

Department of Metallurgical & Materials Engineering  
VNIT, Nagpur

## SCHEME OF EXAMINATION FOR 170 Credits System

### B. Tech. (MME)

#### III Semester B. Tech. (MME)

Course Code	Course Title	Credits	L-T-P	Category
MML 211	Introduction to Materials Science & Engineering	04	3-1-0	DC
MML 210	Engineering Physical Metallurgy	03	3-0-0	DC
MML 224	Testing of Materials	03	3-0-0	DC
MML 212	Mineral Dressing	03	3-0-0	DC
	Numerical Methods & Statistics	04	3-1-0	DC
MMP 210	Engineering Physical Metallurgy Lab.	01	0-0-2	DC
MMP 224	Testing of Materials Lab.	01	0-0-2	DC
MMP 212	Mineral Dressing Lab.	01	0-0-2	DC
	<b>Total Credits</b>	<b>20</b>		

#### IV Semester B. Tech. (MME)

Course Code	Course Title	Credits	L-T-P	Category
MML 213	Polymeric Materials	03	3-0-0	DC
MML 215	Transport Phenomena	03	3-0-0	DC
MML 216	Metallurgical Thermodynamics & Kinetics	04	3-1-0	DC
MML 218	Ceramic Materials	04	3-1-0	DC
MML 214	Theory & Technology of Heat Treatment	03	3-0-0	DC
MMP 213	Polymeric Materials Lab.	01	0-0-2	DC
MMP 215	Transport Phenomena Lab.	01	0-0-2	DC
MMP 219	Theory & Technology of Heat Treatment Lab.	01	0-0-2	DC
	<b>Elective I (ANY ONE)</b>			
MML 220	Fundamentals of defects in Materials	03	3-0-0	DE
MML221	Fuels & Furnaces	03	3-0-0	DE
MML222	Cast Iron Metallurgy	03	3-0-0	DE
MML223	Structure of Materials	03	3-0-0	DE
	HM/OC courses	03	3-0-0	HM/OC
	<b>Total Credits</b>	<b>23</b>		

### V Semester B. Tech. (MME)

Course Code	Course Title	Credits	L-T-P	Category
MML 371	Metal Working Processes	04	3-1-0	DC
MML 372	Principles of Non-Ferrous Extraction Metallurgy	03	3-0-0	DC
MMP 372	Principles of Non-Ferrous Extraction Metallurgy Lab.	01	0-0-2	DC
MML 373	Ferrous Extraction Metallurgy	03	3-0-0	DC
	<b>(Elective II ) (ANY ONE)</b>	03	3-0-0	DE
MML 378 PHL 305	Wear of Engineering Materials / Electrical & Magnetic Materials			
	<b>Elective II Lab</b>	01	0-0-2	DE
MMP 378 PHP 305	Wear of Engineering Materials Lab./ Electrical & Electronic Materials Lab.			
	<b>(Elective III) (SELECT ANY TWO)</b>			
MML 351	Process Optimization/	03	3-0-0	DE
MML 368	Industrial Metallurgy /	03	3-0-0	DE
MML 576	Bio-materials /	03	3-0-0	DE
MML 388	Chemical Characterization of Materials	03	3-0-0	DE
	HM/OC courses	03	3-0-0	HM/OC
	<b>Total Credits</b>	<b>21</b>		

### VI Semester B. Tech. (MME)

Course Code	Course Title	Credits	L-T-P	Category
MML 374	Characterization of Materials	03	3-0-0	DC
MMP 374	Characterization of Materials Lab.	01	0-0-2	DC
MML 365	Steel Making Technology	04	3-1-0	DC
MML 382	Solidification Processing & Advanced Foundry Technology	03	3-0-0	DC
MMP 382	Solidification Processing & Advanced Foundry Technology Lab.	01	0-0-2	DC
	<b>(Elective IV) (ANY ONE)</b>			
MML 375	Joining of Materials /	03	3-0-0	DE
MML 383	Light Metal Alloys /	03	3-0-0	DE
	<b>(Elective IV) LAB</b>	01	0-0-2	DE
MMP 375 MMP 383	Joining of Materials Lab. / Light Metal Alloys Lab.			
	<b>(Elective V) (SELECT ANY TWO)</b>			
MML 384	Alloy Steels & High Temperature Alloys/	03	3-0-0	DE
MML 355	Particulate Technology/	03	3-0-0	DE
MML 386	Semiconductor Technology/	03	3-0-0	DE

MML 385	Hydro & Electro Metallurgy	03	3-0-0	DE
MML389	Financial Engineering or Any HM/OC course	03	3-0-0	HM/OC
	<b>Total Credits</b>	<b>22</b>		

### VII Semester B.Tech. (MME)

Course Code	Course Title	Credits	L-T-P	Category
MML 471	Structural Metallurgy	03	3-0-0	DC
MMP 471	Structural Metallurgy Lab.	01	0-0-2	DC
MML 472	Environmental Degradation of Metallic Materials	03	3-0-0	DC
MMP 472	Environmental Degradation of Metallic Materials Lab.	01	0-0-2	DC
	<b>(Elective VI) (SELECT ANY FOUR)</b>			
MML 474	X ray Diffraction & Electron Microscopy/	03	3-0-0	DE
MML 443	Metallurgy of Nuclear Materials /	03	3-0-0	DE
MML 479	Selection of Materials/	03	3-0-0	DE
MML 469	Non-Destructive Testing/	03	3-0-0	DE
MML 477	Secondary & Special Steel Making/	03	3-0-0	DE
MML 480	Fracture Mechanics/	03	3-0-0	DE
MML 445	Adhesive Technology/	03	3-0-0	DE
MML490	Quality control & specifications/	03	3-0-0	DE
	OC / HM courses	03	3-0-0	OC/HM
	Project Phase – I	02		DC
	<b>Total Credits</b>	<b>22</b>		

### VIII Semester B.Tech. (MME)

Course Code	Course Title	Credits	L-T-P	Category
MML 453	Composite Materials	03	3-0-0	DC
MMP 453	Composite materials lab.	01	0-0-2	DC
	<b>(Elective VII) (SELECT ANY FOUR)</b>			
MML 481	Deformation Behavior/	03	3-0-0	DE
MML 487	Continuous Casting of Steels/	03	3-0-0	DE
MML 486	Failure Analysis/	03	3-0-0	DE
MML 488	Nano Materials/	03	3-0-0	DE
MML 490	High temperature corrosion /	03	3-0-0	DE
MML 489	Surface Engineering/	03	3-0-0	DE
	OC/HM Courses	03	3-0-0	OC/HM

MMD 402	Project Phase – II	04		DC
	<b>Total Credits</b>	<b>20</b>		

## Syllabus

### MML211 INTRODUCTION TO MATERIALS SCIENCE & ENGINEERING (3-1-0) 4 credits

Introduction, Concept of Material Science and Engineering, Classification of Materials, Introduction to Material: Metals, Ceramics and Glasses, Polymers, Composites.

Level of structure and Basics of structure property relationship.

Structure of solids, ionic, covalent and metallic solids, crystalline and non crystalline phases.

Phase transformation, Kinetics of Diffusion in Solids

Electrical, magnetic, thermal and optical properties of materials in terms of band and free electron theory, super conductivity.

Introduction to Advanced Engineering Materials

Degradation of Engineering Materials

#### Text / Reference Books :

1. V. Raghavan. (PHI); Materials Science and Engineering - A First Course
2. A. Guy. ; Introduction to Materials Science; McGraw Hill
3. Van Vlack.; Materials Science
4. John Wolf ; Materials Science & Engineering
5. William Callister ; Introduction to Materials Science & Engineering
6. Askeland. D.R.; Introduction to Materials Science & Engineering  
Shackelford.; Materials Science

### MML210 ENGINEERING PHYSICAL METALLURGY (3-0-0) 3 credits

Crystalline and amorphous materials, Bonding, Elements of Crystallography, Crystal Structure of Metals, Crystallographic notation of atomic planes and directions, Imperfections in metal crystals, Allotropy in metals, Single crystal and polycrystalline aggregates.

Solidification of metals and alloys, Cooling curves, Concepts of nucleation and growth, Heat transfer associated in nucleation and growth, Homogeneous and Heterogeneous nucleation, Structure of metal ingots, Dendritic and other growth processes.

Construction of binary alloys, Formation of alloy phases, viz. Solid solutions – substitutional and interstitial, Intermetallic compounds, Phase mixtures etc. Binary equilibrium diagrams of various systems, systems with partial solid solubilities involving eutectic and peritectic and other reactions.

Binary equilibrium diagrams involving monotectic, eutectoid and peritectoid reactions, Lever and phase rule and its applications, Solid state transformations, Ternary diagrams, Order disorders transformations.

Detailed study of Fe-C, Cu-Zn, Cu-Sn, Al-Si, Al-Cu, Al-Li and other nonferrous alloys, Babbit metals and their equilibrium diagrams, discussion on structures, properties and uses of some industrially important alloys based on the above systems.

Selection and preparation of specimens for metallurgical examination, Macro and Microscopic examinations, Etching reagents, Metallurgical Microscope, Properties of objectives viz. Numerical aperture, resolving power, depth of focus etc. Empty magnifications, Bright and dark field illumination, Principles and use of polarized light microscope, Phase contrast microscope and high temperature microscope.

**Text / Reference Books :**

1. Avner S.H.; Introduction to Physical Metallurgy
2. Dr. Khangaonkar. P.R.; Physical Metallurgy (Vol. I & II)
3. R. Khel.; Principles of Metallographic Practice
4. Higgins R.A.; Engineering Metallurgy (Vol. I & II)
5. Askeland D.R.; The Science and Engineering of Materials

**MMP210 ENGINEERING PHYSICAL METALLURGY LAB (0-0-2)1 Credit*****Specimen Preparation of Ferrous and Non - Ferrous Metals.***

1. Numericals Based on Phase Diagrams.
2. Study of Iron - Iron Carbide Diagram.
3. Study of Microstructure of Steels.
4. Study of Cast Irons.
5. Al - Si Diagram.
6. Study of Babbitts.
7. Study of Microstructures of Brasses
8. Study of Microstructures of Bronzes.

**MML224 TESTING OF MATERIALS (3-0-0) 3 credits**

Introduction : Type of engineering materials and their applications, testing of materials for evaluation, characterization and selection of various applications. Types of testing systems, significance of measurement of properties and test conditions, interpretation of test results.

Tensile Testing : Scope of tensile testing and significance of parameters measured in the test Necking during tension test, instability in tension, diffuse necking, stress distribution at the neck, ductility measurement in tensile testing – effect of gauge length.

Effect of strain rate and temperature on flow properties. Machine stiffness in tensile testing systems, measuring instrument computerization.

Torsion Test : Mechanical properties in torsion. Torsional stresses for large plastic deformation, torsional failure, torsion Vs. tension test.

Hardness Test : Hardness testing system, elastic and plastic behaviour during hardness testing. General consideration such as indenter size, shape, friction type of loading etc. in hardness testing. Concept of micro hardness. Major hardness testing systems such as Rockwell, Brinell, Vickers. Special hardness tests such as superficial, micro and shore.

Elements of brittle fracture elliptical crack and Griffith theory of Brittle fracture. Ductile to brittle transition. Notch effective in fracture.

Impact testing for brittle fracture. Notched bar tests, instrumented charpy test. Drop weight crack arrest test, Introduction to fracture toughness testing.

