College of Engineering, Pune
(An Autonomous Institute of Govt. of Maharashtra, Permanently Affiliated to S.P. Pune University)

Department of Metallurgy and Material Science

Curriculum Structure & Detailed Syllabus (UG Program)

Final Year B. Tech.
(Revision: A.Y. 2017-18, Effective from: A.Y. 2018-19)

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Program Education Objectives (PEOs):

The following are the PEOs set by the department...

I. To prepare students to excel in postgraduate programs or to succeed in industry/technical profession through global and comprehensive education.

II. To provide students with a solid foundation in mathematical, scientific and engineering fundamentals required to solve engineering problems and also to pursue higher studies.

III. To train students with good scientific and engineering breadth so as to comprehend, analyze, design and create novel products and solutions for real life problems.

IV. To inculcate in students professional and ethical attitude, effective communication skills, teamwork skills, multidisciplinary approach and an ability to relate engineering issues to broader social context.

V. To prepare student with an academic environment aware of excellence, leadership, written ethical codes and guidelines and the life-long learning needed for a

successful professional career.

Program Outcomes (POs):

The Undergraduate Students will demonstrate...

1. Knowledge of basic sciences (i.e. Physics, chemistry, mathematics, biology etc.) to solve metallurgical and materials engineering issues.
2. Ability to design and conduct experiments, interpret and analyze data and report results.
3. Ability to perform experiments in metallurgy, characterization and proper materials selection.
4. Ability to function in engineering and science laboratory teams as well as on multidisciplinary projects.
5. Ability to identify, formulate and solve metallurgy and materials science problems.
6. Understanding of their professional and ethical responsibilities.
7. Ability to communicate effectively in both verbal and written form.
8. Confidence to apply engineering solutions in global and societal context.
9. Capability of self – education and lifelong learning.
10. Awareness of project management and finance related issues.
11. Ability to use modern engineering software tools and equipments to analyze metallurgy and materials science problems.

Correlation between the PEOs and the POs

PO→ PEO↓	1	2	3	4	5	6	7	8	9	10	11
I	✓	✓	✓		✓		✓				
II	✓	✓	✓	✓	✓	✓	✓				
III	✓	✓	✓	✓	✓	✓					
IV				✓	✓					✓	✓
V							✓		✓	✓	✓

Note: The cells filled in with ✓ indicate the fulfilment/correlation of the concerned PEO with the PO.

List of Abbreviations

Abbreviation	Title	No of courses	Credits	% of Credits	
BSC	Basic Science Course	12/13	30/33	18-20	Approx. 40-45 %
EFC	Engineering Foundation Course	9	22	13	
MLC	Mandatory Learning Course	4	0	0	
ILOE	Institute Level Open Elective Course	2	6	3.5	
SLC	Self Learning Course	1	3	2	
HSMC	Humanities/Social Sciences/Management Course	5/6	8/11	4.5 / 6.5	
LLC	Liberal Learning Course	1	1	1.18	
SBC	Skill Based Course	8	17/21	10 to 12.5	Approx. 55- 60 %
PCC	Program Core Course				
DEC	Department Elective Course				
LC	Laboratory Course				
S.P. P.U.	Savitribai Phule Pune University				
A.Y.	Academic Year				

Curriculum Structure
Final Year Metallurgical Engineering
Semester VII

Sr. No.	Course Type	Course Code	Course Name	Teaching Scheme L	T	P	Credits
1	LLC		Liberal Learning Course	1	-	-	**1**
2	MLC	ML-18001	Intellectual Property Rights	1	-	0	**0**
3	SBC	MT-18001	Project Stage-I	0	-	4	**2**
4	PCC1	MT-18002	Corrosion and Surface Protection	3	-	0	**3**
5	PCC2	MT-18003	Materials Joining	3	-	-	**3**
6	PCC3	MT-18004	Electronic and Magnetic Materials	3	-	-	**3**
7	DEC	MT(DE)-18001 MT(DE)-18002 MT(DE)-18003 MT(DE)-18004 MT(DE)-18005	**Department Elective-II** • Nanomaterials and Nanotechnology • Fracture of Engineering Materials • Biomaterials • Powder Metallurgy • MOOC*	3	-	-	**3**
8	LC	MT-18005	Corrosion and Surface Protection Laboratory	-	-	2	**1**
9	LC	MT-18006	Materials Joining Laboratory	-	-	2	**1**
10	ILOE	ILE-18014	Institute Level Open Elective	3	-	-	**3**
			Total Academic Engagement and Credits	**25**			**20**

N.B.: *The subject for MOOC will have to be selected from the courses available on internet and duly approved by the department.

No.	Semester	Minor Course	Honors Course	Lectures	Credits
1	VII	Bio-materials	Theory and Practice of Sintering / Phase Transformations	3	**3**

Institute Level Open Elective

Sr. No	Course Type	Course Code	Course Name	Teaching Scheme L	T	P	Credits
1	ILOE	ILE-18014	Selection of Materials & Processes	3	-	-	**3**

Final Year Metallurgical Engineering
Semester VIII

Sr. No.	Course Type	Course Code	Course Name	Teaching Scheme			Credits
				L	T	P	
1	LLC		Liberal Learning Course	1	-	-	**1**
2	SBC	MT-18007	Project Stage-II	0	-	8	**6**
3	PCC1	MT-18008	Design and Selection of Materials	2	1	-	**3**
4	PCC2	MT-18009	Failure Analysis of Engineering Materials	3	-	-	**3**
5	DEC	MT(DE)-18006 MT(DE)-18007 MT(DE)-18008 MT(DE)-18009	**Department Elective-III** • Nuclear Materials • Surface Processing of Materials • Light Metals and Alloys • Laser Materials Processing	3	-	-	**3**
6	DEC	MT(DE)-18010 MT(DE)-18011 MT(DE)-18012 MT(DE)-18013 MT(DE)-18014	**Department Elective-IV** • Forging Technology • Advanced Ceramic Technology • Secondary Steel Making • Modeling of Engineering Materials • MOOC**	3	-	-	**3**
			Total Academic Engagement and Credits	**23**			**19**

N.B: 1. Students are required to undergo minimum of 4 weeks training in industry/research organization in any of the vacations by the start of 6th semester.

2. **The subject for MOOC will have to be selected from the courses available on internet and duly approved by the department.

