NATIONAL INSTITUTE OF TECHNOLOGY DURGAPUR

DEPARTMENT OF METALLURGICAL AND MATERIALS ENGINEERING

Revised Curriculum and Syllabi

Program Name
Master of Technology in Metallurgy and Materials Technology (MT)
Effective from the Academic Year: 2021-2022

Recommended by DPAC	: 04.08.2021
Recommended in PGAC	: 16.08.2021
Approved by the Senate	: 22.08.2021

TABLE OF CONTENTS

PROGRAM OBJECTIVES*

PO1: An ability to independently carry out research/investigation and development work to solve practical problems.
PO2: An ability to write and present a substantial technical report/document.
PO3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.
PO4: An ability to handle techno-scientific challenges of the society.

***The POs have been prepared in accordance with the Self-Assessment Report (SAR) format of the National Board of Accreditation (NBA)

DEPARTMENT OF METALLURGICAL AND MATERIALS ENGINEERING

M. Tech in Metallurgy and Materials Technology (MT)

CURRICULUM

SEMESTER-I

Sl. No.	Subject Code	Subject	L - T - P	Credit
1	MT1001	Thermodynamics and Kinetics of Materials	3 - 0 - 0	3
2	MT1002	Advanced Physical Metallurgy	3 - 1 - 0	4
3	MT1003	Advanced Process Metallurgy	3 - 1 - 0	4
4	MT903X	Elective - I	3 - 0 - 0	3
5	MT903X	Elective - II	3 - 0 - 0	3
6	MT1051	Advanced Physical Metallurgy Laboratory	0 - 0 - 4	2
7	MT1052	Process Metallurgy Laboratory	0 - 0 - 4	2
TOTAL			**15-2-8**	**21**

SEMESTER-II

Sl. No.	Subject Code	Name of the Subject	L - T - P	Credit
1	MT2001	Principles and Techniques of Materials Characterisation	3 - 1 - 0	4
2	MT903X	Elective - III	3 - 0 - 0	3
3	MT903X	Elective - IV	3 - 0 - 0	3
4	MT903X	Elective - V	3 - 0 - 0	3
5	MT903X	Elective - VI	3 - 0 - 0	3
6	MT2051	Principles and Techniques of Materials Characterisation Laboratory	0 - 0 - 4	2
8	MT2053	Minor Project with Seminar	0 - 0 - 6	3
TOTAL			**15-1-10**	**21**

SEMESTER-III

Sl. No.	Subject Code	Name of the Subject	L-T-P	Credit
1	MT9071	Audit Lectures/Workshop	0-0-2	0
2	MT3051	Dissertation-I	0-0-24	12
3	MT3052	Seminar – Non-Project / Evaluation of Summer Training	0-0-4	2
TOTAL			**0-0-30**	**14**

SEMESTER-IV

Sl. No.	Subject Code	Name of the Subject	L-T-P	Credit
1	MT4051	Dissertation – II / Industrial Project	0-0-24	12
2	NT4052	Project Seminar	0-0-4	02
			0-0-28	**14**
		TOTAL	**30-3-76**	**70**

LIST OF ELECTIVE PAPERS

Sl. No.	Subject Code	Name of the Subject
1	MT9031	Advances in Production of Non-Ferrous Metals
2	MT9032	Advances in Agglomeration Processes
3	MT9033	Secondary Steel Making
4	MT9034	Surface Engineering
5	MT9035	Materials Modelling and Simulation
6	MT9036	Advanced Welding Metallurgy
7	MT9037	Advanced Metal Forming Processes
8	MT9038	Mechanical Behaviour of Materials
9	MT9039	Composite Material and its Development
10	MT9040	Advanced Ceramic Materials
11	MT9041	Advanced Powder Metallurgy
12	MT9042	Nano-Materials and Nano-Technology
13	MT9043	Human Behavior and Management
14	MT9044	Electron Microscopy
15	MT9045	Strengthening Mechanisms of Materials
16	MT9046	Environmental Degradation of Materials
17	MT9047	Advanced Casting Processes
18	MT9048	Physical and Finite Difference Based Modelling Approaches in Metallurgy
19	MT9049	Plasma Technology for Metallurgical Applications
20	MT9050	Technology of Advanced Materials
21	MT9051	Severe Plastic Deformation
22	MT9052	Finite Element Method for Metallurgy and Materials
23	MT9053	Solidification Phenomena
24	MT9054	Environmental Management in Metallurgical Industries
25	MT9055	Corrosion Engineering

LIST OF CORE PAPERS WITH THEIR DEVELOPERS' NAMES

Subject code	Name of the Subject	L - T - P	Credit	Name of the developer
MT1001	Thermodynamics and Kinetics of Materials	3 - 0 - 0	3	Dr. M. K. Mondal&Dr.S. Pramanik
MT1002	Advanced Physical Metallurgy	3 - 1 - 0	4	Prof. J. Maity
MT1003	Advanced Process Metallurgy	3 - 1 - 0	4	Dr. S. Pramanik& Dr. A. K. Mandal
MT2001	Techniques of Materials Characterization	3 - 1 - 0	4	Prof. J. Maity&Dr. B. K. Show

LIST OF ELECTIVE PAPERS WITH THEIR DEVELOPERS' NAMES

Subject Code	Name of the Subject	L-T-P	Credit	Name of the developer
MT9031	Advances in Production of Non-Ferrous Metals	3 - 0 - 0	3	Dr. A.K. Mandal

MT9032	Advances in Agglomeration Processes	3 - 0 - 0	3	Dr. S.Ghorai
MT9033	Secondary Steel Making	3 - 0 - 0	3	Dr. M. K.Mondal& Dr. S. Ghorai
MT9034	Surface Engineering	3 - 0- 0	3	Dr. D. Mandal
MT9035	Materials Modelling and Simulation	3 - 0 - 0	3	Dr. M. M. Ghosh
MT9036	Advanced Welding Metallurgy	3 - 0 - 0	3	Prof. K. S. Ghosh
MT9037	Advanced Metal Forming Processes	3 - 0 - 0	3	Dr. M. M. Ghosh
MT9038	Mechanical Behaviour of Materials	3 - 0 - 0	3	Dr. B. K. Show & Dr. S. Bera
MT9039	Composite Material and its Development	3 - 0 - 0	3	Prof. J. Maity& Dr. S. Bera
MT9040	Advanced Ceramic Materials	3 - 0 - 0	3	Dr. M. Mallik
MT9041	Advanced Powder Metallurgy	3 - 0 - 0	3	Dr. M. Mallik
MT9042	Nano-Materials and Nano-Technology	3 - 0 - 0	3	Dr. S. Bera
MT9043	Human Behavior and Management	3 - 0 - 0	3	Dr. S. Pramanik
MT9044	Electron Microscopy	3 - 0 - 0	3	Dr. S. Bera
MT9045	Strengthening Mechanisms of Materials	3 - 0 - 0	3	Dr. D. Mandal
MT9046	Environmental Degradation of Materials	3 - 0 - 0	3	Dr. S. Pramanik
MT9047	Advanced Casting Processes	3 - 0 - 0	3	Dr. D. Mandal & Dr. B. Maji
MT9048	Physical and Finite Difference Based Modelling Approaches in Metallurgy	3 - 0 - 0	3	Dr. M. K. Mondal
MT9049	Plasma Technology for Metallurgical Applications	3 - 0 - 0	3	Dr. A. K. Mandal
MT9050	Technology of Advanced Materials	3 - 0 - 0	3	Dr. D. Mandal & Dr. M. Mallik
MT9051	Severe Plastic Deformation	3 - 0 - 0	3	Dr. M. K. Mondal& Dr. D. Mandal
MT9052	Finite Element Method for Metallurgy and Materials	3 - 0 - 0	3	Dr. M. K. Mondal
MT9053	Solidification Phenomena	3 - 0 - 0	3	Dr. S. Pramanik& Dr. K. P Yagati
MT9054	Environmental Management in Metallurgical Industries	3 - 0 - 0	3	Dr. A. K. Mandal
MT9055	Corrosion Engineering	3 - 0 - 0	3	Prof. K. S. Ghosh

LIST OF LABORATORY & SESSIONAL PAPERS

SUBJECT CODE	SUBJECT	L-T-P	CREDIT
MT1051	Advanced Physical Metallurgy Laboratory	0 - 0 – 4	2
MT1052	Process Metallurgy Laboratory	0 - 0 – 4	2
MT2051	Principles and Techniques of Materials Characterization Laboratory	0 - 0 – 4	2

LIST OF PROJECT/DISSERTATION/SEMINAR PAPERS

SUBJECT CODE	SUBJECT	L-T-P	CREDIT
MT2053	Minor Project with Seminar	0 - 0 –6	3
MT9071	Audit Lectures / Workshops	0 - 0 –0	0
MT3051	Dissertation - I	0 - 0 –24	12
MT3052	Seminar-Non-Project / Evaluation of Summer Training	0 - 0 –4	2
MT4051	Dissertation – II / Industrial Project	0 - 0 –24	12
MT4052	Project Seminar	0 - 0 –4	2

<table>
<tr><td colspan="9">Department of Metallurgical & 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>MT1001</td><td>Thermodynamics and Kinetics of Materials</td><td>PCR</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">NIL</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">On completion of the course the learner shall be able to:
• CO1:Understand the concepts, formulations and applications of thermodynamics and kinetics of Engineering Materials.
• CO2: Identify and solve reaction kinetics and mechanism of single and multi-steps reactions.
• CO3: Analyze and solve various practical problems on applications of metallurgical systems.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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 diagramsphase 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.
[14]

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.
[10]

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

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

Kinetics of liquid –solid transformation –driving force. Homogeneous and</td></tr>
</table>

	heterogeneous Nucleation kinetics, kinetics of growth, kinetics of alloy solidification. **[4]** 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. **[4]** Overall transformation Kinetics-Johnson-Mehl and Avram's model, kinetics of non-random nucleation, kinetics of diffusion controlled isothermal and non-isothermal analysis.**[4]**
Text Books, and/or reference material	**Text Books:** 1. Introduction to Metallurgical Thermodynamics – David R. Gaskell. 2. Textbook of Materials and Metallurgical Thermodynamics- A. Ghosh 3. Problems in Metallurgical Thermodynamics and Kinetics-G.S. Upadhyay and R. K. Dube. 4. Problems in Applied Thermodynamics- C. Bodsworth and A.S. Appleton. 5. Kinetics of Metallurgical Reactions – H. S. Ray 6. Metallurgical Thermochemistry-O. Kubaschewski, E.LL. Evans and C.B. Alcock. **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.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	CO1	CO2	CO3
PO1	✓	✓	✓
PO2	✓	✓	✓
PO3	✓	✓	✓
PO4	-		✓