Fatigue Tests : Stress cycles and SN curve statistical nature of fatigue. Effect of mean strain concentration, size and surface condition on fatigue. Fatigue testing machines and equipments. Creep stress rupture tests. Creep cure and its analysis. Stress rupture test. Presentation of engineering creep data. Equipment test set up in creep testing.

Non – destructive Testing : Methods and classification. Elements and instrument in visual magnetic, radiographic, ultrasonic, electromagnetic, penetrant tests, their applications in quality control and inspection.

**Text / Reference Books :**

1. George E.D.; Mechanical Metallurgy; McGraw Hill Publication, UK, 1988.
2. Raj Baldev, Jayakumar T., Practical Non – Destructive Testing; Narosa Publisher, New Delhi, 1997.
3. Metal Hand Book; 9<sup>th</sup> Edition Vol – 8; Mechanical Testing; ASM International, 1985
4. Davis H.E., Testing of Engineering Materials, McGraw Hill Publication, 1982.

**MMP224 TESTING OF MATERIALS LAB (0-0-2) 1 Credit**

1. Hardness Testing on “Rockwell Hardness Tester”.
2. Hardness Testing on “Vickers Hardness Tester”.
3. Hardness Testing on “Microhardness Tester”.
4. Hardness Testing on “Brinell Hardness Tester”.
5. Tensile Testing.
6. Effect of Temperature on Tensile Properties.
7. Impact of Testing on Charpy.
8. Effect of Temperature on Impact Strength and Model of Fracture.
9. Effect of Strain Rate on Tensile Properties.
10. Demonstration of Ultrasonic Flaw Detector.
11. Demonstration of Magnetic Particle Testing.

**MML212 MINERAL DRESSING (3-0-0) 3 credits**

Mineralogy : Studies of important metallic and non metallic minerals and their characteristics, origin etc. application of non metallic minerals. Sea as a source of minerals. Status of mineral beneficiation industry in India. Study of some representative beneficiation practices with flow sheets. Sampling methodology and equipments.

Communication : Primary, secondary and special crushers and their performances. Cylindrical and cylindro-conical ball mills. Rod mill, Tube / Pot mills and their performances, capacities, reduction ratios etc. Dry and Wet Grinding. Open and closed circuit grinding. Laws of crushing and grinding. Work index calculations. Interlocking and liberation of materials.

Screening, Sizing and Classification : Standard screening tests and graphical representations of the results. Practical size distribution. Sorting, Sizing and pneumatic classifiers and their performances. Thickness, Hydrocyclones etc. Theory and practice of sedimentation and filtration. Working of Rotary vacuum filters.

Gravity Concentration Techniques : Principles of Jigging, Tabling and Heavy Media Separation. Processes with equipments used, important controlling factors in operation and application. Beneficiation practice for arsenopyrite containing scheelite.

Froth Flotation : Natural and Artificial Flotability of minerals, frothers, Collectors, Depressants, Activators / Deactivators, PH Modifiers, etc. flotation machines, Study of representative sulphide and non sulphide minerals and non metallic ores. Conditioning in flotation, multistage flotation and Column Flotation.

Electrostatic and Magnetic Separation : Principles of Electrostatic and Magnetic Separation (Dry and Wet Type). Separation units used in practices and examples in the industries. Calculation of recovery and ratio concentration and Mass balance calculations in ore dressing. Industrial set up of Ore Dressing Plant.

**Text / Reference Books :**

1. Gaudin A.M.; Principles of Mineral Dressing; McGraw Hill Boo, TMH Edition, 1971.
2. Taggart A.F. ; Elements of Ore Dressing; J.Wiley & Sons, 1951, London / NY.
3. Jain S.K.; Ore Processing; Oxford & IBH Publishing Company, 1986.
4. Taggart.; Handbook of Mineral Dressing, Wiley Handbook Series.

### **MMP212 MINERAL DRESSING (0-0-2) 1 credit**

1. To study the performance of Single Toggle Blake Jaw Crusher.
2. To study the performance of Rolls Crusher.
3. Grinding Studies of Sample in a Ball Mill.
4. Study of Flow Charts.
5. Sampling of Ores.
6. To study the principle of magnetic separation of mineral (Dry & Wet Separators)
7. Study of Disc Crusher.
8. Study of Pelletization of Iron Ore Fines.
9. Study of Electrostatic Separation.
10. Study of Tabling Process.
11. To verify Gaudin's Equation.
12. Study of Micro-pulverizer.
13. Study of Hydraulic Jig.
14. Study of Froth Flotation (Denver Type)

### **MAL205 NUMERICAL ANALYSIS AND PROBABILITY THEORY (3-1-0) 4 credits**

**Numerical Analysis:** Solutions of algebraic and transcendental equations by Iteration method, method of false position, Newton-Raphson method and their convergence.

Solutions of system of linear equations by Gauss elimination method, Gauss Seidal method, LU decomposition method. Newton-Raphson method for system of nonlinear equations.

Eigen values and eigen vectors : Power and Jacobi methods.

Numerical solution of ordinary differential equations: Taylor's series method, Euler's modified method, Runge-Kutta method, Adam's Bashforth and Adam's Moulton, Milne's predictor corrector method.

Boundary value problems: Shooting method, finite difference methods.

#### **Probability theory:**

Random variables, discrete and continuous random variable, probability density function; probability distribution function for discrete and continuous random variable joint distributions.

Definition of mathematical expectation, functions of random variables, The variance and standard deviations, moment generating function other measures of central tendency and dispersion, Skewness and Kurtosis.

Binomial, Geometric distribution, Poisson distribution, Relation between Binomial and Poisson's distribution, Normal distribution, Relation between Binomial and Normal distribution.

Introduction to Stochastic Processes: Random processes, continuous and discrete, determinism, stationarity, ergodicity etc. correlation functions, autocorrelation and cross-correlation, properties and applications of correlation functions.

#### **Text / Reference Books :**

1. Numerical methods for engineers and scientists, Wiley, Iyengar and Jain, Jain
2. An introduction to probability and statistics, Wiley, Rohatgi and Sateh.
3. Elementary numerical analysis, an algorithm approach, McGraw-Hill, Cante and De Boor
4. Probability, statistics with reliability, queuing and computer science and applications, Prentice Hall, Trivedi.

### **MML 213 POLYMERIC MATERIALS (3-0-0) 3 credits**

Introduction to polymer - Classification of polymer - Polymerization - Polymer structure - Physical Characteristics of polymer - Mol.wt., Tg etc., Engg and specially polymers - Elastomer.

Structure and properties of polymer - morphology, thermal and Rheological behaviour of polymers.

Chemical characterization of polymers - IR, NMR, GC etc. techniques - Analysis of results.

Polymer blend and composites - De-gradation and re-cycling of polymer - applications of polymers.

Processing of polymer - additives, moulding, extrusion, forming etc.

Testing and Characterization of Polymers, Characteristics of some important thermoplastics and thermo-set system.

Set of practicals based on the above which contains Determination of Melt flow index, density Vicat softening point etc.

**Text / Reference Books :**

- 1) Clegg D.W., Collyer A.A.; Structure & Properties of Polymeric Materials; Matls. Publ., London , 1993.
- 2) Fried J.R.; Polymer Science and Technology; Prentice Hall of India, New Delhi, 2000.
- 3) Willam D. Callistor J.R.; Material Science & Engineering; John Wiley & Sons, 1997.
- 4) Jones; Engineering Materials (Vol. I / II); ASM Hand Book.
- 5) Maiti Sukumar; Analysis & Characterization of Polymers; Anusandhan Prakashan, Midnapure, 2003.

**MMP 213 POLYMERIC MATERIALS LAB (0-0-2) 1 credit**

Set of practicals based on the above which contains Determination of Melt flow index, density Vicat softening point etc.

**MML 215 TRANSPORT PHENOMENA (3-0-0) 3 credits**

Introduction, importance of heat and mass transfer, heat transfer aspects in heating – reheating of steels, parameters, step heating, significance in heating – reheating of steels.

Steady state heat conduction, Fourier's law , one dimensional steady state heat conduction through composite walls, spheres, cylinders, critical radius of insulation, General three Dimensional equations with and without internal heat generation, Finite difference method. Transient conduction, types, Analysis of transient heat conduction, lumped heat capacity analysis, Analytical methods, Transient heat conduction in semi-infinite bodies, error function analysis, Heisler charts and their application to transient heat conduction.

Radiation heat transfer, nature of thermal radiations, black and gray bodies, laws of radiation, Radiation shape factor, heat transfer between black bodies, gray body radiation heat transfer for different geometries, interchange factor, Radiation shields, combined effects of conduction, convection and radiation.

Fluid flow and their classification, Laminar and turbulent flow, Fluid flow through plates, tubes, ducts and channels, hydrodynamic boundary layer, Differential boundary layer equations, Continuity and momentum equations, Blasius and Van-Kerman integral energy equations. Application of Dimensional analysis to convective heat transfer, Dimensional numbers and their significance, Empirical equations for free and forced convection for laminar and turbulent flow for different configuration, Liquid metal convective heat transfer.

Conduction –convection systems, Fins , types, heat transfer analysis of Fins, Fin efficiency and effectiveness, Heat exchangers, classification, fouling factor , overall heat transfer coefficient, thermal analysis of heat exchangers, LMTD and NTU method, design problems in heat exchangers.

Mass transfer, processes, classification, concentration, velocity and flux, Fick's law of diffusion, Mass diffusion equations, steady state diffusion, equimolar diffusion, Mass transfer coefficient, convective mass transfer and application.

**Text Books and Reference books:**

- 1) D.S.Kumar: Heat & Mass transfer
- 2) J.P.Hollman: White PRS: Heat Transfer, Mcgraw Hill Company
- 3) E.R.G. Eckert: Robert M. Drake, Analysis of Heat and Mass Transfer, McGraw- Hill,
- 4) GP Incropera, DP Dewitt: Fundamentals of heat and mass transfer, Wiley
- 4) S.P.Sukhtme: A text book on Heat transfer.
- 5) Handbook on Making , shaping and treating of steels.
- 6) Trinks : Industrial furnaces – Vol I and Vol. II

**MMP 215 TRANSPORT PHENOMENA LAB (0-0-2) 1 credit**

1. Numericals on basic principles of heat transfer by conduction, convection and radiation.
2. Numericals on steady state conduction heat transfer.
3. Problems on transient heat conduction.



4. Problems on fluid flow and calculation of heat transfer rate under free convection condition.
5. Problems on determination of heat transfer by forced convection for different fluid flow conditions.
6. Numericals on radiation heat transfer in black bodies.
7. Problems on calculation of radiant energy in gray bodies and radiation shields.
8. Design calculations of heat exchangers by thermal analysis using LMTD method.
9. Thermal analysis of heat exchangers by NTU method.
10. Problems on conduction - convection systems : Fins (calculation of heat transfer, fin efficiency curves etc.)

### **MML 216 METALLURGICAL THERMODYNAMICS & KINETICS (3-1-0) 4 credits**

Scope and concept – Energy and its forms systems, path and state properties, Thermodynamics processes, Thermodynamic equilibrium, Reversible and Irreversible processes. First law of thermodynamics, Internal energy, Specific heat, Enthalpy and their derivative. Thermo-chemistry – Thermo-chemical laws and applications.

Second law of thermodynamics – Entropy and its derivative. Concept of free energy, Criterion of equilibrium, thermodynamic potential. Zeroth and third law of thermodynamics.

