits and demerits, applications. Lubrication in metal working: Rolling, forging, drawing and extrusion. Bearing materials, bearing constructions, oil seals, shields and gaskets

Design of Tribological Elements: Tribological consideration in design, Mechanisms of tribological failures in machines, Design Hydrodynamic bearings, and Performance analysis of gears, seals, piston rings, machine tool slide ways, cams and follower. Surface Engineering for Wear and Corrosion resistance: Diffusion, coating, electro and electro-less plating, hot deep coating, metal spraying, cladded coating, crystallizing coating, selection of coating for wear and corrosion resistance, potential properties and parameters of coating

Books and References:

1. M. M. Khonsari & E. R. Booser, "Applied Tribology", John Willey &Sons, New York, 2001.
2. E. P. Bowden and Tabor.D., "Friction and Lubrication ", Heinemann Educational Books Ltd., 1974.
3. A. Cameron, "Basic Lubrication theory", Longman, U.K.., 1981.
4. M. J. Neale, "Tribology Handbook", Newnes. Butterworth-Heinemann, U.K., 1995
5. B. Bhushan," Principles and Application of Tribology" Wiley,

[MSD-323] Electronic Materials for industry **3 Credits (3-1-0)**

Semiconductor Fundamentals: Band structure, indirect and direct band gap,optical properties, carrier statistics

Semiconductor Growth: semiconductor material purification andcrystal growth, epitaxy, CVD and MBE,

Processing: Specific material requirements, Doping by implantation and diffusion, dielectric and insulators, ohmic and barrier contacts, band edge behaviour, empirical rule, alloy design,PN Junction, Schottky and MaS device structures,.

Dielectric& Ferroelectrics Materials: Dielectric constant and polarization, polarization mechanism, linear and nonline dielectric, pyro-piezo,and ferroelectric properties, application

Magnetism: diamagnetism paramagnelism, polypararnagnetism, ferro, antiferro, and ferrimagntism. Soft andhard magnet materials, permanent magnet and transformers.

Books and References:

1. Elements of Materials Science and Engineering, L. H. Van Vlack (Addison-Wesley)
2. Materials Science and Engineering: An Introduction, W. D. Callister, (WILEY)
3. The Science and Engineering of Materials, Donald R. Askeland (Chapman & Hall)
4. Solid State electronic Devices, B.G. Streetman (PHI)

[MSD-324] Failure Analysis **3 Credits (3-1-0)**

Introduction to Failure analysis and Prevention: Concepts, root causes analysis, primary root causes, design deficiencies, material defects, manufacturing/installation defects, categories of failure, failure prevention

Type of Stresses: Elastic stress distributions for simple shapes, Thermal residual stresses, Metallurgical residual stresses, Mechanical residual stresses, Chemical effects on residual stresses.

Mode of Fractures: Brittle fracture, Brittle fracture of normally ductile steels, Characteristics of Brittle fracture, Microstructural aspect of brittle fracture, Combined fracture modes, Ductile fracture, Characteristics of ductile fracture, Microstructural aspects of ductile fracture, Fatigue fracture, Types of fatigue fracture, Stages of fatigue fracture, Microscopic and macroscopic characteristics of fatigue fracture.

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.

Tools and Techniques in Failure Analysis: General Practices, Photography, X-rays, metallographictechniques, Fractography. Examples of component failures in metals,Ceramics, polymers and plastics.

Books and References:

1. Hertz berg R W, “Deformation and fracture mechanics of Engineering materials” secondedition John Wiley sons inc, New York 1983.
2. Knott. J.F, “Fundamentals of Fracture Mechanics” Butterworth London, 1973
3. Evalds H L and RJH Warnhil, ”Fracture Mechanics”, Edward Arnold Ltd, Baltimore,1984.
4. Deformation and Fracture Mechanics of Engineering Materials/R. W. Hertzberg/ John Wiley & Sons. 1996.

[MSD-325] Material Characterization **3 Credits (3-1-0)**

Introduction: Meaning/importance/need/role of examination & testing of materials, Scope of various examination and testing methods available viz Microscopic Examination/Metallography, Macroscopic Examination, Chemical Methods, Mechanical methods, Non-Destructive Testing (NDT) Methods, Spectroscopy.

Metallography/Microscopic Examination of Metals: Preparation & Etching of Specimens of metals & alloys. Principle, Construction & working of metallurgical microscope, Various Properties of microscope objectives, Defects in lenses & their remedies, Various types of objectives and eye pieces, TEM and SEM microscope

Macroscopic Examination of Metals: Introduction, Importance & scope of Macro etching, Sulphur/Phosphorus/Oxide Printing. Flow Lines

Chemical Methods: Gravimetric, Volumetric, Colorimetric, Electro-gravimetric, Fire Assaying & Polarographic Methods of Analysis

Mechanical Methods: Hardness testing, Tensile testing, Impact testing, Creep, Fatigue, Fracture, Nano indentation technique.

Non-Destructive Testing: X-ray/Gamma ray radiography, Ultrasonic testing, Magnetic methods- Magnetic particle test/Magna Flux, Zyglo/Die penetration test, Eddy current test, X-ray diffraction.