Department of Metallurgical & 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 1002	**Advanced Physical Metallurgy**	PEL	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		CT+EA					
Course Outcomes	On completion of the course the learner shall be able to: • **CO1:** Understand the concept of bonding and evolution of three dimensional solid. • **CO2:** Conceive phase transformation in qualitative and quantitative (analytical) terms. • **CO3:** Understand the application of phase transformation • **CO4:** Understand detailed structure-property correlation in materials						
Topics Covered	Origin of ionic, covalent and metallic solids in view of atomic structure and chemical bonding; Free-energy composition diagram; Phase equilibria in binary and ternary alloy systems: binary phase diagrams, ternary phase diagrams in view of ternary two-phase, three-phase and four-phase equilibria.**[8]** Introduction and classification of phase transformation; conventional classification: homogeneous and heterogeneous phase transformations; Solidification: role of temperature gradient and interface velocity; planar, cellular, cellular dendritic, columnar dendritic and equiaxed dendritic growth in view of solidification parameter; 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]** 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. [**12**] Application of solid state phase transformation: Thermal treatment/Heat treatment: different heat treatment processes: annealing, normalizing, hardening and tempering; TTT and CCT diagram, Grange-kiefer approximation, effect of alloying						

	elements on TTT/CCT diagram; Precipitation hardening (age hardening): PTT diagram, age hardening behaviour of aluminium alloys and aluminium metal matrix composites. [10] Structure-property correlation: Material deformation under load with regard to crystal structure and inherent crystal defects; role of dislocation; strengthening mechanism; Hall-Petch effect; Quantum confinement effect; strength, ductility, toughness, fatigue and creep properties in relation to material structure. [10]
Text Books, and/or reference material	**Text Books:** 1. Physical Metallurgy Principles,R.E.Reed-Hill and R. Abbaschian, 3rd ed, PWS-Kent Publishing, 1992. 2. The Theory of Transformations in Metals and Alloys- J.W. Christian, Pergamon Press, 1965. 3. Phase transformations in metals and alloys- D.A. Potter and K.E. Easterling, CRC Press,1992 . 4. T.H. Courtney, Mechanical Behavior of Materials, McGraw-Hill, 2nd Ed., 2000. 5. Physical Metallurgy Principles,R.E.Reed-Hill and R. Abbaschian, 3rd ed, PWS-Kent Publishing, 1992. 6. The Structure and properties of Materials (I – IV) – R.M. Rose, L. A. Shepard and J. Wulff, Wiley, 1966 7. Materials Science and Engineering: An Introduction - William D. CallisterJr. and David G. Rethwisch, Wiley 2018 **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.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	PO2	PO3	PO4
CO1	√	-	-	√
CO2	√	√	√	
CO3	-	√	-	√
CO4	√	√	√	-

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	
MT1003	**Advance Process Metallurgy**	PCR	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		CT+EA					
Course Outcomes	On completion of the course the learner shall be able to: • **CO1:** Study the thermodynamic properties of Iron and Steel Extraction. • **CO2:** Ability to solve problems on Iron and Steel Extraction. • **CO3:** To obtain detailed understanding of current methods and technological principles used in extraction of iron and steel that are applied both in industrial and lab scale.						
Topics Covered	A brief process overview of process metallurgy including physicochemical principle and practice. **[8]** Basics and advanced technologies for mineral processing, including pyro, hydro, electrometallurgy and associated impact on costs, pollution, energy, cycle time, simplification. **[10]** Compelling innovative measures in agglomeration, BF technology, BOF, EAF, MBF, EOF and other such routes involving DRI/HBI. **[8]** Underlining principles of steel refining, physical chemistry, Continuous casting, Near net shape casting. [**6**] Recent advances in casting practice; Thixocasting, Semisolid Processing, Rhiocasting. **[4]** Recent advancements in extractive metallurgy of nonferrous metals like Al,Cu, Pb, Zn, Ti, Mg etc. and their present status and application in India. [**8**]						
Text Books, and/or reference material	**Text Books:** 1. B.F. Iron making principles – Biswas (1985) 2. Physical chemistry of iron & steel manufacture – C. Bodsworth (1980) 3. Iron and steel making, theory and practice – Ghosh and Chatterjee (2012) 4. Fuels, Furnaces And Refractories,- R. C. Gupta (2016) 5. Extraction of Nonferrous Metals-H.S. Ray, R. Sridhar, K.P. Abraham **Reference Books:** 1. Proceedings of international seminar on innovative technologies for clean, green & automated steel plants- A better tomorrow – Steel tech/ NIT Durgapur, sept. 2015 2. The Production of aluminium and alumina, Vol. 20-Alfred Richard Burkin 3. Extractive Metallurgy of Copper-A. K. Biswas & W. G. Davenport 4. Blast Furnace Ironmaking: Analysis, Control, and Optimization- Ian Cameron, MitrenSukhram , Kyle Lefebvre & William Davenport (Published						

	by Elsevier, 2020)

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	PO2	PO3	PO4
CO1	√	√	√	-
CO2	√	√	√	-
CO3	√	-	-	√

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MT 1051</td><td>Advanced Physical Metallurgy Laboratory</td><td>PCR</td><td>0</td><td>0</td><td>4</td><td>4</td><td>2</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">NIL</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">On completion of the course the learner shall be able to:
• CO1: Understand the evolution of phases through reconstructive phase transformation and diffusional displacive phase transformation along with morphological appearances.
• CO2: Understand the evolution of phases through diffusionlessdisplacive phase transformation along with morphological appearances.
• CO3: Understand the evolution of dual-phase structure in correlation to morphological appearances.
• CO4: Understand phase evolution and associated structural variation with regard to change in chemical composition and adopted heat treatment routes.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Experiment 1: An 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]
Part II: Investigation of the microstructure of Normalized Low Carbon Steel (subjected to normal air cooling). [6]
Part III: Investigation of the microstructure of Normalized Low Carbon Steel (subjected to forced air cooling). [6]

Experiment 2:Diffusionlessdisplacive phase transformation and study of the evolved microstructure.
Part I: Hardening treatment of Low carbon (0.2%C) steel [6]
Part II: Hardening treatment of High carbon (0.6%C) steel [6]

Experiment 3:An investigation on evolution of combined soft and hard phases through Intercritical heat treatment of low carbon steel. [6]

Experiment 4:A study on phase evolution and associated structural variation with regard to change in chemical composition and adopted heat treatment routes.
Part I: Study of the microstructure of as-carburized steel [6]
Part II: Study of the microstructure of Carburized and core refined steel. [6]
Part III: Study of the microstructure of carburized, core refined and case refined</td></tr>
</table>

	(case hardened) steel. **[6]**
Text Books, and/or reference material	**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. Principles of the heat treatment of plain carbon and low alloy steels- C.R. Brooks, ASM International, 1996 **Reference Books:** 1. Heat treatment of metals- B. Zakharov, CBS publishing, 1998. 2. *Heat Treatment*: Principles and Techniques- T. V. *Rajan*, C. P. Sharma and A. *Sharma*, PHI Learning Pvt. Ltd., 2012.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	PO2	PO3	PO4
CO1	√	√	√	√
CO2	√	√		√
CO3	√			√
CO4	√	√	√	√

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MT1052</td><td>Process Metallurgy Laboratory</td><td>PCR</td><td>0</td><td>0</td><td>4</td><td>4</td><td>2</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">NIL</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">On completion of the course the learner shall be able to:
• CO1: Learn the different methods of raw materials characterization.
• CO2: Learn the operational aspect of different properties of burden materials.
• CO3: Analyze and solve industrial problems to meet the contemporary need.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">1.Pelletization with different ferrous and non-ferrous ores[3]
2. Study of sintering of ferrous material with change of parameters such as bed height, velocity of air, amount of limestone.[3]
3. Froth floatation of ores and different slag for recovery of metal.[3]
4. Characterization of raw materials (a)density, (b)porosity (c)angle of repose [3]
5. Study on the Reduction behavior of iron ore pellets [3]
6. Study the effect of velocity and nozzle diameter and no of nozzles on the diameter and depth of Crater formed in a water model of LD Converter [3]
7. Study the effect of inclusions in single-strand continuous casting model.[3]
8. To Study the defects of the wax ingot in the context of steel ingot.[3]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1.Gupta R.C. Theory and Laboratory Experiments in Ferrous Metallurgy, PHI Learning Pvt. Ltd, New Delhi, India
2. Ghosh, A. and Chatterjee, A., Principles, and Practices in Iron and Steelmaking, Prentice Hall of India, New Delhi, 2008.
Reference Books:
1.Modeling of Steelmaking Processes,D.Mazumdar and J. W. Evans.</td></tr>
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Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	PO2	PO3	PO4
CO1	√	√	-	-
CO2	√	√	-	-
CO3	-	-	√	√

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	
MT2001	**Principles and Techniques of Materials Characterization**	PEL	3	1	0	4	4
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		CT+EA					

Course Outcomes	On completion of the course the learner shall be able to: • **CO1:** Learn fundamentals of X-ray diffraction, optical and electron microscopy. • **CO2**: Identify the crystal structure and index the diffraction patterns of different phases. • **CO3:** Solve diffractograms of different difficulty levels through tutorials. • **CO4:** Learn different applications of X-ray diffraction and different microscopes.
Topics Covered	**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]** **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]** **Application of X-ray diffraction:** Crystal structure determination; determination of precise lattice parameter; Phase diagram determination, Residual stress measurement,Chemical analysis by diffraction, particle size determination.**[8]** **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]** **Thermal Analysis:** Differential thermal analysis, Differential scanning calorimetry and Thermogravimetricanalysis. **[8]**
Text Books, and/or reference material	**Text Books:** 1. "Elements of X-Ray Diffraction", by B.D. Cullity, Addision Wesley Publishing Co., Massachusetts, 1968. 2. 2. "X-ray diffraction-a practical approach", by C. Suryanarayana and M. Grant Norton, Springer, 1998. 3. 3. "X-ray Diffraction: Its Theory and Applications", by S. K. Chatterjee, Prentice-Hall of India Pvt. Limited,2004. 4. 4. "Electron Microscopy in the Study of Materials", by P.J. Grundy and G.A. Jones, Arnold, London, 1976. **5.** 5. "Transmission Electron Microscopy: A Textbook for Materials Science (4 Vol set)", by David B. Williams and C. Barry Carter, 2nd ed., Springer, 2009. **Reference Books:** 1. "Electron Microscopy and Analysis", by Peter J. Goodhew, John Humphreys and Richard Beanland, Third Edition, CRC Press, 2000. 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.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	PO2	PO3	PO4
CO1			√	
CO2	√		√	
CO3		√	√	√
CO4	√			√