Fugacity, activity, equilibrium constant, chemical equilibrium, partial molar properties and chemical potential. Thermodynamics of vapour phase in equilibrium with solids and liquids.

Thermodynamics of solution – Raoult's Law, Henry's Law, ideal, non – ideal and regular solutions, Gibbs – Duhem equation and its solution and applications – Multi-component solution, interaction parameter.

Ellingham diagrams for oxides, sulphides, halides etc. and their applications to metallurgical processes.

Thermodynamics of Electro-chemical Cell and Application.

Kinds of metallurgical processes – order of reaction, Arrhenius equation, Absolute reaction rate.

#### **Text / Reference Books :**

1. Kapoor. M.L.; Chemical & Metallurgical Thermodynamics Vol. I & II; Nemchand & Bros Roorkee, 1984
2. Darken L.S. , Gurry. R.W.; Physical Chemistry of Metals; McGraw Hill, 1953.
3. Upadhaya G.S., Dube R.K.; Problems in Metallurgical Thermodynamics and Kinetics; Pergamon Press, N. York, 1977.
4. Gaskell D.R.; Metallurgical Thermodynamics; McGraw Hill, USA, 1995.
5. Dr. Tupkary R.H.; Introduction to Metallurgical Thermodynamics.
6. A. Ghosh; Text book of Materials & Metallurgical Thermodynamics; Prentice Hill of India, Delhi, 2003.

### **MML 218 CERAMICS MATERIALS (3-0-0) 6 credits**

Introduction, Definition of ceramic materials, Spectrum of applications, Classification of Ceramics.

Basis of crystal structures in ceramics, Crystal Structures (Rock salt, NiAs, CsCl, Wurtzite, Rutile, Fluorites, Antifluorites, Perovskites, Silicates etc.).

Imperfection in ceramic materials – Kroger-Vink notation, Defect reactions, Stoichiometry and non-stoichiometry.

Processing of ceramic materials –Powder synthesis techniques, Consolidation techniques (slip casting, tape casting etc.), Sintering theory and mechanisms, Advanced techniques of sintering

Principles of Characterization of powders and sintered bodies (particle size and distribution, porosity, density, shrinkage, surface area etc.)

Basics of ceramic properties (Physical, Electrical, Mechanical, Magnetic, and thermal) Structure-Property co-relationship.

Classification of refractory materials into Acidic, basic, neutral, rarer refractories. Requirements of a refractory and applications.

Introduction to Advanced Ceramics and Applications (electro-ceramics, bio-ceramics, ultra-high temperature ceramics, thin films etc.), Opportunities and Challenges.

#### **Text / Reference Books:**

1. Modern ceramic engineering, Taylor and Francis, D.W. Richerson
2. Ceramic materials, B. Carter and G. Norton
3. Sintering theory and practice, R.M. German
4. Powder metallurgy and particulate materials processing, R.M. German.

### **MML214 THEORY AND TECHNOLOGY OF HEAT TREATMENT (3-0-0) 3 credits**

Recapitulation of Fe-C equilibrium diagram, Eutectoid transformation in steels, and its significance, Time-Temperature Transformation diagrams, characteristics of pearlite and bainite transformations, Continuous cooling transformations, Characteristics of martensite transformation, critical cooling rate, Concept of Hardenability .Methods of determining hardenability, effect of various parameters on hardenability, Correlation of hardenability data.

Technology of heat treatment, Annealing, Normalizing, Hardening, Quenching media and their evaluation, Sub-zero treatment. Tempering, changes in structure and properties of steels during tempering, Temper embrittlement, Austempering, Martempering, Patenting.

Principles, Techniques, and applications of surface hardening treatments, Carburising, Nitriding, Cyaniding, Flame and Induction Hardening, Heat Treatment of surface hardened components.

Heat Treatment Atmospheres, Protective atmospheres, Defects due to heat treatment, causes and prevention, Case studies, Quenching stresses and defects.

Non-ferrous alloys-study of structure and properties, heat- treatment and uses of industrially important alloys : Aluminum base wrought and cast alloys, Aluminum and Beryllium bronzes.

#### **Text / Reference Books :**

1. ASM Hand Book.
2. Prabhudev K.H.; Hand Book of Heat Treatment of Steels; Tata McGraw Hill, 2000.
3. Avner SH; Physical Metallurgy, tata McGraw Hill.

### **MMP 214 THEORY AND TECHNOLOGY OF HEAT TREATMENT (0-0-2) 1 credit**

Set of experiments based on the above syllabus

### **MML 220 FUNDAMENTALS OF DEFECTS IN MATERIALS (3-0-0)3 credits**

A study of point, line and planar defects and their effects on properties of crystalline solids

Syllabus: Introduction to Basic Crystallography; Classification of Defects; Point Defects, Extrinsic and Intrinsic Point Defects, Diffusion; Introduction to Dislocations, Dislocation Theory; Overview of Stacking Faults, Twin Boundaries and Grain Boundaries; Defects and Properties of Crystalline Solids; Characterization of Defects.

#### **Text / Reference Books :**

1. D. A. Porter and K. E. Easterling: Phase Transformation in Metals and Alloys, 2nd ed. Chapman and hall, 1992.
2. D. Hull and D. J. Bacon: Introduction to Dislocation, 5th ed., Butterworth-Heinemann, 2011.
3. A. Kelly and G. W. Groves, Crystallography and Crystal defects, Addison – Wesley, 2000.
4. P. Shewmon, Diffusion in Solids, A Publication of the Minerals, Metals & Materials Society, 1989.
5. J. Weertman and J. R Weertman, Elementary Dislocation Theory, Oxford, 1992.
6. J. P. Hirth, Theory of Dislocations, 2nd edition, A Wiley-Interscience Publication, 1982

**MML 221 FUELS & FURNACES (3-0-0)3 credits—Syllabus missing**

**MML 222 CAST IRON METALLURGY (3-0-0)3 credits**

Classification of various types of cast irons based on their mechanical properties and microstructure engineering applications of various grade of cast iron.

Raw materials and melting units used for cast irons, construction and operation of cupola, for Cast Irons melting. Divided blast balanced blast and hot blast cupola other melting units for Cast Irons.

Grey cast iron – Melting and Foundry Practices. Various grades of Grey Cast Iron Alloy Cast Irons, Compacted Graphite and Molted Iron, Mehanite Castings.

Malleable Iron and Ductile Iron Melting and Foundry Practice. Pre-inoculation techniques for malleable irons post treatments for ductile iron casting austempering of ductile irons structure property correlations.

Effect of alloying elements on performance of various types of cast irons. Carbodic austempered ductile iron (CADI) casting process parameters control during austempering.

Structure property correlations study of fractures in various types of cast irons. Evaluation of wear properties weldability of various types of cast irons. Analysis of casting defects.

**Text / Reference Books**

**MML 223 STRUCTURE OF MATERIALS (3-0-0)3 credits**

Classification of materials, properties of materials and their origin, brief introduction to bonding in materials, symmetry, motivation to study symmetry, lattice, crystal, motif, classification of solids based on structure, definition of crystal (lattice+motif), primitive and non-primitive cells, planar (2D) lattice, 3D lattices (14 Bravais lattices), role of symmetry in defining lattices and crystals, mystery of missing Bravais lattices, concept of space filling, sub-lattices and sub-crystals, crystal systems, very brief introduction to advanced definition of crystal (symmetry + space group).

Classic crystals: SC, BCC, FCC, CsCl, NaCl, DC crystal. Millers indices (for directions), family of directions, Millers indices (planes), family of planes, Cubic vs hexagonal crystal, Miller Bravais indices, classification of solids (crystals, quasi-crystals, amorphous), short and long range order, molecular and non-molecular crystals (metallic. Covalent, ionic), coordination number, closed packed structures, packing fraction, atomic density, voids. Examples of ordered structures (Fe<sub>3</sub>Al, CuZn and few more). Types of solid solutions.

Ideal vs real crystals, definition of microstructure. Defect structure-points defects and its equilibrium concentration, methods of producing point defects, dislocations – edge, screw and mixed. Volterra model of dislocation, Burgers vector, dislocation line, dislocations in BCC, FCC and HCP crystals, energy of dislocations, partial dislocations, slip systems in BCC, FCC and HCP, stress field of a screw dislocation. Random vs structural dislocations. 2D defects, classification (surface, grain boundary, stacking faults, twin boundaries, anti-phase boundaries), interfaces (coherent and in-coherent), concept of terraces, ledges and kinks. Types of grains boundaries (low angle and high angle), types of twins. A brief introduction to role of structure on diffusion phenomenon.

How dislocations in ordered phase and ionic crystals differ from normal metallic system? Quasi-crystal – introduction, systems which form quasi –crystal, how they differ from normal crystals. Description of microstructure, nature/distribution of phases during equilibrium and non-equilibrium transformations, simple phase diagrams.

Non-crystalline state, hard sphere model, random-walk model, network model and fractal model (introduction only). Liquid-crystalline state – nematic phase, twisted nematic phase, smectic phase, columnar phase , plastic crystals (introduction only).

**Text Book:**

The structure of Materials, Samuel M. Allen and Edwin L. Thomas, Wiley, MIT Series, 1998.

**MML371 METAL WORKING PROCESSES (3-0-0) 3 credits**

Introduction to Metallurgical Processing, Steps involved in processing and their scope. Elastic and Plastic behaviour of Materials, Engineering Stress – strain curve. True stress strain and flow curve, Important relations of flow curve. Concept of stress and strain in two dimension. Principal stresses, Mohr's circle, Yield Criteria.

Crystal cells and transnational symmetry, plastic deformation by slip and Twinning, Edge and screw Dislocation in crystals, their elementary properties, stacking faults, Deformation of single crystals, Strain hardening mechanisms, Cross slip. Flow cure for FCC single crystal. Grain boundaries, sub grain boundaries, solute atom and II phase particle effects on plastic deformation, annealing cycles, re-crystallization and variables of annealing cycles.

Fundamentals of Metal Working, Classification of processes, Metal working system. Mechanics of metal working, Deformation energy and slab analysis approach. Temperature Effects, Hot working, Strain rate effects. Effect of metallurgical structure. Friction and lubrication in working. Workability, Residual stress, Experimental techniques in working. Computer aided working. Rolling Processes, Definition, Classification products and processing sequences in hot and cold rolling mills. Rolling mill types layouts, Mill line equipments, accessories for flat and shape rolling. Analytical aspects of rolling. Rolling load torque and power calculations, variables of rolling. Rolling mill controls. Defects in rolled products causes and remedies. Metallurgical aspects related to heating, re-heating, deformation during rolling and post rolling practices.

Forging process, Main forging operation, Open and closed die forging. Forging equipments, hammers process, special forging equipments for isothermal ring rolling, near net shape. Analytical aspects of open die forging and design aspects of closed die forging, Forging defects. Forged shape classification and study of forged components for various industrial applications with respect to forging practices, suitable materials and their Metallurgical aspects.

Extrusion processes, Direct and Indirect Extrusion, Extrusion tooling, Analysis of simple extrusion, variables of extrusion. Products and materials suitable for extrusion. Process like impact, Hookers and other based on extrusion principle. Tube drawing operations and their analysis. Wire rod drawing operations, Analysis of wore rod drawing. Drawing load and energy calculations. Elementary concepts wire rod processing with new techniques of controlled cooling, Metallurgical aspects. Sheet Metal forging operation, Formability concepts. Drawing or stretching deep drawing, analysis of basic process, LDR, diffuse necking and formability limit diagram. Anisotropy and its effect drawability tests.

