National Institute of Technology Durgapur

Department of Metallurgical And Materials Engineering

M.TECH in Metallurgy and Materials Technology
(Revised effective from JULY, 2019)

Semester I

Sl. No	Code	Course Title	L	T	S	CP
1	MT 1001	Thermodynamics and kinetics of Engineering Materials	3	1	0	4
2	MT 1002	Phase Transformation and Heat Treatment	3	1	0	4
3	MT 1003	Mechanical Behaviour of Materials	3	1	0	4
4		Elective I	3	1	0	4
5		Elective II	3	1	0	4
6	MT 1051	Laboratory I (Phase Transformation and Heat Treatment)	0	0	6	3
7	MT 1052	Seminar (Non-Project)	0	0	2	1
		Total Credit	**15**	**5**	**8**	**24**

Semester II

Sl. No	Code	Course Title	L	T	S	CP
1	MT 2001	Technology of Advanced Materials	3	1	0	4
2	MT 2002	Advances in Process Metallurgy	3	1	0	4
3	MT 2003	Principles and Techniques of Materials Characterisation	3	1	0	4
4		Elective III	3	1	0	4
5		Elective IV	3	1	0	4
6	MT 2051	Laboratory II (Principles and Techniques of Materials Characterisation)	0	0	6	3
7	MT 2052	Project I	0	0	2	1
		Total Credit	**15**	**5**	**8**	**24**

Semester III

Sl. No	Code	Course Title	L	T	S	CP
1	MT 3051	Project II				11
2	MT 3052	Project Seminar –I				02
		Total Credit				**13**

Semester IV

Sl. No	Code	Course Title	L	T	S	CP
1	MT 4051	Project III				11
2	MT 4052	Project Seminar –II & Viva- Voce				03
		Total Credit				**14**

Part- Time

Semester I

Sl. No	Code	Course Title	L	T	S	CP
1	MT 1001	Thermodynamics and kinetics of Engineering Materials	3	1	0	4
2	MT 1002	Phase Transformation and Heat Treatment	3	1	0	4
3	MT 1003	Mechanical Behaviour of Materials	4	0	0	4
4	MT 1051	Laboratory I (Phase Transformation and Heat Treatment)	0	0	6	3
		Total Credit	**10**	**2**	**6**	**15**

Semester II

Sl. No	Code	Course Title	L	T	S	CP
1	MT 2001	Technology of Advanced Materials	4	0	0	4
2	MT 2002	Advances in Process Metallurgy	4	0	0	4
3	MT 2003	Principles and Techniques of Materials Characterisation	3	1	0	4
6	MT 2051	Laboratory II (Principles and Techniques of Materials Characterisation)	0	0	6	3
		Total Credit	**10**	**1**	**6**	**15**

Semester III

Sl. No	Code	Course Title	L	T	S	CP
1		Elective I	4	0	0	4
2		Elective II	4	0	0	4
3	MT 1052	Seminar (Non- Project)	0	0	2	1
		Total Credit	**8**	**0**	**2**	**9**

Semester IV

Sl. No	Code	Course Title	L	T	S	CP
1		Elective III	4	0	0	4
2		Elective IV	4	0	0	4
3	MT 2052	Project I	0	0	2	1
		Total Credit	**8**	**0**	**2**	**9**

Semester V

Sl. No	Code	Course Title	L	T	S	CP
1	MT 3051	Project II				11
2	MT 3052	Project Seminar				02
		Total Credit				**13**

Semester VI

Sl. No	Code	Course Title	L	T	S	CP
1	MT 4051	Project III				11
2	MT 4052	Project Seminar-II & Viva- Voce				03
		Total Credit				**14**

Elective Subjects

Sl. No.	Course	Course Title
1	MT 9011	Advances in Iron & Steel Making
2	MT 9012	Production of Ferro Alloys
3	MT 9013	Secondary Steel Making
4	MT 9014	Surface Engineering
5	MT 9015	Material Modelling and Simulation
6	MT 9016	Advanced Welding Metallurgy
7	MT 9017	Advanced Metal Forming Processes
8	MT 9018	Advanced Physical Metallurgy
9	MT 9019	Fatigue, Creep & Fracture Analysis
10	MT 9020	Composite Materials and its Development
11	MT 9021	Ceramics Technology
12	MT 9022	Powder Metallurgy Technology
13	MT 9023	Foundation of Nano- Technology
14	MT 9024	Industrial Management
15	MT 9025	Electron Microscopy
16	MT 9026	Structure & Properties of Metals and Alloys
17	MT 9027	Environmental Degradation of Materials
18	MT 9028	Advanced Foundry Practice of Commercial Casting
19	MT 9029	Computational Fluid Dynamics
20	MT9030	Foundation of Physical Metallurgy
21	MT9031	Corrosion Engineering
22	MT9032	Plasma Technology for Metallurgical Applications

SUMMARY OF COURSES

Sub Discipline: DEPARTMENTAL CORE

CODE	COURSE TITLE	L-T-P	CREDIT	DEVELOPER
MT 1001	Thermodynamics and Kinetics of Engineering Materials	3-1-0	4	DR. S.K.MITRA & MR. R.N. RAY
MT 1002	Phase Transformation and Heat Treatment	3-1-0	4	DR. J. MAITY
MT 1003	Mechanical Behaviour of Materials	3-1-0	4	DR. M.M. GHOSH & DR. B.K. SHOW
MT 2001	Technology of Advanced Materials	3-1-0	4	DR. D. MANDAL & DR. M. MALLIK
MT 2002	Advances in Process Metallurgy	3-1-0	4	DR. A. GANGULY
MT 2003	Principles and Techniques of Materials Characterisation	3-1-0	4	DR. J. MAITY & DR. B.K. SHOW

Sub Discipline: DEPARTMENTAL ELECTIVES

CODE	COURSE TITLE	L-T-P	CREDIT	DEVELOPER
MT 9015	Materials Modelling	3-1-0	4	DR. M.M.GHOSH
MT 9022	Powder Metallurgy Technology	3-1-0	4	DR. M.MALLIK
MT 9012	Production of Ferro Alloys	3-1-0	4	DR. A.GANGULY
MT 9024	Industrial Management	3-1-0	4	DR. S.PRAMANIK
MT 9020	Composite Materials and its Development	3-1-0	4	DR. J.MAITY & DR. M.K.MONDAL
MT 9027	Environmental Degradation of Materials	3-1-0	4	DR.S.K. MITRA & DR. S.PRAMANIK
MT 9013	Secondary Steel Making	3-1-0	4	DR. M.K.MONDAL
MT 9016	Advanced Welding Metallurgy	3-1-0	4	DR. A.BHATTACHARY

Sub Discipline: LABORATORY & SESSIONAL COURSES

CODE	COURSE TITLE	L-T-P	CREDIT	DEVELOPER
MT 1051	Phase Transformation and Heat Treatment Laboratory	0-0-6	3	DR.J.MAITY & DR. M.MALLIK
MT 2051	Principles and Techniques of Characterisation Laboratory	0-0-6	3	DR. J.MAITY & DR. B.K.SHOW

Sub Discipline: PROJECT, SEMINAR etc.

MT 1052	Seminar (Non- Project)	0-0-2	1	DR. M.MALLIK
MT 2052	Project I	0-0-2	1	CONCERNED TEACHERS
MT 3051	Project II	0-0-0	11	CONCERNED TEACHERS
MT 3052	Project Seminar-I	0-0-0	02	CONCERNED TEACHERS
MT 4051	Project III	0-0-0	11	CONCERNED TEACHERS
MT 4052	Project Seminar – II & Viva-Voce	0-0-0	03	CONCERNED TEACHERS

DETAILED SYLLABI OF COURSES

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 1001	**THERMODYNAMICS AND KINETICS OF ENGINEERING MATERIALS**	3-1-0	4	

Introduction and important thermodynamics functions : Laws of thermodynamics –enthalpy, heat capacity, entropy, free energy and their interrelationships : Solutions – chemical potential, Raoult Henry's law Gibbs-Duhem equations activity determination properties of different solutions, quasichemical theory: Heterogeneous systems-equilibrium constants. Ellingham-Richardson diagrams predominant area diagrams, Evolution of Phase diagrams-phase rule free-energy-composition diagrams solidus-liquidus lines, Interfaces-energy: segregation at external and internal interfaces, solid electrolytes; Effect of high pressure on phase transformation. Point imperfections in crystalline solids –elementary and compound crystals. [16 hours]

Role of kinetics, heterogeneous and homogeneous kinetics. Role of heat & mass transfer in Metallurgical kinetics rate expression. Effect of Temperature and concentration on reaction kinetics effect of temperature (Arrhenius Equation). Effect of concentration (order of a reaction), significance and determination of activation energy. Kinetics of solid-fluid reaction: Definition of various resistance in series, shrinking core model, Chemical reaction as rate controlling step, Product layer diffusion as rate controlling step. Mass transfer through external fluid as rate controlling step, Heat transfer as the rate controlling step. Concentration boundary layer definition and significance of heat and mass transfer coefficient. Theoretical models for mass transfer coefficients. Correlations for heat and mass transfer coefficients. Kinetics of liquid-liquid reaction. [16 hours]

Solid state phase changes-classification nucleation and growth processes: [2 hours]

Diffusion-driving force, Ficks laws, Diffusion coefficients. [2 hours]

Kinetics of liquid –solid transformation –driving force. Homogeneous and heterogeneous Nucleation kinetics, kinetics of growth, kinetics of alloy solidification. [4 hours]

Kinetics of solid-state phase transformation-scope and classification kinetics of homogeneous and heterogeneous nucleation, interface growth velocity, kinetics of special transformations (Widmanstatten, massive, polymorphic, coarsening, recrystallization, age hardening) kinetics of invariant and moving boundry transformation, kinetics of phase transition in polymers, glass, ceramics. [6 hours]

Overall transformation kinetics-Johnson-Mehl and Avram's model, kinetics of non-random nucleation, kinetics of diffusion controlled isothermal and non-isothermal analysis. [2 hours]

Text Books:

1) Introduction to Metallurgical Thermodynamics – David R. Gaskell.
2) Problems in Metallurgical Thermodynamics and Kinetics-G.S. Upadhyay and R. K. Dube.