Advanced Characterization Techniques: Scanning probe microscope, X-ray fluorescence technique, Atomic absorption spectroscopy, Differential thermal analysis (DTA), differential scanning calorimeter (DSC), Thermo gravimetric analysis (TGA), Thermo mechanical analysis (TMA)

Books and References:

1. Qualitative and Quantitative Analysis/Alexive/MIR Publisher 1982.
2. Chemical and Metallurgical Analysis/ Vogel/Longman Scientific and Technical 1999.
3. X-ray Diffraction/B D Cullity/Addison-Wesley 1956
4. Testing of Materials/Davis and Troxell/McGraw-Hill 1998
5. Principles of Metallographic Laboratory Practice/G L Kehl/McGraw-Hill 1980

[MSD-326] Surface Engineering **3 Credits (3-1-0)**

Introduction: Role of surface on various Engineering phenomena, Technological properties of surfaces, Need for modification of surfaces.

Tribology: Surface dependent engineering properties, viz., wear, friction, corrosion, fatigue, reflectivity, emissivity, etc.; common surface initiated engineering failures; mechanism of surface degradation; importance and necessity of surface engineering; classification and scope of surface engineering in metals, ceramics, polymers and composites, tailoring of surfaces of advanced materials.

Characterization Techniques: Film Thickness Measurements Using Optical Techniques, Corrosion Testing of Coatings, Evaluation of Mechanical Properties of Thin Films, Microstructural Characterization of Coatings and Thin Films, Wear and Erosion Testing of Coatings.

Plating Processes: Fundamentals of electroplating, Electrodeposition from plating baths, Electroless plating, Mentalliding, Selective plating, Hard anodizing, Other plating processes, Applicability of plating for wear resistance

Surface Coatings: Dip, Barrier and Chemical conversion coatings, Vacuum and controlled-atmosphere coating

Books and References:

1. Friction and Wear of materials/ Ernest Rabinowicz/John Wiley & Sons2008
2. Kenneth G Budinski. "Surface Engineering for Wear Resistance". Prentice Hall Inc. Engelwood Cliff., New Jersey. USA 1988
3. Engineering Tribology/Amandeep Singh Wadhwa/Shalom Akhai/DhanpatRai& Co. 2012
4. "Surface Engineering of Metals: Principles, Equipment, Technologies/ adeuszBurakowskiTadeuszWierzchon"/CRC 1998

[MSD-328] Electronic Materials Laboratory **2 Credit (0-0-3)**

1. Make the pellet of given material.
2. Deposit the thin film of prepared pellet using Pulse layer deposition.
3. Four probe resistivity measurements of thin film.
4. Low temperature transport studies of thin film.
5. Determine the Hall coefficient, Hall mobility of semiconductors.
6. Synthesis and characterization of conducting polymers and their composites.
7. Impedance spectroscopy / A.C. conductivity of thin film.
8. Study the optical properties of thin film.
9. I/V characteristics of FET.
10. LED Characteristics.

[MSD-329] Material Characterization Laboratory **2 Credit (0-0-3)**

1. Determination of precision determination of lattice parameters using an x-ray diffractometer pattern.
2. Study the absorption spectra of given specimen using UV-Vis also calculate band gap.
3. Determine the structures of molecules using FTIR
4. Study the chemical composition and structure of material using Raman Spectroscopy
5. Study the absorption spectra of given specimen using Photoluminescence.
6. Study the surface morphology using Atomic Force Microscopy
7. Study recording media or magnetic sample using Magnetic Force Microscopy.
8. Study the distribution of grains using Scanning force Microscopy and also find average the grain size.
9. Calculate the particle size using zeta seizure.
10. Optical microscopy of ferrous samples.(Mild Steel , High Carbon Steel, Cast Iron, Stainless Steel
11. Optical Microscopy of Non –Ferrous Samples. (Cu, Zink Brass, Pb-Sn).

[MSD-411] Advanced Functional Oxide Materials **3 Credits (3-1-0)**

Fundamental: Introduction to Functional Materials, Processing methods (Bulk and Thin films) and Characterization techniques (XRD, SEM, etc.) in brief.

Structure of Typical Materials: Ferroelectricity, Piezoelectricity, Pyroelectricity, dielectric ,electrooptic effect, multiferroic materials, Impedance spectroscopy.

Magnetism: Introduction to magnetism in brief, Magnetoresistance (GMR, CMR etc), magnetocaloric materials, Magnetostriction, Spintronics, Magnetic Recording, Magnetic sensors, Thermoelectricity and related effects, Seebak effect, thermoelectric materials, thermoelectric generator, Figure of Merit, Recent updates at each step, , Composite or Hybrid materials , Nano-X (X = materials, wires, tubes, dots , magnetism, etc)

Introduction of Thin Film Deposition Techniques: Thermal evaporation, E-beam evaporation, RF sputtering, DC sputtering, Chemical Vapor Deposition (CVD), Spin coating, Electrolytic deposition, Molecular beam epitaxy, Spray Pyrolysis, Laser ablation method, etc.,

Mechanical Properties of Films: elastic and plastic behavior, Optical properties: Reflectance and transmittance spectra, Multilayer films, Anisotropic and isotropic films, Electric properties to films: Conductivity in metal, semiconductor and insulating films, Thin film devices: fabrication and applications.