**Text / Reference Books :**

1. Dieter,G.E., Mechanical Metallurgy, McGraw Hill Book Company; Metric Edition,1988.
2. Rowe G. H ,
3. Hosford W.F. and Caddell.Metal, Forming Mechanics and Metallurgy; Prentice Hall, 1983.
4. Dowling Norman E., Mechanical Behavior of Materials, Prentice Hall, 1999.
5. ASM Handbook Vol. 14.; Forming & Forging; Metals Handbook (10<sup>th</sup> Edn.) ASM Intl., 1996.
- 6.
7. Roberts W.L.; Hot Rolling and Steels, Marcel Dekker, 1983.

**MMP371 METAL WORKING PROCESSES LAB. (0-0-2) 2 credits**

A set of practicals based on the above syllabus.

**MML372 PRINCIPLES OF NON FERROUS EXTRACTION METALLURGY (3-0-0) 3 credits**

General methods of extraction in Pyrometallurgy - Drying, Calcination, Roasting, Smelting, Carbothermic and Metallurgical reduction, Refining techniques like Liqation, Distillation, Vacuum Distillation etc. Principles of hydro and electrometallurgy with suitable examples.

Leaching techniques, Leaching solvents, Theory of leaching, Bacterial leaching, Electrochemical nature of leaching, Gold and silver extraction.

Pressure leaching, Sherritt - Gordon process for Copper, Nickel, Cobalt ores; Solvent extraction, Ion exchange.

Electrometallurgy - Electrolysis of aqueous solutions and fused salts, Cell design, Recovery of metal values by Cementation, Electro-winning, Electro-refining etc. Principles and important applications.

Extraction of metals from oxides - Magnesium and Titanium extraction, Bayer's process, Hall Heroult process.

Extraction of metals from sulphides, Extraction of Copper, Lead, Zinc, Nickel.

#### **Reference / Text Books :**

- 1) Ray H.S., Sridhar R., Abraham K.P.; Extraction of Non-ferrous Metals; West Publ., 1990
- 2) Rosenquist T; Principles of Extractive Metallurgy; McGraw Hill Koga Kusa, 1985.
- 3) Serynkova; General Metallurgy
- 4) Volsky A.; Theory of Metallurgical Processes; Mir Publication, 1971.
- 5) Philipova N.; Theory of Metallurgical Processes, Mir Publication; 1975.
- 6) Jackson Eric; Hydrometallurgical Extraction; John Wiley & Sons, 1986.
- 7) Bray J.L.; Extraction of Non-ferrous Metals; John Wiley & Sons, 1959
- 8) Dr. Venkatachalam; Hydrometallurgy; Narosa Publishline House, 1998.

#### **MMP372 PRINCIPLES OF NON FERROUS EXTRACTION METALLURGY LAB. (0-0-2) 1 credit**

Set of experiments based on the above syllabus.

#### **MML 373 FERROUS EXTRACTION METALLURGY (3-0-0) 3 credits**

Iron making historical, raw materials, quality testing and characterization, agglomeration of oxide feed, improved coke making.

Burden distribution control, impact of burden quality on efficiency of iron making processes.

Thermo-kinetics of reactions in blast furnace, hot metal quality, external treatment.

Design and construction details of blast furnace, product handling.

Modern trends in blast furnace design and operation.

Alternate iron making technologies viz. mini blast furnace, rotary kilns, gas based shaft furnaces etc.

#### **Text / Reference Books:**

1. Dr. Tupkary R.H.; Introduction to Modern Iron Making; Khanna Publishers, 1996.
2. Biswas A.K; Principles of Blast Furnace Iron Making; SBA Publication, Calcutta.

#### **MML 378 WEAR OF ENGINEERING MATERIALS (3-0-0) 3 credits**

Introduction, Tribology and wear, industrial importance of wear, wear classification, Sliding wear, mechanism, variables, sliding wear of metallic and non metallic materials, wear maps, test method

Wear by abrasion, types, models of abrasion, Factors affecting abrasive wear, abrasive behaviour of engineering materials, abrasive wear testing, abrasion resistant materials

Wear by erosion, models of erosion, factors affecting erosion, erosion behaviour of engineering materials, erosion resistant materials, test method

Friction and laws of friction, frictional behaviour of metals and non metallic materials

Wear characterization techniques, Miscellaneous forms of wear, Lubrication, types, Liquid and solid lubricants

#### **Text / Reference Books:**

1. Huchings I.M.; Tribology, Friction and wear of Engineering Materials; Butterworth & Heinemann, 1992.
2. Arnell R.D., Davies P.B.; Tribology - Principles and Design Applications; Spriger Verlag, 1991.
3. A.S.M. Handbook : Friction, Lubrication Wear and Tribology (Vol. 18); ASM.

### **MMP 378 WEAR OF ENGINEERING MATERIALS LAB. (0-0-2) 1 credit**

1. Study of various wear testing equipments.
2. Sliding wear test of ferrous and non-ferrous metals using pin on disc apparatus.
3. Dry sand rubber wheel abrasion testing of metallic materials.
4. To study the effect of operational variables on slurry erosion of steels.
5. Study of wear by solid particle erosion of metals and non metals.

### **PHL 305 ELECTRICAL & MAGNETIC MATERIALS (3-0-0) 3 credits**

**Magnetic Materials :** Concept of Magnetism, Classification of magnetic materials, diamagnetic, paramagnetic, ferromagnetic, anti-ferromagnetic and ferromagnetic materials. Spontaneous magnetization, ferromagnetic domains soft magnetic, magnetic materials, hard magnetic materials ferrites.

**Dielectric Materials :** Fundamental concepts, Types of polarization, electronic, ionic, orientational polarization polar and non-polar dielectrics, ferroelectricity and piezoelectricity spontaneous polarization, Curie-Weiss law, Electroceramics, Processing and applications of electroceramics, Transducers.

**Industrial Lasers :** Basic concepts, properties of lasers, Nd:YAG laser, CO<sub>2</sub> laser, Industrial applications of lasers, drilling, cutting, welding, heat treatment

**Electrical Conductivity Materials :** Conduction in Metals Free electron theory, Ohm's Law, Joule's Law, Factors affecting electrical resistivity of metals. Properties of Coppers, Brass, Aluminium, Materials for conducting applications, Hard and Soft Solders, electrical fuses heating elements, Ionic conductors, Superconductors, Silsbee's rule, Meissner effect, type – I and type – II superconductors, Applications of superconductors.

**Semiconductor I :** Semiconducting materials, element semiconductors, II – IV compounds, III – V compounds, ternary and quaternary compounds, oxide semiconductors, refractory semiconductors, magnetic semiconductors, organic semiconductors.

**Semiconductors – II :** The p-n junction diode, half wave and full wave rectifier, voltage stabilization, light emitting diode, the junction transistors, silicon controlled rectifiers (thyristors), integrated circuits, different types of ICs, metal oxides, silicon ICs.

#### **Text / Reference Books:**

1. Dekkar A. J.; Electrical Engineering Material (19<sup>th</sup> Edition); Prentice Hall India, 1997
2. Kenneth Krane; Modern Physics; (2<sup>nd</sup> Edition); John Wiley Eastern, 1998
3. Kasap S. O.; Principal of Electronic Materials and Devices (2<sup>nd</sup> Edition); TATA McGraw-Hill

### **PHP 306 ELECTRICAL AND ELECTRONIC MATERIALS LAB. (0-0-2) 1 credit**

- 1) To study the temperature variation of resistivity for a semiconductor and find its band gap by Four – Probe method.
- 2) To find the mobility and carrier concentration in the sample (metal or semiconductor) using Hall effect setup.
- 3) To determine the conductivity of given sample by Kelvin's Bridge Method.
- 4) To determine the coefficient of Thermal Conductivity of a bad conductor by Lee's disc method.
- 5) To study the Transmission of AC voltage through optical fibre and Co-axial cable and compare the result using Fibre Optics Kit.
- 6) To determine the Coercivity, Saturation Magnetisation, Retentivity and Hysteresis Loss of a given sample using Hysteresis Curve Tracer.
- 7) To measure the Dielectric Constant of a liquid dielectric and to study the temperature dependence of dielectric constant.
- 8) To determine the Magnetic Susceptibility of Paramagnetic solution by Quinke's Tube Method.
- 9) Application of LASER as a Particle Size Analyzer.
- 10) To determine the dielectric constant of given solid dielectric (Bakelite, Glass, Plywood and PZT sample) and analyze the result.
- 11) To study the variation of dielectric constant of PZT sample with temperature and determine its Curie temperature.
- 12) To study the variation of energy loss of ferromagnetic material with temperature and to determine its Curie temperature.

### **MML351 PROCESS OPTIMIZATION (3-0-0) 3 credits**

Principles of Quality Engineering : Traditional concept of quality, Quadratic Loss Function ,Variations of Quadratic Loss Function,Noise Factors – Causes of Variation,Average Quality Loss,Classification of Parameters: P Diagram,Optimization of Product or Process Design,Role of various quality control activities

Orthogonal Arrays :- Different test strategies,Degrees of freedom, selection of a standard orthogonal array,ANNOVA,Case study 1 - matrix experiment using orthogonal arrays,Designing a optimized product / process Case study 2 – Selection of noise factors and testing conditions,Quality characteristics and objective function,Control factors and their levels,Matrix experiment and Data Analysis

Signal to Noise Ratios:- S/N ratios for static problems,S/N ratios for dynamic problems, Statistical Process Control, Control Charts

#### **Text / Reference Books:**

Quality engineering using robust design, Madhav S. Phadke  
Taguchi techniques for quality engineering, Philip J. Ross

### **MML 368 INDUSTRIAL METALLURGY (3-0-0) 3 credits**

#### **Unit – I:**

Introduction to various terms used in foundry, Study of various unit operations required in foundry, Principles of sand molding, molding materials & processes, Sand Testing Methods, Reclamation of Sand. Introduction to various terms used in gating & risering systems and their functions. Casting defects & their remedies, melting units in foundries, recent trends in molding and casting processes.

#### **Unit II:**

Survey of the welding processes, present status, classification, joint design, importance of backing and welding symbols. Introduction to Welding Processes. Inspection & testing in welding, Introduction to welding metallurgy, weldability, study of special welding processes.

#### **Unit III:**

Introduction to Powder Metallurgy Techniques, advantages / disadvantages of PM techniques. Powder production methods. Sintering furnaces and their types; Sintering atmospheres, Testing & evaluation of powder.

#### **Text / Reference Books :**

1. Principles of metal casting, McGraw-Hill, Hiene and Rosenthal.
2. Welding and welding technology, McGraw-Hill, Littile
3. A textbook of powder metallurgy, Sands and Shakespears.
4. ASM Handbook on welding.

### **MML576 BIOMATERIALS (3-0-0) 3 credits**

Introduction- Clasification-General Characteristics-Structure & Properties of Materials-Relevance – Crystal/Molecular Structure-Imperfections-Phase Diagrams.

Implant Materials-Metallic, Ceramic,Polymer, Composite

Characterization of Biomaterials-Mechanical, Chemical, Thermal, etc.Structural evolution of biocompatibility with reference to corrosion. Structural property correlation

Application of Biomaterials-Orthopaedic, Dentistry, Cardiac Devices, etc.