<table>
<tr><td colspan="9">Department of Metallurgical and Materials Engineering</td></tr>
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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MT2051</td><td>Principles and Techniques of Materials Characterization Laboratory</td><td>PCR</td><td>0</td><td>0</td><td>4</td><td>4</td><td>2</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">NIL</td><td colspan="5">CT+EA</td></tr>
</table>

Course Outcomes	On completion of the course the learner shall be able to: • **CO1:** Learn fundamentals of X-ray diffractometer and different microscopes. • **CO2:** Identify the crystal structure and index the X-ray diffraction patterns of different phases. • **CO3:** Learn the operational aspect of X-ray diffractometer and different microscopes. • **CO4:** Ability to analyze diffractograms of industrial samples to meet contemporary need.
Topics Covered	**Experiment 1:** Characterization of a metal matrix composite. Part (I): Charaterization.by optical Metallography and Hardness measurement. **[6]** Part (II): Characterization by X-Ray diffraction. **[6]** **Experiment 2:** Indexing the X-ray diffraction (XRD) pattern of different phases. Part (I): Indexing the XRD pattern of BCC structure. **[4]** Part(II): Indexing the XRD pattern of FCC structure. **[4]** Part(III): Indexing the XRD pattern of HCP structure. **[4]** Part(IV): Indexing the XRD pattern containing a mixture of BCC and FCC phases. **[6]** **Experiment 3:** Characterization of a nanocrystalline thin film electrodeposite by XRD. **[6]** **Experiment 4:** X-ray diffraction of powders exhibiting the effect of powder size on peak broadening. **[6]** **Experiment 5:** Interpretation of microstructures obtained through scanning electron microscopy. **[6]** **Experiment 6:** Indexing selected area diffraction patterns (SADP) obtained through transmission electron microscopy. **[6]**
Text Books, and/or reference material	**Text Book:** 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. 3. Principles of Metallographic Laboratory Practice – G. L. Kehl, London: McGraw-Hill Publishing Co., Ltd., 1939. **Reference Book:** 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.Metallography*, Principles and Practice-George F. *Vander Voort*,ASM International, 1984.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	PO2	PO3	PO4
CO1			√	
CO2	√	√	√	
CO3			√	
CO4	√	√		√

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**	
MT2053	**Minor Project With Seminar**	PCR	0	0	6	6	3
Pre-requisites		Course Assessment methods: (Continuous evaluation (CE) and end assessment (EA))					
NIL		CE+EA					
Course Outcomes	On completion of the course the learner shall be able to: **CO1:**Ability to conduct literature review on selected topic. **CO2:**Ability to write and present a technical report with suitable conclusion.**CO3:**Ability to discuss and defend the outcome of the mini project in a seminar.						
Topics Covered	Topics will be provided						
Text Books, and/or reference material	To be notified separately.						

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	PO2	PO3	PO4
CO1		√		
CO2		√		
CO3		√		

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**	
MM3051	**Dissertation-I**	PCR	0	0	24	24	12
Pre-requisites		Course Assessment methods: (Continuous evaluation (CE) and end assessment (EA))					
NIL		CE+EA					
Course Outcomes	On completion of the course the learner shall be able to: • **CO1:**Ability to conduct exhaustive literature review on a selected domain of interest. • **CO2:**Ability to interpret ideas and thoughts into practice in a project. • **CO3:**Ability to analyze and finding out the unexplored area of research. • **CO4:** Ability to conduct experimental or theoretical work independently. • **CO5:**Ability to write a technical report.						
Topics Covered	Topics will be provided						
Text Books, and/or reference material	To be notified separately.						

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	PO2	PO3	PO4
CO1	√	√		
CO2	√		√	√
CO3	√		√	√
CO4	√		√	√
CO5		√		

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)#</td><td>Total Hours</td></tr>
<tr><td>MM3052</td><td>Seminar – Non Project / Evaluation of Summer Training</td><td>PCR</td><td>0</td><td>0</td><td>4</td><td>4</td><td>2</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (As per PG regulation)</td></tr>
<tr><td colspan="3">NIL</td><td colspan="5">AS PER PG REGULATION</td></tr>
<tr><td colspan="2">Course Outcomes</td><td colspan="6">On completion of the course the learner shall be able to:
CO1:Ability to conduct literature review on selected advances topic.
CO2:Ability to summaries the concept of the chosen topic systematically from different sources.
CO3:Ability to write and present a technical report with suitable conclusion.
CO4: Ability to discuss and defend the outcome of the report in a seminar</td></tr>
<tr><td colspan="2">Topics Covered</td><td colspan="6">Topics will be provided</td></tr>
<tr><td colspan="2">Text Books, and/or reference material</td><td colspan="6">To be notified separately.</td></tr>
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Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	PO2	PO3	PO4
CO1	√	√		
CO2	√	√		
CO3		√		
CO4			√	

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)#</td><td>Total Hours</td></tr>
<tr><td>MM4051</td><td>Dissertation – II / Industrial Project</td><td>PCR</td><td>0</td><td>0</td><td>24</td><td>24</td><td>12</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (As per PG regulation)</td></tr>
<tr><td colspan="3">NIL</td><td colspan="5">AS PER PG REGULATION</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">On completion of the course the learner shall be able to:
• CO1:Ability to analyze and interpret ideas and unexplored area of research.
• CO2:Ability to conduct experimental or theoretical work independently.
• CO3:Ability to analyse/interpret the results of experimental and theoretical work.
• CO4:Ability to write report and technical documents as per international standard</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Topics will be provided</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">To be notified separately.</td></tr>
</table>

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	PO2	PO3	PO4
CO1	√	√	√	√
CO2	√		√	√
CO3		√		
CO4		√		

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)#</td><td>Total Hours</td></tr>
<tr><td>MT4052</td><td>Project Seminar</td><td>PCR</td><td>0</td><td>0</td><td>4</td><td>4</td><td>2</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (As per PG regulation)</td></tr>
<tr><td colspan="3">NIL</td><td colspan="5">AS PER PG REGULATION</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">On completion of the course the learner shall be able to:
• CO1:Ability to assess and validate knowledge gained through years of study in the subject and the project.
• CO2:Ability to integrate technical question through all the years of study.
• CO3:Ability to express and communicate.
• CO4:Ability to evaluate technical confidence.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Topics will be provided</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">To be notified separately</td></tr>
</table>

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	PO2	PO3	PO4
CO1	√	√	√	√
CO2	√		√	√
CO3		√	√	√
CO4		√	√	√

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	**Advances in Production of Non-Ferrous Metals**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		CT+EA					
Course Outcomes	**CO1**: Ability to build up the concepts of non-ferrous metals production. **CO2**: Ability to learn the modern advance technologies for nonferrous metal extraction **CO3:** Ability to analyze and solve various industrial problems during production and operation in nonferrous metal industries						
Topics Covered	**Aluminium:** (08L) Bayer process, its chemistry and practice, Soda-Lime Sinter Process. Hall Heroult process: carbon anodes, theoretical principles, factors influencing the process, current and energy efficiencies. Alternane Al production like, Mitsubisi Kwara process. Modern development of Aluminium production like Inert anode drained cathode **Copper:**(08L) Advances in Concentration, Roasting, matte smelting, converting, fire-refining and electro-refining process. Slag-Matte characteristics. Recent development in concentration, roasting and smelting process .Outokumpu and INCO process, Ausmelt / Isasmelt process **Zinc:**(06L) Pyrometallurgy, sinter-roasting and Electrical and Blast furnace process. Hydrometallurgical extraction: roasting, leaching and electro- winning. Double leaching/ Jarosite process, Direct leaching process **Lead:** (06 L) Direct smelting of lead (ISP) , thermodynamic consideration, Modern practices Refining of lead bullion. **Titanium:** (02L) Up-gradation of ilmenite and Hunter and Kroll process, Specific advantages and limitations **Uranium:** (02L) Acid and alkali processes for digestion of uranium ores. Production of reactor grade uranium. **Gold:**(01L) Cyanidation process. Carbon-in pulp process. **Nickel and Magnesium** (04L)						

	Different production routes their advantages and limitation in Nickel and Magnesium production (04L) **Status of Non-ferrous metal production in India**. (01L) **Environmental aspects of Non-ferrous metal production**(01L)
Text Books, and/or reference material	**Textbooks:** 11. K. Grjortheim and B.J. Welch: Aluminiu m Smelter Technology, Aluminium-Verlag. 2. A.K.Biswas and W.G. Davenport: Extractive Metallurgy of Copper, Pergamon. 3. S.W.K Morgaon: Zinc and its Alloy, Mac Donald and Evans. 4. H.S.Ray, R. Sridhar and K.P. Abraham: Ex traction of Non-Ferrous Metals, Affiliated East – West. **Reference books:** A.R. Burkin (ed.) : Production of Aluminium and Alumina Wiley. 2. A.R. Burkin (ed.): Extractive Metallurgy of Nickel, Wiley. 3. C.D.Harrington and AE. Reuhle: Uranium Production Technology, VanNaostrand. 4. N. Sevryukov, B.Kuzumin and Y. Chelishchev: General Metallurgy, Mir. 5. FathiHabashi; Principles of Extractive metallurgy, vol 1, 2, 3 and 4; Gordon and Breach

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	PO2	PO3	PO4
CO1	√	-	√	-
CO2	√	-	√	-
CO3	√	-	-	√

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MT9032</td><td>Recent Advances in Agglomeration of iron ore fines</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">NIL</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: Ability to understand the fundamentals of different types Agglomeration techniques
CO2: Ability to learn the fundamental basis of recent developments taking place in agglomeration technology.
CO3: Ability to analyze and solve the utilization iron ore fines and wastes generated in iron and steel industry</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Topic 1:General Introduction: Need and scope, Different types of agglomerations techniques, Standard procedure for characterization of raw materials as well as agglomerates. [5]

Topic 2:Sintering: Introduction to Sintering Process, Raw materials requirements and Preparation of Charge, Fundamentals of sintering reactions, liquid phase formation and bonding mechanism, Heat transfer in sintering layers, Gas dynamics in sintering process, Sinter productivity, Sinter mineralogy and its effect on quality, Environmental aspects of sintering. [12]

Topic 3:Pelletization: General introduction to Pelletization, Raw materials requirements and Preparation of Charge, Different types of binders both inorganic and organic binders, Mechanism of green pellet formation and kinetics of ball growth, Reactions and Formation of Phases During Induration, Environmental aspects. [8]