No.	Semester	Minor Course	Honors Course	Lectures	Credits
1	VIII	Failure Analysis of Engineering Materials	Amorphous materials / High Temperature Corrosion	3	**3**

Semester-VII

(MT-18001) Project Stage - I

Teaching Scheme:
Practicals: 4 hrs/week

Examination Scheme:
Oral:100 Marls
Term Work: 100 Marks

Course Outcomes:
At the end of course students will be able to
1. analyse technical gaps or lacuna in literature.
2. identify, formulate and solve metallurgy and materials science problems
3. communicate effectively in both verbal and written form
4. imbibe capability of self-education and lifelong learning

The B. Tech. Project is aimed at training the students to analyze independently any problem in the field of Metallurgical Engineering and Material Science. The project may be analytical, computational, experimental or a combination of the three in a few cases. The project report is expected to show clarity of thought and expression, critical appreciation of the existing literature and analytical, computational, experimental aptitude of the student. The progress will be reviewed in two stages - in the middle of the two semesters (Project I) and at the end of second semester (Project II). In the final stage, it will be externally evaluated on the basis of oral/seminar talk.

(MT-18002) Corrosion and Surface Protection

Teaching Scheme:
Lectures : 3 Hrs/week

Examination Scheme:
T1 and T2: 20 Marks each
End-Sem Exam: 60 Marks

Course Outcomes:

At the end of course students will be able to

1. apply fundamental knowledge and concepts in corrosion
2. solve numerical and problems on corrosion
3. select, test materials and apply corrosion prevention methods

Unit I: [7 **hrs**]

Importance of corrosion, Thermodynamics and Kinetics of Electrode Processes, Free energy concept, Pourbiax Diagram for Metal Water System, Applications and Limitations, Nernst's Equation, Emf Series, Galvanic Series, anodic and cathodic reactions, electrochemical cell analogy, Concept of Over-Potential, Polarization Curves, Evan's Corrosion Diagram, mixed potential theory, Kinetics Of Passivity and Transpassivity.

Unit II: [**8 hrs**]

Various Forms of Corrosion Such as Uniform Corrosion, Galvanic Corrosion, Crevice Corrosion, Pitting Corrosion, filliform corrosion, Intergranular Corrosion, Selective Leaching, Erosion Corrosion, Stress corrosion cracking (SCC), Environmental assisted cracking (EAC), fretting damage, Hydrogen Damage, corrosion fatigue, hydrogen embrittlement and microbes induced corrosion.

Unit III: [7 **hrs**]

Mechanical, Metallurgical and Environmental Aspects. Material Selection for Specific Corrosion Applications Such as Marine Industry, Petrochemical Industry, High Temperature Service, Chemical Industry and Selection of Suitable Design for Corrosion Control

Unit IV: [7 **hrs**]

Principles of Protection, Materials selection, Modification/Alteration of environment, Design, Inhibition, Cathodic protection, Anodic protection, Coating Application Methods for Corrosion Control.

Unit V: [7 **hrs**]

Corrosion Testing by Physical and Electrochemical Methods. Use of ASTM standards like G-8, G-5, G-1, A262 etc. NACE standards / their equivalents, Surface Preparation, Exposure Technique salt spray, cyclic corrosion test, weatherometer, immersion test, Corrosion Rate Measurements. Few case studies.

Text Books:

- M.G.Fontana - Corrosion Engineering, 3rd ed., TATA Mc Graw Hill, 2008.
- R.W.Revie & H.H. Uhlig - Corrosion and Corrosion Control, An Introduction to Corrosion Science & Engineering, 4th ed., Wiley Interscience ,2008.

Reference Books:

- D.R. Jones - Principals and Prevention of Corrosion, 2nd intl. Ed., Prentice Hall International Singapore, 1995.
- L.L. Shreir- Corrosion Volume I & II, Butterworths, London,1994,
- Cramer, Stephen D., Covino, Bernard S. Jr., ASM handbook, Volume 13 A, Corrosion: Fundamentals, testing and protection, ASM international, 2010.
- Cramer, Stephen D., Covino, Bernard S. Jr., ASM handbook, Volume 13 B, Corrosion: Materials, ASM international, 2010.
- NPTEL website

(MT-18003) Materials Joining

Teaching Scheme:
Lectures : 3 Hrs/week

Examination Scheme:
T1 and T2: 20 Marks each
End-Sem Exam: 60 Marks

Course Outcomes:
At the end of course students will be able to

1. identify, formulate, and solve engineering problems related to welding
2. use the techniques, skills, and modern engineering tools necessary for materials joining
3. select and design welding materials, processes and inspection techniques based on application, fabrication and service conditions.
4. identify the defects in welded joints and perform the failures analysis and report in professional manner

Unit I: [7 **hrs**]
Classification of Joining Processes, Heat Sources in Welding, Electric Arc, its Structure, Characteristics and Power, Metal Transfer and Mass Flow, Chemical Heat Source, Contact Resistance Heat Source

Unit II: [**8 hrs**]
Fusion Welding, Oxyacetylene Welding, Shielded Metal Arc Welding, TIG Welding, MIG Welding, Plasma Arc Welding, Flux-Core Arc Welding, Submerged Arc Welding, Electro Slag Welding, Electron Beam Welding, Laser Beam Welding, Thermit Welding.

Unit III: [7 **hrs**]
Heat Source, Efficiency, Heat Flow in Welding, Rosenthal‟s Two-Dimensional and Tree Dimensional Equations, Effect of Welding Parameters, Fluid Flow in Arcs, Fluid Flow in Weld Pool, Metal Evaporation.

Unit IV: [7 **hrs**]
Chemical Reactions in Welding, Gas-Metal, Slag-Metal Reactions, Metal Evaporation, Residual Stresses, Distortion, Fatigue of Welded Joints.

Unit V: [**7 hrs**]
Fusion Zone, Solidification, Effect of Cooling Rate, Partially Melted Zone, Liquation, Heat Affected Zone, Defects in Welded Joints, Micro-Segregation, Macro-Segregation, Banding, Gas Porosity, Inclusions, Weld Metal Cracking, Liquation Cracking, Hydrogen Cracking.

Unit V: [**7 hrs**]

Principles of Solid Phase Welding, Diffusion Welding, Forge Welding, Butt Welding, Flash Butt Welding, Spot Welding, Projection Welding, Seam Welding, Ultrasonic Welding, Explosion Welding, Principles of Solid/Liquid State Joining, , Joining of Non Metallic Materials: Joining of polymers, ceramics, polymer – metals, ceramic – metals, polymer – ceramics and composite materials, Soldering and Brazing, Adhesive Bonding.