Reference books:

1) Physical Chemistry of Metals-Lawrence S, Darken and Robert W. Gurry;
2) Thermodynamics of Solids-Richard A. Swalin.
3) Stoichiometric and Thermodynamics of Metallurgical Processes- Y.K.Rao.
4) Chemical Kinetics-Keith J. Laidler.
5) Metallurgical Thermodynamics- R. H. Tupkary.
6) Problems in Applied Thermodynamics- C. Bodsworth and A.S. Appleton.
7) Kinetics of Metallurgical Reactions – H. S. Ray
8) Metallurgical Thermochemistry-O. Kubaschewski, E.LL. Evans and C.B. Alcock.

SUBJECT	SUBJECT	L-T-P	CREDIT	DEVELOPER

CODE				
MT 1002	**PHASE TRANSFORMATION AND HEAT TREATMENT**	3-1-0	4	

Introduction and classification of phase transformation; conventional classification: homogeneous and heterogeneous phase transformations; solid state phase transformations: thermally activated transformation, athermal transformation; Buerger's classification: reconstructive transformation and displacive transformation; paraequilibrium state, concept of invariant plane strain; reconstructive and displacive transformations in steel: evolution of allotriomorphic ferrite, idiomorphic ferrite, massive ferrite, pearlite, Widmanstatten ferrite, acicular ferrite, pearlite, bainite and martensite. [10 hours]

Analytical treatment to solid state phase transformation: stable and metastable matrix, concept of fluctuation, embryo, volume free energy change, surface energy, strain energy, free energy change for formation of an embryo, critical embryo, activation energy for critical embryo formation, homogeneous nucleation, heterogeneous nucleation, expressions of homogeneous nucleation rate and heterogeneous nucleation rate, effect of strain energy on shape of embryo, temperature dependence of nucleation rate, time dependence of heterogeneous nucleation rate, effect of prior cold working on nucleation rate, expression of growth rate, Johnson-Mehl equation- overall transformation rate, origin of time-temperature-transformation (TTT) diagram. [20 hours]

Heat treatment: heating, soaking and cooling, factors affecting heating rate, stages of quenching, effect of physical properties of quenchant on quenching, properties and effectiveness of different quenchants-water, brine, oil, air, gases and synthetic quenchants; different heat treatment processes: annealing: homogenizing/diffusion annealing, Full annealing, isothermal annealing, intercritical annealing, spheroidizing annealing, recrystallization annealing and process annealing; normalizing, hardening and tempering, TTT and CCT diagram, Grange-kiefer approximation, effect of alloying elements on TTT/CCT diagram, incubation period, critical cooling rate, hardenability, factors affecting hardenability, severity of quench (Grossmann number); Quantitative hardenability: Grossmann critical diameter, ideal critical diameter, Jominy end quench test, determination of hardenability from chemical composition and grain size; Precipitation hardening (age hardening): solution treatment, quenching and aging; factors affecting age hardening- aging temperature and time, coherency, size and shape of precipitate, long range order of the precipitate; age hardening behaviour of aluminium alloys; age hardening behaviour of aluminium metal matrix composites. [20 hours]

Text books:

1. The Theory of Transformations in Metals and Alloys- J.W. Christian, Pergamon Press, 1965.
2. Phase transformations in metals and alloys- D.A. Potter and K.E. Easterling, CRC Press,1992 .
3. Transformations in Metals**,** P.G. Shewmon**,** Mc-Graw Hill, 1969.
4. Phase transformation in materials- A. K. Jena and M. C. Chaturvedi**,** Prentice Hall, 1992.
5. Solid state phase transformations, V. Raghavan, PHI Learning Pvt. Ltd., 2004.

Reference books:

1. Heat treatment of metals- B. Zakharov, CBS publishing, 1998.
2. Principles of the heat treatment of plain carbon and low alloy steels- C.R. Brooks, ASM International, 1996.
3. Heat Treatment: Principles and Techniques- T. V. Rajan**,** C. P. Sharma and A. Sharma**,** PHI Learning Pvt. Ltd., 2012.

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 1003	MECHANICAL BEHAVIOUR OF MATERIALS	3-1-0	4	

Introduction to deformation behaviour: Concept of stresses and strains, engineering stresses and strains, Different types of loading and temperature encountered in applications, Tensile Test - stress-strain response for materials, elastic region, yield point, plastic deformation, necking and fracture, Bonding and Material Behaviour, theoretical estimates of yield strength in materials.

[8 hours]

Elasticity Theory: The State of Stress and strain, stress and strain tensor, principal stress and strain, elastic stress-strain relation, anisotropy, elastic behaviour of materials. [4 hours]

Yielding and Plastic Deformation: Hydrostatic and Deviatoric stress, Octahedral stress, yield criteria and yield surface, texture and distortion of yield surface, true stress and true strain, effective stress, effective strain, flow rules, strain hardening, stress -strain relation in plasticity, plastic deformation of materials. [8 hours]

Microscopic view of plastic deformation: crystals and defects, classification of defects, thermodynamics of defects, geometry of dislocations, slip and glide, dislocation generation - Frank Read and grain boundary sources, stress and strain field around dislocations, force on dislocation - self-stress, dislocation interactions, partial dislocations, twinning, dislocation movement and strain rate, deformation behavior of single crystal, critical resolved shear stress (CRSS), deformation of poly-crystals - Hall-Petch and other hardening mechanisms, grain size effect - source limited plasticity, Hall-Petch breakdown, dislocations in materials. [10 hours]

FRACTURE: Different types of fractures in metals; theoretical cohesive strength of metals, Different design philosophies; stress concentration effects of flaws; Linear elastic plastic fracture mechanics (LEFM): Griffith's theory of brittle fracture; The energy release rate; R-curve; Different modes of loading; Stress analysis of cracks, crack tip plasticity; concepts of plane stress and plane strain. Elastic plastic fracture mechanics: CTOD, J integral, HRR singularity; microstructural aspects of fracture; Different toughening mechanisms; Fracture toughness testing of metals: K_{1C}, CTOD and J_{1C}. [10 hours]

Deformation under cyclic load - Fatigue: S-N curves, Low and high cycle fatigue, Life cycle prediction, application of fracture mechanics for fatigue cracking, cyclic stress strain curve; low cycle fatigue; effect of stress concentration on fatigue; size effect; surface effects;

effect of metallurgical variables on fatigue; cumulative fatigue damage rule; concept reverse plastic zone; corrosion fatigue; fretting; high temperature fatigue. [6 hours]

Deformation at High temperature: Time dependent deformation - creep, different stages of creep, creep and stress rupture, creep mechanisms and creep mechanism maps, Superplasticity; microstructural aspects of creep and design of creep resistant alloys, Presentation of engineering creep data; Prediction of long time properties; Creep-fatigue interaction. [4 hours]

Text books:

1. Mechanical Metallurgy, George E. Dieter, International Student Edition, Mc. Graw-Hill Kogakusha Ltd. /Fourth(S. I. Metric) Edition, 1988.
2. Mechanical Behavior of Materials, Marc André Meyers and Krishan Kumar Chawla, Cambridge University Press, 2008.

Reference books:

1. Introduction to dislocations, D. Hull and D.J. Bacon, Fifth Edition, Butterworth-Heinemann, 2011.
2. Plastic Deformation of Metals, R. W. K. Honeycombe, Edward Arnold, 1984.
3. Deformation and Fracture Mechanics of Engineering Materials, Richard W. Hertzberg, Richard P. Vinci, Jason L. Hertzberg, 5th Edition, 2012.

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 1051	**PHASE TRANSFORMATION AND HEAT TREATMENT LABORATORY**	3-0-0	6	

Experiment 1: Annealing and Normalizing (with normal air cooling & Forced air cooling) Treatments of low carbon steels and investigation of the microstructures primarily evolved through reconstructive phase transformation and diffusional displacive phase transformation.

Part I: Investigation of the microstructure of Annealed Low Carbon Steel. [6 hours]

Part II: Investigation of the microstructure of Normalized Low Carbon Steel (subjected to normal air cooling) [6 hours]

Part III: Investigation of the microstructure of Normalized Low Carbon Steel (subjected to forced air cooling). [6 hours]

Experiment 2: Hardening treatment of low carbon and High carbon steels involving diffusionless displacive phase transformation and study of the evolved microstructure.
Part I: Hardening treatment of Low carbon (0.2%C) steel [6 hours]

Part II: Hardening treatment of High carbon (0.6%C) steel [6 hours]

Experiment 3: Intercritical heat treatment of low carbon steel and investigation of the

evolved microstructure. [6 hours]

Experiment 4: Carburizing treatment of low carbon steel and investigation of the microstructure.