Special Topics: Optoelectronics, Superconductive electronics

Books and References:

1. Milton Ohring The Materials Science of Thin Films , academic Press Sanden, 1992
2. Thin Film Phenomemna/ Kasturi. L. Chopra. Malabar/Robert E. Krieger Publishing Company 1979
3. D. Jiles, Introduction to Magnetism and Magnetic Materials, Chapman & Hall, 1991
4. S.Blundell, Magnetism in Condensed Matter ,Oxford Master Series in Condensed Matter Physics,2001

[MSD-412] Semiconductor Devices and their Processing 3 Credits (3-1-0)

Basic Semiconductor: Energy bands, donors and acceptors, carrier concentration, carrier transport, generation recombination processes, basic equations for device operation,

Devices: P-N junctions: electrostatics, space charge, abrupt and linearly graded, current-voltage and capacitance-voltage characteristics, junction breakdown, Bipolar Transistor: transistor action, current gain, static characteristics, frequency response, transient behaviour, junction breakdown, Metal-Semiconductor contact: Ohmic and non-ohmic, Schottky effect, current-voltage characteristics, metalinsulator-semiconductor (MIS), Metal-Oxide-Semiconductor (MOS) diode, C-V characteristics of MOS, Charge couple devices (CCD). Field Effect Transistor, MISFET, MOSFET, CMOS, Bi-CMOS

Processing: Oxidation, diffusion (oxidation enhanced diffusion, transient enhanced diffusion), ion implantation, deposition (chemical and physical vapour techniques), etching; Lithography; Device and process integration, with MOSFET as an example.

Books and References:

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

[MSD-421] Thin Film Technology **3 Credits (3-1-0)**

Introduction: Physical Vapor Deposition - Hertz Knudsen equation; mass evaporation rate; Knudsen cell, Directional distribution of evaporating species Evaporation of elements, compounds, alloys.

Raoult'sLaw: E-beam, pulsed laser and ion beam evaporation, Glow Discharge and Plasma, Sputtering - mechanisms, Bias sputtering, magnetically enhanced sputtering systems, reactive sputtering, Hybrid and Modified PVD- Ion plating, reactive evaporation, ion beam assisted deposition.

Deposition Techniques: Chemical Vapor Deposition - reaction chemistry and thermodynamics of PVD, CVD Methods of producing thin films: PVD, CVD, sputtering, epitaxial films, film thickness measurement growth of thin films.

Chemical Techniques: Spraypyrolisis, Electrodeposition, Sol-gel and Langmuir Blodgett techniques

Nucleation &Growth: Capillarity theory, atomistic and kinetic models of nucleation, basic modes of thin film growth, stages of film growth & mechanisms, amorphous thin films.

Epitaxy: Homo, hetero and coherent epilayers, lattice misfit and imperfections, epitaxy of compound semiconductors, scope of devices and applications.

Books and References:

1. Milton Ohring The Materials Science of Thin Films , academic Press Sanden, 1992
2. Handbook of Thin Film Technology/Maissel and Glange/McGraw Hill. 1970
3. Thin Film Phenomemna/ Kasturi. L. Chopra. Malabar/Robert E. Krieger Publishing Company 1979
4. Handbook of Thin Film Materials: Deposition and processing of thin films/HariSinghalwa, Academic Press 2002

[MSD-422] Composite Materials **3 Credits (3-1-0)**

Introduction: General introduction and historical development, Concept of Composite materials, Basic definitions, Various types of composites, Classification based on Matrix Material, Classification based on reinforcements, Comparison with Metals, Advantages & limitations of Composites.

Polymer Matrix Composites (PMCs): Fabrication of PMCs, Structure and Properties of PMCs, Interface in PMCs and their Applications.

Metal Matrix Composites (MMCs): Fabrication of MMCs, interface in MMCs, Discontinuous reinforcement of MMCs, Properties and Applications of MMCs

Ceramic Matrix Composites (CMCs): Fabrication of CMCs, Structure and Properties of CMCs, Interface in CMCs and their Applications.

Advances in Composites: Carbon / carbon composites – Advantages of carbon matrix – limitations of carbon matrix Carbon fibre-chemical vapour deposition of carbon on carbon fibre perform. High field Composites Superconductors, In-Situ and Powder Metallurgy Fabrications

Mechanics of Composites: Lamina Constitutive Equations: Lamina Assumptions – Macroscopic Viewpoint. GeneralizedHooke's Law.Reduction to Homogeneous Orthotropic Lamina– Isotropic limit case, OrthotropicStiffness matrix (Qij), Definition of stress and Moment Resultants. Strain Displacement relations.Basic Assumptions of Laminated anisotropic plates. Laminate Constitutive Equations – Coupling Interactions, Balanced Laminates, Symmetric Laminates, Angle Ply Laminates, Cross Ply Laminates.Laminate Structural Moduli.Evaluation of Lamina Properties from Laminate Tests.Quasi-Isotropic Laminates. Determination of Lamina stresses within Laminates

Books and References:

1. Mathews F. L. and Rawlings R. D., "Composite Materials: Engineering and Science", Chapman and Hall, London, England, 1st edition, 1994.
2. Chawla K. K., "Composite materials", Springer – Verlag, Second Edition, 1998.
3. Strong, A.B., "Fundamentals of Composite Manufacturing", SME, 1989.
4. Sharma, S.C., "Composite materials", Narosa Publications, 2000.
5. Broutman, L.J. and Krock,R.M., " Modern Composite Materials", Addison-Wesley, 1967.