Tissue Engineering- Soft Biomaterials

Case Studies, Proliferation of Biomaterials for development of Medical Technology & mankind

#### **Books:**

1. Biomaterials- Sujata Bhat
2. Handbook of Materials Behaviour Models, Vol.3- Multiphase Behaviour
3. Biomaterials- Artificial organs & Tissue Engineering (Handbook)
4. Science & Engineering of Materials- D.R. Askeland
5. Light Alloys- Polmear
6. Physical Metallurgy Principles- R. Reed-Hill

## 7. Physical Metallurgy of Stainless Steel- F.B Pickering

### **MML 388 CHEMICAL CHARACTERIZATION OF MATERIALS (3-0-0) 3 credits**

Classification of various methods of analysis – Gravimetric, Volumetric, Gas Analysis, Calorimetric, Nephelometric electro – chemical methods; preparation of substances for analysis, error in quantitative analysis, Calculations of Gravimetric and Volumetric analysis results.

Principles of Gravimetric analysis, requirement for precipitates, choice and amount of precipitant, salt effect, effect of temperature, hydrogen ion concentration and complex formation on completeness of preparation; formation of amorphous and crystalline precipitates co-precipitation, washing of precipitates.

Principles of volumetric analysis, classification of methods, requirements of reactions, preparation of standard solutions.

Neutralization method : principle, theory of indicators, titration curves for titration of strong acid with strong alkali, weak acid with strong alkali, weak bases with strong acids, buffer action, indicator errors in titration.

Oxidation – Reduction methods, oxidation potentials, direction of reactions, equilibrium constants, titration curves and indicators, rate of reaction and side reaction.

Principles of redox titration – Permanganometry, dichrometry, iodometry, bromatometry, etc., standard solutions, and indicators.

Precipitation and complex forming methods, principles, titration curves, methods of determining the equivalence point etc. EDTA titrations.

#### **Text / Reference Books :**

1. V. Alexeyev ; Qualitative Analysis; MIR Publishers, 1959
2. Jain S.P. & Agrawal BC; Text book of Metallurgical Analysis; Khanna Pub. Co., 1976.
3. W.V. Soot.; Standard methods of Chemical Analysis
4. A.I. Vogel.; Text book of Quantitative Inorganic Analysis; English Language Book Services, 1978
5. Young R.S.; Chemical Analysis in Extractive Metallurgy; Charles, Griffin & Co. Ltd, 1971

### **MMP 388 CHEMICAL CHARACTERIZATION OF MATERIALS LAB (0-0-2) 1 credit**

1. Determination of Carbon and Sulphur in Ferrous Materials by “Stroheleins Apparatus”
2. Determination of Manganese in steel by sodium Bismuthate method.
3. Determination of Chromium in steel by ammonium Persulphate method.
4. Determination of Phosphorus in steel by ammonium Nitromolybdate method.
5. Determination of Silicon in steel by gravimetric method.
6. Determination of Nickel in steel by Dimethylglyoxime method.
7. Determination of Sulphur in steel by Iodometric method.
8. Determination of Copper in steel by Iodometric and Electrogravimetric method.
9. Determination of Iron in iron ore by Volumetric method.
10. Preparation of standard solutions and standardization of standard solutions.

### **MML374 CHARACTERIZATION OF MATERIALS (3-0-0) 3 credits**

Introduction to materials characterization, its importance, structure sensitive/insensitive properties, structure-property correlation, crystallography basics, resolution, depth of field/focus, aberrations (spherical, chromatic and astigmatism), remedial measures for aberrations, levels of characterization (macro, meso and micro).

Optical microscopy (OM) – reflected/transmitted light microscope, theoretical and practical resolution of optical microscope, numerical aperture, principle of image formation, microscope construction and working, effective/empty magnification, different



light sources, flat field correction, types of illumination - bright field, dark field, polarized light and phase contrast, applications of each type of illumination.

Sample preparation for optical microscopy, features of an image, introduction to scanning electron microscope (SEM), advantages/disadvantages as compared to OM, mechanics of SEM, types of electron gun and comparison between them (resolution, brightness, efficiency, cost and stability), ray diagram of SEM, working and construction, magnification.

Electron-specimen interaction, imaging modes (secondary and backscattered), effect of spot size, apertures, accelerating voltage on SEM image, Everhart-Thornley detector, Robinson detector, solid state segmented detector, atomic number and topological contrast, critical probe current.

Chemical analysis using SEM, EDS/WDS working principle, construction, spot analysis, line scan and area scan, resolution of EDS/WDS detector, advantages/disadvantages, calibration of EDS/WDS, qualitative and quantitative analysis.

X-ray diffraction – Generation of X-rays, characteristic X-ray spectrum, Bragg's Law, Diffraction methods - Laue method, rotating crystal method, powder method, Principle, equipment and applications, structure factor, derivation of diffraction conditions for SC, BCC and FCC Bravais lattice, X-ray diffractometer, filters and counters/detectors, applications of X-ray diffraction in materials characterization – determination of crystal structure, lattice parameter, introduction of GIXRD.

Thermal analysis techniques – Importance, principles and applications of differential thermal analysis, differential scanning calorimetry and thermogravimetric analysis, accuracy, sensitivity, calibration and differences.

Characterization for materials selection and design case studies.

#### **BOOKS:**

1. Hebbbar K R, "Basics of X-Ray Diffraction and its Applications", I.K. International Publishing House Pvt Ltd, New Delhi, 2007
2. Phillips V A, "Modern Metallographic Techniques and their Applications", Wiley Eastern, 1971.
3. Cherepin V T and Mallic A K. "Experimental Techniques in Physical Metallurgy", Asia Publishing Co, Bombay, 1967.
4. Class notes.

#### **REFERENCES:**

1. Cullity B D., Stock S R "Elements of X-ray Diffraction", Prentice Hall, Inc 2001.
2. Whan R E (Ed), ASM Handbook, Volume 10, Materials Characterization "", Ninth edition, ASM international, USA, 1986.
3. Vander Voort, "Metallography: Principle and practice", Mc Graw Hill Inc., 1984.
4. Kehl G L., "The Principles of Metallographic Laboratory Practice", McGraw Hill Book Company, 1949.

### **MMP374 CHARACTERIZATION OF MATERIALS LAB. (0-0-2) 1 credit**

*Set of experiments based on the above syllabus)*

### **MML 365 STEEL MAKING TECHNOLOGY (3-0-0) 3 credits**

Raw materials for steel making, thermodynamics and kinetics of steel making reactions viz, decarburization, dephosphorization, deoxidation, desulphurization etc.

Historical steel making – Besemer, open hearth and modified open hearth steel making.

Operation of top and bottom down blown oxygen steel making furnaces, process control and efficiency.

Electric steel making practice and secondary steel making processes.

Ingot casting and continuous casting process.

#### **Text / Reference Books:**

1. Dr. Tupkary R.H.; Introduction to Modern Steel making; Khanna Publishers, 1996.
2. Turkdogan E.T.; Fundamentals of steel making; The Institute of Materials, 1996.

### **MML382 SOLIDIFICATION PROCESSING AND ADVANCED FOUNDRY TECHNOLOGY (3-0-0) 3 credits**

Solidification of metals and alloys, segregation and shrinkage phenomena in castings, solidification values for steels, calculation of solidification time for casting, heat transfer calculations in metal casting. Principles of gating, fluid flow equations and application in gating design, aspiration in down sprue and at sharp corners, step gates stack molding, gating design for cast irons, spheroidal graphite iron and steel castings. Riser design techniques, riser design, calculation of feeding distance of riser for bars and plates. Directional solidification in steel castings, principles of chill design, insulating and exothermic sleeves, hot tears. Ferrous foundry practice, general principles underlying molding, core making, riser and gating design in grey cast iron, malleable cast iron, S.G. iron and steel, plant layout considerations. Nonferrous foundry practice, recent trends in casting practice, analysis of casting defects, case studies.

#### **Text / Reference Books :**

1. Flinn R.A.; Fundamentals of Metal Casting; Addison Wesley Pub. Co., 1963.
2. Mukherjee P.C.; Principles of Metal Casting
3. Bray J.L.; Nonferrous Foundry Metallurgy; John Wiley & Sons, 1959.
4. Wladaver; Directional Solidification in steel castings.
5. Briggs R.W.; Metallurgy of Steel Casting; McGraw Hill, 1946.

### **MMP382 SOLIDIFICATION PROCESSING AND ADVANCED FOUNDRY TECHNOLOGY LAB. (0-0-2)**

#### **1 credit**

Set of experiments based on the above syllabus.

### **MML 375 JOINING OF MATERIALS (3-0-0) 3 credits**

Survey of the welding processes, present status, classification, joint design, importance of backing and welding symbols.

Study of welding processes such as Gas, Electrodes, Resistance, Spot, Seam, Electron beam, laser beam etc. Scope, instruments, limitations, applications and standards, welding specifications, study of VA characteristics and different parameters affecting quality and electrode classifications.

Study of special welding processes such as TIG, MIG submerged arc, thermit welding underwater ultrasonic welding and friction welding etc. scope, instruments, limitations applications, standards, welding specifications.

Welding problems and remedies in steels, cast iron and non-ferrous metals and alloys, requirements of quality control, inspection and testing in welding.

Importance of welding metallurgy, weldability, tests assessment techniques, heat flow in welding HAZ and distortion, numericals based on heat transfer and welding metallurgy.

Analysis of welding defects, dissimilar metal welding problems and remedies, welder accessibility test.

#### **Books:**

1. Welding & Welding Technology Little R McGraw Hill, 2002. ASM Handbook No. 6 on Welding
2. Brazing & Soldering.
3. G.E.; Welding Metallurgy Vol. 1, Linnert AWS 1965.
4. Welding Technology Khanna O.P. Dhanpat Rai Publications, 1999.
5. Principles of Welding Technology Gourd.

### **MMP 375 JOINING OF MATERIALS LAB (0-0-2) 1 credit**

Set of practical based on the above syllabus.

### **MML 383 LIGHT METAL ALLOYS (3-0-0) 3 credits**

Classification of light metal alloys, their properties, importance of strength / wt ratio in engineering applications. Detailed engineering applications, Indian / International specifications.  
Melting methodology of light metal alloys used of melting / refining flows.  
Casting characteristics of light metal alloys (Al, Mg, Ti alloys).  
Light metal alloys foundry practices, master alloy used in melting.  
Physical metallurgy of light metal alloys, rolling, sheet metal working, extrusion etc.  
Special Alloys: Duralumin, Al-Li, Mg-Li alloys - production and processing techniques & applications.  
Titanium alloys: Alloying elements and their effects, types of alloys, their processing, heat treatment, properties and selection.  
Strategic applications of light metal alloys., air craft industries. Functional considerations  
Defects analysis in cast and rolled products  
Failure analysis of light metal alloys components.

#### **Text / Reference Books :**

1. Raudebaugh R.J.; Non-ferrous Physical Metallurgy; Pitmavi Publishing Corp., 1952.
2. Polmear I.J.; Light Alloys (3<sup>rd</sup> Edition); Arnold, 1995.
3. Bickert C.M.; Light Metals; Minerals Metals & Materials Society, 1990.
4. Brooks C.R.; Heat Treatment Processing & Structure Properties of Non Ferrous Alloys; ASM, 1984.