Text Books:

- A.Ghosh and A. K. Mallik - Manufacturing Science, 2nd Ed., Affiliated East-West Press Private Limited, New Delhi, 2010
- Sindo Kou - Welding Metallurgy, 2nd ed, John Wiley 2003.
- J.F. Lancaster – Metallurgy of Welding, 6th Ed., Woodhead Publishing Series in Welding and other Joining Technologies 1999
- Robert D. Messler Jr., Principles of Welding Processes, Physics, Chemistry and Welding 2nd Ed.,Wiley – VCH 2004

Reference Books:

- ASM Metals Handbook - Welding and Joining, Vol. 6, 9th Ed., ASM Metals Park Ohio 2011

(MT-18004) Electronic and Magnetic Materials

Teaching Scheme:
Lectures : 3 Hrs/week

Examination Scheme:
T1 and T2: 20 Marks each
End-Sem Exam: 60 Marks

Course Outcomes:
At the end of course students will be able to

1. get insights into structure - property relationship of modern electrical engineering materials
2. get exposure to the innovations taking place on the fronts of the synthesis, processing and applications of modern electrical engineering materials.
3. understand the applications of modern electrical materials in various fields
4. get prepared to engineer the synthesis-structure property relationship for the electronic materials according to recent commercial applications

Unit I: [6 **hrs**]
Electrical and Thermal Conduction In Solid metal and conduction by electrons, Resistivity and its Temperature dependence. Temperature coefficient of Resistivity, Impurity Effect, Resistivity Mixture Rule, Skin Effect. Electrical Conductivity of Non-Metals: Ionic Crystals and Glasses, Semiconductors, Thermal Conductivity, Thermal Resistance.

Unit II: [6 **hrs**]
Semiconductors, Extrinsic, Intrinsic, Semiconductor Devices, Compound Semiconductor, Microelectronic Devices Such as LED, CMOS, MOSFETS, BPT etc, Manufacturing Methods and Applications.

Unit III: [6 **hrs**]
Magnetic Properties: Magnetic Field and Quantities, Classification of Magnetic Materials, Ferromagnetism Origin, Exchange Interaction, Saturation Magnetization, Curie Temperature, Ferromagnetic Domains, Magnetostriction, Demagnetization.

Unit IV: [6 **hrs**]
Magnetic Alloys: Soft and Hard Magnetic materials, Ferrites, Magnetic Recording Materials, Magnetic Resonance Imaging. Superconductivity: Zero Resistance, Meissner Effect, Type I and II Superconductors, BCS Theory.

Unit V: [6 **hrs**]
Optical Properties of Materials: Light and Electromagnetic Spectrum, Refraction, Absorption, Transmission and Reflection of Light, Luminescence, Laser, and Optical Fibers. Optical Anisotropy, Electrooptic Effect, Electrooptic Ceramics, Antireflection Coating on Solar Cell.

Unit VI: [6 **hrs**]
Dielectric Materials and Insulation: Polarization, Relative Permitivity, Polarization

Mechanisms, Dielectric Constant, Dielectric Loss, Capacitors and Insulators, Piezoelectric, Ferro Electric and Pyroelectric Materials.

Text Books:

- William F. Smith , Javed Hashemi, Ravi Prakash- Foundation of Materials Science and Engineering, TATA Mc Graw-Hill International Edition,4th Edition, 2008.
- N. Braithwaite and G. Weaver - Materials in Action Series -Electronic Materials, Butterworths Publication.
- S. O. Kasap - Principles of Electronic Materials and Devices, Tata Mc Graw-Hill Publication, 2nd Edition, 2002.

Reference Books:

- Schroder, Klaus, Electronic Magnetic and Thermal properties of Solids, Marcel Dekker, New York 1978.
- Electronic Materials Handbook**,** ASM International, Materials Park, 1989.
- Buschow K.H.J. (Ed.), Handbook of Magnetic Materials, Amsterdam: Elsevier, Volume 15, First Edition December 2003.

Department Elective-II

(MT(DE)-18001) Nanomaterials and Nanotechnology

Teaching Scheme:
Lectures : 3 Hrs/week

Examination Scheme:
T1 and T2: 20 Marks each
End-Sem Exam: 60 Marks

Course Outcomes:
At the end of course students will be able to

1. know the length scale and surface area to volume ratio of materials with decreasing size of particles and to compare the properties of nanomaterials to that of bulk.
2. know the effect of particles or grains size on mechanical, thermal, optical and electrical properties of nanomaterials and synthesis the nanomaterials by top-down and bottom up approaches.
3. understand the theoretical concepts of synthesis, purification and applications of carbon nanotubes.
4. apply the knowledge to prepare and characterize nanomaterials and their nanocomposites
5. understand the applications of nanomaterials in different field

Unit I: **[6 hrs]**
Length scales, surface area/volume ratio of micron to nanoscale materials, Importance of Nanoscale and Technology, Top down and bottom up approaches, Classification of nanomaterials, effect of particle size on thermal properties, electrical properties, mechanical properties, magnetic properties, opticalproperties and chemical sensitivity. Examples of inspiration from the Nature and ancient history

Unit II: [**6hrs**]
Synthesis of Nanomaterials: Top-down approaches-lithography, mechanical alloying, severe plastic deformation, Bottom-up approaches-physical vapour deposition, chemical vapour deposition, molecular beam epitaxy, colloidal or wet chemical route, green chemistry route, sol-gel method, atomic layer deposition.

Unit III: [6**hrs**]
Synthesis, purification, properties and applications of carbon nanotubes (CNT). Synthesis, properties and applications of graphene. Synthesis, properties and applications of nanowires. Fabrication and properties of polymer matrix nanocomposites filled with CNT, graphene, nanowires, clay nanoparticles. Trade-off between the composites and nanocomposites.

Unit IV: [6**hrs**]
Characterization of Nanomaterials: Basic principle and applications of X-ray diffraction (XRD), Optical spectroscopy, Surface area analysis (BET method), Light scattering method, Scanning electron microscope (SEM), Transmission Electron Microscope (TEM), Scanning probe microscopy- Atomic force microscope (AFM) and scanning tunneling microscope (STM), X-ray photoelectron spectroscopy.

Unit V: **[6hrs]**

Applications of nanomaterials: nanofluids, hydrogen storage, solar energy, antibacterial coating, self-cleaning coating, nanotextiles, biomedical field, water treatment, automotive sector, catalysts.

Unit VI: **[6 hrs]**

Challenges of nanomaterials, Risks and toxicity from metallic and oxide nanoparticles, Recent advances in nanoscience and nanotechnology.