Topic 4:Briquetting: General Introduction to Briquetting, Raw materials requirements and Preparation of Charge, Basic Industrial Technologies of Briquetting, Metallurgical Properties requirements of Briquettes. [2]
Topic 5:Advances in agglomeration: Utilization of other source of fines and wastes like slimes, Blue dust, LD sludge, BF dust and also slag, Micropelletization and sintering, Composite agglomeration techniques, Nonconventional pellet strengthening process.[15]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
Agglomeration of Iron Ores, Ram PraveshBhagat, CRC Press
Pelletizing of iron ores, Kurt Meyer, Springer-Verlag
Reference Books:
Agglomeration in Metallurgy ByAitberBizhanov, Valentina Chizhikova, Springer Publication</td></tr>
</table>

Mapping of CO (Course Outcome) and PO (Programme Outcome)

POs / COs	PO1	PO2	PO3	PO4	PO5
CO1	2	1	3	1	2
CO2	3	1	3	1	3
CO3	3	1	3	3	3

Correlation levels 1, 2 or 3 as defined below :

1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MT 9033</td><td>Secondary Steel Making</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">Transport Phenomena</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: Learn fundamentals of physico-chemical principles of Secondary steel making.
CO2: Identify and solve reaction kinetics and mechanisms.
CO3: To learn the design & operational aspects of Vacuum technology.
CO4: Ability to analyze industrial processes to meet the current need.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">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 equipment and processes, preheating and recycling of ladles.[4]
Chemical equilibrium, Activity-Composition relationships: Concentrated solutions, Activity-Composition relationships: dilute solutions, interaction coefficient, chemical potential and equilibrium, physico-chemical principles of Secondary steel making, Slag basicity and capacities. [4]
Fluid flow in steel melts in Gas-Stirred ladle. [3]
Mixing, Mass transfer and kinetics: Introduction, mixing in steel melts in Gas-stirred ladles, kinetics of reactions among phases, Mass transferin a Gas-Stirred ladle, Mixing Vs. Mass transfer control. [4]
Powder injection refining: Introduction, Advantages and disadvantages, transitory and permanent contact reaction, bubbling-jetting phenomena.[3]
Core wire injection: Introduction, Advantages and application [1]
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. [5]
Degassing and Decarburization in liquid steel: Introduction, thermodynamics of reactions in vacuum degassing, side reactions during degassing, fluid flow and mixing in vacuum degassing, rates of vacuum degassing and decarburization, decarburization for Ultra-low carbon (ULC) and stainless steel. [6]
Desulfurization in secondary steelmaking: Introduction, thermodynamics aspects, desulfurization with only top slag, injection metallurgy for Desulfurization. [6]
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. [5]
Inclusions and inclusion modification: Introduction, origin of nonmetallic inclusions, Types and properties of inclusions, Influence of inclusions on the mechanical properties of steel, Inclusion identification and cleanliness assessment, formation of inclusions during solidification, inclusion modification. [5]
Clean steel technology: Introduction, refractories for secondary steelmaking, Tundish metallurgy for clean steel. [3]
Alloying of steel: Introduction, Dissolution mechanism, Methods of alloying[1]</td></tr>
</table>

Text Books, and/or reference material	**Text Books:** 1. A. Ghosh, and A. Chatterjee, , Principles and Practices in Iron and Steel making, Prentice Hall of India, New Delhi, 2008. 2. A. Ghosh, Secondary Steelmaking, CRC Press, Boca Raton, 2000. **Reference Books:** 1. Making, Shaping and Treating of Steel (Steelmaking and Refining), 10th Edition, 1985, AISE, Pittsburgh

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	CO1	CO2	CO3	CO4
PO1	✓	✓	✓	✓
PO2	✓	✓	✓	✓
PO3	✓	✓	✓	✓
PO4	-	-	✓	✓

Department of Metallurgical & 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 9034	**Surface Engineering**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		CT+EA					

Course Outcomes	**CO1**: To understand the basic principle for surface degradation of materials **CO2:** To learnsurface morphology of different kind of materials and their response in working conditions **CO3:** To understand principles, theory, mechanism and key variables of different advanced surface modification techniquies.
Topics Covered	**Introduction of conventional casting:** Introduction of surface engineering, Philosophy of surface, general applications and requirements. Engineering components, surface dependent properties and failures, importance and scope of surface engineering. [4 hours] **Surface Degradation**: Basic principles of electrochemistry and aqueous corrosion processes; Oxidation and related concept; Mechanical Friction and Wear like abrasive, erosive and sliding wear etc.; Interaction between wear and corrosion. Surface engineering processes and their types (only basic idea, Conventional surface heat treatment processes. 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). [12 hours] **Surface engineering Process:** General classification, scope and principles, types and intensity/energy deposition profile; Laser assisted microstructural modification – surface melting, hardening, shocking and similar processes; Laser assisted compositionalmodification – 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. [12 hours] **Advanced Process:** Physical vapourdeposition, PEPVD, Chemical vapourdeposition, Electrodeposition, Anodizing, Galvanizing, Thermal Spraying (all types), Plasma based techniques like plasma nitriding, plasma carburizing, PSII, LSH, LSA, LSM etc.Weldsurfacing, friction surfacing, explosive cladding. [12 hours] **Characterization of engineeredsurface:** XRD, XPS, surface-mechanicalcharacterization, corrosion study etc. (Apartfromcommon techniques) [4 hours]

Text Books, and/or reference material	**Text Books:** 1. T Burakowski and T. Wierzchon, Surface engineering of metals, CRC Press 2. A. W. Batchelor, L. N. Lam and M. Chandrasekaran, Materials degradation and its control by surface engineering, Imperial college press 3. S Grainger and J. Blunt, Engineering coatings, William Andrew Publishing **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

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	**PO2**	**PO3**	**PO4**
CO1	√	√	√	-
CO2	√	√	√	-
CO3	√	√	√	√

Department of Metallurgical & 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 9035	**Materials Modelling and Simulation**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and End Assessment (EA))					
NIL		CT+EA					
Developer		M.M. Ghosh					
Course Outcomes	**CO1:**To understand the concept of materials modelling and simulation for structure and properties of materials. **CO2:** To understand molecular dynamics simulation. **CO3:**To understand FEM simulation. **CO4:** To apply materials modelling methodologies for extracting behaviour of materials in real applications						
Topics Covered	1. Introduction to materials modelling and simulation; concept of multiscale materials modelling; different approaches used in materials modelling and their benefits and drawbacks **[4 h]** 2. General overview of atomistic modelling techniques - molecular dynamics (MD) and montecarlo (MC) technique applied to engineering materials; DFT calculations; Ab-initio molecular dynamics; kinetic montecarlo simulation **[3 h]** 3. 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 **[18 h]** 4. 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 h]** 5. 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 h]** 6. Coding and use of software for materials modelling using MD and FEM technique **[6 h]** 7. Demonstration of a multiscale model developed by coupled MD - FEM simulation **[3 h]**						

Text Books, and/or reference material	**Text Books:** 1. Understanding Molecular Simulation: *D. Frenkel and B. Smit*, Academic Press, 2002 2. The Finite Element Method for Engineers, 4th Edition: *Kenneth H. Huebner, Donald L. Dewhirst, Douglas E. Smith, Ted G. Byrom*, Wiley, 2001 **Reference Books:** 3. The Art of Molecular Dynamics Simulation: *D.C. Rapaport*, Cambridge University Press, 2004 4. Statistical mechanics: *Donald A. Mcquarrie*, Harper Row, 1976 5. An Introduction to the Finite Element Method (Mcgraw Hill Series in Mechanical Engineering)3rd Edition: *J. N. Reddy*

Mapping of CO (Course Outcome) and PO (Programme Outcome)

CO/PO	PO1	PO2	PO3	PO4
CO1	√	√	√	√
CO2	√		√	
CO3	√		√	
CO4	√	√	√	√

Department of Metallurgical & 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 9036	**Advance Welding Metallurgy**	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Pysical Metallurgy and Materials Engineering	CT+EA

Course Outcomes	**CO1:**To learn the principles of all the welding and other joining processes. **CO2:** To know the metallugy of welding, and welding metallugy of different enginneing metal/alloys. **CO3:**To assess the all-metal welding destructive and non-destructive tests and weld performace.
Topics Covered	**Introduction**: Historical introduction, classification, abbreviation for welding processes, welding procedure, welding terms and characteristics, welding design, welding positions, welding vs. other joining processes. (06) **Gas Welding**: oxy-acetylene welding, flame characteristics, advantages and drawbacks of gas welding, oxy-acetylene cutting. (02) **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), advantages, limitations and applications; Gas Metal Arc Welding (GMAW), shielding gases, modes of metal transfer, avantages, limitations and applications; Gas Tungsten Arc Welding (GTAW), process description, welding techniques, advantages, limitations and applications. (10) **Resistance Welding**: Heat generation and process description, welding sequence, resistance seam welding, limitations and application, projection welding. (03) **Radiant Welding**: Electron beam welding (EBW), process description, power density, weld characteristics, advantages, limitations and applications; Laser beam welding (LBW) – principles of LASE generation, process description, laser welding units, advantages, limitations and applications. (06) **Other Welding processes**: Friction welding, diffusion welding, induction, welding, thermit welding, ultrasonic welding etc. (04) **Welding Metallurgy**:introduction, structure and characteristics of weld metal, weld composition, heat affected zone, weldability, carbon equivalent, weldability vs. hardenability, actual weldability tests. (08) **Welding of Specific Alloys**: Welding of stainless steels, welding of cast irons, welding of copper base alloys, welding of dissimilar metals and alloys. (04) **Weld Defects and Cracking:** Weld defects, hot cracking, cold cracking, etc. (03) **Testing and Inspection**: All weld tests – tension, best, hardness, impact. Non destructive tests, quality assurance, reliability of the weld. (02) **Brazing and soldering:** Introduction, brazing process, brazing filler metals, soldering,

	soldering processes, solder alloys, applications. (02)
Text Books, and/or reference material	**Text Books:** 1. Welding Engineering and Technology. R S Parmar, Khannna Publisher, New Delhi, 1997. 2. Welding Metallurgy, Sindo Kou, John Wiley and Sons, New York,1987. 3. Theory of Weldabilty of Metals and Alloys, Ivan Hrivnak, Elseview, Amsterdam, 1992 . 4. Introduction to the Pysical Metallurgy of Welding. Kenneth Eaterling, Butterworths, London, 1983. 5. Welding Technology. N K Srinivasan, Khannna Publisher, New Delhi, 1994. **Refernce book:** 1. AWS WedldingHandboook, Vol 1 – Fundamental of Welding, AWS, Miami, Florida,1976.