Part I: Study of the microstructure of as-carburized steel [6 hours]

Part II: Study of the microstructure of Carburized and core refined steel. [6 hours]

Part III: Study of the microstructure of carburized, core refined and case refined (case hardened) steel. [6 hours]

Text books:
1. Phase transformations in metals and alloys- D.A. Potter and K.E. Easterling, CRC Press,1992 .
2. Solid state phase transformations, V. Raghavan, PHI Learning Pvt. Ltd., 2004.
3. Heat treatment of metals- B. Zakharov, CBS publishing, 1998.

Reference books:
1. Principles of the heat treatment of plain carbon and low alloy steels- C.R. Brooks, ASM International, 1996.
2. Heat Treatment: Principles and Techniques- T. V. Rajan**,** C. P. Sharma and A. Sharma**,** PHI Learning Pvt. Ltd., 2012.

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 2001	**TECHNOLOGY OF ADVANCED MATERIALS**	3-1-0	4	

Introduction: Importance of Advanced Materials [4 hours]
Advanced High Strength Steels (AHSS);
Classification of AHSS, Strengthening mechanism of AHSS steels, Processing, properties and application of DP steels, HSLA steels, TRIP & TWIP Steels, Q&P Steels [6 hours]
High temperature Materials;
Basic alloying features, Nickel based super alloy, Ti base super alloys, Processing, Properties and Applications of super alloys, Structural intermetallic compounds, Aluminium alloys, Al-Li alloy, Rapid solidification processing of Al alloys. [6 hours]
Ultra Light Materials and Metallic Foams:
Material Definition and Processing, Classification of making metal foams, Characterisation of cellular Metals, Materials Properties and application. [4 hours]
Smart Materials:
Introduction to smart structure, Classification of smart materials, Introduction to sensors and actuators, Piezo-electrics, shape memory alloys [4 hours]
Bio-Materials
Requirements for biomaterials, Classification of biomaterials, Dental Materials, Materials for replacement of joints and surgical [4 hours]

Advanced Ceramics: Material Selection, Structure of ceramics, Properties and Applications. [4 hours]

Ultra High Temperature Ceramics and Composites: Classification, ZrB_2 and HfB_2 based Ultra High Temperature Ceramic Composites, Processing, mechanical behaviour and oxidation resistance [4 hours]
Bulk Metallic Glass: Criteria for glass formation, Examples and mechanical behaviour. [4 hours]
Nano-materials: Classification, Processing and properties of nanocrystalline materials, Nanofluids. [4 hours]
Advanced Processes applied for Advanced Materials: Rapid Solidification, Sputtering, Physical and Chemical Vapor Deposition. [4 hours]
Intermetallics: Structure, processing, properties and application [4 hours]

Text books:

(1) Materials Science and Engineering- An Introduction W. D. Callister, John Wiley & Sons Inc 1985 New York.
(2) W. O. Soboyejo and T. S. Srivastan (ed.), Advanced Structural Materials: Properties, Design, Optimization and Applications, CRC Press, New York (2007).
(3) G.W. Meetham and M.H. Van de Voorde, Materials for High Temperature Engineering Applications, Springer, Berlin (2000).

Reference books:

(1) D. Vollath, Nanomaterials: Synthesis, Properties and Application, WILEY_VCH, Germany (2008).
(2) Lecture Notes and Published Papers
(3) Introduction to Ceramics - Kingery, Bowen and Uhlmann 2. ASM Handbook Volume 21: Composites

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 2002	ADVANCES IN PROCESS METALLURGY	3-1-0	4	

Introduction: Vision of evolution of process metallurgy in the development of metals including iron & steel from ores and minerals to production and process practices. [8 hours]

Basics and advanced technologies for mineral processing, including pyro, hydro, electro metallurgy and associated impact on costs, pollution, energy, cycle time, simplification. [8 hours]

Compelling innovative measures in agglomeration, BF technology, BOF, EAF, MBF, EOF and other such routes involving DRI/HBI, Iron Carbide through fluidised bed, Hot metal, phenomena of spontaneous combustion of DRI and other such related issue. [10 hours]

Underlining principles of steel refining, physical chemistry, continuous casting, rolling and finishing, quality control [10 hours]

A window to recent advancements in extractive metallurgy of non ferrous metals like Al, Cu, Ni, Zn etc. and their present status and application in india [6 hours]

Text books:
i) Proceedings of internation seminar on innovative technologies for clean, green & automated steel plants- A beeter tomorrow – Steel tech/ NIT Durgapur , sept. 2015
ii) B.F. Iron making principles – Biswas (1985)
iii) Physical chemistry of iron & steel manufacture – C. Bodsworth (1980)
iv) Iron and steel making, theory and practice – Ghosh and Chatterjee (2012)

Reference books:
i) Direct Reduced Iron, technology and economics of production and use - R.L. Stephenson & R.M. Smailer year 1980
ii) Relevant reprints of papers by DR. A. Ganguly (from 1990-2010)

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 2003	**PRINCIPLES AND TECHNIQUES OF MATERIALS CHARACTERISATION**	3-1-0	4	

Optical Metallography: metallographic specimen preparation, metallurgical microscope, magnification, numerical aperture, resolving power; quantitative metallography: Stereological approach: determination of volume fraction of different phases-point count method; grain size measurement-planimetric method, intercept method etc.; principles of quantitative image analysis. [8 hours]

X-ray diffraction Techniques: The continuous and characteristic spectrum; Absorption; Filters; Real and reciprocal lattice ; Bragg's Law; Ewald sphere construction; Diffraction methods–Laue method, rotating crystal methods, powder methods; Diffractometers; Diffraction under non- ideal condition. Intensity of diffracted beams: scattering by an electron- Coherent scattering, Incoherent scattering; scattering by an atom-atomic scattering factor, Scattering by a unit cell: Structure factor, Structure factor calculations; Extinction rules, indexing. [12 hours]

Application of X-ray diffraction: Crystal structure determination; determination of precise lattice parameter; Phase diagram determination, Chemical analysis by diffraction, residual stress determination, particle size determination. [8 hours]

Electron Microscopy: Specimen beam interaction; Interaction volume; Construction, modes of operation and application of Scanning electron microscope; Different contrast formation; Effect of different operational variables on the resolution and depth of field of a SEM; Specimen preparation; EDS and WDS. Transmission electron microscopy (TEM): basic principles of electron diffraction in transmission electron microscope in view of Ewald sphere construction, Selected area diffraction: generation of spot pattern, spotted ring pattern and continuous ring pattern; basic relationship of electron diffraction in transmission electron microscope ($Rd = L\lambda$); Interpretation of SAD pattern for fine grained polycrystalline material: Indexing ring pattern, determination of camera constant; Interpretation of SAD patterns of single crystal (single grain): Indexing spot pattern; interpretation of the standard patterns from different crystals, viz simple cubic, BCC, FCC etc. [12 hours]

Thermal Analysis: Differential thermal analysis, Differential scanning calorimetry and Thermogravimetric analysis. [8 hours]

Text books:
1. "Elements of X-Ray Diffraction", by B.D. Cullity, Addision Wesley Publishing Co., Massachusetts, 1968.

2. “X-ray diffraction-a practical approach”, by C. Suryanarayana and M. Grant Norton, Springer, 1998.
3. “X-ray Diffraction: Its Theory and Applications”, by S. K. Chatterjee, Prentice-Hall of India Pvt. Limited, 2004.
4. “Electron Microscopy in the Study of Materials”, by P.J. Grundy and G.A. Jones, Arnold, London, 1976.

Reference books:
1. “Transmission Electron Microscopy: A Textbook for Materials Science (4 Vol set)”, by David B. Williams and C. Barry Carter, 2nd ed., Springer, 2009.
2. “Electron Microscopy and Analysis”, by Peter J. Goodhew, John Humphreys and Richard Beanland, Third Edition, CRC Press, 2000.
3. Principles of Metallographic laboratory Practice – G. L. Kehl, London: McGraw-Hill Publishing Co., Ltd., 1939.
4. Metallography, Principles and Practice-George F. Vander Voort, ASM International, 1984.

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 2051	**PRINCIPLES AND TECHNIQUES OF MATERIALS CHARACTERISATION LABORATORY**	0-0-6	3	

Experiment 1: Characterization of a metal matrix composite.
Part (I): Charaterization.by optical Metallography and Hardness measurement. [6 hours]
Part (II): Characterization by X-Ray diffraction. [6 hours]
Experiment 2: Indexing the X-ray diffraction (XRD) pattern of different phases.

Part (I): Indexing the XRD pattern of BCC structure. [4 hours]

Part(II): Indexing the XRD pattern of FCC structure. [4 hours]

Part(III): Indexing the XRD pattern of HCP structure. [4 hours]

Part(IV): Indexing the XRD pattern containing a mixture of BCC and FCC phases.[6 hours]

Experiment 3: Characterization of a nanocrystalline thin film electrodeposite by XRD. [6 hours]
Experiment 4: X-ray diffraction of powders exhibiting the effect of powder size on peak broadening. [6 hours]
Experiment 5: Interpretation of microstructures obtained through scanning electron microscopy. [6 hours]
Experiment 6: Indexing selected area diffraction patterns (SADP) obtained through transmission electron microscopy. [6 hours]

Text books:
1. “Elements of X-Ray Diffraction”, by B.D. Cullity, Addision Wesley Publishing Co., Massachusetts, 1968.

2. “Electron Microscopy in the Study of Materials”, by *P.J. Grundy and G.A. Jones*, Arnold, London, 1976.

Reference books:

1. “Transmission Electron Microscopy: A Textbook for Materials Science (4 Vol set)”, by David B. Williams and C. Barry Carter, 2nd ed., Springer, 2009.