Departmental Electives

[MSE-413(a)] Light Metal & Alloys **3 Credits (3-1-0)**

Introduction: Light Metals & Alloys Importance of Strength to weight Ratio. Classification Of Light metals &alloys.Review of Methods of Extraction of Al, Mg, Ti

AlAlloy: Principles of Age Hardening , trace elements effect ,Hardening Mechanism,Ageing process, Wrought Alalloy, production, designation of alloy and temper, New alloy developm ent ,ALi alloy, AlCuLi alloy, super plastic alloys, SAP alloy, Rapid solidification processing, Joining of wrought Al-alloy ,Application of Wrought Al-alloy.

Cast Al-Alloy, Designation temper and Characteristics of cast Al-alloy, Reviewof AlSi system, modification, High strength alloy, AlMgalloy, New casting process(rheocasting, sque eze casting, cosworth process), Joining etc.

Introduction and Classification of Tialloy Basic Principle of Heat Treatment , Alfa-alloy, near alfa-alloy, fully alfa alloys and their heat treatment, Ti-Cu age hardenable alloy,alfa/beta Ti-allloy,. Effect of Quenching from Beta- phase field, Tempering of Ti-martensite, decomposition of metastable betaalloy,betaalloy, fabrication, recent trends in shape memory alloy, Ti-alloy casting ,application,

Introduction, Melting and Casting of Mgalloy Grain Refinement , Alloy Designation and t emper, MgAl- alloy,MgLi alloy system,MgAlZn alloy, MgZr alloy Mg- rare earth metals,Mg Y alloy,Wrought alloy, forging alloy, extrusion alloy, Noval alloy(Squeeze alloy),Fabrication & their application.

Books and References:

1. Light Alloys: Metallurgy of the Light Metals by I. J. Polmear , Hodder Arnold H& S (1981)
2. Raudebaugh R.J.; Non-ferrous Physical Metallurgy; Pitmavi Publishing Corpn., 1952.
3. Polmear I.J.; Light Alloys (3rd Edition); Arnold, 1995.
4. Bickert C.M.; Light Metals; Minerals Metals & Materials Society, 1990.
5. Brooks C.R.; Heat Treatment Processing & Structure Properties of Non Ferrous Alloys; ASM, 1984.

[MSE-413(b)] Electron Microscopy **3 Credits (3-1-0)**

Basics of Crystallography and Electron Optics: Introduction – Electron Optics – microscopy and the concept of resolution – interaction ofelectrons with matter – depth of field and depth of focus, crystallography – symmetry elements– symmetry operations, point groups, space groups, indexing planes, indexing lattice directions– plane normals – zones and the zone law, stereographic projection – Wulff Net.

Electron Diffraction Theory: Basics of electron diffraction – scattering by an individual atom, scattering by a crystal – Bragglaw – Laue conditions, reciprocal lattice and diffraction by a single crystal – Ewald sphereconstruction, elastic scattering, inelastic scattering, Structure Factor, intensity distribution inreciprocal space - standard spot patterns

Transmission Electron Microscopes: Working principle of TEM – important aspects of microscope operation and alignment –aberration correction – resolution, formation of diffraction patterns and images – SAED –bright and dark field images – Centered dark field images - weak beam images – samplepreparation, advanced TEMs – HRTEM

Diffraction Analysis: Types of diffraction patterns – ring pattern – spot pattern – Kikuchi pattern, indexing diffractionpatterns – spots/ kikuchi lines produced by planes in one zone – spots/ kikuchi lines arisingfrom different zones – imperfect patterns – kikuchi maps – Electron Back Scattered DiffractionPattern (EBSD), standard spot patterns, uniqueness in indexing diffraction patterns - 180°ambiguity, usage of electron diffraction patterns – orientation relationship determination –second phase identification – defect analysis, other diffraction spots – extra spots, satellitespots and streaks – identification of materials

Scanning Electron Microscopes: Working principles of SEM, depth of field (focus), interaction volume, secondary electrons,backscattered electrons, Spectroscopy – Energy Dispersive X-ray spectroscopy – wavelengthdispersive X-ray spectroscopy – Electron energy loss spectroscopy, microscope operation –imaging – sample preparation, advanced SEMs – Scanning Transmission Electron Microscope (STEM)

Books and References:

1. Thomas G., “Transmission electron microscopy of metals”, John Wiley, 1996.
2. Peter J. Goodhew, John Humphreys, Richard Beanland, “Electron Microscopy and Analysis”, 3rd Edition, Taylor and Fransis, II New Fetter Lane, London, 2001.
3. David B. Williams and C. Barry Carter, “Transmission Electron Microscopy: A Text Book for Materials Science”, Publisher: Springer, USA, 2009.
4. J. W. Edington, “Electron Diffraction in the Electron Microscope”, N. V. Philips’ Gloeilampenfabrieken, Eindhoven, 1975.