Department of Metallurgical & Materials Engineering

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	CO1	CO2	CO3
PO1	✓	✓	✓
PO2	✓	✓	✓
PO3	✓	✓	✓
PO4	✓	-	✓

<table>
<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 9037</td><td>Advanced Metal Forming Processes</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>52</td><td>4</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and End Assessment (EA))</td></tr>
<tr><td colspan="3">NIL</td><td colspan="5">CT + EA</td></tr>
<tr><td colspan="3">Developer</td><td colspan="5">M.M. Ghosh</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To understand the theories and practices of advanced metal forming processes
CO2: To know about advanced forming methods in comparison with conventional forming methods
CO3: To solve problems and analyse the data related to various advanced forming processes</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction of metal forming as a manufacturing process, and its relation with other processes. [4]

Theoretical analyses (theory of elasticity and plasticity in 3 dimensions): stress-strain relationships, strain hardening, plastic deformation, yield criteria, flow rule, initiation and extent of plastic flow, forming limit diagram, solving problems.[10]

Overview of various metal forming operations: conventional vs high velocity forming methods, effects of strain rate and temperature, materials behavior, mechanics of various plastic flow problems - rolling; forging; extrusion; drawing; sheet metal forming; workability; solving problems and case studies. [14]

Details of high energy rate forming (HERF) processes: electro-magnetic forming, explosive forming; electro-hydraulic forming; stretch forming; contour roll forming, superplastic forming, etc.[16]

Severe plastic deformation: principles and different techniques. [8]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. Mechanical Metallurgy, SI Metric Edition, George E. Dieter, McGraw-Hill Book Company, London, 1988
2. Principles of Industrial Metal Working Processes, G.W. Rowe,CBS Publishers & Distributors, New Delhi, 2005
3. Metal Forming: Mechanics and Metallurgy, 3rd Edition, William F. Hosford and Robert M. Caddell, Cambridge University Press, New York,</td></tr>
</table>

	2007 4. Principles of Metal Working, *Surender Kumar*, Oxford & IBH Publishing Company, 1985 **Reference Books:** 5. Metal Forming: Processes and Analysis, *B. Avitzur*, McGraw-Hill Book Company, New York, 1968 6. Mechanical Working of Metals: Theory and Practice, *J.N. Harris*, Pergamon Press, 1983 7. An Introduction to Plasticity, *G.C. Spencer*, Chapman & Hall, London, 1968 8. Advanced High Energy Rate Forming, American Society of Tool Manufacturing, *Henry E. Conrad* (Editor), 2013 9. Severe Plastic Deformation: Methods, Processing and Properties, *GhaderFaraji, H.S. Kim, HessamTorabzadeh Kashi*, Elsevier, 2018 10. Severe Plastic Deformation: Toward Bulk Production of Nanostructured Materials, *BurhanettinAltan*, Nova Science Publishers, Inc, 2006

Mapping of CO (Course Outcome) and PO (Programme Outcome)

CO/PO	PO1	PO2	PO3	PO4
CO1	√	√	√	√
CO2	√		√	
CO3	√	√	√	√

Department of Metallurgical & 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 9038	**Mechanical Behaviour of Materials**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Inroduction to materials science and engineering		CT+EA					
Course Outcomes	CO1: Acquire fundamental understanding of mechanical behaviour of solid materials CO2: Develop detailed understanding of plastic deformation, fracture mechanics, creep, and fatigue CO3: Solve different design problems CO4: Ability to analyze and solve industrial problems to meet the contemporary need						
Topics Covered	Crystal geometry: Basics of crystal structure, Crystal system, Crystallographic points, directions and planes, Lattice defects. [4 hours] Plastic deformation: Deformation by slip, Slip in a perfect lattice, Dislocation movement and slip, Concept of critical resolved shear stress, Twin, Stacking fault, Strain hardening of single crystal. [10 hours] Basics of dislocation theory: Fundamental concept, Types of dislocation, Concept of Burger vector, Dislocation in the fcc, bcc and hcp lattice, Dislocation interactions, Climb, Jogs, Sources of dislocation, Dislocation pile ups. [7 hours] Mechanism of strengthening: Basic of strengthening mechanism, Different types of strengthening mechanism, Grain boundary strengthening, Hall-Petch equation [4 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; Rcurve; 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: K1C, CTOD and J1C. [12 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.						

	[8 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. [5 hours]
Text Books, and/or reference material	**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, ButterworthHeinemann, 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.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	**PO2**	**PO3**	**PO4**
CO1	-	-	√	-
CO2	√	-	√	-
CO3	√	√	-	-
CO4	√	-	-	√

Department of Metallurgical & 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	
MT9039	**Composite Material and its Development**	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
Developer	Prof. J. Maity + S. Bera
Knowledge on Physics, Chemistry, Mathematics, and B.Tech. level knowledge-base on Engineering Materials and Basic Physical Metallurgy	CT+EA

Course Outcomes	CO1: To understand classification and different synthesis routs of composite materials in view of industrially practised routes of synthesis and industrial application. CO2: To learn the different steps of processing composites through powder metallurgy route and casting route; in turn, the correlation of evolved microstructure with properties. CO3: To learn the application of transient liquid phase diffusion bonding process for joining metal matrix composites with regard to basic process mechanism and joint efficiency achieved along with industrial relevance.
Topics Covered	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. Micromechanics of 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. (6 hours)
Text Books, and/or reference material	**Text Books:** 1. Metal Matrix Composites - Chawla and Chawla, Springer, 2006. 2. ‘Joining of aluminium based metal matrix composites’- JoydeepMaity, 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. 3. Materials Science and Engineering:An Introduction - William D. Callister, Jr., John Wiley & Sons, Inc., 2007. 4. Fundamentals ofMetal-Matrix Composites - Andreas Mortensen and Alan Needleman, Butterworth-Heinemann, 1993. 5. An Introduction to CompositeMaterials–Derek Hull, Cambridge University Press, 1981. 6. Composite Materials –Deborah D.L. Chung, Springer, 2009. 7. Metal-Matrix composite – P.K. Rohatgi, Defence Science Journal, Vol 43, No 4, October 1993, pp 323-349. 8. Y. B. Liu, S. C. Lim, L. Lu, M. O. Lai, Recent development in the fabrication of metalmatrix-particulate composites using powdermetallurgy techniques, Journal of MateralsScience 29 (1994) 1999-2007.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	**PO2**	**PO3**	**PO4**
CO1	√	√	-	√
CO2	√	√	√	-
CO3	√	√	√	-

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MT 9040</td><td colspan="2">Advanced Ceramic Materials</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">NIL</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="8">• CO1: Describes generic classification of ceramics and their specific engineering applications.
• CO2: Learn structure-property relationships of ceramics
• CO3: Solve problems of fabrication of high performance ceramic parts</td></tr>
<tr><td>Topics Covered</td><td colspan="8">Topic 1: Introduction: Processing, characterization and applications of Advanced Ceramics [12]

Topic 2: Ceramic Structures: Microstructural Design of Ceramics, Mesoscopic Ceramic Structures in One, Two, and Three Dimensions; Bulk Ceramic Nanostructures [10]

Topic 3: Classification and properties: Oxides; Nitrides; Carbides; Mechanical Properties; Thermal, Electrical, and Magnetic Properties [10]

Topic 4: Applications: Structural Applications; Nanosized and Nanostructured Hard and Superhard Materials and Coatings; High-Temperature Engineering Ceramics; Advanced Ceramic Glow Plugs; Thermal Barrier Coatings [10]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="8">Text Books:
1. Ceramics Science and Technology, Edited byRalf Riedel and I-Wei Chen, 2008 WILEY-VCH
2. Advanced Ceramic Materials, Ashutosh Tiwari, Rosario A. Gerhardt, Magdalena Szutkowska, Wiley, 2016
Reference Books:
1. Advances in Ceramics - Characterization, Raw Materials, Processing, Properties, Degradation and Healing Edited by Costas Sikalidis, InTech 2011</td></tr>
</table>

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	PO2	PO3	PO4
CO1	√		√	√
CO2	√	√	√	√
CO3	√	√		√

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MT 9041</td><td>Advanced Powder Metallurgy</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">NIL</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: Learn science and technological aspects of the Advanced Powder Metallurgy Techniques.
• CO2: Emphasis is put on methods for those types of powders that are important for production of engineering components.
• CO3: Solve problems of near net shape fabrication of powder metallurgy parts through tutorials/ assignment/ group task.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Topic 1: Introduction: Basic powder production and characterization; Powder Treatment and Sintering [12]

Topic 2: Advanced Powder Synthesis:Advances in atomisation techniques; Powders by electrolysis; Mechanochemical synthesis of nanocrystalline powders; Plasma synthesis of metal nanopowders; Powder metallurgy for steel; Powder metallurgy of titanium alloys[10]

Topic 3: Advanced Densification Processes: Microwave sintering; Spark Plasma Sintering; Hot Pressing [10]

Topic 4: Applications:Powder metallurgy in automotive applications; Applications of powder metallurgy in biomaterials; Applications of powder metallurgy to cutting tools[10]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. Powder Metallurgy – A Upadhyaya and G S Upadhyaya.
2. Powder Metallurgy Science – R. M. German, 2nd Edition, MPIF, 1994
3. Advances in powder metallurgy- Edited by Isaac Chang and Yuyuan Zhao, Woodhead Publishing Limited, 2013
Reference Books:
1. Powder metallurgy: principles and applications, Fritz V. Lenel, Metal Powder Industries Federation, 1980</td></tr>
</table>

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	PO2	PO3	PO4
CO1	√		√	√
CO2	√	√		√
CO3	√	√		√

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MT9042</td><td>Nano-Materials and Nano-Technology</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">Knowledge on physics, chemistry, mathematics, basic knowledge of materials</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: Learn the history of nano-technology
CO2: Learn the synthesis, characterization and properties of nanomaterails
CO3: Application of nano-materials, uses of nano-technology in environment and our daily life</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction; Basics of nano-scale, History of nano-technology, Uses of technology (natural and manufactured) in nano-scale, advantages and disadvantages (4h)

Nano-materails, different types of nano-materails (6h)

Basics of mechanical, electrical, magnetic and optical properties of materials (6h)

Effect of miniaturization (nano-scale) on mechanical, electrical, magnetic and optical properties of materials (12h)

Synthesis of nano-materials, characterization of nano-materials (14h)