2. Principles of Metallographic laboratory Practice – G. L. Kehl, London: McGraw-Hill Publishing Co., Ltd., 1939.

3. Metallography, Principles and Practice-George F. *Vander Voort*, ASM International, 1984.

SYLLABUS OF ALL ELECTIVES

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 9011	**ADVANCES IN IRON & STEEL MAKING**	3-1-0	4	

Iron making: Modern trends in Blast Furnace Operation, alternative routes of Iron Production (COREX, MBF), direct reduction process: HYL, SL/RN processes, Midrex, fluidized bed. [8 hours]

Steel making: Review of electric and L.D.Steel making processes, Hybrid steel making processes, Ajax, Twin hearth, Tandem, SIP, OBM, high tension electric steel making, plasma arc steelmaking processes. [12 hours]

Continuous Steel making processes: WORCRA, IRSID, Spray steel making, INRED, ELRED processes. [6 hours]

Production of High purity steel: Nonmetallic inclusions and their effect on properties of steel. Refining techniques, ESR, VAR, and Vacuum Degassing of liquid steel. [8 hours]

Alloy steel making, Tool steels and stainless steel making practice. Review of Iron and steel Industry in India. [6 hours]

Text books:

1. Reduction of Iron Ores – VAN BOGDANDY.
2. Aspects of Modern ferrous Metallurgy – J.S.KIRKALDY & G.WARD.
3. IIM-Silver Jubilee Symposium on Recent Developments in Materials Science and Technology.

Reference books:

1. Making, Shaping Treating of Steel published by United States Steel Corporation.
2. Introduction of Modern Iron Making – R.H.TUPKARY. 6. Introduction of Steel making – R.H.TUPKARY

SUBJECT	SUBJECT	L-T-P	CREDIT	DEVELOPER

CODE				
MT 9012	**PRODUCTION OF FERRO ALLOYS**	3-1-0	4	

Introduction & Background of ferro alloys development, Ferro alloys in development of steels and recent market development. [5 hours]

Basics of ferro alloys processing – General theory of ferro alloys production, Heat & mass transfer and technologies " ferro silicon, ferro manganese, ferro chrome, silico manganese etc." [8 hours]

Furnaces used for ferro alloys production, preparation of furnace feed materials, Submerged arc furnace technologies etc. [7 hours]

Downstream processing in ferro alloys processing. [10 hours]

Specific ferro alloys usage, availability of corresponding ores in the country, Environmental issues. [8 hours]

Recent advancement design and technology for exclusive alloys. [4 hours]

Text books:
i) Handbook of ferro alloys (Theory and technology) by Gasik
ii) Glimpses of recent advances in Iron & Steel by Debashish Bhattacharjee, Monojit Dutta

Reference books:

i) Indian Steel Industry- A reference book by Joint Plant Committe

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 9013	**SECONDARY STEEL MAKING**	3-1-0	4	

Introduction: Brief review of primary steel making processes, composition of the crude steel, need for secondary refining, objective of secondary steel making, secondary steel making equipments and processes, preheating and recycling of ladles. [4 hours]

Chemical equilibrium, Activity-Composition relationships: Concentrated solutions, Activity-Composition relationships: dilute solutions, chemical potential and equilibrium, physico-chemical principles of Secondary steel making, Slag basicity and capacities. [6 hours]

Fluid flow in steel melts in Gas-Stirred ladle. [3 hours]

Mixing, Mass transfer and kinetics: Introduction, Mixing in steel melts in Gas-stirred ladles, kinetics of reactions among phases, Mass transferrin a Gas-Stirred ladle, Mixing Vs. Mass transfer control. [6 hours]

Deoxidation of liquid steel: Introduction, slag Carry-over: Impact on Ladle Metallurgy, Thermodynamics of deoxidation of molten steel, Kinetics of deoxidation of molten steel,

deoxidation in industry. [4 hours]

Degassing and Decarburization in liquid steel: Introduction, thermodynamics of reactions in vacuum degassing, fluid flow and mixing in vacuum degassing, rates of vacuum degassing and decarburization, decarburization for Ultra-low carbon (ULC) and stainless steel. [6 hours]

Desulfurization in secondary steelmaking: Introduction, thermodynamics aspects, desulfurization with only top slag, injection metallurgy for Desulfurization. [4 hours]

Gas absorption during tapping and teeming from surrounding atmosphere, temperature changes of molten steel during secondary steelmaking, phosphorus control in secondary steelmaking, Nitrogen control in steel making. [4 hours]

Inclusions and inclusion modification: Introduction, Influence of inclusions on the mechanical properties of steel, Inclusion identification and cleanliness assessment, origin of nonmetallic inclusions, formation of inclusions during solidification, inclusion modification. [6 hours]

Clean steel technology: Introduction, refractories for secondary steelmaking, Tundish metallurgy for clean steel. [3 hours]

TEXT BOOKS:

1. A. Ghosh, and A. Chatterjee, , Principles and Practices in Iron and Steel making, Prentice Hall of India, New Delhi, 2008.

REFERENCE BOOKS:

1. A. Ghosh, Secondary Steelmaking, CRC Press, Boca Raton, 2000.

2. Making, Shaping and Treating of Steel (Steelmaking and Refining), 10th Edition, 1985, AISE, Pittsburgh.

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 9014	**SURFACE ENGINEERING**	3-1-0	4	

Introduction: Engineering components, surface dependent properties and failures, importance and scope of surface engineering. [6 hours]

Surface and surface energy: Structure and types of interfaces, surface energy and related equations. [6 hours]

Surface engineering by material removal: Cleaning, pickling, etching, grinding, polishing, buffing / puffing (techniques employed, its principle). Role and estimate of surface roughness, material addition: From liquid bath - hot dipping (principle and its application with examples). [8 hours]

Surface modification of steel and ferrous components: Pack carburizing (principle and scope of application); Surface modification using liquid/molten bath: Cyaniding, liquid carburizing (diffusion from liquid state) (principle and scope of application). Surface modification using

gaseous medium: Nitriding, carbonitriding (diffusion from gaseous state) (principle and scope of application). [10 hours]

Advanced surface engineering: Surface engineering by energy beams: General classification, scope and principles, types and intensity/energy deposition profile; Laser assisted microstructural modification – surface melting, hardening, shocking and similar processes; Laser assisted compositional modification – surface alloying of steel and non-ferrous metals and alloys; surface cladding, composite surfacing and similar techniques; Electron beam assisted modification and joining; Ion beam assisted microstructure and compositional modification. [10 hours]

Surface engineering by spray techniques: Flame spray (principle and scope of application); Plasma coating (principle and scope of application), HVOF, cold spray (principle and scope of application). Characterization of surface microstructure and properties for different surface engineering techniques. [10 hours]

Text books:

1. Materials and Surface Engineering: Research and development, J Paulo Davim (Editor), Woodhead publishing, 2012.
2. Introduction to surface engineering and functionally engineered materials, Peter Martin, Wiley, 2011

Reference Books:

1. K.G. Budinski, Surface Engineering for Wear Resistances, Prentice Hall, Englewood Cliffs, 1988.
2. Laser Surface Engineering Processes and Applications, ***J. R. Lawrence, C. Dowding, D. Waugh and J. B. Griffiths,*** A volume in Woodhead Publishing, 2015

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 9015	**MATERIALS MODELLING**	3-1-0	4	

Introduction to materials modelling and simulation; concept of multiscale materials modelling; different approaches used in materials modelling and their benefits and drawbacks [5 hours]

General overview of atomistic modelling techniques - molecular dynamics (MD) and monte carlo (MC) technique applied to engineering materials; DFT calculations; Ab-initio molecular dynamics; kinetic monte carlo simulation [3 hours]

Molecular dynamics modelling and simulation - general steps; ensembles; interatomic potential; initial and boundary conditions; force calculation; phase space evolution; integration algorithms; thermostatting and barostatting; MD data analysis and property calculations [13 hours]

General overview of continuum modelling techniques - finite element method (FEM) modelling and simulation - advantages and drawbacks of the method; types and applications of the method [3 hours]

FEM modelling - general steps; different approaches for deriving element properties: direct approach, variational approach, and Galerkin's method; types of elements and interpolation functions; condensation and substructuring; continuity requirements; mesh refining; Gauss quadrature; FEM modelling for structural and thermal problems [15 hours]

Coding and use of software for materials modelling using MD and FEM technique [6 hours]

Demonstration of a multiscale model developed by coupled MD - FEM simulation [3 hours]

Text Books:

- Understanding Molecular Simulation*: D. Frenkel and B. Smit*, Academic Press, 2002
- The Art of Molecular Dynamics Simulation: *D.C. Rapaport*, Cambridge University Press, 2004
- Statistical mechanics: *Donald A. Mcquarrie*, Harper Row, 1976

Reference books:

- The Finite Element Method for Engineers, 4th Edition: *Kenneth H. Huebner, Donald L. Dewhirst, Douglas E. Smith, Ted G. Byrom,* Wiley, 2001
- An Introduction to the Finite Element Method (Mcgraw Hill Series in Mechanical Engineering) 3rd Edition: *J. N. Reddy*

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 9016	**ADVANCED WELDING METALLURGY**	3-1-0	4	

Introduction: Historical of development of welding processes, classification, abbreviation for welding processes, welding procedure, welding terms and characteristics, welding design, welding positions, welding vs. other joining processes. [4 hours]

Gas Welding: Introduction, oxy-acetylene welding, flame characteristics, welding techniques, advantages and drawbacks of gas welding, oxy-acetylene cutting. [2 hours]