[MSE-413(c)] X-Ray Techniques **3 Credits (3-1-0)**

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.
Diffractometer – General feature and optics, proportional, Scintillating and Geiger counters.
Analysis of X-Ray Diffraction: Line broadening, particle size, crystallite size, Precise parameter measurement, Phaseidentification, phase quantification, Phase diagram determination X-ray diffraction applicationin the determination of crystal structure, lattice parameter, residual stress – quantitative phaseestimation, ASTM catalogue of Materials identification.
X-ray Fluorescence Spectroscopy: Moseley's law, Compton scattering, Energy Dispersive XRF (EDXRF), Wave Dispersive XRF (WDXRF)
X-ray Absorption Spectroscopy: Synchrotron as X-ray Source, X-rays Absorption, Absorption Edge and its Position, XAFS, XANES, EXAFS, NEXAFS, SEXAFS
X-ray Photo-Electron Spectroscopy: Photo-Electrinc Effect, XPS Spectra, Orbital Splitting, Spin-Orbital Splitting, Total Angular Momentum, Surface Charging, Energy Analyzer, X-ray Induced Auger emission, Depth Profilling.

Books and References:

1. Cullity, B. D.," Elements of X-ray diffraction", Addison-Wesley Company Inc., New York,3rd Edition, 2000
2. Joseph Goldstein, Dale Newbury, David Joy, et al., "Scanning Electron Microscopy and X-ray Microanalysis", Kluwer Academic / Plenum Publishers, New York, 2003
3. Phillips V A, "Modern Metallographic Techniques and their Applications", Wiley Eastern, 1971.
4. Brandon D. G, "Modern Techniques in Metallography", VonNostrand Inc. NJ, USA,1986.
5. Thomas G., "Transmission electron microscopy of metals", John Wiley, 1996.
6. Weinberg, F., "Tools and Techniques in Physical Metallurgy", Volume I & II, Marcel and Decker, 1970.
7. Whan R E (Ed), ASM Handbook, Volume 10, Materials Characterisation ", Nineth edition, ASM international, USA, 1986.

[MSE-414(a)] Spectroscopy **3 Credits (3-1-0)**

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 chemiluminescence – Beer-Lambert law; qualitative and quantitative analyses – limitations – visible absorption spectroscopy.

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

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

Emission Spectroscopy –fluorescence 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

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

Miscellaneous Spectroscopy Techniques: Mass Spectroscopy, Mossbauer Specroscopy, Neutron Diffraction, Atomic Absorption Spectroscopy.

Books and References:

1. Kalsi .P.S. Spectroscopy of organic compounds, 6th Edition, New Age International Publishers,2006
2. William Kemp, Organic Spectroscopy, 3rd Edition, Palgrave publishers, 2007
3. G.D Christian, " Analytical Chemistry" , 6th Edn., John Wiley Press (2006).
4. D.A. Skoog, F.J. Holler and S.R. Crouch, "Principles of Instrumental Analysis" 6th Edition, Thomas Brookes/Cole, 2007.

[MSE-414(b)] Computational Materials Science **3 Credits (3-1-0)**

Introduction and Basic concepts: Theoretical Background, Basic equations for interacting electrons and nuclei, Coulomb interaction in condensed matter, Independent electron approximations, Exchange and correlation, Periodic solids and electron bands, Structures of crystals: lattice + basis, The reciprocal lattice and Brillouin zone, Excitations and the Bloch theorem

Time reversal and inversion symmetries, Integration over the Brillouin zone and special points Density of states Uniform electron gas and simple metals. Non-interacting and Hartree-Fock approximation, The correlation hole and energy. Density functional theory: foundations, Thomas-Fermi-Dirac approximations: example of a functional. The Hohenberg-Kohn theorems, constrained search formulation of density functional theory, Extensions of Hohenberg-Kohn theorems, The Kohn-Sham ansatz. Replacing one problem with another: The Kohn-Sham variational equations Exc, Vxc and the exchange correlation hole meaning of the eigenvalue. Intricacies of exact Kohn-Sham theory.

Functionals for exchange and correlation, The local spin density approximation (LSDA), Generalized-gradient approximation (GGAs) , LDA and GGA expressions for the potential Vxc(r), Non-collinear spin density, Non-local density formulations: ADA and WDA, Orbital dependent functionals I: SIC and LDA+U. Orbital dependent functional II: OEP and EXX, Hybrid functionals , Tests of functionals Solving Kohn-Sham equations – Self-consistent coupled Kohn.Sham equations - Total energy functionals, Achieving self-consistency – Numerical mixing schemes, Force and stress.

Determination of electronic structure –Atomic sphere approximation in solids, Plane waves and grids: basics - The independent particle Schrodinger equation in a plane wave basis. The Bloch theorem and electron bands - Nearly free-electron-approximation - Form factors and structure factors. Plane-wave method - 'Ab initio' pseudopotential method - Projector augmented waves (PAWs) - Simple crystals: structures, bands, - Supercells: surfaces, interfaces, phonons, defects - Clusters and molecules. Localized orbitals: tight-binding –Tight-binding bands: illustrative examples - Square lattice and CuO2 planes - Examples of bands: semiconductors and transition metals - Electronic states of nanotubes. Localized orbitals: full calculations –Solution of Kohn-Sham equations in localized bases. Analytic basis functions: gassians - Gassian methods: ground state and excitation energies - Numerical orbitals - Localized orbitals: total energy, force, and stress - Applications of numerical local orbitals - Green's function and recursion methods - Mixed basis.