Text Books:

- Rajendra Kumar Goyal, Nanomaterials and Nanocomposites: Synthesis, Properties, Characterization Techniques and Applications by CRC Press, 2017, ISBN: 978-14987616662017.
- B.S. Murty, P. Shankar, Baldev Raj, B B Rath, James Murday, Textbook of Nanoscience and Nanotechnology, 2013, University Press (I) Pvt. Ltd. (e-ISBN: 978-3-642-28030-6).
- Gábor Louis Hornyak, Harry F. Tibbals, Joydeep Dutta, Introduction to nanoscience and nanotechnology, 2009, CRC Press (ISBN: 1420047795, 9781420047790).
- Charles P. Poole, Jr. and Frank J. Owens, Introduction to Nanotechnology, 2003, Wiley (ISBN: 978-0-471-07935-4).

Reference Books:

- Dieter Vollath, Nanomaterials: An introduction to synthesis, properties and applications, 2nd Edition, Aug 2013, Wiley-CVH (ISBN: 978-3-527-33379-0)
- Kenneth J. Klabunde, Nanoscale Materials in Chemistry, Aug 2003, Wiley-Interscience (ISBN: 9780471460787)
- Hari Singh Nalwa, Encyclopedia of Nanoscience and Nanotechnology, Volume 1, 2003, American Scientific Publishers (ISBN: 1588830012).
- Bharat Bhusan, Springer Handbook of Nanotechnology, , 3rd Revision, 2010, Springer-Verlag Publ media (ISBN: 978-3-642-02524-2)
- Guozhong Cao and Ying Wang, Nanostructures and Nanomaterials: Synthesis, Properties and Applications, 2nd Edition, 2011, World Scientific (ISBN: 978-981-4322-50-8)

Department Elective-II
(MT(DE)-18002) Fracture of Engineering Materials

Teaching Scheme:
Lectures : 3 Hrs/week

Examination Scheme:
T1 and T2: 20 Marks each
End-Sem Exam: 60 Marks

Course Outcomes:
At the end of course students will be able to

1. identify failure modes and analyze the reasons of failures of the components in service.
2. differentiate macro and microscopic aspects of fracture mechanisms.
3. apply the fracture mechanics approach to characterize fracture behavior and efficacy of different fracture toughness parameters in ensuring safety of a component.
4. apply the various metallurgical principles used for improving fracture toughness

Unit I: [6 **hrs**]
Introduction : What is fracture, different types of fracture & identify factors responsible, An atomic view of fracture- ideal strength/ fracture stress and its estimation, Stress concentration factor and its limitation to characterize fracture. Difference between a crack and a notch.

Unit II: [**6 hrs**]
Linear Elastic Fracture Mechanics: Griffith's theory of brittle fracture, Irwin –Orwan modification of Griffith equation- strain energy release rate, limitations of conventional approach. Three basic modes of separation of crack surface during loading , Stress intensity factor (K_{IC}) and its use in establishing conditions of fracture and ensuring safety of engineering components.

Unit III: [6 **hrs**]
Elastic Plastic Fracture Mechanics : Limitation of LEFM - plastic zone ahead of a crack tip, Crack Tip Opening Displacement (CTOD), Elastic - plastic analysis with the J- integral, relation between J and CTOD, Crack growth resistance curves(K-R and J-R), experimental determination of fracture toughness as per standards, strength of materials vs. fracture mechanics approach of engineering design.

Unit IV: [6 **hrs**]
Fracture Mechanisms in Metals : Ductile Fracture - Void Nucleation, Growth and Coalescence, Brittle fracture- cleavage initiation and fracture, inter granular fracture, Macro and microscopic aspects of fracture, Ductile - Brittle Transition, Approaches for controlling brittle fracture and fracture toughness improvement.

Unit V: [6 **hrs**]
Fatigue: Stress cycles, S- N curve, Low cycle fatigue, Effect of mean stress and metallurgical factors on fatigue life, Structural features of fatigue failure, Cumulative

fatigue damage estimation, Use of fracture mechanics to study fatigue crack propagation, Methods for improving fatigue life.

Unit VI: [6 **hrs**]

Creep: Temperature - stress- strain relations in a creep test and important creep parameters for engineering applications, Extrapolation procedures for creep- rupture data, Deformation mechanism maps, Creep fracture micro mechanisms, Creep- fatigue interactions, Creep resistant materials and Alloy design principles for creep resistance.

Text Books:

- R.E. Smallman and R.J. Bishop , Modern Physical Metallurgy and Materials Engineering,
- Reed Educational and Professional Publishing Ltd, UK, Sixth Edition , 1999.
- Dieter, G.E., Mechanical Metallurgy, Third Edition, McGraw- Hill Education Pvt Ltd, New Delhi (India), 2016.
- Courtney, T.H. , Mechanical Behaviour of Materials, Second Edition, Overseas Press, New Delhi (India) , 2006

Reference Books:

- T. L. Anderson, Fracture Mechanics : Fundamentals and Applications, Third Edition , CRC Press, USA, 2005
- Richard W. Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, Wiley India Edition, 2011.
- ASM Hand Book Vol 19: Fatigue and Fracture, ASM International ,USA, 1996.

Department Elective-II

(MT(DE)-18003) Biomaterials

Teaching Scheme:	**Examination Scheme:**
Lectures : 3 Hrs/week	T1 and T2: 20 Marks each End-Sem Exam: 60 Marks

Course Outcomes:
At the end of course students will be able to
1. correlate structure properties relationship of biomaterials
2. select biomaterials for a particular application
3. analyze mechanical properties of biomaterials
4. evaluate biocompatibility of the materials for the intended application

Unit I: [7 **hrs**]
Structure and property relationships of different classes of biomaterials; Interactions of materials with the human body, Classification of Biomaterials

Unit II: [**8 hrs**]
Composite materials and applications, Nanostructured biomaterials, Criteria for selection of biomaterials for specific medical applications

Unit III: [6 **hrs**]
Concepts of biocompatibility, evaluation of biocompatibility, mechanical properties of biomaterials

Unit IV: [6 **hrs**]
Corrosion and biodegradation, simulated body fluids and their effect on biodegradation

Unit V: [6 **hrs**]
Orthopedic implants, dental materials, vascular grafts, ocular materials, drug delivery carriers, introduction to tissue regeneration scaffolds

Reference Books:

- Biomaterials Science: An Introduction to Materials in Medicine, 3rd Edition, Buddy D. Ratner, Allan S. Hoffman, Frederick J. Schoen, Jack E. Lemons, 2013, Academic press, UK.
- Biomaterials, Medical Devices & Tissue Engineering: An integrated approach. Fredrick H. Silver, 1994, Chapman & Hall, UK.