Arc Welding: Arc welding power sources, power source characteristics (PSC); Shielded Metal Arc Welding (SWAM) - welding electrodes, AWS and BIS electrodes specifications, arc blow, weaving, advantages and drawbacks; Submarged arc welding (SAW) - process description, advantages, limitations and applications; Gas Metal Arc Welding (GMAW) – process description, shielding gases, modes of metal transfer, avantages, limitations and applications; Gas Tungsten Arc Welding (GTAW), process description, welding techniques, advantages, limitations and applications. [8 hours]

Resistance Welding: Heat generation and process description, welding sequence, resistance seam welding, limitations and application, projection welding. [2 hours]

Radiant Welding: Electron beam welding (EBW), introduction, process description, power density, weld characteristics, Types of units, advantages, limitations and applications; Laser beam welding (LBW) – principles of LASE generation, process description, laser welding units, advantages, limitations and applications. [6 hours]

Other Welding processes: Friction welding, diffusion welding, induction, welding, thermit

welding, ultrasonic welding, Friction Stir Welding etc. [3 hours]
Heat Flow in Welding [4 hours]
Welding Metallurgy: Structure and characteristics of weld metal (WM), weld composition, heat affected zone (HAZ), weldability, carbon equivalent (CE), weldability vs. hardenability, actual weldability tests. [8 hours]
Welding of Specific Alloys: Welding of stainless steels, welding of cast irons, welding of copper base alloys, welding of dissimilar metals and alloys. [4 hours]
Weld Defects & Cracking: Weld defects, hot cracking, lamellar tearing etc. [3 hours]
Testing and Inspection: All weld tests – tension, best, hardness, impact. Non destructive tests, quality assurance, reliability of the weld. [2 hours]
Brazing and soldering: Introduction, brazing process, brazing filler metals, soldering, soldering processes, solder alloys, applications. [3 hours]

Text books:

1. An introduction to Welding - R S Parmar
2. Principles of welding technology – L M Gourd, Edward Arnold / ELBS, London, 1980.
3. Welding for Engineers – H. Udin, E. R. Funk and J Wulff, John Wiley, New York.
4. Welding Engineering, B. E. Rossi, McGraw Hill New York

Reference books:

1. Welding Metallurgy, Sindo Kou, A John Wiley and Sons Incorporation Publication.
2. American Society of Metals, Metal Handbook, Welding.

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 9017	**ADVANCED METAL FORMING PROCESSES**	3-1-0	4	

Introduction of metal forming as a manufacturing process, and its relation with other processes from systems point of view. [6 hours]
Theoretical analysis (theory of plasticity), Stress-strain relationship, Strain hardening, Material incompressibility, Work of plastic deformation, Work hardening, Yield criteria, Flow rule, Yield criterion and flow rule for Anisotropic material, Initiation and extent of plastic flow- Problems. [12 hours]
Overview of various metal forming operations: Conventional Vs High velocity forming methods – Material behavior – Mechanics of Various Plastic Flow Problems Forging; Workability of testing techniques, Tribology in metal forming and other phenomena. [12 hours]

Sheet forming: Mechanics – Flow Rules – Anisotropy - Formability of sheet, Formability tests,Forming limit diagrams, Case studies. [10 hours]

Pressing and Sintering: Workability Studies – Densification - Problems & Case Studies. [10 hours]

Text Books:

1. Surender Kumar, Technology of Metal Forming Processes, Prentice - Hall, Inc., 2008.

2. Henry S. Valberg, Applied Metal Forming - Including FEM Analysis, Cambridge University
Press, 2010.

Refernce Books:
1. Advances in Metal Forming Expert System for Metal Forming, Hingole, Rahulkumar Shivajirao, Springer, 2015

2. Metal Forming: Technology and Process Modelling, Uday S. Dixit, R. Ganesh Narayanan, McGraw Hill, 2013.

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 9018	**ADVANCED PHYSICAL METALLURGY**	3-1-0	4	

Atomic Structure, Electron quantum state, electronic configuration, Bonding in solids, crystal structure: translational periodicity and symmetry, atomic packing, voids in packing, crystal imperfections, effect on material properties. [10hours]
Phase Equilibria: Free energy-composition diagrams for different kind of solutions, origin and interpretation of phase diagrams, Binary phase diagrams, Tie line, Lever rule, Solid-liquid Miscibility gap; invariant reaction; Ternary phase diagrams: ternary two-phase, three-phase and four-phase equilibria, Tie triangle. [10 hours]
Diffusion: Phenomenological equation of diffusion, Fick's first law of diffusion, Diffusion in ideal solution and in solutions with positive and negative deviation; Uphill diffusion, atomic mechanism of diffusion, concept of jump frequency and jump distance, Steady state diffusion and transient diffusion; Fick's second law of diffusion, solution of Fick's second law: analysis of homogenizing annealing, carburizing and decarburizing processes; solution of Fick's second law for variable diffusivity: Boltzmann-Matano analysis, Matano interface, determination of diffusivity as a function of concentration; Diffusion in substitutional solid solution: Kirkendall effect, Darken's analysis. [10 hours]
Liquid-Solid Phase Transformation: Principles of Solidification in metals and alloys: thermodynamic aspects, temperature inversion, thermal super cooling and constitutional super cooling, dendritic solidification; eutectic and peritectic Solidification, Homogeneous and heterogeneous nucleation of solid, Mechanisms of crystal growth; Rapid Solidification Processing; isothermal solidification during transient liquid phase diffusion bonding. [10 hours]
Solid State Phase Transformations: Nucleation and growth Kinetics, homogeneous and heterogeneous transformation, Precipitation: Coherency, age hardening, particle Coarsening; Ostwald ripening, Order-disorder transformation, spinodal decomposition, massive transformations, Solid state phase transformation in steel: formation of allotriomorphic ferrite, idiomorphic ferrite, Widmannstatten ferrite, acicular ferrite and massive ferrite; bainitic transformation, micromechanism of martensitic transformation and shape memory effect. [10 hours]

Text Books:
1. Phase Transformations in Metals and Alloys, Third Edition (Revised Reprint), David A. Porter, Kenneth E. Easterling, Mohamed Sherif, CRC Press, 2009.
2. The Theory of Transformations in Metals and Alloys, J.W. Christian, Elsevier, 2002

Reference Books:

1. Solid state phase transformations, V. Raghavan, PHI Learning Private Limited, New Delhi, 1987.
2. Principles of physical metallurgy, Reed Hill, Reza Abbaschian, Lara Abbaschian, Robert E Reed-Hill, Wadsworth Publishing Co Inc; 4th edition, 2008.

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 9019	**FATIGUE FAILURE & FRACTURE ANALYSIS**	3-1-0	4	

FATIGUE OF STRUCTURE : S.N. curves - Endurance limits - Effect of mean stress, Goodman, Gerber and Soderberg relations and diagrams - Notches and stress concentrations - Neuber's stress concentration factors - Plastic stress concentration factors - Notched S.N. curves. [10 hours]

STATISTICAL ASPECTS OF FATIGUE BEHAVIOUR: Low cycle and high cycle fatigue - Coffin - Manson's relation - Transition life - cyclic strain hardening and softening - Analysis of load histories - Cycle counting techniques -Cumulative damage - Miner's theory - Other theories. [10 hours]

PHYSICAL ASPECTS OF FATIGUE: Phases in fatigue life - Crack initiation - Crack growth - Final Fracture - Dislocations - fatigue fracture surfaces. [10 hours]

FRACTURE MECHANICS: Strength of cracked bodies - Potential energy and surface energy - Griffith's theory - Irwin - Orwin extension of Griffith's theory to ductile materials - stress analysis of cracked bodies - Effect of thickness on fracture toughness - stress intensity factors for typical geometries. [10 hours]

FATIGUE DESIGN ANDTESTINIG: Safe life and Fail-safe design philosophies - Importance of Fracture Mechanics in aerospace structures - Application to composite materials and structures. [10hours]

TEXT BOOKS

1. Deformation and Fracture Mechanics of Engineering Materials, by Richard W. Hertzberg, Richard P. Vinci and Jason L. Hertzberg, Wiley, 2012.
2. Knott, J.F., "Fundamentals of Fracture Mechanics", Buterworth & Co., Ltd., London, 1983.

Reference books:

1. Sin, C.G., "Mechanics of fracture" Vol. I, Sijthoff and w Noordhoff International Publishing Co., Netherlands, 1989.
2. Prasanth Kumar – "Elements of fracture mechanics" – Wheeter publication, 1999.