Augmented plane waves (APW's) and 'muffin-tins' –Solving APW equations: examples Muffin-tin orbitals (MTOs). Linearized augmented plane waves (LAPWs) - Applications of the LAPW method - Linear muffin-tin orbital (LMTO) method -Applications of the LMTO method - Full potential in augmented methods - Molecular dynamics (MD): forces from the electrons - Lattice dynamics from electronic structure theory - Phonons and density response

functions - Periodic perturbations and phonon dispersion curves - Dielectric response functions, effective charges - Electron-phonon interactions and superconductivity

Books and References:

1. H.Skriver, The LMTO Methods, Springer (1984).
2. Electronic Structure Basic Theory and Practical Methods Richard M. Martin, Cambridge University Press (2004).
3. Modeling Materials Continuum, Atomistic and Multiscale Techniques ELLAD B. TADMOR, Cambridge University Press (2012).
4. Atomic and Electronic Structure of Solids, Efthimios Kaxiras, Cambridge University Press (2003).
5. Computational Chemistry of Solid State Materials, Richard Dronskowski, WILEY-VCH (2005).
6.Mizutani U. Introduction to the Electron Theory of Metals (CUP,2001).
7. Roessler U. Solid State Theory.. An Introduction (2ed., Springer, 2009)

[MSE-414(c)] Corrosion Engineering **3 Credits (3-1-0)**

Introduction to Corrosion: Examples of corrosion, Economic and Technical significance of Corrosion, Chemical and Electrochemical reactions, Electro motive force, Electrode potenti al, Galvanic Series, Electrochemical Equilibrium, Potential - pH diagram, Electrode kinetics, Evans diagram, Polarization and types of polarization. Mixed potential theory. Passivity; Effect of oxides, solution velocity and galvanic coupling.

Types of Corrosion: Uniform pitting, Intergranular, Stress corrosion. Corrosion fatigue. Erosion corrosion, Crevice corrosion, High temperature oxidation, Hydrogen embrittlement, dezincification.Their causes and remedial measures.

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.

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 prevention: Selection of proper materials, Design rules and its modifications, Alloying additions, Environmental conditioning, Cathodic and anodic protection, Organic and inorganic coating, Surface engineering, Inhibitors and passivators.

Books and References:

1. M.G. Fontana& N.D Greens, Corrosion Engineering, Mc Graw Hill publishing company (2006).
2. H.H. Uhlig, Corrosion & Corrosion control- John Wiley & Sons, (2000).
3. Daniels and Alberty, Physical Chemistry; 4. Raj Narayan; 'An Introduction to Metallic Corrosion & its Prevention'; Oxford & IBH Publishing Co. Pvt. Ltd., 1988.

[MSE-423(a)]Nanodevices **3 Credits (3-1-0)**

Introduction: MEMs / NEMs, Electronic Transport in Nanostructures, Semiconductordevices to Single electron Transistors, Micro fluidics and their Applications, Materials for Microfluidic devices, active and smart passive Micro fluidics devices, Lab-on-a-chip for Biochemicalanalysis.

Micro/Nanofabrication Techniques: Stamping techniques for Micro andNanofabrication**,** Material aspects of MEMS and NEMS. Packaging and characterization ofsensors; Packaging& Reliability. Method of packaging.

Micro and Nano-sensors: Fundamentals of sensors, Temperature Sensors, SmokeSensors, Sensors for aerospace and defense, Accelerometer, Pressure Sensor, Night VisionSystem, Nano tweezers, nano-cutting tools, Integration of sensor with actuators and electroniccircuitry.

Molecular Devices: Molecular-scale elements, Molecules that emulate conventionalelectronic circuit elements, Logic circuits using molecular diodes, Semiconductor nanocrystals,Directed self-assembly of molecular circuits, Properties of DNA and its potential applications inmolecular electronics, possible self-assembled molecular-scale circuits of the future.

Books and References:

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

[MSE-423(b)] Electronic and Optical Properties of Materials 3 Credits (3-1-0)

Introduction: Review of quantum mechanical concepts, Inadequacies of free electron theory,Electron in metals-consequences of interaction with lattice, Brillouin zones and nearly freeelectron model, Tight binding model for d-states.

Electrical Conducting Materials: Electrical resistivity of metals, Alloys, Multiphase solids andMattheissen rule, Nordheims Rule, Kondu and spin glass alloys, Ionic and superionic conductors, Properties and their applications.

Semiconducting Materials: Semiconductor band diagrams, direct and indirect bandgap, applications of semiconductors; Degenerate and non-degenerate semiconductors, intrinsic and extrinsic semiconductors, determination of dopant levels and mobility measurements;

Dielectric and Insulating Materials: Review of polarization, ClausiusMosotti 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, Materials properties including case studies, Ferroelectric thin films, Integrated ferroelectrics, Actuators and Smart materials.