### **MMP 383 LIGHT METAL ALLOYS LAB (0-0-2) 1 credit**

Set of practical based on the above syllabus.

### **MML384 ALLOY STEELS & HIGH TEMPERATURE ALLOYS (3-0-0) 3 credits**

Classification of Alloy Steels depending on alloying content, effect of alloying elements on the constitution, structure and properties of steels, ferrite former and carbide former, alloy cast irons.

Studies of low alloy structural steels, High strength low alloy steels, Dual phase steels, General Engineering Steels, Medium alloy and high alloy tool steels such as H13, HSS etc.

Corrosion resistant stainless steels, processing and heat treatment of Hadfield's Mn Steel, spring steel, electrical sheet steels, steels for magnetic application, Maraging steel, Austempered steel and TRIP Steels.

Heat treatment equipments, techniques employed for low, medium and high alloy steels with special emphasis on high speed tool steel, stainless steel, spring steels, alloy cast iron, ,

Various specification viz. AISI, BSS, DIN & IS for alloy steels and alloy cast iron.

Heat resistant alloys - general properties, metallurgical structure, processing, applications and limitations, Super base alloys- Ni-base alloys, Co-base alloys, Fe-base alloys, Ni-Fe base alloys.

Titanium alloys for high temperature aeronautical applications, their processing, properties, selection.

#### **Text / Reference Books :**

1. Roberts G.A.; Tool Steels; American Society of Metals, 1980.
2. Clark, Varney W.R.; Metallurgy for Engineers; East West Press, 1962.
3. Peter Payson; The Metallurgy of Tool Steels; John Wiley & Sons, 1962.
4. ASM Handbook –Vol.1 (10<sup>th</sup> Edition); ASM International, 1995.

### **MML355 PARTICULATE TECHNOLOGY (3-0-0) 3 credits**

Introduction, Methods of powder preparation (mechanical, chemical), Methods and equipments of powder compaction (Die compaction, Isostatic), Slip casting, Tape casting, Extrusion, Sintering – Method, Equipments, Atmospheres, Applications (Porous products, electrical contacts, Friction parts etc.)

**Books:**

Particulate Tech - A Textbook of Powder Metallurgy by Sands & Shakespears,  
Powder Metallurgy by AK Sinha

**MML 386 SEMICONDUCTOR TECHNOLOGY (3-0-0) 3 credits**

Physics and Properties of Semiconductors materials: crystal structure, energy bands, Fermi level, carrier concentration at thermal equilibrium, carrier transport phenomena, Hall Effect, recombination mechanism, optical and thermal phenomenon.

Device Processing Technology: oxidation, diffusion, ion-implantation, deposition, lithography, etching and interconnect. p-n Junction: depletion region, diffusion, generation-recombination, current-voltage characteristics, junction breakdown, charge storage and transient behavior.

Metal-Semiconductor Contacts: equilibrium, idealized metal semiconductor junctions, ohmic contacts, Solar energy-definitions, its intensity distribution, variation and spectrum, thermodynamics of solar energy spectrum, mechanism of heat losses, efficiency, photo thermal conversion materials and their preparation and characterization.

Design of material for solar applications: collectors, selective surface, composite semiconductors, solar reflectors and concentrators, thermo-electric conversion, chalcogenide and alloy semiconductors, criteria for material selection, spectral response, efficiency.

Types of Photovoltaic (PV) cells; p-n homo and hetero junction, First, Second and Third Generation PV devices.

PV materials: silicon - single crystalline, polycrystalline, ribbon, amorphous, nanocrystalline; CdS, Cu(In,Ga)Se<sub>2</sub>, Cd-Te/Se, GaAs, In-P/As, ZnMgO, PbS.

PV Material qualification for terrestrial and space application, radiation damage, arrays and solar cell systems, energy storage-thermal, chemical, electrochemical storage and hydrogen generation. Challenges and Solutions for Manufacturing of PV solar cell, Understanding the defect related issues

**BOOKS**

1. S.M. Sze, Physics of Semiconductor Devices, John Wiley & Sons, 2nd Edition (2001)
2. Antonio Luque and Steven Hegedus, Handbook of Photovoltaic Science and Engineering, John Wiley & Sons, 1 st Edition (2008)
3. S.S. Islam, Semiconductor Physics and Devices, Oxford University Press, 2nd Edition (2006)

**MML385 HYDRO AND ELECTRO METALLURGY (3-0-0) 6 credits**

**Introduction:** Justification of Hydrometallurgical selection of solvent processing, Eh-Ptt diagrams Principles underlying hydrometallurgical processes, various commercial hydrometallurgical processes. Criteria for selection of solvents, Types of Solvents.

- Thermodynamics & kinetics of hydrometallurgical processes.
- Unit operations in hydrometallurgical processing, Thickness & filters, counter current decantation.
- Applications of hydrometallurgy to Copper, Zinc, Precious metals etc.
- Solvent Extraction & Ion Exchange.

- Purification methods of leach solutions.
- Recovery of metal values from solution.
- Precipitation methods Thermodynamics & Kinetics of concentration.
- Electrolytic Recovery-  
Electrowining of methods from Aq. Solutions Electro Refining.
- Fused Salt Electrolysis – Extraction of Aluminium & Magnesium from their ores.

Mass balance calculations.

## **BOOKS**

H. S. Ray, K. P. Abraham and R. Sridhar, Extraction of Non-Ferrous Metals , Affiliated East- West Press.

T. Rosenquist , Principles of Extractive Metallurgy

S. Venkatachalam, Hydrometallurgy Narosa Publication Co

E. Jackson, Hydrometallurgical Processing & Reclamation, John Wicky & Sons.

## **MML389 FINANCIAL ENGINEERING(3-0-0) 3 credits**

Following syllabus has six units. The aim of this course is to overcome some basic concepts of financial engineering: the issues that arise in modeling, analysis and decision making involving financial instruments. Discrete time models and computational tools will be the focus.

Principles of Finance: Concept of Business Finance, Finance Function, Scope, Responsibilities of Finance Executive, Goals and Objective Of Finance Management, Source of Financing – LONG TERM : Shares, Debentures, Term Loans, Lease and Hire Purchase, Retained Earnings, Public Deposits, Bonds (Types, Features and Utility); SHORT TERM: Bank Finance, Commercial Paper And Trade Credit and Bills Discounting.

Mathematics: An Understanding of Mathematics and Their Applications in Finance, Business, and Economic. Time Value of Money, Methods of Calculations, Compounding and Discounting, Future Value and Present Value.

Financial Statement Analysis: Balance Sheet, Profit & Loss Account, Ratio Analysis Its Importance, Classification and formula for comparison; Funds Flow Statements Financial Analysis , Decision Capital Budgeting , Budgetary Control, Standard Costing and Variance, Investments Appraisal.

Financial Risk Management: Concept of Risk, Its Types and how to measure it. Measurements rate of return of a stock, how its arises and Financial Derivatives.

Financial Market: Derivative Commodities: Types Of Derivative Contracts, History Of Financial Derivatives Markets, Participants in a derivative market , Economic Function of the derivative market, Trading of Derivatives Contracts Futures and Options Trading System, The Trader Workstation, Futures and Options Market Instruments, Criteria's For Stocks and Index Eligibility For Trading, Charges, Clearing And Settlement – Clearing Mechanism, Settlement Procedure.

Portfolio Theory: Risk and Return for one security, Two Security and Portfolio. Effect frontier, Investor Utility, Capital Market Theory – Background, Risk Free Asset, The Market Portfolio, Capital Asset Pricing Model, Systematic and Unsystematic Risk, CML, SML, Arbitrage pricing theory – empirical test of APT, Sharpe's single index model.

## **MML471 STRUCTURAL METALLURGY (3-0-0) 3 credits**

Elements of Crystallography, Miller indices and Miller Bravais indices of planes and directions, stereographic projections and its uses.

Principles of X-ray generation, Characteristics and continuous radiation, absorption, choice of filters, Laue equations and Bragg's law, Laue, Powder and Rotating crystal techniques.

Interpretation of different patterns, Study of powder method in detail, Structure factor and its calculation for simple cubic, BCC and FCC lattices. Indexing of powder pattern and determination of lattice parameter, Application of x-rays for determining orientation, crystal perfection, grain size, phase diagram, long range order, preferred orientation, chemical analysis and residual stresses.

Diffusion in metals and alloys, self diffusion and alloy diffusion, Fick's first law and second law, solution of Fick's second law using Grube-Jedal method and Matano's method, Non-steady state diffusion in semi-infinite medium, Kirkendall effect, intrinsic and extrinsic diffusion coefficients; Factors affecting diffusion, atomistic mechanism of diffusion. Principles of reaction rate theory.

Dislocation theory. Recapitulation of geometrical aspects of dislocations, movement of dislocation, multiplication of dislocations, elastic properties of dislocations, elastic interaction between dislocations, dissociation of dislocations, Thompson tetrahedron interaction of grain boundaries with dislocations, intersection of moving dislocations, interaction of solute atoms with dislocations, yield point phenomenon and strain aging, mechanism of solid solution hardening, interaction of moving dislocations with second phase particles. Immobile dislocations, theories of work hardening, review of strengthening mechanisms.

Kinetics and mechanism of phase transformations, Homogeneous and heterogeneous nucleation in solidification, solid state nucleation - coherent and incoherent nucleation. Study of various solid state phase transformations, precipitation and age hardening, pearlite transformation, bainite transformation, martensite transformation, order-disorder transformation, recovery-recrystallization and grain growth.

Recapitulation of fatigue behaviour of S-N curve, Effect of mean stress, cyclic stress-strain curve, low cycle fatigue, strain life equation, Structural features of fatigue, fatigue crack propagation, mechanical and metallurgical factors affecting fatigue life. Introduction to creep, analysis of creep curve, structural changes during creep, deformation mechanism maps, introduction to fracture mechanics, strain energy, release rate, stress intensity factors, Fracture toughness and design.

#### **Text / Reference Books:**

1. Cullity B.D.; Elements of X-Ray diffraction; Prentice Hall Inc., USA, 2001.
2. Dieter G.; Mechanical Metallurgy; McGraw Hill, N. York, 1986.
3. Wulff John; Structure and Properties of Materials; WWF Series - Vol. I to 4
4. R Reed. Hill ; Physical metallurgy Principles; East West Publication.
5. Shawmon P.G.; Diffusion in Solids; McGraw Hill, USA, 1973.
6. Honey Comb RWK ; Plastic Deformation in Metals; McGraw Hill, 1963
7. Barrett C.S., T.B. Massalaski; Structure & properties of Materials; McGraw Hill, USA, 1966
8. V. Raghavan ; Solid state transformation; Prentice Hall of India, Delhi, 1987.

#### **MMP 471 STRUCTURAL METALLURGY LAB (0-0-2) 1 credit**

1. Problems on Crystallography – Stereographic projection – Determination of standard projection.
2. Problems on X-ray diffractions – Filters, Indexing, Stress analysis, Solvus line etc. Indexing – Determination of Bravais lattice, Lattice parameter from Debye-scherrer pattern.
3. problems on Diffusion – Ficks 1<sup>st</sup> and 2<sup>nd</sup> law, Analysis of Matano and Grube Jedal method, Kirkendall effect – Diffusion in Semi-infinite medium i.e. Carburizing, Nitriding etc.
4. Problems on Plastic deformation – Determination of CRSS, Energy of dislocation, Thomson's Tetrahedra etc.
5. Problems on Phase transformation and Rate of reaction.