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 9020	**COMPOSITE MATERIALS AND ITS DEVELOPMENT**	3-1-0	4	

Introduction: Classification of composites based on matrix and reinforcement: Metal matrix composite, polymer matrix composites, ceramic matrix composite and carbon-carbon composite; application of different composite materials. [10 hours]

Synthesis routes of composites: casting route and powder metallurgy route. [4 hours]

Powder metallurgy processed Composite: High energy milling, Mechanical alloying: Fundamentals and parameters; Compaction and Sintering: material dependent routes and process parameters; process parameter-structure-property correlation. [15 hours]

Cast metal matrix composites: different synthesis routes: dispersion process (stir casting, compocasting and screw extrusion)-contact angle, wettability and particle-matrix bonding; Liquid metal impregnation/infiltration (pressure infiltration, squeeze casting and Lanxide process)- principle of molten metal infiltration-capillary flow of molten metal; Spray process (Osprey process and rapid solidification process); In-situ production of dispersoids-XD process; evolved microstructure: structural defects in cast metal matrix composites- porosity, particle segregation (macrosegregation and microsegregation), interfacial reaction and particle degradation; structure-property correlation. [15 hours]

Joining of metal matrix composites, limitations of conventional fusion welding, Application of transient liquid phase (TLP) diffusion bonding, basic mechanism and different stages of TLP bonding process for monolithic and composite system, process parameters of TLP bonding, joint efficiency. [6hours]

Text books:

1. Metal Matrix Composites - Chawla and Chawla, Springer, 2006.
2. Materials Science and Engineering:An Introduction - William D. Callister, Jr., John Wiley & Sons, Inc., 2007.
3. Fundamentals of Metal-Matrix Composites - Andreas Mortensen and Alan Needleman, Butterworth-Heinemann, 1993.
4. An Introduction to Composite Materials –Derek Hull, Cambridge University Press, 1981.
5. Composite Materials –Deborah D.L. Chung, Springer, 2009.
6. Metal-Matrix composite – P.K. Rohatgi, Defence Science Journal, Vol 43, No 4, October 1993, pp 323-349.

Reference books:

1. 'Joining of aluminium based metal matrix composites'- Joydeep Maity, in 'Engineered Metal Matrix Composites: Forming Methods, Material Properties and Industrial Applications', Editor: Luca Magagnin, 2012, NOVA Science Publishers, Inc., New York, USA, pp 329-354.
2. Y. B. Liu, S. C. Lim, L. Lu, M. O. Lai, Recent development in the fabrication of metal matrix-particulate composites using powder metallurgy techniques, Journal of MateralsScience 29 (1994) 1999-2007.

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 9021	**CERAMICS TECHNOLOGY**	3-1-0	4	

Introduction:
Types, nature, conventional and advanced ceramics, applications, etc. review of crystallography, bonding, and ionic and super ionic conductivity. [6 hours]

Structure of Ceramics:
Basic structure: atomic packing, paulings rules, structure of silicates, silica, glass, ceramic oxides, perovskite structure. [6 hours]

Defects in Ceramics:
Point, surfaces, interfaces and non-equilibrium structure in ceramics. [6 hours]

Properties of Ceramics:
Mechanical properties, thermal properties, electrical properties, optical properties, magnetic
properties, failure modes in ceramics, property structure relationship, measuring of properties. [8 hours]

Ceramic Phase Diagrams and Phase equilibrium:
Uniary, binary, ternary, and quaternary systems, miscibility gap in glasses, devitrification in glasses, phase diagrams in ceramics. [6 hours]

Processing:
Powder synthesis and sintering, glass forming processes, drawing, hot and cold pressing, fibre forming, blowing, powder crushing, slip casting, hydro plastic forming, extrusion, centring, jiggering, sol-gel processing, anvil technologies, ceramic coating, fusion casting, dyeing and firing, gas phase, liquid phase, solid phase ceramic fabrication processes, CVD, directed metal oxidation, reaction bonding, polymerisation, metal casting, ceramic composites processing, thermal barrier coatings, etc. [10 hours]

Special types and applications:
Toughened ceramics, cermets, functionally graded materials, piezoelectric ceramics, ceramic magnets, high temp. super-conducting magnets, glass ceramic composites, chemically bonded ceramics, ceramics in electrical applications, electro ceramics, advanced ceramics. [8 hours]

Text Books:

1. Introduction to ceramics, W. D. Kingery, Harvey Kent Bowen, Donald Robert Uhlmann. 2nd edition, Wiley, 1976.
2. Ceramic Materials: Science and Engineering, C. Barry Carter, M. Grant Norton, Springer, 2013.

Reference Books:

1. Ceramic Processing and Sintering, M. N. Rahman, Marcel Dekker, CRC Press, 2003.
2. Mechanical Properties of Ceramics, Watchman J. B., John Wiley, New York, Wiley, 2009

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 9022	**POWDER METALLURGY TECHNOLOGY**	3-1-0	4	

Introduction [2 hours]

Powder fabrication methods: preparation of metallic, ceramic and composite powders, Approaches to forming specific metal powders. [8 hours]

Powder Characterization: particle size, shape, distribution, surface area, flow, compressibility, structure, morphology and composition [8 hours]

Treatment of powders: Powder mixing and blending [4 hours]

Shaping and compaction: design rules, behavior of powder during compaction, compaction in rigid dies, cold isostatic compaction, powder injection molding, extrusion and forging, roll compaction, tape forming, slip casting and sol-gel casting [8 hours]

Sintering and full density processing: Solid state sintering, liquid phase sintering, reaction sintering, hot pressing, hot isostatic pressing and self propagating combustion sintering, sintering maps, sintering furnaces, effect of sintering atmosphere, advanced consolidation methods: SPS, MW, etc. [8 hours]

Properties of P/M materials: effect of porosity and alloying [4 hours]

Applications of P/M materials: Refractory metals, cemented carbides, porous parts, structural parts, aerospace applications, magnetic applications. [3 hours]

Text Books:

1. Powder Metallurgy – AUpadhyaya and G S Upadhyaya.
2. Powder Metallurgy Science – R. M. German, 2nd Edition, MPIF, 1994

Reference books:

1. Powder metallurgy: principles and applications, Fritz V. Lenel, Metal Powder Industries Federation, 1980
2. Powder Metallurgy Technology, Cambridge International Science Publishing, 2002

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 9023	**FOUNDATION OF NANO-TECHNOLOGY**	3-1-0	4	

Basic concept of Nanotechnology: Nanotechnology, Nanotech Generation, Nanoscience, New form of Carbon, Nanocomposites, Polymer Nanocomposites, Nanometerials, Properties of nanomaterials, One, two and three dimensional nanometerials, Molecular nanotechnology, Nanostructured materials by self-assembly, Nanocrystals, nanopoures, nanoionics, nanomechanics, Nanorobotics. [12 hours]

Tools to measure and make nanostructures: Tools and Techniques, microscopy, Metrology, Simulation, Carbon Nanotube (CNT) – fabrication, Purification of CNTs, Dispersion, Scanning Probe Microscopes (SPM), Atomic Force Microscopy (AFM), Single Molecule Techniques, Microlithography and MEMs, Electron beam lithography and focused ion bombardment. [12 hours]

Applications of Nanotechnology: Identified potential applications, Expected benefits from nanotechnologies, Energy and Energy Efficiency, new energy producers, Medicine, security, Other Applications. [12 hours]

Impact of Nanotechnology: Societal impact of nanotechnology, Social and ethical impact, Health and environmental impact, Risks with nanotechnology, Indian Scenario in nanotechnology. [12 hours]

Text Books:

1. Introduction to Nanoscience, S. M. Lindsay, Oxford Press, 2009.
2. Nano: The Essentials, T. Pradeep, Tata McGraw Hill, 2007

Reference books:

1. Nanotechnology: technology Revolution of 21st Century Rakesh Rathi, S. Chand & Company, 2010.
2. Nanomaterials, Nanotechnologies and Design, 1st Edition, Schodek & Ferreira & Ashby, Butterworth-Heinemann, 2009.

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 9024	INDUSTRIAL MANAGEMENT	3-1-0	4	

Framework of human resource development: influences on employee behaviour, learning and HRD, assessing HRD needs, designing and implementing HRD programmes, evaluating HRD programmes; [12 hours]

Applications of human resource development: employee socialization and orientation, skills and technical training, coaching and performance management, mentoring, employee counselling and wellness services, career management and development, management development; Organization development and change; [16 hours]

Contemporary issues: knowledge management and learning organizations, competency mapping, intellectual capital management, BPR, TQM, and empowerment, stress and time management. [12 hours]

Text Books:

1. Ghosh A.K., Human Resource Management, Manas Publications, 2007

Reference books:

1. Dessler G. Fundamentals of Human Resource Management Pearson Education; First edition, 2010.

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 9025	**ELECTRON MICROSCOPY**	3-1-0	4	

The Transmission Electron Microscope and Basics of Microscopy: The transmission electron microscope, Electron beam sources, Vacuum systems, pumps, etc., Electron lenses and sources of aberrations, Electron optics, Resolution of an imaging system, Specimen preparation for TEM, Electron detectors and digital imaging. [12 hours]

Electron Diffraction: Crystal lattices, reciprocal lattice, structure factors, Basic crystallography, Electron diffraction: Kinematical theory, Electron diffraction: Dynamical theory, Ewald sphere, relrods, and the deviation parameter, Diffraction patterns and indexing, Kikuchi diffraction, Double diffraction, twins, polycrystalline materials, amorphous materials, Convergent-beam electron diffraction (CBED). [12 hours]
Imaging: Mass-thickness contrast, amplitude contrast, and phase contrast mechanisms, Diffraction contrast imaging of defects, High resolution imaging: Phase contrast, High resolution imaging: Z-contrast, Moiré, Lorentz, and holographic imaging, Digital image processing. [12 hours]
Microanalysis: Fast electrons-specimen interactions, Physical background for microanalysis: Inelastic electronic scatterings, Electronic excitations of solids and spectroscopic notation, Electron energy-loss spectroscopy (EELS), Energy-filtered imaging and energy-filtered diffraction, X-ray microanalysis (EDS), Electron-beam-induced specimen damage and contamination. [12 hours]

Textbooks:
1. Transmission Electron Microscopy: A Textbook for Materials Scienc, D. B. Williams, C.B. Carter, 2nd ed.; Springer, 2009.
2. Transmission Electron Microscopy and Diffractometry of Materials, B. Fultz, J. Howe, 4th ed.; Springer, 2013.