Optical Materials: electron-hole recombination, solid state LEDs, lasers and IR detectors, bandgap engineering; Light interaction with materials transparency, translucency and opacity, refraction and refractive index, reflection, absorption and transmission

Books and References:

1. Sze, S.M., Physics of Semiconductor Devices, Wiley (2007).
2. Bhattacharya, P., Semiconductor Opto-electronic Devices, PHI (2006).
3. Wilson, J. & Hawkes, J.F.B., Optoelectronics- PHI (1988)
4. S. Campbell, The Science and Engineering of Microelectronics Fabrication, Oxford, 1996

[MSE-423(c)] Non-Ferrous Metallurgy **3 Credits (3-1-0)**

Copper and Copper Alloys: Methods of Production of Copper, Properties and applications of metallic copper. Major alloys of copper and designation- Brasses. Phase diagram of industrially relevant portion. Different compositions, characteristics and uses. Bronzes: Tin bronze. Composition, properties and uses. Other bronzes like Cu-Al, Cu-Si, Cu-Mn and Cu-Be alloys. Cu-Ni alloys. Typical microstructure of copper alloys.

Aluminium and its Alloys: Methods of Production of Aluminium- Properties of metallic aluminum. Alloys of aluminum and designation, classification. Wrought and cast alloys. Heat treatable and non heat treatable alloys. Age hardening of Al-Cu alloy. Al-Mg-Si, Al-Zn-Mg and Al-Li alloys. Typical microstructure of aluminum alloys. Applications of Al alloys.

Magnesium and Titanium Alloys: Methods of Production of Magnesium- properties and uses. Magnesium alloys and designation. Methods of Production of Titanium- unique characteristics of the metal alpha, alpha+beta and beta titanium alloys- major types. Titanium aluminides their properties and uses. Typical microstructure of magnesium and titanium alloys and their applications in industries.

Nickel and Zinc Alloys: Methods of Production of Nickel-Properties and uses of nickel. Nickel alloys and designation–their properties and uses. Nickel aluminides. Methods of Production of Zinc-Use of zinc in corrosion protection of ferrous materials. Zinc alloys – properties and uses. **Lead, Tin and precious metals:** Methods of Production of Lead and Tin-Major characteristics and applications of lead and tin and their alloys and designation. Low melting nature of solder alloys. Gold, silver and platinum–nobility of these metals. Engineering properties and applications of these metals and their alloys. Typical microstructure of solder alloys

Books and References:

1. K.G.Budinski and M.K.Budinski, "Engineering Materials-- Properties and Selection", PHI Learning Pvt.Ltd., NewDelhi,2009.
2. Sidney H. Avner, "Introduction to Physical Metallurgy", Tata McGraw-Hill, 2nd Edition,1997.
3. W.H. Dennis, "Metallurgy of the Nonferrous Metals", Sir Isaac Pitman and Sons, London,1967

[MSE-424(a)] Materials for Green Energy **3 Credits (3-1-0)**

Silicon Processing Methods: Dry and wet chemical processes used to develop new materials and micro-engineered products. Principles for electrochemical power sources, photovoltaic and their relevance in current energy industry.

Fabrications: Gas-solid and liquid-solid reactions-their role in micro engineering. Various reactors and methods of fabrication methods, such as physical and chemical vapour deposition techniques, photolithography, electroless and electrochemical deposition, etching, and through mask plating and common models to describe these processes.

Newer Energy Materials: Carbon nano-tubes (CNTs) and multiwall carbon nanotubes (MWCNTs) -methods of production, properties and its utility in energy devices. Polymers and composites -classification, methods of production, properties, fabrication methods, and its utility in making energy devices.

Sustainable Energy: Dye-sensitized solar cells (DSSCs), polymer solar cells, hybrid polymer solar cells, polymer based light emitting diodes, fuel cell-proton exchange membranes – operating principles, fabrication/assembling, testing methods and its specific application.

Recent advances in new energy materials

Books and References:

1. A First Course in Electrochemical Engineering, The Electrochemical Consultancy Arlesford Press.
2. W. Menz, J. Mohr and O. Paul, Microsystems Technologies, VCH Verlag.
3. R Kirkwood and A Longley, Clean Technology and the Environment, Blackie October 1994.
4. P. White, I. Franke, P. Hindle, Integrated Solid Waste Management: A Lifecycle Inventory pub. Chapman & Hall 1994.
5. M. Charter and U. Tischner, Sustainable Solutions, Greenleaf Publishing, 2001.
6. J Fiksel, Design for Environment, Mcgraw Hill, 1996.
7. Ed K. Mulder, Sustainable Development for Engineering, Greenleaf Publishing, 2006.
8. V. R. Gowarikar, N.S. Viswanathan, J. Sreedhar, Polymer science, sixth reprint 1993.
9. G.S. Misra, Introductory Polymer Chemistry, 1993
10. W. Billmeyer, Textbook of Polymer Chemistry, F1984.
11. Charles E. Carraher, Introductory Polymer Chemistry, CRC press, 2010.
12. F.L. Mathews F.L. Chapman and Hall, Composite materials: Engineering and science, 1994
13. M.M. Schwartz, Composite Material Hand Book, Mcgrow Hill Book Co., 1984.
14. Frederick C. Krebs, Polymer photovoltaics- A practical approach, SPIE Press, 2008.
15. E. Chiellini, H. Gil, G. Braunegg, J. Buchert, P. Gatenholm, M. Van-der Zee, Bio-related polymers, sustainable polymer science and technology, 2001.
16. M. Graziani and P. Fornasiero, Renewable resources and renewable energy- A global challenge, CRC-Taylor and Francis, 2007.