Department Elective-II

(MT(DE)-18004) Powder Metallurgy

Teaching Scheme:
Lectures : 3 Hrs/week

Examination Scheme:
T1 and T2: 20 Marks each
End-Sem Exam: 60 Marks

Course Outcomes:
At the end of course students will be able to

1. identify various powder manufacturing processes
2. explain effect of particle size and shape on compressibility of powders, consolidation of powder, secondary operations and applications
3. apply various characterization techniques for knowing phase transformation and properties
4. analyze sinter part for sinterability of the powders
5. evaluate microstructural features of sintered products
6. design sintering cycle and process for the given alloy

Unit I: [6 **hrs**]
Production of Metal Powders: Introduction to a) Mechanical Processes: Machining, Crushing, Milling, Shotting Graining, Atomization. b) Physico – Chemical Processes: Condensation, Thermal Decomposition, Reduction, Electrodeposition, Precipitation From Aqueous Solution, Intergranular Corrosion, Oxidation and Decarburisation.

Unit II: [6 **hrs**]
Characterization and Testing of Metal Powders: Sampling, Particle Size and Distribution- Sieve Analysis, Light Scattering, Sedimentation, Microscopy and Image Analyzer, Chemical Analysis of Metal Powders, Surface Area, Density and Porosity of Metal Powder, Apparent and Tap Density of Metal Powder, Flow Rate, Compressibility and Green Strength.

Unit III: [6 **hrs**]
Consolidation of Metal Powder: Powder Conditioning, Cold Die Compaction Techniques, Choice of Tooling System for Die Compaction, Role of Lubrication, Hot and Cold Isostatic Pressing of Metal Powders, Roll Compacting, Powder Forging, Injection Molding, High Energy Rate Forming Process.

Unit IV: [6 **hrs**]
Sintering: Different Stages of Sintering and Development of Microstructures During Sintering, Different Mechanisms of Sintering, Liquid Phase Sintering and Activated Sintering, Sintering Furnaces and Furnace Atmospheres.

Unit V: [6 **hrs**]
Secondary operations Performed on Powder Metallurgical Material, Inspection and Quality Control on Powder Metallurgical Materials. Application: Detailed Study on

Processing of any 03 Components used in following applications: Bearing Materials, Tool Materials, Ferrites, Cermets, Friction Materials, Medical and Dental Applications, Nuclear Applications, Automotive Applications.

Unit VI: [6 hrs]

Ceramic Materials: Crystalline structure, Glasses and other non-crystalline ceramics, Processing of Ceramics, Traditional and Technical Ceramics, Electrical, Thermal and Mechanical properties of ceramics, Effect of Temperature on Mechanical Behaviour, Strengthening of Ceramics

Text Books:

- F.Thumler and R. Oberacker –Introduction to Powder Metallurgy, 1993
- Gopal S. Upadhyaya - Powder Metallurgy Technology, Cambridge International Science Publishing, Cambridge, 2002
-

Reference Books:

- ASM W.D.Kingery, Introduction to Ceramic Material, Volume 18, Wiley 1960.
- Powder Metallurgy, ASM Handbook, Vol – VII, 1984.
- Rehamann, Processing of Ceramics and Sintering 2nd edition, 2007
- Sands & Shakespeare - Powder Metallurgy, Newnes: 1966.
- Barsaum - Fundamentals of Ceramics- 2003.

(MT-18005) Corrosion and Surface Protection Laboratory

Teaching Scheme:
Lectures : 2 Hrs/batch/week

Examination Scheme:
Term Work: 50 Marks each
Oral Exam: 50 Marks

Course Outcomes:
At the end of course students will be able to
1. establish correlation between theory and practical.
2. conduct actual practical independently and acquaint with knowledge of testing procedure and use of standards
3. interpreting results and solve numerical involved

A Set of 08 Number of Experiments Based on the Theory Syllabus.
1. Measurement of potential of various metals (Fe, Cu, Zn etc.)
2. pH measurement
3. Crevice corrosion in stainless steel
4. Intergranular corrosion of austenitic stainless steel
5. Use of inhibitors in preventing corrosion
6. Hot dip zinc coating for corrosion prevention
7. Weight loss method for corrosion rate determination
8. Salt spray exposure
9. Cyclic corrosion test
10. Stress corrosion cracking (U bend test)
11. Polarization and Electrochemical Impedance Study
12. Characterization by optical, SEM, XRD method

(MT-18006) Materials Joining Laboratory

Teaching Scheme:
Lectures : 2 Hrs/batch/week

Examination Scheme:
Term Work: 50 Marks each
Oral Exam: 50 Marks

Course Outcomes:
At the end of course students will be able to

1. design and conduct experiments, as well as to analyze and interpret data related to material joining process
2. select and design welding materials, processes and inspection techniques based on application, fabrication and service conditions.
3. identify the defects in welded joints and perform the failures analysis and report in professional manner

Minimum 8 assignments from the following areas are required to be completed.

1. Working on welding machines for different welding processes such as manual arc welding, MIG welding, TIG welding, Spot welding,
2. Diffusion welding of two dissimilar metals,
3. Case studies of welding defects, application of NDT and remedies
4. Soldering and brazing practice
5. Measurement of hydrogen in weld metal of welded steels

Courses for B.Tech Minor (Metallurgical Engineering)

(MT-) Biomaterials

Teaching Scheme:
Lectures : 3 Hrs/week

Examination Scheme:
T1 and T2: 20 Marks each
End-Sem Exam: 60 Marks

Course Outcomes:
At the end of course students will be able to
1. correlate structure properties relationship of biomaterials
2. select biomaterials for a particular application
3. analyze mechanical properties of biomaterials
4. evaluate biocompatibility of the materials for the intended application

Unit I: [8 **hrs**]
Structure and property relationships of different classes of biomaterials; Interactions of materials with the human body, Classification of Biomaterials

Unit II: [7 **hrs**]
Composite materials and applications, Nanostructured biomaterials, Criteria for selection of biomaterials for specific medical applications

Unit III: [6 **hrs**]
Concepts of biocompatibility, evaluation of biocompatibility, mechanical properties of biomaterials

Unit IV: [6 **hrs**]
Corrosion and biodegradation, simulated body fluids and their effect on biodegradation

Unit V: [6 **hrs**]
Orthopedic implants, dental materials, vascular grafts, ocular materials, drug delivery carriers, introduction to tissue regeneration scaffolds

Reference Books:

- Biomaterials Science: An Introduction to Materials in Medicine, 3rd Edition, Buddy D. Ratner, Allan S. Hoffman, Frederick J. Schoen, Jack E. Lemons, 2013, Academic press, UK.
- Biomaterials, Medical Devices & Tissue Engineering: An integrated approach. Fredrick H. Silver, 1994, Chapman & Hall, UK.