Reference books:
1. Transmission Electron Microscopy: Physics of Image Formation, L. Reimer, H. Kohl, 5th ed., 2008.
2. Sample Preparation Handbook for Transmission Electron Microscopy: Methodology J. Ayache, L. Beaunier, J. Boumendil, G. Ehret, D. Laub, Springer, 2010.

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 9026	**STRUCTURE & PROPERTIES OF METALS AND ALLOYS**	3-1-0	4	

STRUCTURE OF MATERIALS:
Structure of atom – Atomic models – Bonding in solids – Bonding forces and energies – Ionic, Covalent, metallic and van der Waals Bond - Crystal structure - Unit Cell – Bravais lattice – BCC – FCC – HCP - Interstitial sites – NaCl crystal – CsCl crystal – Perovskite structure – Diamond structure – Graphite – Crystal directions and planes. [10 hours]

STRUCTURE OF METALS AND ALLOYS:

Imperfection in crystals – Point defects – Dislocations – Slip plane – Movement of dislocations – Planar defects and grain boundaries – solid solutions – Hume Rothery rule – Phase diagram – Lever rule – Gibb's phase rule – Phase diagram for binary alloys – Eutectic – Peritectic – Eutectoid – Zone refining. [10 hours]

FERROUS AND NON FERROUS ALLOYS:
Allotropy and phase change of pure iron – Classification of steels and cast iron – iron – carbon equilibrium diagram – Microstructure of iron and steel - Ferrous alloys and their applications –Heat treatment - Factors affecting conductivity of a metal – Electrical Resistivity in alloys – Thermal conductivity of metals and alloys – Silver, Copper and aluminum – High Resistivity alloys – nichrome, manganin, constantan and kanthal and their composition and applications – Super hard materials - Tungsten carbide and Boron nitrides. [10 hours]

CERAMIC AND COMPOSITE MATERIALS:
Advanced Ceramic Materials - Crystal Structures - Silicate Ceramics - Glasses – Glass Ceramics – Functional properties and applications of ceramic materials – Classification of composites - Fiber reinforced materials – Law of mixtures – Continuous fibers – discontinuous fibers – Particle-reinforced materials – Cermets – Dispersion strengthened materials – Laminates - Application of composites in electrical and mechanical components – nuclear industry. [10 hours]

POLYMER MATERIALS:
Classification of polymer – Mechanisms of polymerisation - Some commercially important individual polymer – Thermoplastics - Elastomers – Thermosets – Engineering plastics - Liquid crystal polymers - Conductive polymers – High Performance fibers - Biomedical applications – Photonic polymers. [10 hours]

Text Books:
1. William D. Callister, Jr., Materials Science and Engineering an Introduction, 6th Edition , John Wiley & Sons, Inc., 2004.
2. Structure of Metals, 3rd revised edition, C. S. Barrett, T. B. Massalski, Pergamon press Oxford, 1981.

Reference Books:
1. William F.Smith, Structural Properties of Engineering Alloys, Tata Mc-Graw-Hill, Inc., 1993.
2. Kingery. W.D., Bowen H.K. and Uhlmann D.R., Introduction to Ceramics, 2nd Edition, John Wiley & Sons, New York, 1976.

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 9027	**ENVIRONMENTAL DEGRADATION OF MATERIALS**	3-1-0	4	

Technological importance of corrosion study, corrosion as non equilibrium process, corrosion rate expressions, electrochemical principles of corrosion-cell analogy, concept of single electrode potential, reference electrodes, polarization, passivity, modern theory of corrosion [6 hours]

Different forms of corrosion-uniform attack, galvanic, crevice, pitting, intergranular corrosion, selective leaching, erosion, stress corrosion cracking-their characteristic features, causes and remedial measures. [5 hours]

Principles of corrosion prevention-material selection, control of environment including inhibitors, cathodic and anodic protection, coatings and design considerations. Corrosion testing methods. [6 hours]

Fault tree diagram, Case studies related to industrial components failure. [5 hours]
Methods of study for failure analysis. Case studies of Failure analysis. [5 hours]

Introduction to high temperature corrosion, Pilling-Bedworth ratio, oxidation kinetics, oxide defect structures, catastrophic oxidation, internal oxidation. Scaling of binary and ternary alloys, Considerations in high temperature alloy design, prevention of high temperature corrosion-use of coatings. [10 hours]

Hot Corrosion, Study of corrosion of weld joints. [3 hours]

Chemical degradation of non-metallic materials like ceramics, timbers. Corrosion during transit . [5 hours]

Study of Delhi Iron Pillar – 'the rustless wonder' [2 hours]

TEXT BOOKS:

1. Corrosion Engineering – Mars G. Fontana, McGraw- Hill Publication, 1987.
2. Introduction of High Temperature Corrosion – N. Birks and G. H. Meier

REFERENCE BOOKS:

1. Kutz M., Kutz M., Associates, Handbook of Environmental Degradation of Materials, 978-1-4377-3455-3, 1012.

2. Chatterjee U.K., Bose S.K., Roy S.K., Environmental Degradation of Metals, 2001.

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 9028	**ADVANCED FOUNDRY PRACTICE OF COMMERCIAL CASTINGS**	3-1-0	4	

Solidification of Casting: Concept of solidification of metals. Homogenous and heterogeneous nucleation. Growth mechanism. Solidification of pure metals and alloys. Mechanism of columnar and dendritic growth. Coring or Segregation. Solidification time and Chvorinov's rule. Concept of progressive and directional solidifications. [6 hours]

Principles of Gating and Risering: Purpose of the gating system. Components of the gating System and its functions. Design of the gating System. Different types of gates. Gating ratio and its functions. Definition and functions of the riser. Types of risers and their application. Design of the riser - its shape. Size and location. Use of insulating material and exothermic compounds in risers. [6 hours]

Design of Casting: Factors to be considered in casting design. Design consideration in pattern making, moulding techniques and core making and assembly. Cooling stresses and hot spots in casting and modification in casting geometry to overcome them. [4 hours]

Casting Quality Control: Casting defects and factors responsible for them. Different inspection and testing methods to evaluate the casting. Quality control activities in a foundry. Salvaging methods of defective casting. [4 hours]

Furnace Technology: Study of various furnaces used in foundry, construction and operation of crucible and hearth furnaces. Resistance, Arc and Induction furnaces-their construction.
Operation and application. Heat treatment furnaces and drying ovens used in foundry. [4 hours]

Gray Cast - Iron Foundry Practice: Chemical Composition and structure of gray cast iron. Moulding, gating and risering techniques. Melting of gray cast iron in Cupola and induction furnace. Inoculation of gray cast iron. Application of gray cast iron castings. [4 hours]

Malleable Cast Iron: Chemical composition and structure of White-heart and black-heart malleable cast iron. Melting malleabilisation heat treatment and application of malleable cast iron. [3 hours]

Ductile Cast Iron: Chemical composition and structure of ductile cast iron. Melting and spherodisation treatment. Inoculation of ductile iron Properties and application of ductiles iron casting. [3 hours]

Steel Casting Practice: Common steel casting, their composition, structure and properties. Melting and refining of steel. Gating and risering of steel castings cleaning of steel castings. [4 hours]

Aluminium Foundry Practice: Composition, properties and application of common aluminum alloy casting. Melting and casting of AI-alloys. Gating and risering of AI-alloy casting. [4 hours]

Copper Alloy Foundry Practice: General characteristics of common cast copper alloys. Melting and casting of copper alloys. Gating and risering of cu-alloy castings. [4 hours]

Foundry Mechanization and Modernization: Introduction to modernization. Mechanization of foundry and its advantages. Mechanization of sand plant, moulding and core making mechanization in melting, pouring and shakeout units. Material handling equipments and conveyor systems. Brief sketches and description of layouts of job. Captive and mechanized foundries. [6 hours]

Text Books:
1. Foundry Technology, P.R. Beelely, Butterworth, 1972.
2. Principle of Metal Casting - Heine, et. al - Tata-McGraw-HiII Publication - 2003.

REFERENCE BOOKS:

1. Casting technology and cast alloys, A. K. Chakrabarti, PHI Learning Pvt. Ltd., 2005
2. A Test Book of FoundryTechnology, M. Lal and O.P. Khanna, Dhanpat Rai Publication.