Aapplication of nano-materials, environmental concern (8h)</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:
1. Materials Science and EngineeringAn Introduction - William D. Callister, Jr., John Wiley & Sons, Inc., 2007
2. Nanomaterials Nanotechnologies and design – D.L.Schodek,P. Ferreira,M.F.Ashby, Butterworth-Heinemann, 2009
3. Introductio to Nanotechnology – C.P.Poole,F.J. Owens, Wiley Interscience, 2003</td></tr>
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Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	PO2	PO3	PO4
CO1		√		√
CO2	√	√	√	
CO3	√	√	√	√

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<tr><td colspan="9">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>MT9043</td><td>Human Behavior and Management</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">Nil</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To study the behavior of human resources
CO2: To study the understanding of the perennial issues and problems which arise when working with people.
CO3: To obtain knowledge of different aspects of labor in an industry</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Manage Individual Behaviour, Perceptual Process, Perceptual Grouping, Impression Management; Self Fulfilling Prophecy; Attributions: Kelly's theory of attribution, Locus of control; [3h]

Social learning theory; Behaviour modification [2h]

Emotions: Primary emotions, Emotional Labour, Emotional intelligence;

Positive and Negative affectivity; relation of Job satisfaction with work behaviour, Performance and customer satisfaction; causes and consequences of organizational commitment; psychological contracts; [5h]

Content and process theories of motivation; [2h]

Goal setting and self-efficacy; Job design practices; Performance evaluation, reinforcement theory, Rewards; Organizational Justice- Distributive and procedural justice, equity sensitivity; QWL; Employee Involvement in decision making; Creativity in workplace. [8h]

Personality and Stress management; Kelly's theory of Personality; Big Five Personality dimensions; MBTI; Personality and Vocational choice; Transactional analysis; Characteristics of Healthy personality; Self Development. Concept of stress; stress model; [8h]

Work stressors-Individual group, organizational; Stress moderators; stress prevention and management. Group behaviour and the dynamics of interpersonal Influence by knowing the details of Groups, Types of groups, group formation and development, Characteristics of groups, Group dynamics, communication in groups, group decision making; [8h]

Leadership. Management of Conflict and Negotiation, Causes of Inter group conflict,</td></tr>
</table>

	consequences of dysfunctional inter group conflict; managing inter group conflict through resolution; stimulating constructive inter group conflict; negotiations-tactics; increasing negotiation effectiveness. [6h]
Text Books, and/or reference material	Text books: 1. Organizational Behaviour, Robbins, Judge &Sanghi, Pearson Education Publication. 2. Organizational Behaviour, McShane &Glinow, McGraw Hill Publication.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	PO2	PO3	PO4
CO1	✓	-	✓	✓
CO2	-	✓	✓	✓
CO3	✓	-	-	✓

Department of Metallurgical & 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	
MT9044	**Electron Microscopy**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Basic physics, optics		CT+EA					
Course Outcomes	CO1: To learn the fundamentals of light and electron optics, be familiar with Scanning and Transmission electron microscope and understand the concept of image formation andcrystallographic analysis CO2: To identify the difficulties and subsequent measurements associated with electron microscop CO3: To learn the proper utilizationof the tool for different requirements in materials science						
Topics Covered	**Basics on light and electron microscopes:**Basic optics; Image formation; Magnification, resolution, depth of field; Abberations; Comparison between elctron and light **6h** **Electron-specimen interaction:** Electrons; Scattering of electrons by an atom; Generation of different signals and their utilization **5h** **Componenets of electron microscope:** Electron Gun; Magnetics lenses **5h** **Electron diffraction:** Geometry of electron diffraction; Use of reciprocal lattice; Diffraction patterns and analysis; Other types of diffraction patterns, Electron back scattered diffraction **10h** **Scanning electron microscope:** Mechanism of image formation; Different types of images/information; Crystallographic information; Operating parameters **10h** **Transmission electron microscope:** Basic mechanism; Contrast mechanism **8h** **Chemical analysis:** Generation of X-rays; Quantitative analysis **4h** **Sample preparation technique:** Powder sample preparation; Solid sample preparation **2h**						
Text Books, and/or reference material	Text Books: 1. Electron Microscopy and Analysis, 3rd Edition: Peter J. Goodhew, John Humphreys, Richard Beanland 2.Transmission Electron Microscopy: David B. Williams, C. Barry Carter						

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	Program Outcomes			
	PO1	**PO2**	**PO3**	**PO4**
CO1	√	√	√	-
CO2	√	-	√	√
CO3	√	√	√	√

Department of Metallurgical & 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	
MT9045	**Strenghening Mechanism of Materials**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		CT+EA					
Course Outcomes	**CO1:** To understand the basic Fundamentals of strengthening mechanism of materials **CO2:**To learn the presence of different kinds of defects in metal or crystal that has significant effect on material properties. **CO3:** To learn science and technological aspects for designing high temperature materials or materials for adverse emvironments						
Topics Covered	**Introduction:** Basic structure of alloys, ceramics, polymer and composites. Relation between the structure of materials and their mechanical, thermal chemical and electrical magnetic properties. [4 hours] **Elemental Plasticity and dislocation theory:** Mechanism and micromechanism of strengthening in engineering materials. Plastic flow in metals and alloys, Strengthening and dislocation structure and solid solution strengthening, Resistance to dislocation induced flow, Strengthening due to sub and grain boundaries, precipitation strengthening, dispersion strengthening, martensitic strengthening, grain size strengthening, order hardening, dual phase. Physical phenomena that contribute towards high mechanical strength in engineering materials. Principle for designing high strength materials will be addressed, High temperature materials.Two Phase hardening, Solution hardening, Order strengthening. Strengthening mechanism of amorphus materials, Polymer, ceramic, glass and composites materials, fiber reinforcement, Four stage of deformation, tensile strength, Anisotropy.Strengths at High Temperature, Strengthening against diffusion flow, Strengthening against dislocation creep, Strengthening against high rate of deformation. [20 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, and/or reference material	**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. 3. George Dieter, Mechanical Metallurgy, McGraw-Hill, 3rd Edition **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.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	PO2	PO3	PO4
CO1	√	√	√	-
CO2	√	√	√	-
CO3	√	√	√	√

<table>
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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MT9046</td><td>Environmental Degradation of Materials</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">Nil</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To study the degradation of materials in specific environment
CO2: To study the causes of failure analysis of materials
CO3: To obtain detailed understanding of current methods and technological principles used in combating degradation of materials in specific environment</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Fault tree diagram, Case studies related to industrialcomponentsfailure. Gas plant leakage , welding failure. Methods of study for failure analysis. Case studies ofFailureanalysis such s automotive component, railway bridge. [10h]
Study of cement structures and RCC structures and their failures [5h]
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-useof coatings [10h]
Study of corrosion ofweldjoints. [2h]
Chemical degradation of non-metallic materials like ceramics, timbers. Corrosion during transit [3h]
Corrosion of Composite Materials : Galvanic Effects Matrix Nature Reinforcement Nature Prevention [3h]
Paints and detailed analysis for corrosion combat [2h]
Corrosion Control: By design and electrical Methods [3h]
Study of Delhi Iron Pillar – 'therustlesswonder' [2 h]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text books:
1. Principles and Prevention of Corrosion (2nd Edition) By Denny A. Jones Prentice Hall, 1995.
2. Environmental Degradation of Materials, R Balasubramaniam, Cengage International, 2010.
3. Corrosion and Corrosion Control, H.H. Uhlig and W. Revie, Wiley, New York, 2007.
4. Corrosion Science and Technology,By David Talbot, James Talbot, CRC Press, 1998.</td></tr>
</table>

	5. Corrosion Engineering By Mars. G. Fontana, Third ed., TMH. 6. Corrosion Basics:An Introduction By Pierre R. Roberge, 2nd Edition, NACE Press Book, 2006.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	PO2	PO3	PO4
CO1	✓	✓	✓	-
CO2	✓	✓	✓	-
CO3	✓	-	✓	✓

Department of Metallurgical & 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	
MT9047	**Advanced Casting and Solidification**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		CT+EA					
Course Outcomes	**CO1:** To understand the Fundamentals of solidification of metals. **CO2:** To understand the basic meachanism and difficulties of different metal casting process **CO3:** To identify the major challenges encountered in metal casting and solification industrial production of a components						
Topics Covered	**Introduction of conventional casting:** Introduction of casting, Design of Casting: Factors to be considered in casting design. Conventional casting process of Cast iron, Steel and non-ferrous alloys. [4 hours] **Solidification of Casting:** Concept of solidification of metals. Homogenous and heterogeneous nucleation. Growth mechanism, Solidification of pure metals and alloys. Eutectic solidification, Eutectic alloys, Peritectic solidification, Solidification of ingots and casting, Mechanism of columnar, dendritic growth and freezing in alloys. Freezing in Ingots.The evolution of solidification microstructure, grain structure, segregation, inclusions, gas porosity, Inverse segregation and homogenisation in casting,Solidification time and Chvorinov's rule. Concept of progressive and directional solidifications. Principle of solidification processing, [15 hours] **Special Casting:** Near net shape casting, Thixocasting, Rheocasting, Mechanical Stirring, Magnetohydrodynamic Stirring, Spray casting, Chemical grain refining, Cooling slope, Investment casting, Electro slag refining, Rapid solidification, Thin slab casting, Effect of Process parameters on different casting methods. [10 hours] **Case Studies of some practical casting:** Continuos casting, Casting of carbon and low alloy steels, Casting of High speed tool steels, Solidification of fusion welds, Solidification during quenching from the melt, Processing of Superalloys, Tialloys, [8 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. The methods used to identify the defective casting. To use of analytical tools for the design, understanding and use of solidification. [5 hours]						

Text Books, and/or reference material	**Text Books:** 1. Phase Transformations in Metals and Alloys, D.A Porter, K.E Easterling and M.F Sherif 2. Foundry Technology, P.R. Beelely, Butterworth, 1972. 3. 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.
Department of Metallurgical & Materials Engineering	

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	PO2	PO3	PO4
CO1	√	√	√	-
CO2	√	√	√	-
CO3	√	√	√	√