Courses for B.Tech Honors (Metallurgical Engineering)

(MT-) Theory and Practice of Sintering

Teaching Scheme:
Lectures : 3 Hrs/week

Examination Scheme:
T1 and T2: 20 Marks each
End-Sem Exam: 60 Marks

Course Outcomes:
At the end of course students will be able to

1. control the various processing parameters so as to control the microstructure developed during sintering
2. apply the various densifying and non-densifying mechanisms to control density/porosity
3. select appropriate method of sintering for required applications.
4. establish correlations between structure and properties.

Unit I: [6 **hrs**]
Science and Technology of the sintering of materials- Driving force and variables, role of defects, Kroger-Vink Notation, diffusion, chemical potential, Ambipolar Diffusion.

Unit II: [6 **hrs**]
Mechanisms of Sintering, Theoretical Analysis of Sintering - Development of scaling laws and their application. Grain Growth and Microstructure Control, Normal and abnormal grain growth, Mechanisms Controlling the Boundary Mobility**,** Grain Growth and Pore Evolution in Porous Solids, Simultaneous Densification and Grain Growth

Unit III: [6 **hrs**]
Fabrication Principles for Ceramics/metals with Controlled Microstructure, Microstructure development models and maps, Derivation of sintering and grain growth models and a critical review of their uses and limitations. Mapping approaches. Coverage of single phase, multiphase and composite systems.

Unit IV: [6 **hrs**]
Liquid-Phase Sintering**-** Stages, Thermodynamic And Kinetic Factors, Basic Mechanisms, Use of Phase Diagrams, Activated Sintering, Vitrification, Solid Solution Additives

Unit V: [6 **hrs**]
Sintering With Chemical Reaction- Reaction Sintering. Viscous sintering, Viscous Sintering with Crystallization, Pressure Sintering**,** Microwave sintering, Gases in pores and sintering atmospheres, Plasma Sintering, Additive manufacturing

Unit VI: [6 **hrs**]
Case studies of specific ceramic and metal systems

Text Books:

- Randall German, Powder Metallurgy Science, Metal Powder Industry; 2 Sub Edition, 1994.
- Randall German, Powder Metallurgy & Particulate Materials Processing, Metal Powder Industry, 2005
- M. N. Rahaman, Ceramic Processing and Sintering, 2nd Edition, Marcel Dekker Inc., NY, 2003.
- W.D. Kingery, H.K. Bowen and D.R. Uhlman, Introduction to Ceramics, Ceramic Science and Technology, John Wiley and Sons, Singapore, 1991.
- M.W. Barsoum, Fundamentals of Ceramics, 2nd Edition, IoP Publications, UK, 2003

Reference Books:

- Randall German, Sintering Theory and Practice, Wiley-Inter science; 1 Edition, 1996.
- ASM Handbook: Volume 7: Powder Metal Technologies and Applications (Asm
- Handbook), ASM International; 2nd Edition, 1998.
- Claus G. Goetzel, Treatise on Powder Metallurgy, VOLUME II, III, Applied and Physical
- Powder Metallurgy, Interscience Publishers Inc., New York, 1950

Courses for B.Tech Honors (Metallurgical Engineering)

(MT-17) Phase Transformations

Teaching Scheme:
Lectures : 3 Hrs/week

Examination Scheme:
T1 and T2: 20 Marks each
End-Sem Exam: 60 Marks

Course Outcomes:
At the end of course students will be able to

1. emphasize the role of phase transformations in the development of microstructure changes and properties of materials
2. understand principles underlying solid-solid phase transformations in materials
3. provide an understanding of how diffusion enables changes in microstructures of materials and ability to address or solve problems involving steady-state and non steady-state diffusion of varying degree of complexity
4. understand a variety of phase transformation and the effects of temperature and driving force on the nature of transformation and its impact on the resulting microstructure

Unit I: [7 **hrs**]
Basics of solution thermodynamics, concept of excess free energy, regular solution model, Binary and ternary phase diagrams and interpretations of tie line in ternary isotherms

Unit II: [**8 hrs**]
Kinetics of phase transformation, Classification of phase transformations, Mechanism of diffusion in solids, steady state and non-steady state diffusion, factor affecting diffusion rate, Kirkendall effect.

Unit III: [7 **hrs**]
Energy aspects of homogeneous and heterogeneous nucleation, Fraction transformed at constant rates of nucleation and growth, Nucleation in solids. Austenite to pearlite transformation, temperature effect on pearlite transformation, Austenite to bainite transformation.

Unit IV: [7 **hrs**]
Martensitic transformation:
Crystallographic aspects and mechanism of atom movements, comparison between twinning and martensitic transformation, Effect of grain size, Plastic deformation, arrested cooling on kinetics.

Unit V: [**7 hrs**]
Order-Disordered transformations: Common structures in ordered alloys, variation of order with temperature, Determination of degree of ordering. Effect of ordering on properties, applications.

Unit V: [**7 hrs**]

Precipitation hardening: Structural changes, Mechanism and integration of reactions, Effect of retrogression, Double peaks, Spinoidal decomposition. Recovery, Recrystallization and grain growth: Property changes, Driving forces, N-G aspects, Annealing twins, textures in cold worked and annealed alloys, polygonization, Phase transformations in ceramics

Text Books:

- Solid State Phase Transformations by V. Raghavan, Prentice-Hall of India (P) Ltd., N. Delhi, 1987.
- Phase Transformation in Metals and Alloys by David A. Porter, Kenneth E. Easterling, and Mohamed Y. Sherif, CRC Press, 3rd Ed. (Indian reprint), 2009.

Reference Books:

- Materials Science and Engineering, An introduction, by William D. Callisters, Jr., 7th Edition, John Wiley & Sons, Inc, 2011.
- Modern Physical Metallurgy and Materials Enginering by R. E. Smallman and R.J. Bishop, 6th Edition, Butterworth Heinemann, 1999.
- Recovery Recrystallization & Grain Growth in Metals – P. Cotterill& P. R. Mould-SurreyUniversity Press
- Physical Metallurgy – Cahn, Haasen, North Holland Physics Publication.

Institute Level Open Elective

(ILE-18014) Selection of Materials and Processes

Teaching Scheme:
Lectures : 3 Hrs/week

Examination Scheme:
T1 and T2: 20 Marks each
End-Sem Exam: 60 Marks

Course Outcomes:
At the end of course students will be able to

1. select appropriate materials and manufacturing processes for the given application
2. identify alternative manufacturing process for given application
3. interpret mechanical properties of materials and apply these material properties in the design of components and processes
4. explain the inter-relationship between design, function, materials and process.