SUBJECT CODE	SUBJECT	L-T-P	CREDIT	DEVELOPER
MT 9029	**COMPUTATIONAL FLUID DYNAMICS**	3-1-0	4	

Introduction: What is computer simulation?, Advantages of computer simulation, Methods of predication, conservation of chemical species, Energy equation, A momentum equation, The Time-Averaged Equation for Turbulent Flow, the Turbulent-kinetic-Energy equation, Application of fluid flow and heat transfer, why is computer simulation necessary in Fluid Flow and Heat Transfer? [8 hours]
Mathematical description of Physical Phenomena: Classification of PDEs, Elliptic, Parabolic and Hyperbolic Equations, Initial and Boundary conditions, Initial value and Boundary value problems, How many Initial and boundary conditions do you need for completely defining a problem? Nature of Coordinates, the nature of Numerical methods, Method of Deriving the discretization equations, Four basic rules. [6 hours]

Heat Conduction: Introduction, the basic equations, the grid spacing, the interface conductivity, Nonlinearity, source-term Linearization, boundary conditions, Solution of the linear algebraic equations, the general discretization equation, explicit, Crank-Nicoloson, and Fully Implicit Schemes, Discretization equation for two dimensions, Discretization equation for three dimensions, Overrelaxation and underrrelaxation, location of the control-volume faces, others coordinates systems, problems. [12 hours]

Convection and diffusion: Steady one dimensional convection and diffusion: A preliminary derivation, the Upwind Scheme, The exact Solution, The exponential scheme, The Hybrid Scheme, The Power-law Scheme, A generalized Formulation, Consequences of various schemes. Discretization equation for two dimensions: Details of the derivation, The final Discretization equation, Discretization equation for three dimensions, A one- way space coordinate, false diffusion. [12 hours]
Calculation of The flow field: The main difficulty, velocity-Based Methods, Representation of the pressure-gradient Term, Representation of the Continuity equation, the staggered Grid, The momentum equations, the pressure and velocity correction, The pressure-Correction equation, the SIMPLE algorithm, SIMPLER algorithm, Problems. [12 hours]

TEXT BOOKS:

1. S. V. Patankar, Numerical Heat Transfer and Fluid flow, Taylor & Francis, 2004.

2. P. S. Ghoshdastidar, Computer simulation of Flow and heat transfer, TMH, New Delhi, 1998.

REFERENCE BOOKS:

1. T. J. Chung, Computational Fluid Dynamics, Cambridge University Press.

2. H.K.Versteeg & W. Malalasekera,An Introduction to Computational Fluid Dynamics, Longman Scientific & Technical.

<table>
<tr><td colspan="8">Department of Metallurgical and Materials Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)#</td><td>Total Hours</td></tr>
<tr><td>MT 9030</td><td>Foundation of Physical Engineering</td><td>PEL</td><td>4</td><td>0</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="4">Course Assessment methods (Continuous (CT) and end assessment (EA))</td><td colspan="2">Developed By</td></tr>
<tr><td colspan="2"></td><td colspan="4">CT+EA</td><td colspan="2">Prof. K.S.Ghosh</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">To understand the cystal lattice and structure in details of metals and ceramics.
To know the solidification processing and determine grain size.
To learn atomic mechanism of diffusion.
To understand the Free energy-composition diagram.
To acquaint with different types of phse diagrams and invariant points.
To analyze diffusion mechanisms in different kinds of solid solutions.
To learn Fe-Fe_3C phase diagram and phase transformations in steel.
To know different heat treatment processes.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">The crystalline and the noncrystalline states; The space lattice and units cells, Crystal systems and Bravais lattice, Principles metallic crystals structures – BCC, FCC and HCP crystals, Atom positions in cubic unit cells, lattice directions and lattice planes in cubic and hexagonal systems; atomic packing, voids in FCC, BCC and HCP crystals; crystal imperfections– point defect, line defect, surface defect and volume defect; equilibrium concentration of point defect; polymorphism or allotropy. [12]
Solidification of metals and alloys. Optical metallographic, ASTM grain size and grain diameter determination. Constitution of alloys. Level of structure and structure-property relationships in materials. [6]
Phase diagrams: The phase rule, single component system. Binary phase diagrams – isomorphous, eutectic, peritectic, eutectoid, peritectoid, monotectic, nonequilibrium cooling, with intermediate compounds, invariant points, ternary phase diagrams. Phase diagram of Al-Si, Al-Cu, Cu-Zn, Cu-Sn system etc.
Phase Equilibria: Thermodynamics of phase changes, phase diagrams and equilibria in relation to Free energy-composition diagrams. [12]
Diffusion: Fick’s first law of diffusion, diffusion coefficient (diffusivity), representation of diffusion flux in terms of chemical potential gradient; Uphill diffusion, Fick’s second law of diffusion; solution of Fick’s second law: analysis of carburizing and decarburizing processes; Kirkendall effect, Darken’s analysis. [5]
The iron-iron carbide equilibrium system, cooling curves of pure Fe, slow cooling of steel; carbon solubility in iron. Different conventional heat treatment processes - annealing, normalizing, hardening, and tempering treatments of plain carbon steels. TTT and CCT diagrams. Concept of hardenability and End-quench, Infuence of alloying elements of hardenability. Pack Carburizing of steels, Post-carburizing heat treatment, Measurement of case depth. [13]</td></tr>
</table>

Text book/ Reference	1) William F Smith and Javad Hashemi, Foundation of Materials Science and Engineering, McGraw Hill Publication, 4th Edition, International Edition 2006. 2) Sidney H. Avner, Introduction to Pyhsical Metallurgy, McGraw Hill Internatinal Book Company, Internatinal Student Editions,2nd Edition. 3) Robert E. Reedhill, Pyhsical Metallurgy Principles, Affiliated East-West Press Pvt. Ltd. New Delhi, 2nd Edition. 4) V. Raghavan, Materials Science and Engineering A First Course, Prentice Hall India Pvt. Ltd., New Delhi, 2003, 4th Edition.

Department of Metallurgical and Materials Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)#	Total Hours	
MT 9031	Corrosion Engineering	PEL	4	0	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))				Developed By	
		CT+EA				Prof. K.S.Ghosh	
Course Outcomes	To learn the principles of corrosion and concept of polarisation. To understand of different forms of corrosion and their mechanism. To know the different methods of Corrosion Prevention or Combat. To acquaint with different actual corrosion testing. To learn the principles, mechanism and prevention of high temperature corrosion						
Topics Covered	**Introduction**: Cost of corrosion, corrosion engineering, definition of corrosion, Environments [2] **Corrosion principles:** Introduction, corrosion rate expression, electrochemical reaction, thermodynamics, free energy, electrode potential, cell potential, EMF series, galvanic series, IUPAC convention of cell reaction, electrode kinetics, exchange current density, polarisation, activation polarisation, concentration polarisation, passivity, Poubaix diagram (E – pH diagram), reference electrode. [12] **Forms of corrosion:** Uniform attack. Galvanic or two-metal corrosion - Definition, EMF series and galvanic series, environments effects, metallurgical effects, beneficial effects and prevention. Intergranular corrosion. Crevice corrosion. Pitting corrosion. Selective leaching. Erosion corrosion. Environment Assisted /Induced Cracking (EAC/ EIC) - Stress corrosion cracking (SCC), Corrosion fatigue (CF) and Hydrogen damage (HE) and Biological Induced Corrosion etc. [15] **Corrosion prevention:** Materials selection, alteration environments, design, cathodic and anodic protection, coating. [6] **Corrosion testing:** Corrosion rate expression, pitting, intergranular corrosion – Streicher test for stainless steel, stress corrosion test, Slow strain rate test (SSRT), polarisation techniques – Tafel extrapolation, linear polarisation (resistance polarization) and AC impedance technique. [6] **High temperature corrosion:** Introduction, Pilling –Bedworth ratio, electrochemical and morphological aspects, oxidation kinetics and salt induced high temperature corrosion (hot corrosion). [6]						

Text book/ Reference	1) Mars G Fontana, Materials Science and Engineering, McGraw Hill Internatinal Editions, Materials Science and Metalurgy Series, 3rd Editions. 2) Kennth R Trethewey and John Chamberlin, Materials for Science and Engineering, Adition Wesley Longman Ltd. 3) Denny A Jones, Principles and Prevention of Corrosion**,** Macmilliaan Maxwell Publication. 4) L. L. Shrier, Corrosion vol 1 and vol 2. 5) U. R. Evans, The Corosion and oxidation of Metals.

Department of Metallurgical and Materials Engineering							
Course Code	Title of the course	Program Core (PCR) / Electives (PEL)	Total Number of contact hours				Credit
			Lecture (L)	Tutorial (T)	Practical (P)	Total Hours	
MT-**9032**	Plasma technology for metallurgical applications	PEL	4	0	0	4	4

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))	Developed By
MT-2002: Advances in Process Metallurgy	CT+EA	Dr. A. K. Mandal

Course Outcomes	• CO1: Acquire an idea about the principle and application of plasma technology • CO2: To learn the methods of methods of metal extraction by plasma technology • CO3: To learn about the surface modification of metals and alloys by plasma treatment • CO4: Introduced to clean steel making by the plasma smelting route
Topics Covered	**Introduction:** Historical developments in plasma technology [1hr] **Fundamentals:** Plasma metallurgy-Basic principles, types of arcs, arc characteristics [4hrs] **Plasma Generation:** Electrical and mechanical components, types of plasma torches, comparison of AC and DC plasma, evaluation of plasma techniques as compared to conventional in the light of energy, environment and economy. [10hrs] **Applications:** **Iron Making**: Plasmasmelt, plasmared, plasmacan, Elred, Sustained Shockwave Plasma(SSP)[5hrs] **Steel making:** Inmetco process, SKF plasma dust process[3hrs] **Steel melting and Alloy Technology**: Plasma Arc Scrap Melting Unit, Plasma Induction Furnace, Plasma Progressive Casting Furnace (PPCF) [5hrs] **Ferro-Alloy Technology**: Carbo-thermic smelting reduction (Fe-Cr, Fe-Mn, Fe-Si, Fe-V). [4hrs] **Plasma Arc Remelting:** Techniques and applications.[2hrs] **Plasma in Nonferrous Metals:** Processing of sulphide ores(Mo and Cu) and oxide ore(Ti)[3hrs] **Plasma Technology in Ceramic Material Coating**.[1hr] Assessment, Development and Future Prospects.
Text Books, and/or reference material	**Textbooks:** 1. V Dembovsky: Plasma Metallurgy -The Principle (Elsevier) 2. J. Feiman: Plasma technology in Metallurgical Processing; Iron & Steel Society, USA **Reference books:** 1. Mintek Review, No.6,1987. 2.FP Edernal, Electro metallurgy of Ferro alloy, 01, MIR Publication 1979