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 9048	**Physical and Finite Difference Based Modelling Approaches in Metallurgy**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Transport Phenomena		CT+EA					
Course Outcomes	**CO1:**To learn fundamentals of Modelling. **CO2:** To identify nature of engineering problems and solving by numerical methods. **CO3:**To build physical and mathematical models to describe the complex physical phenomena pertaining to real world.						
Topics Covered	Basic principles of physical and mathematical modelling. Similarity criteria and dimensional analysis, physical modelling of iron making and steel making processes. (5) Classification of Partial Differential Equations (PDEs), Elliptic, Parabolic and Hyperbolic Equations, Initial and Boundary Conditions, initial Value and Boundary value problems , Basic concept of discretization process, method, mesh and cells/elements. (4) Introduction to finite difference method, Central, Forward and Back difference expressions for a uniform Grid, Central Difference Expression for a non-uniform grid, Numerical Errors, Accuracy of solution, method of Choosing Optimum step Size. (4) Methods of solving sets of Algebraic equations: Direct methods, Iterative Methods, Nonlinear systems. (4) One Dimensional Steady-state systems: Diffusive systems, Diffusive-Convective System, Diffusive-convective System with Flow, MATLAB Code. (4) Multidimensional parabolic Systems: Simple Explicit method, Combined Method, Alternative Direction Implicit (ADI) method, Alternative Direction Explicit (ADE) method, Modified Upwind Method, MATLAB Code. (8) Elliptic Steady-State diffusion, Elliptic Velocity Field for Incompressible, Constant Property, Elliptic Two-Dimensional Flow, Hyperbolic Convection (Wave) equation, Hyperbolic Heat Conduction equation, System of Vector Equations, MATLAB code. (6) Nonlinear Diffusion: Lagging properties by One Time Step, Use of Three-Time level Implicit Scheme, Linearization, Method of False Transients for solving Steady-State Diffusion, Simultaneous Conduction and Radiation in participating Media-Diffusion Approximation, Newton-Raphson Method for solving Nonlinear system of equations, MATLAB Code. (6) Phase Change Problems: Mathematical Formulation of Phase Change Problems, Variable Time Step Approach for Single-Phase solidification, Variable Time Step Approach for two-Phase solidification, Enthalpy Method. (5) Application related to metallurgical processes (4)						
Text Books, and/or reference material	**Text Books:** 1. Finite difference Method in heat transfer- M. N. Ozisik 2.Computational Fluid dynamics and heat transfer – P.S. Ghoshdastidar 3.The Mathematical and Physical Modelling of Primary Metals Processing Operations-J. Szekely, J.W. Evans and J.K. Brimacombe **Reference Books:** 1. Getting Started with MATLAB 7: A Quick Introduction for Scientists and Engineers- R.						

	Pratap. 2. Numerical Methods for Engineers - D. Vaughan Griffiths and .I.M. Smith

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	CO1	CO2	CO3
PO1	✓	✓	✓
PO2	✓	✓	✓
PO3	-	✓	✓
PO4	-	-	✓

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MT-9049</td><td>Plasma technology for metallurgical applications</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">MT-2002:
Advances in Process Metallurgy</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: Ability to understand the concepts of plasma technology
CO2: Ability to learn the applications in various metallurgical fields
CO3: Ability to analyze and solve various practical industrial problems on applications of plasma in surface modification and clean steel making</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction: Historical developments in plasma technology [1h]
Fundamentals: Plasma metallurgy-Basic principles, types of arcs, arc characteristics [4h]
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. [10h]
Applications:
Iron Making: Plasmasmelt, plasmared, plasmacan, Elred, Sustained Shockwave Plasma(SSP) [6h]
Steel making: Inmetco process, SKF plasma dust process [5h]
Steel melting and Alloy Technology: Plasma Arc Scrap Melting Unit, Plasma Induction Furnace, Plasma Progressive Casting Furnace (PPCF) [6h]
Ferro-Alloy Technology: Carbo-thermic smelting reduction (Fe-Cr, Fe-Mn, Fe-Si, Fe-V). [6h]
Plasma Arc Remelting: Techniques and applications. [2h]
Plasma in Nonferrous Metals: Processing of sulphideores(Mo and Cu) and oxide ore(Ti) [4h]
Plasma Technology in Ceramic Material Coating. [4h]
Assessment, Development and Future Prospects.</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Textbooks:
1. V Dembovsky: Plasma Metallurgy -The Principle (Elsevier)
2. Jerome Feiman: Plasma technology in Metallurgical Processing; Iron & Steel Society, USA

Reference books:
1. Mintek Review, No.6,1987.</td></tr>
</table>

	2.FP Edernal, Electro metallurgy of Ferro alloy, 01, MIR Publication 1979

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	**PO2**	**PO3**	**PO4**
CO1	√	-	√	-
CO2	√	-	√	-
CO3	-	-	-	√

Department of Metallurgical & 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 9050	**Technology of Advanced Materials**	PEL	3	0	0	3	3

Pre-requisites	Course Assessment methods (Continuous (CT) and end assessment (EA))
NIL	CT+EA

Course Outcomes	CO1: To understand the Fundamentals of materials design for advanced applications. CO2: To understand the principles, theory and mechanisms of different kind of advanced metarial processing techniques. CO3: To learn science and technological aspects of the advanced materials
Topics Covered	**Introduction:** Introduction of Advanced materials. Importance of Advanced Materials. Classification of Engineering materials, advanced Metals [2 hours] **Advanced Metallic Metals:** Classification of Metals, advanced metals. Advanced High Strength Steels (AHSS), Types of AHSS, Strengthening mechanism of AHSS steels, Processing, structure and properties of Dual phase (DP), High strength low alloy (HSLA), Back Hardening (BH), Complexphase (CP), Transformation Induced Plasticity (TRIP) and Twin Induced plasticity (TWIP) and quenched and tempered (Q&P) steels. [8 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, and/or reference material	**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

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	PO2	PO3	PO4
CO1	√	√	√	-
CO2	√	√	√	-
CO3	√	√	√	√

Department of Metallurgical & 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 9051	**Severe Plastic Deformation**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		CT+EA					
Course Outcomes	**CO1:** To understand the Fundamentals of Severe Plastic Deformation. **CO2:** To understand the principles of ultrafine grained (UFG) and nanostructured bulk metal production processes. **CO3:** To identify the major challenges encountered in severe plastic deformation (SPD) is the industrial production of ultrafine-grained (UFG) and nanograined (NG) metals.						
Topics Covered	The ultrafine-grained and nanostructured materials,First approach: Bottom-Up: Inert Gas Condensation, Spray Conversion Processing, Chemical Vapor Condensation,Top-Down methods: High-Energy Ball Milling, Physical Vapor Deposition, Sputtering,Severe Plastic Deformation Methods. (4 hours) **Fundamentals of Severe PlasticDeformation:**History: The Ancient Age,The Scientific Age and The Microstructural Age, Basic Principles of Severe Plastic Deformation Methods, Difference between Severe Plastic Deformation and Conventional Metal-Forming Processes, Grain Refinement Mechanisms under Severe Plastic Deformation conditions: Face-Centered Cubic (FCC) Metals an Hexagonal Close-Packed (HCP) Metals. (4 hours) **Severe Plastic Deformation Methods for Bulk Samples:** High-Pressure Torsion, Equal-Channel Angular Pressing, Dual Equal Channel Lateral Extrusion, Channel Angular Pressing With ConvergingBillets, Nonequal Channel Angular Pressing, Torsion Extrusion,Multiple Direct Extrusion, Accumulated Extrusion, Pure Shear Extrusion, Equal Channel Forward Extrusion, C-Shape Equal Channel Reciprocating Extrusion, Twist Extrusion, Multidirectional Forging, Multiaxial Incremental Forging And Shearing, Repetitive Forging, Repetitive Upsetting, Cylinder Covered Compression, Repetitive Upsetting And Extrusion, Cyclic ExtrusionCompression, Cyclic ExpansionExtrusion, Accumulative Back Extrusion, Cyclic ForwardBackward Extrusion, Half-Channel Angular Extrusion, Accumulative Channel-Die CompressionBonding, Machining, The Combined Methods. (9 hours) **Severe Plastic Deformation Methods For Sheets:**Accumulative Roll-Bonding, Cone-Cone Method, Constrained Groove Pressing,Friction Stir Processing, Equal Channel Angular Rolling, Repetitive Corrugation And Straightening, Epetitive Corrugation And Straightening By Rolling, Asymmetric Rolling, Continuous Frictional Angular Extrusion, Continuous Cyclic Bending. (5 hours) **Severe Plastic Deformation Methods for Tubular Samples**: Equal Channel Angular Pressing For Hollow Parts, High-Pressure Tube Twisting, Tube High-Pressure Shearing, Modified High-Pressure Tube Twisting, Accumulative Spin Bonding, Tubular Channel Angular Pressing, Parallel Tubular Channel Angular Pressing, Combined Ptcap, Tube Channel Pressing, Cyclic Flaring And Sinking, Tube Cyclic ExtrusionCompression, Tube Cyclic ExpansionExtrusion, Rubber Pad Tube Straining, Other Combined Methods, General Limitations Of UFG TubeManufacturing Methods. (6 hours) **Severe Plastic Deformation for Industrial Applications:**Integrated Extrusion And Equal Channel Angular Pressing, Ecap-Conform, Equal Channel Angular Drawing, Ecap With Rolls, Incremental Ecap, Porthole-Equal Channel Angular Pressing, Continuous Confined Strip Shearing, Conshearing, Continuous Cyclic Bending, Caliber Rolling, Ring High-Pressure Torsion, High-Pressure Sliding, High-Pressure Sliding, Continuous High-Pressure Torsion,						

	Severe Torsion Straining, Integrating Forward Extrusion And Torsion Deformation, Kobo Process, Cryo-Rolling. (6 hours) **Effective Parameters For The Success of Severe Plastic Deformation Methods:**Grain Size, Equivalent Plastic Strain And Hydrostatic Stress, Dislocations And Disclinations, Grain Boundaries, Multiphase Materials, Texture. (4 hours) **Mechanical Properties ofUltrafine-Grained andNanostructured Metals:**Superior Strength And Ductility, Mechanical Anisotropy, Young's Modulus, Fracture Toughness, Hardness, Fatigue Properties, Wear Resistance. (4 hours) **Physical, Chemical, and Functional Properties of UFG and NS Metals:**Electrical Conductivity, Thermal Conductivity,Thermal Stability, Thermoelectricity, Hydrogen Storage Capability, Magnetic Properties, Corrosion, Biocorrosion, Biocompatibility, Cryogenic Properties. (4 hours) **Applications of Ultrafine-Grained and Nanograined Metals:**Biomedical, Structural Examples, Hydrogen Storage Capacity Of NanostructuredMg Alloys, Sputtering Targets for The SemiconductorIndustry,Superplastic Properties, Military Applications, Sport, Microforming, Nanostructured Magnets, Anostructured Al And Cu Alloys With High Conductivity and Strength, UFG Metals for Semisolid Forming. (5 hours)
Text Books, and/or reference material	**Text Books:** 1. Severe Plastic Deformation Technology-ARosochowski, Whittles Publishing, 2017. 2. Severe Plastic Deformation: Methods, Processing and Properties- GhaderFaraji, H.S. Kim, and HessamTorabzadehKashi, Elsevier, 2018. 3. Severe Plastic Deformation: Toward Bulk Production of Nanostructured Materials- BurhanettinAltan, Nova Science Publishers, Inc., New York, 2006. **Reference Books:** 1. Investigations and Applications of Severe Plastic Deformation-Terry C. LoweandRuslan Z. Valiev, Springer, 2000.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	PO2	PO3	PO4
CO1	√	√	√	-
CO2	√	√	√	-
CO3	√	√	√	√