#### **MML 472 ENVIRONMENTAL DEGRADATION OF METALLIC MATERIALS (3-0-0) 3 credits**

Introduction to corrosion, Examples of corrosion, Economic and Technical significance of Corrosion. Chemical and Electrochemical reactions. Electro motive force, Electrode potential, Galvanic Series, Electrochemical Equilibrium, Potential - pH diagram (Examples H<sub>2</sub>O, Zn-H<sub>2</sub>O and Fe - H<sub>2</sub>O system)

Electrode kinetics, Evans diagram, Polarization and types of polarization. Mixed potential theory. Passivity. Effect of oxidizers, solution velocity and galvanic coupling.

Classification of various forms of corrosion and their mechanisms. Details of General pitting, crevice, intergranular, selective leaching, stress corrosion cracking, Hydrogen embrittlement, high temperature oxidation, Hot corrosion, etc. Wagner Electrochemical oxidation theory, Hauffe's valency affects.

Methods of testing in corrosion, high temperature oxidation and hot corrosion. Methods like Gravimetric, Potential-time, Potentiodynamic polarization, Linear polarization, Electrochemical Impedance, Spectroscopy, Electrochemical noise, etc. with case studies.

Corrosion behaviour of industrial metals and alloys like steels, stainless steels, copper and copper alloys, nickel and nickel alloy, aluminium and aluminium alloys, titanium and titanium alloys etc. Application of these metals and alloys. Effect of environment on their corrosion behaviour.

Methods of corrosion control (practical and fundamental approach) like selection of material, inhibition, coatings, alloying, heat treatment, change in design, change in corrosive environment, etc. Types of inhibitors, types of coatings. Cathodic and anodic protection. Instruments and accessories for cathodic and anodic protection.

#### **Text / Reference Books :**

1. Mars G. Fontana; 'Corrosion Engineering', 3<sup>rd</sup> Edition; McGraw Hill Book Company, 1987.
2. Raj Narayan; 'An Introduction to Metallic Corrosion & its Prevention'; Oxford & IBH Publishing Co. Pvt. Ltd., 1988.

#### **MMP 472 ENVIRONMENTAL DEGRADATION OF METALLIC MATERIALS LAB. (0-0-2) 1 credit**

1. Weight loss (gravimetric) based corrosion rate determination.
2. Effect of Cl<sup>-</sup> ion concentration on corrosion rate of various metals and alloys (gravimetric)
3. Effect of pH on corrosion rate of various metals and alloys (gravimetric).
4. Effect of oxidizer (FeCl<sub>3</sub>) on corrosion rate of various metals and alloys (gravimetric).
5. Potential – time behaviour of various metals and alloys.
6. Cathodic polarization for corrosion rate determination of various metals and alloys.
7. Anodic polarization behaviour of various metals and alloys. (passivation behaviour)
8. Effect of pH on anodic polarization behaviour.
9. Testing on crevice corrosion behaviour.
10. Testing on galvanic corrosion.
11. Studies of reference electrode.
12. Determination of corrosion tendency of re-bars in RCC.
13. Effect of coating on corrosion rate.

#### **MML 474 X-RAY DIFFRACTION & ELECTRON MICROSCOPY (3-0-0) 3 credits**

Introduction to crystallography, Symmetry – point group and space group, reading of the space group tables, X-ray diffraction – Generation of X-rays, characteristic X-ray spectrum, Bragg's Law, Diffraction methods - Laue method, rotating crystal method, powder method, Principle, equipment and applications, structure factor, derivation of diffraction conditions for SC, BCC and FCC Bravais lattice, X-ray diffractometer, filters and counters/detectors, texture, importance of texture, measurement of texture, pole figures (stereographic projections), orientation distribution function, sample symmetry, and its importance, applications of X-ray diffraction in materials characterization – determination of crystal structure, lattice parameter, examples of textures in cubic materials, Introduction of GIXRD, instrumental configuration for texture measurement and GIXRD.

Electrons as source, properties of electron beam, elastic and inelastic scattering of electrons, importance in electron microscopy, resolution, principles of transmission electron microscopy, construction, ray-diagram, working, sample preparation, contrast mechanisms, ring and spot diffraction patterns, detectors and imaging modes, kikuchi lines, measurement of lattice parameter, orientation relationship determination, Introduction to HRTEM.

**REFERENCES:**

1. Cullity B D., Stock S R "Elements of X-ray Diffraction", Prentice Hall, Inc 2001.
2. Brandon and Kaplan, Microstructural characterization of materials.
3. ASM Handbook of characterization of materials.
4. Class notes.

**MML443 METALLURGY OF NUCLEAR MATERIALS (3-0-0) 3 credits**

Introduction: Physico-chemical properties of Nuclear metals used as fuels (Uranium, Plutonium, Thorium etc.) and of Beryllium & zirconium as neutron moderator & fuel cladding metal respectively.

Physico-chemical & thermodynamics principles of extraction processes viz. chemical ore break breakdown, solvent extraction, Ion-exchange, Halogenation.

Consolidation, vacuum Refining & Ultra purification.

Thermodynamics of metallothermic reduction.

Extraction of Uranium, production of Uranium in India.

Production of plutonium, conversion of plutonium compounds to metallic state.

Extraction of Thorium.

Extraction of Zirconium & Beryllium. Nuclear Fuel production.

**Text Books**

1. Sunderam C.V., Gupta C.K, Nuclear metals & materials in chemical technology, CSIR, New Delhi(1980).
2. Prakash B, Kantan S. R., Rao N. K., Metallurgy of Thorium production monograph 221 IAEA
3. Bellmay R & Hill N. A., Extraction & Metallurgy of Uranium Thorium & Beryllium Pergamon, Press Oxford (1963).
4. H. S. Ray, K. P. Abraham & R. Sridhar, Extraction of Non ferrous Metals, Affiliated East- West Press PP 419-487.

**MML 479 SELECTION OF MATERIALS (3-0-0) 3 credits**

Introduction, engineering properties of materials and applications, property parameters for selection, materials selection and processing, factors affecting material selection, material selection vis-a-vis design,

Selection of material for static strength, assessment of strength levels of engineering materials, selection criterion for static strength. Materials selection for stiffness, importance of stiffness, stiffness of engineering materials, geometric stiffness, stiffness of sections, panel structure, material selection criterion for stiffness.

Selection of materials for toughness, assessment of toughness, transition temperature approach, fracture mechanics, linear elastic fracture mechanics, EPFM assessment of fracture toughness design and material selection for fracture toughness. case studies

Material selection for fatigue strength, mechanisms, evaluation of fatigue life, effect of mean stress fracture mechanics and fatigue factors, factor affecting fatigue of metallic materials, fatigue of polymeric materials, fatigue design philosophies.

Material selection for creep, evaluation of creep resistance, Creep curve. Effect of stress and temperature, development of creep resistant alloys, materials vis-a-vis service temperature, selection criterion.

Selection of materials for wear resistance, mode and mechanism of wear, material for resistance to adhesion, abrasion and erosion, guidelines for selection. Case studies

**Text / Reference Books:**

1. Charles J.A.; Crane FAA, Furness JAG; Selection & Use of Engineering Materials; Butterworth & Heinemann,
2. Dieter G.E.; Mechanical Metallurgy; McGraw Hill, 1988.
3. Ashby M.F., Jones D.R.; Engineering Materials; Pergamon Press, 1992.
4. Askeland DR : Engineering Materials
5. ASM Handbook : Vol.20: Material Selection : ASM



### **MML469 NON-DESTRUCTIVE TESTING (3-0-0) 3 credits**

Introduction and scope of non-destructive testing and evaluation (NDT/NDE) methods. Visual examination, principles and equipments, optical aids.

Liquid penetrant testing: principle, procedure, penetrant materials and methods, applications.

Principles of magnetic particle testing, procedures and equipment's for MPT, magnetic field testing; limitations of MP methods, electromagnetic testing for residual stress measurement. Eddy current testing, principle and instrumentation, techniques like high sensitivity, multifrequency, high area, pulsed ECT, inspection of ferro-magnetic material, application and limitation ECT.

Radiographic inspection, principle, radiation sources, radiation attenuation's; film effect.

Radiographic imaging: geometric factors film, screens, sensitivity parameters, exposure etc.

Imaging techniques: single wall, double wall, penetration, single image etc., applications and case studies; limitations.

Ultrasonic Testing:

Basic principles, type of sound waves and their characteristics, ultra transducers characteristics, inspection methods, normal incident pulse echo through transmission. Angle beam, probe selection criterion, sensitivity, penetration and resolution. Modes of display, A,B,C types of scan, immersion testing applications, case studies, limitations.

Special / advanced techniques of NDE /AET, thermography, replica microscopy (in situ). Leak testing, remote field ECT, microwave inspection, topography, holography (only principle and applications).

Criteria for selection of NDT methods and instruments related to metallurgical processes / defect in cast, forged and rolled, heat treated and fabricated items (one case study for each category), reliability in NDT. Statistical method & quality control in NDT codes and standard specifications.

#### **Text / Reference Books :**

1. Baldev Raj & T. Jayakumar ; Practicals Non-destructive Testing; Nanda Publishers, 1997.
2. Gordon & Breach ; Non-Destructive Testing; 1971
3. Ultrasonic Testing,; Krautkammer Norsa Publ., 1993
4. Feigenbanm A.V.; Total Quality Control
5. Metal Handbook ASM 8<sup>th</sup> Edition, Vol. II
6. Non-destructive testing and quality control.
7. Davis Toxell; Non destructive evaluation of properties of materials.

### **MML 477 SECONDARY & SPECIAL STEEL MAKING (3-0-0) 3 credits**

The concept of cleanliness of steels, non-metallic inclusions, dissolved gases. Tramp & residual elements in steels and their effect on steel properties.

Thermodynamic and kinetics consideration of deoxidation, desulphurization, decarburization and degassing of steel melts.

Limitations of primary steel making, unit operations and unit processes in ladle metallurgy, slag free tapping.

Ladle furnaces design and operation, injection metallurgy.

Operation of degassing reactors viz. DH, RH, tank degassers etc., Re-melting refining technologies.

Special steel making processes viz. AOD, VOD continuous steel making etc.

#### **Text / Reference Books:**

1. Ghosh Ahindra; Principles of Secondary Processing & Casting of Liquid Steels; Oxford & IBH.
2. Ghosh Ahindra; Secondary Steel Making, Principles & Applications; CRC Press.

### **MML480 FRACTURE MECHANICS (3-0-0) 3 credits**

Concept and scope of fracture mechanics, Fracture Mechanics approach as evolved from the classical theory of fracture approach. Irwin's contribution to establish the fracture toughness as a fundamental property in LEFM and PYFM, Concept of fast fracture and toughness GC based on energy criterion. Gc related to Ke for different materials. Distribution of stress and strain at the notch tip. Stress singularity at notch tip stress intensity factor. Plane strain fracture Toughness, conditions for a valid KIC value. Plane strain fracture Toughness Testing. Elements of ASTM E-399 for fracture toughness tests.

Plasticity corrections for ductile materials Post Yield Fracture Mechanics. COD and CTOD concept and measurements. J-Integral approach and its application. R-Curve and its utility for materials selection on the basis of fracture toughness.

Metallurgical structure and fracture toughness, Micromechanism of fracture.

Use of fracture toughness for other application like fatigue crack growth da/dN studies, stress corrosion cracking (KICC), impact tests and empirical relations. Fracture toughness as a tool for design against fracture in structures.