[MSE-424(b)] Energy Storage Devices and Fuel Cells 3 Credits (3-1-0)

Battery Characteristics: Voltage, current, capacity, electricity storage density, power, discharge rate, cycle life, energyefficiency, shelf life

Primary batteries: The chemistry, fabrication, performance aspects, packing and rating of zinc-carbon, magnesium, alkaline, manganous dioxide, mercuric oxide, silver oxide batteries, zinc/air and lithium button cells- solid electrolyte cells.

Secondary Batteries: The chemistry, fabrication and performance aspects and rating of lead acid and valveregulated (sealed) lead acid, nickel-cadmium, nickel-zinc, lithium and lithium ion batteries -Rechargeable zinc alkaline battery. Reserve batteries: Zinc-silver oxide, lithium anode cell,thermal batteries.

Batteries for electric vehicles: Metal/air, zinc-bromine, sodium-beta alumina and lithium/iron sulphide batteries. (Outline only) Photo galvanic cells. Battery specifications for cars, heart pacemakers, computer standby supplies etc.

Fuel Cells: Introduction – relevance, importance and classification of fuel cells. Background theory - thermodynamic aspects of electrochemistry-energy conversion and its efficiency – factor saffecting the efficiency, electrode kinetics of electrochemical energy conversion.

Types of Fuel Cells: Description, working principle, components, applications and environmental aspects of thefollowing types of fuel cells: alkaline fuel cells, phosphoric acid, solid oxide, molten carbonate,direct methanol fuel cells. Proton Exchange Membrane fuel cells - basic aspects – workingand high temperature operation – recent development in technology.

Hydrogen as Fuel, Solar Cell and Environment: Sources of hydrogen and preparation – clean up and storage – use as fuel in cells.Energy conversion devices, photovoltaic and photo electrochemical cells – photo biochemicalconversion cell.

Future prospects-renewable energy and efficiency of renewable fuels – economy of hydrogen energy – life cycle assessment of fuel cell systems.

Books and References:

1. AuliceScibiohM.andViswanathan B, “Fuel Cells – principles and applications’, University Press (India), 2006
2. 2 Pletcher D and Walsh C, “Industrial Electrochemistry”, Blackie Academic and Professional, 1993
3. Christopher M A Brett, “Electrochemistry – Principles, Methods and Applications”, Oxford University,2004.
4. Newman J S and Thomas -Alyea K.E. “Electrochemical systems” (3rd ed) Wiley, Hoboken, NJ 2004.
5. Hoogers G (Ed), “Fuel cell handbook” CRC, Boca Raton, FL 2003
6. Lindon David, “Handbook of Batteries”, McGraw Hill, 2002
7. Dell, Ronald M Rand, David A J, “Understanding Batteries”, Royal Society of Chemistry,2001
8. Barbir F “PEM fuel cells: theory and practice” Elsevier, Burlington, MA 2005.

[MSE-424(c)]Electronic Ceramics **3 Credits (3-1-0)**

Introduction: Atomic structure including ionic and covalent bonding, Ceramic crystal structures, Clay structures, and amorphous materials. Atomic defects including intrinsic and extrinsic point defects, Kroger-Vink notation

Synthesis and Microstructure Development: Microstructure development in equilibrium and nonequilibrium phases, Solid- state sintering, densification vs. coarsening processes, Grain boundary mobility, Porosity evolution (stability/entrapment), Liquid phase sintering, constrained sintering, Ceramic coatings and their deposition.

Electrical Properties: Conductors: electrodes, varistors, thermistors, Insulators and Dielectrics: polarization, charge displacement, dielectric strength, dielectric constant and loss, equivalent circuits, Ferroelectricity, Piezoelectrics, Pyroelectrics, actuators and sensors. Classification of super ionic solids-Alumina and oxide based super ionic conductors and their applications in fuel cells and batteries.

Magnetic Properties: Spinel, normal and inverse, Weiss domains, ferrites, soft and hard, super-exchange, garnets, permeability, microstructure-property relations, dia, para, ferro and ferrimagnetic materials, chemical substitutions, device performance and applications.

Thermal and Mechanical Properties: Heat capacity, Thermal conductivity, Thermal expansion, Creep and thermal stresses. Mechanical properties: Strength, Toughness and micro structural design.

Multiferroic and Spintronic Materials and Their Applications: Single phase and composite multiferroic material, $BiFeO_3$, $RMnO_3$, Magnetoelectric coupling.

Books and References:

1. Electro ceramics: Materials, Properties and Applications/A. J. Moulson and J. M. Herbert/John Wiley & Sons 2003
2. Ceramic Science and Technology/W. D. Kingery, H. K. Bowen and D. R. Uhlman/John Wiley and Sons, Singapore. 1991
3. Ceramic Processing and Sintering, 2nd Ed/M. N. Rahaman/CRC Press. 2003
4. R. C. Buchanan, Ceramic Materials for Electronics, Marcel Dekker, 1986
5. C. J. Brinker, D. E. Clark and D. R. Ulrich, Better Ceramics through Chemistry, North Holland, 1984
6. F. F. Y. Wang, Ceramic Fabrication Processes, Academic Press, 1976
7. L. L. Hench and J. K. West, Principles of Electronic Ceramics, John Wiley and Sons, New York, 1990.