Unit I: [6 **hrs**]
Interaction between Function, Material, Shape and Process, Revision of engineering materials and properties, Material properties interrelationship charts such as Youngs modulus-density, Strength-density, Youngs modulus-Strength, wear rate hardness, Youngs modulus – relative cost, strength-relative cost and others

Unit II: [6 **hrs**]
Materials selection, selection strategy: material attributes, translation of design requirements, screening attribute limits, ranking by indices, search supporting information, Local conditions, method of finding indices, Weighted-Properties Method, computer aided selection, structural index

Unit III: [6 **hrs**]
Case studies related to automotive, aerospace, ship building and telecommunication industries: flywheel, springs, elastic hinges, seals, pressure vessels, kiln wall, passive solar heating, precision devices, bearings, heat exchangers, airframes, ship structures, engines and power generation, automobile structures

Unit IV: [6 **hrs**]
Materials Substitution, Pugh Method, Cost–Benefit Analysis, Cost basis for selection, causes of failure in service, Specifications and quality control, Selection for static strength, toughness, stiffness, fatigue, creep, corrosion resistance, wear resistance, material databases

Unit V: [6 **hrs**]
Process selection, ranking processes, cost, computer based process selection, Case studies: fan, pressure vessel, optical table, cast tables, manifold jacket, spark plug insulator

Unit VI: [6 **hrs**]

Selection under multiple constraints, conflicting objectives, penalty-functions, exchange constants, Case studies: connecting rods, windings of high field magnets, casing of minidisk player, disk-brake caliper

Text Books:

- Michael F. Ashby, Materials Selection in Mechanical Design, third edition, Butterworth-Heinemann, 2005
- J. Charles, F.A.A. Crane, J. A.G. Furness, Selection and Use of Engineering Materials, third edition, Butterworth-Heinemann, 2006

Reference Books:

- ASM Metals Handbook, Materials Selection and Design, Vol. 20,2010
- Myer Kutz, Handbook of Materials Selection, John Wiley & Sons, Inc., New York , 2002ISBN 0-471-35924-6

Semester VIII

(MT-18007) Project stage II

Teaching Scheme:
Practicals: 8 hrs/week

Examination Scheme:
Oral:100 Marls
Term Work: 100 Marks

Course Outcomes:
At the end of course students will be able to

1. design and conduct experiments, interpret and analyze data and report results
2. use modern engineering software tool and equipments to analyse metallurgy and material science problems
3. communicate effectively in both verbal and written form
4. imbibe capability of self-education and lifelong learning

The B. Tech. Project is aimed at training the students to analyze independently any problem in the field of Metallurgical Engineering and Material Science. The project may be analytical, computational, experimental or a combination of the three in a few cases. The project report is expected to show clarity of thought and expression, critical appreciation of the existing literature and analytical, computational, experimental aptitude of the student. The progress will be reviewed in two stages - in the middle of the two semesters (Project I) and at the end of second semester (Project II). In the final stage, it will be externally evaluated on the basis of oral/seminar talk.

(MT-18008) Design and selection of Materials

Teaching Scheme:	**Examination Scheme:**
Lectures : 2 Hrs/week	T1 and T2: 20 Marks each
Tutorials: 1 Hrs/week	End-Sem Exam: 60 Marks

Course Outcomes:
At the end of course students will be able to
1. design process and its relation to material selection.
2. interpret mechanical properties of materials, and apply these material properties in the design of components.
3. determine the mechanical properties of materials, and apply these material properties in the design system components.
4. explain the interrelationship between design, function, materials and process.

Unit I: **[6 hrs]**
Materials in Design, Evolution of Engineering Materials, Design process, Types of design, Design flow chart- tools and material data, Interaction between Function, Material, Shape and Process

Unit II: **[6 hrs]**
Revision of engineering materials and properties, Material properties interrelationship charts such as Young‟s modulus-density, Strength-density, Young‟s modulus-Strength, wear rate-hardness, Young‟s modulus – relative cost, strength-relative cost and others

Unit III: **[6 hrs]**
Materials selection, selection strategy: material attributes, translation of design requirements, screening attribute limits, ranking by indices, search supporting information, Local conditions, method of finding indices, Weighted-Properties Method, computer aided selection, structural index; Case studies: table legs, flywheel, springs, elastic hinges, seals, pressure vessels, kiln wall, passive solar heating, precision devices, bearings, heat exchangers, airframes, ship structures, engines and power generation, automobile structures

Unit IV: **[6 hrs]**
Materials Substitution, Pugh Method, Cost–Benefit Analysis, Cost basis for selection, causes of failure in service, Specifications and quality control, Selection for static strength, toughness, stiffness, fatigue, creep, corrosion resistance, wear resistance, material databases

Unit V: **[6 hrs]**
Process selection, ranking processes, cost, computer based process selection, Case

studies: fan, pressure vessel, optical table, cast tables, manifold jacket, spark plug insulator

Unit VI: **[6 hrs]**

Selection under multiple constraints, conflicting objectives, penalty-functions, exchange constants, Case studies: connecting rods, windings of high field magnets, casing of minidisk player, disk-brake caliper

Text Books:

- Michael F. Ashby, Materials Selection in Mechanical Design, third edition, Butterworth-Heinemann, 2005
- J. Charles, F.A.A. Crane, J. A.G. Furness, Selection and Use of Engineering Materials, third edition, Butterworth-Heinemann, 2006

Reference Books:

- ASM Metals Handbook, Materials Selection and Design, Vol. 20,2010
- Myer Kutz, Handbook of Materials Selection, John Wiley & Sons, Inc., New York, 2002, ISBN 0-471-35924-6

(MT-18009) Failure Analysis of Engineering Materials

Teaching Scheme:
Lectures : 3 Hrs/week

Examination Scheme:
T1 and T2: 20 Marks each
End-Sem Exam: 60 Marks

Course Outcomes:
At the end of course students will be able to

1. understand techniques and stages of failure analysis.
2. understand the fundamentals of fracture mechanics
3. analyse elevated temperature and environmentally induced failures
4. understand the reasons behind failures of various engineering components like shaft, bearing etc.

Unit I: [6 **hrs**]

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

Unit II: [6 **hrs**]

Classification of fatigue and fracture modes, Distortion failure-Mechanism and types, stress system related single fracture of ductile and brittle material, stress verses strength relations in metallic materials, residual stress in engineering components, ductile and brittle fractures, fatigue fracture.

Unit III: [6 **hrs**]

Fundamentals of fracture mechanics**,** Factors affecting fracture mechanics, linear elastic fracture mechanics, elastic-plastic fracture mechanics, Factors affecting facture toughness, fracture toughness testing, fracture mechanics approach to failure

Unit IV: [6 **hrs**]

Casting/ welding related failure**,** Effect of non-metallic inclusions, segregation and dissolved gas on mechanical properties. Metallurgical failure in cast products and weldments.