**Text / Reference Books:**

1. Mechanical Metallurgy by GE Dieter
2. Engg. Materials by MF Ashby

**MML 445 ADHESIVE TECHNOLOGY (3-0-0) 3 credits**

Introduction, Why use adhesives? Historical prospective, applications, Consumptions, advantages / disadvantages.

Joint design, Surface preparation / Surface treatments, FEA, Dispensing methods, curing techniques.

Theories of Adhesion, mechanisms of adhesions, correlation of bond strength with joint design, mechanical behaviour of adhesively bonded joints.

Types of adhesives, selection of adhesives, prototype testing, production scheduling, characteristics of adhesives

Testing of adhesives, NDT, Quality assurance, Failure investigations/analysis Environmental testing and Hazards

Case studies, Selection of adhesives for special surface properties, adhesives for composite structures, adhesives in bio-applications, Aerospace, defense, sports, construction applications etc.

**Text / Reference Books :**

1. The mechanism of adhesion, Elsevier, A.V. Pocius
2. Handbook of adhesive technology, VCH publisher, A. Pizzi and K.L. Mittal.

**MML 490 QUALITY CONTROL & SPECIFICATIONS(3-0-0) 3 credits**

**PROJECT PHASE – I (2 credits)**

**MML453 COMPOSITE MATERIALS (3-0-0) 3 credits**

Introduction -concept and definition of composite materials limitations of conventional materials, classifications of composite materials, scope and applications of composite materials.

Composite matrix and reinforcement, matrix materials like metallic, polymer ,ceramic glass, their structures and properties, reinforcing materials like fibers (glass, carbon etc.) fabric, particles and whiskers and manufacturing methods, properties and characteristics.

Manufacturing techniques of composites - Polymer matrix (normal layout, limitation, vacuum bagging, filament winding, resin transfer, moulding, pultrusion etc), Metal matrix (chemical and physical vapour deposition, sintering melt.) and others.

Characterization of composites - structural, thermal, mechanical, physical, chemical and environmental.

Properties of composites - physical, mechanical, thermal, chemical, electrical and optical properties.

Applications and degradation of composites - automotive, aerospace; and others. Thermal and photo degradation.

**Text / Reference Books :**

1. Friedrich K; Friction & Wear of Polymer Composites Vol. 1(Composite Materials Series); Elsevier, 1986.
2. Matthews F.L ; Composite Materials Engg. & Science; Chapman & Hall, 1996.
3. Composites-ASM Vol.I (10<sup>th</sup> Edition), ASM Internationals, 1995.
4. Holliday L.; Composite Materials; Elseveis Publishing Co.; 1966.

### **MMP 453 COMPOSITE MATERIALS (0-0-2) 1 credit**

Experiments based on above syllabus are conducted. Like fiber volume fraction, mechanical thermal properties, microstructural characterization etc.

### **MML481 DEFORMATION BEHAVIOR (3-0-0) 3 credits**

Elastic and Plastic behaviour of Materials, Engineering Stress – strain curve, flow curve, Important relations of flow curve. Concept of stress and strain in two dimensions. Principal stresses, Mohr's circle, Yield Criteria.

Mechanistic models for elastic, plastic and time-dependant deformation, phenomenological description of plastic deformation in metals – slip, twinning, stacking faults etc. , strengthening mechanisms, deformation modes and mechanisms for polymeric and ceramic materials.

Fatigue of engineering materials, S-N Curve, Characteristics of fatigue fracture, Evaluation of fatigue behavior, mechanical and metallurgical aspects of fatigue life.

High temperature deformation of materials, creep, analysis of creep curve, structural changes during creep ,deformation mechanism maps,

Fracture of materials, types, effect of notch, structure and temperature, concept of toughness and fracture toughness, preliminary concept of LEFM and PYFM, strain energy release rate, stress intensity factors, Fracture toughness, design. Toughening mechanisms in various materials.

#### **Text Books:**

1. Mechanical Metallurgy by GE Dieter,
2. Mechanical Behavior of Materials by Dowling

### **MML 487 CONTINUOUS CASTING OF STEELS (3-0-0) 3 credits**

Introduction, role of key technologies, primary and secondary cooling, heat transfer and control, mould operations, turbulence control, segregation, mould fluxes, nozzle clogging, cracking of steels, electromagnetic stirring, tundish metallurgy, modern trends.

#### References:

1. W.R. Irving, Continuous casting of steel
2. A. Chatterjee and S. Govindrajan, Monograph on continuous casting
3. MSTS, Casting volume, 11<sup>th</sup> edition

### **MML486 FAILURE ANALYSIS (3-0-0) 3credits**

#### **Techniques of failure analysis**

Stage of analysis, procedural sequence, collection of background data, classification of various failure needs, preparation of questionnaire, review of mechanical testing methods used in failure analysis, review of NDT method and their application in failure analysis

Classification of fatigue and fracture modes, fractography and preparation of samples for fractography.

Distortion failure - mechanism & types, stress systems related single load fracture of ductile and brittle material, stress versus strength relations in metallic materials, residual stress in engineering components, ductile and brittle fractures, fatigue fractures.

Fundamentals of fracture mechanics; fracture and Fatigue. Factors affecting fracture mechanics, Linear elastic fracture mechanics, Factors affecting fracture toughness, Fracture toughness testing, Fracture mechanics approach to failure, Numerical in fracture mechanics and fatigue.

Casting / Welding related failures:

Effect of non-metallic inclusions, segregation and dissolved gas on mechanical properties,

Metallurgical failure in cast products and weldments, Corrosion related failures.

Corrosion Failures; Life cycle of a metal, Basic nature of corrosion; types of corrosion (Galvanic, Crevice corrosion, pitting, stress corrosion etc.), Inter crystalline and transcrystalline corrosion in engineering components. Corrosion fatigue. Practical examples and case studies.

Elevated temperature failures. Creep Mechanism, Elevated temperature fatigue, Thermal fatigue, Metallurgical Instabilities.

Environmentally induced failures. Wear Related failure: Wear types, Contact stress fatigue prevention methods. Subsurface origin and surface origin fatigue; Sub-case origin, cavitation fatigue.

Case Studies on: (Metallurgical aspects) Failure of Shaft, bearings etc, Failure of Mechanical fasteners, Failure in Pressure vessels,

Failure in Welded structure, Failure of gears, Advanced experimental techniques in failure analysis.

#### **Text / Reference Books :**

1. Bob Ross; Investigating Mechanical Failures; Chapman & Hall (1<sup>st</sup> Edition), 1995.
2. Wulpi D.J; Understanding How Components Fail; (2<sup>nd</sup> Edition), 1999.
3. Collins J.S.; Failure of Materials in Mechanical Design; A Wiley Interscience Publications, (2<sup>nd</sup> Edition), 1993.
4. ASM; Failure Analysis; The British Engine Technical Reports, 1981.
5. Dieter, G.E.; Mechanical Metallurgy; McGraw Hill \*Metric Edition), 1988.

#### **MML 488 NANO MATERIALS (3-0-0) 3 credits**

Introduction, Electronic and optical properties, Chemical properties, Mechanical properties, Thermal properties, Magnetic properties.

Characterization techniques for nanomaterials.

Methods of synthesis, Consolidation of nanocrystalline materials.

Carbon based materials, Silicon based nanomaterials.

Existing and emerging applications of nanomaterials.

Safety Issues of nanomaterials

#### **Text Books:**

1. Physics and Chemistry of Nanostructured Materials; Shihe Yang and Ping Shen, Taylor & Francis, 2000
2. Handbook of Nano structured Materials and Nano Technology, H. S. Nalwa, Vols 1-5, Academic Press(2000)

#### **MML489 SURFACE ENGINEERING (3-0-0) 3 credits**

**General:** Historical perspective and future trends. Scope and application of surface engineering. Classification of surface engineering methods. Typical thickness and metallurgical structure produced by various surface engineering methods. Difference between surface coating and surface treatment.

**Surface:** Substrate and pretreatment, role of surface cleanliness and surface finish. Type of contaminants and their sources. Methods of surface cleaning; abrasive cleaning, chemical cleaning, chemical polishing, electrolytic cleaning, electrolytic polishing, ultrasonic cleaning, etc. Criteria for selection of cleaning process. Cleaning of ferrous and non-ferrous metals and alloys.

**Plating:** Principles of Electroless and electro-plating. Setup for electro-plating. Baths for electroless plating, Baths for electroplating. Role of bath constituents. Structure of coating. Plating practices for electroplating of Cu, Ni, Cr, Zn, Sn, Cu-alloy, Sn-alloy, Ni-alloy, Cr-alloy, multi-layer alloy plating etc. Electroless plating of Ni, Cu and Au. Electroless plating of industrial alloys

**Hot-dip:** Principle of hot- dip method. Structure of hot-dip coating. Batch process, its scope and limitations. Continuous process, its scope and limitations. Coating Zn, Zn-Al and Sn by hot-dip method. Industrial practices. Pre- and post surface treatments.

**Chemical conversion coatings:** Phosphatizing, chromating, ceramic coatings/linings and anodizing. Baths and role of their constituents.

**Vacuum and atmosphere controlled coatings:** Principle and equipments for coating methods like, Thermal spray coating, Chemical vapour deposition (CVD), Plasma assisted CVD, Physical vapour deposition (PVD), sputter, arc deposition, diffusion coatings and pulsed laser deposition.

**Characterization:** Characterization of coatings; thickness, micro-structure, mechanical properties, stress determination, corrosion resistance, wear resistance

**Industrial applications:** Surface engineering of polymers, metals and alloys.

#### **Books:**

1. Surface Engineering & Heat Treatment- Past, present and Future, Edited by P. H. Morton, Published by The Institute of Metals, London, 1991
2. Electroplating and other surface treatments- A Practical Guide, CD Veghese, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2003
3. ASM Handbook Volume 5- Surface Engineering, Published by ASM International, 1995

#### **MML 490 HIGH TEMPERATURE CORROSION (3-0-0) 3 credits**

Introduction to high temperature corrosion & oxidation of Metals and Alloys, Thermodynamics & Ellingham diagram, vapour species diagram, Isothermal stability diagram, Rate Laws, Kinetics and Mechanics, Wagner's parabolic law of Oxidation, Derivation and Limitations, Role of Diffusion and Defect structure of oxides in Oxidation, Multiple Scale Formation & Cracking, Forms of Corrosion with Special Reference to External and Internal Oxidation. Stress Corrosion Cracking, Hydrogen Embrittlement, Corrosion Fatigue, Liquid Metal Embrittlement, Hot Corrosion, Materials Selection and Design, Alteration of Environment, Inhibition, Metallic and Ceramic Paints, Coatings, Special Treatment. High Temp. Materials: Superalloys, Intermetallics, Ceramics.

#### **Texts / References:**

1. R. Aris - Mathematical Modelling Techniques, Pitman, London 1978.
2. Oxidation of Metals-by Kofstadt
3. High temperature oxidation of metals and alloys –by N. Birks and Meir
4. Fundamentals of corrosion –Scully
5. Riedel H. – Fracture of high temp., Springer – Verlag, Berlin, 1987.
6. J. M. West – Basic Corrosion & Oxidation, 2nd Edition, Ellis Harwood Publication, 1986
7. ASM Metals H. B., Vol. 13, ASM international, Metals park, Ohio, 1986.