Department of Metallurgical & 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 9052	**Finite Element Method for Metallurgy and Materials**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
NIL		CT + EA					
Course Outcomes	**CO1:** To understand the concept of Finite Element Method (FEM). **CO2**: To recognize the important role played by FEM in today's engineering world. **CO3:**To solve the challenging problems of heat transfer and different structural design.						
Topics Covered	**Introduction:** Mathematical models, Numerical Simulations, how does Finite element work? Main ideas of FE, Comparison of Finite-Difference and Finite-Element Methods with Analytical Solutions. (3 hours) **The Weak Formulation :** Nodal Finite Elements, Mesh Elements, The Finite Element Method Procedure, Weak Formulation of Governing Equations, Gradient and Divergence Theorems, Integration by Parts, Weak Formulations, Exercises . (5 hours) **Linear Interpolation Functions:** Parameter Functions and Interpolating Functions, Interpolation, Weighting and Approximation Functions, Linear Interpolation Function for One-Dimensional Analysis, Linear Interpolation Functions for Two-Dimensional Analysis, Linear Interpolation Functions for Three-Dimensional Problems, Other Coordinate Systems Used in Derivation of Shape Functions, Isoparametric Elements, Exercises. (8 hours) **Derivation of Element Matrices, Assembly and Solution of the Finite Element Equation:** Derivation of Element Matrix for One-Dimensional Problems Using the Galerkin Method, Assembly and Solution, Derivation of Element Matrix for Two-Dimensional Problems Using the Galerkin Method, Derivation of Element Matrix for Three-Dimensional Problems Using the Galerkin Method, Transient Problems, Derivation of Matrix Equations for Axisymmetric Problems, sample Solutions on Elements Matrix Computation, Assembly and Solution, One-Dimensional Fourth Order Differential Equation, The Use of Other Coordinate Systems in Derivation of Finite Element Equation, Exercises. (12 hours) **Steps of Finite Element Modeling using MATLAB:** Specifying the Application Type, Drawing the Problem Geometry, Specifying the PDE, Specifying Boundary Conditions, Meshing the Domain and Mesh Refinement, Specifying Initial Conditions for Transient Problems, Solving the PDE, Extracting Values from Plots, Exercises. (5 hours) **Appliactionof Heat Transfer Problems:** Steady-State Heat Transfer, Transient Problems (Heating and Cooling Problems), Transient Problem (Heat Generation in a Tubular Furnace). (5 hours) **Application of Elasticity Problems:** Basics of Elasticity in Finite Element Application, Modeling Elasticity Problems in Materials Engineering, Exercises (5 hours)						

	Computational Micromechanics, Alternative Finite elements models, Nonlinear problems, errors in finite element analysis. (8 hours)
Text Books, and/or reference material	**Text Books:** 1. An Introduction to the Finite Element Method- J. N. Reddy, Mcgraw Hill Series in Mechanical Engineering, 2005. 2.The Finite Element method Basic Concepts and Applications- D. W. Pepper and J. C. Heinrich, CRC Press, 2013 3.Textbook of Finite Element Analysis- P. Seshu, PHI, 2016. **Reference Books:** 1. The Finite Element Method for Engineers -Kenneth H. Huebner, Donald L. Dewhirst, Douglas E. Smith, and Ted G. Byrom, Wiley, 2012. 2. An Introduction to Computational Micromechanics-T. I. Zohdi and P. Wriggers, Springer, Berlin Heidelberg NewYork,2010.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	CO1	CO2	CO3
PO1	✓	✓	✓
PO2	✓	✓	✓
PO3	-	✓	✓
PO4	-	✓	✓

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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MT9053</td><td>Solidification Processing</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">Nil</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To study the solidification of pure metal and alloys
CO2: To understand the behavior of inclusions
CO3: To obtain detailed understanding of solidification of all types of castings to produce defect free product</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Plane front solidification of single-phase alloys, interface stability, Czochralski growth, [8h]

Growth of single crystals of high perfection, cellular solidification, cellular-dendritic transition, plane front solidification of polyphase alloys, macro- and micro-morphology of eutectic growth, growth of graphite in cast irons, some problems in solidification of polyphase alloys, [12h]

Rapid solidification processes (RSP). Classification of high cooling rates. Conventional and unconventional effects. Undercooling and recalescence. Amorphous state. Glaze-ability. Methods for preparing rapidly solidified material. The importance of RSP for heat treatment, foundry, powder metallurgy and beam technologies. [8 h]

Inclusions - their formation and distribution; Rheocasting, thixocasting, electroslag casting, casting of composites. [10h]

Case studies of selected castings. The perspective of solidification processes. [2h]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">TEXT BOOKS:
1. BIRD, R B. -- STEWART, W E. -- LIGHTFOOT, E N. Přenosovéjevy: Sdíleníhybnosti, energie a hmoty. Praha : Academia, 1968. 799 p.
2. Batyšev, A. I. Kristallizacijametallovi splavov pod davlenijem., Izd. Metallurgija, Moskva, 1990.

REFERENCE BOOKS:
1. Kirkwood, D.H. – Suéry, M. – Kapranos, P. – Atkinson, H.V. –</td></tr>
</table>

	Young,K.P. Semi-solid processing of Alloys. Springer – Verlag Berlin Heidelberg, 2010, ISBN 978-3-642-00705-7, e-ISBN 978-3-642-00706-4

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	PO2	PO3	PO4
CO1	✓	-	✓	-
CO2	✓	-	-	-
CO3	✓	✓	✓	✓

<table>
<tr><td colspan="9">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>MT9054</td><td>Environmental Management in Metallurgical Industries</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="2">NIL</td><td colspan="6">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: Ability to gain the knowledge regarding various pollutants and their methods of control in metallurgical industries.
• CO2: Ability to understand the current methods and technological principles used in environmental management in different metallurgical industries
• CO3: Ability to analyze and solve various practical problems related to environment and recycling of wastes on applications of metallurgical industries.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Fundamentals of environmental management [4]
A brief outline of the different metallurgical industries and its status [4]
Sources and types of pollutants (wastes) from metal / minerals industries. [4]
Gaseous emissions: control of SPM, hazardous gases, viz. sulphur dioxide, fluorides, nitrogen oxides. [4]
Greenhouse gases: Greenhouse effect, global warming potential, Kyoto protocol, carbon trading [4]
Emission and control from different ferrous and non-ferrous industries: Coal based DRI unit, Gas based DRI unit, Smelting reduction units, Ferro alloy plants, Foundry industries, Aluminium producing industries, Copper extraction industries, Zinc and led producing industries, Other metallurgical industries [8]
Liquid effluents: treatment of waste water, with examples from metal industries. [4]
Solid wastes: types, disposal and utilization of slime, red mud and spent pot lining, iron and steel slags, Fly and bottom ash [8]
Impact of pollutants on human health, [2]
Management of radioactive wastes, e-waste, noise pollution, thermal pollution. [6]</td></tr>
</table>

Text Books, and/or reference material	**Text Books:** 1. R.C. Gupta: Energy and Environmental Management in Metallurgical Industries, PHI Learning 2. H.S. Ray. B.P. Singh, S. Bhattcharya, V. N. Misra,. Energy in Mineral and Metallurgical Industries, Allied Publisher 3. C. S. Rao: Environmental Pollution Control Engineering, Wiley Eastern Ltd. 4. J. A. Nathanson: Basic Environmental Technology, prentice-Hall India **Reference Books:** 1. R.C. Gupta(ed.): Proc. Environmental Management in Metallurgical Industries(EMMI-2010),Allied Publishers 2. FathiHabashi: Pollution Problems in Mineral and Metallurgical Industries,Metallurgie Extractive Quebec. 3. H.S.Peavy et al.: Environmental Engineering, McGraw Hill

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	PO1	PO2	PO3	PO4
CO1	√	-	√	√
CO2	-	√	-	-
CO3	√	-	-	√

Department of Metallurgical & 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 9055	**Corrosion Engineering**	PEL	3	0	0	3	3
Pre-requisites		Course Assessment methods (Continuous (CT) and end assessment (EA))					
Engineeing Materials and Basic Chemistry		CT+EA					
Course Outcomes	**CO1:**To learn fundamentals ofcorrosion principles. **CO2:** To understand the different forms of aqueous corrosion and high temperature corrosion. **CO3:**To mitigate the methods of corrosion and assess/test and evaluate corrosion.						
Topics Covered	**Introduction**: Cost of corrosion, definition of corrosion, Environments. [01] **Corrosion principles:** Introduction, electrochemical reaction, thermodynamics, free energy, electrode potential, cell potential, EMF series, galvanic series, IUPAC convention of cell reaction, electrode kinetics, exchange current density, polarisation,passivity, Poubaix diagram (E – pH diagram). [10] **Forms of corrosion:** Uniform attack. Galvanic or two-metal corrosion, EMF series and galvanic series, metallurgical effects, beneficial effects and prevention.Intergranular corrosion. Crevice corrosion. Pitting corrosion. Selective leaching. Environment Assisted /Induced Cracking (EAC/ EIC) - Stress corrosion cracking (SCC), and Hydrogen damage (HE). [10] **Corrosion prevention:** Materials selection, alteration environments, inhibitors, cathodic and anodic protection, coating. [06] **Corrosion testing:** Corrosion rate expression, stress corrosion test, SSRT, polarisation techniques, fel extrapolation, linear polarisation and AC impedance technique. [05] **High temperature corrosion:** Introduction, Pilling–Bedworth ratio, electrochemical and morphological aspects,and hot corrosion. [06]							

Text Books, and/or reference material	**Text Books:** 1. Corrosion Engineering – Mars G Fontana, McGraw Hill Publication. 2. The fundamental of corrosion – J C Scully 3. Corrosion vol. 1 and vol. 2 – L LShrier 4. Corrosion and corrosion control – H HUhlig 5. The corrosion and oxidation of metals – U R Evans 6. The principle of electroplating – Shrain and Narain **References** 1. ASM Handbook on Corrosion vol. 13, 13A, 13B, 13C.

Mapping of CO (Course Outcome) and PO (Programme Outcome)

	CO1	CO2	CO3
PO1	✓	✓	✓
PO2	✓	✓	✓
PO3	-	✓	✓
PO4	-	✓	