Corrosion related failure, Corrosion failures, Life cycle of metals, basic nature of corrosion; type of corrosion(galvanic, crevice corrosion, pitting, stress corrosion, etc.), intercrystalline and transcrystalline corrosion in engineering components. Corrosion fatigue. Practical examples and case studies.

Unit V: [6 **hrs**]

Elevated temperature failure, Creep Mechanism, Elevated temperature fatique, thermal fatigue, metallurgical instabilities.

Environmentally induced failures. Wear related failure: wear type, contact stress fatigue prevention methods. Subsurface origin and surface origin fatigue; Sub-case origin, cavitation fatigue.

Unit VI: [6 **hrs**]
Case studies on failure of shaft, bearing, etc., failure of mechanical fasteners, failure in pressure vessels, Failure in welded structure, failure of gears, advanced experimental techniques in failure analysis.

Text Book:

- J.S. Collins, Failure of Materials In Mechanical Design, A Wiley Interscience Publication, 1993

Reference Books:

- Ross Bob, Investigating Mechanical Failures, Chapman & Hall, 1995
- G.E. Dieter, Mechanical Metallurgy, McGraw- Hill Education Pvt Ltd, New Delhi (India), 2016.
- ASM Hand Book Vol 19: Fatigue and Fracture, ASM International ,USA, 1996.

Department Elective-III

(MT(DE)-18006) Nuclear Materials

Teaching Scheme:
Lectures : 3 Hrs/week

Examination Scheme:
T1 and T2: 20 Marks each
End-Sem Exam: 60 Marks

Course Outcomes:
At the end of course students will be able to

1. understand the use of nuclear energy as a major source of energy of the future.
2. understand nuclear reactions, design & working of nuclear reactors and about various materials required for its major components.
3. understand the manufacturing processes & the fabrication methods employed for the production of various materials used in the reactor.

Unit I: [6 **hrs**]
Indian Atomic power plants. Nuclear power plants in India and future trends. Nuclear reactions as sources of energetic particles, nuclear stability, radioactive decay.

Unit II: [6 **hrs**]
Nuclear fission and fusion, brief outline of reactor types design and technology, and their particular demands for high-performance materials.

Unit III: [6 **hrs**]
Introduction to materials issues associated with nuclear power generation. Materials for fuel, cladding, moderator, coolant, shield, pressure vessel; Materials selection influenced by the need for a low capture cross-section for neutrons. The unique conditions in nuclear plant, including the first wall of a fusion reactor.

Unit IV: [6 **hrs**]
Effects of radiation on physical and mechanical properties; Enhanced diffusivity, creep, phase stability, radiation hardening, embrittlement and corrosion. Radiation growth in uranium and graphite, thermal ratcheting of reactor fuel assemblies. Annealing processes. Wigner energy release in graphite.

Unit V: [6 **hrs**]
Nuclear metallurgy; Structures and properties of materials with special relevance for nuclear power generation: uranium and other actinides, beryllium, zirconium, rare-earth elements, graphite. The materials of nuclear fuels and nuclear fuel element fabrication. Reprocessing of nuclear fuel elements. Radiation-resistant construction steels; Overview of structural integrity issues. Fracture mechanics and non-destructive testing. Stress-corrosion cracking.

Unit VI: [6 **hrs**]
World energy supply, fission, fusion, future directions for nuclear power generation,

including use of thorium. Nuclear waste and its containment: Stability and dissolution of nuclear waste glasses. Synroc phases. Radionuclide-adapted mineral structures for fission products. Radiation damage in zircon and related materials.

Text Books:

- Bennet, D. J. & Thomson, J. R. , Elements of Nuclear Power Longman 3rd Edition 1989.
- Benedict, M, Pigford, T.H. & Levi H.W., Nuclear Chemical Engineering, Mcgraw-Hill 2nd Edition 1981.
- Glasstone, S. & Sesonske, A., Nuclear Reactor Engineering Vols 1-2 Chapman & Hall 4th Edition, 1994.

Reference Books:

- Harms, A. A., Principles Of Nuclear Science And Engineering RSP/Wiley 1987
- Martin, A. & Harbison, S. A., Introduction To Radiation Protection Chapman & Hall 4th Edition 1996.
- Nuttall, W.J., Nuclear Renaissance: Technologies And Policies For The Future of Nuclear Power, IOP, 2005.

Department Elective-III

(MT(DE)-18007) Surface Processing of materials

Teaching Scheme:
Lectures : 3 Hrs/week

Examination Scheme:
T1 and T2: 20 Marks each
End-Sem Exam: 60 Marks

Course Outcomes:
At the end of course students will be able to
1. apply fundamental knowledge of surface engineering in iproving various surface properties
2. apply surface preparation and modification methods for various applications
3. solve numerical, test materials, quantify and analyze different properties

Unit I: [7 **hrs**]
Importance of surface processing in modifying the properties of engineering components subjected to abrasion, wear, corrosion and fatigue, Preparation of the substrate for surface processing: Physical, chemical, electrochemical

Unit II: [**8 hrs**]
Various methods of surface modifications such as: Physical Vapor Deposition, Chemical Vapor Deposition (Chromium, Nickel, Titanium, Copper etc.), Ion Implantation method, Coatings for high temperature performance, Electrochemical and spark discharge processes, Plasma coating methods, Organic and Powder coatings, Thermal barrier coating, Advanced electron beam techniques, Laser surface processing, Coating on plastics.

Unit III: [7 **hrs**]
Applications of these methods in the fields like Mechanical, Metallurgical engineering, optical, electronics and surgical instruments, medicine and biotechnology.

Unit IV: [7 **hrs**]
Comparison of solar induced surface transformation of materials (SISTM) in processing of electronic materials with other direct energy methods such as Ions, Laser, Electron beam and Thin film deposition.

Unit V: [**7 hrs**]
Techniques for evaluation and characterization**.**

Text Books:

- Edited By J. R. Davis-Surface Engineering for Corrosion and Wear Resistance, ASM International, 2001
- George J. Rudzki -Surface Finishing Systems. metal and non-metal finishing handbook-

guide Metals Park : ASM, 1983

- James A. Murphy- Surface Preparation and Finishes for Metal, McGraw-Hill, New York (USA) 1971

Reference Books:

- H . Hochman- Ion plating & implantation application to material- ASM .
- P. G. Sheasby and R. Pinner - Surface treatment and finishing of Aluminium and its alloy, Volume-2, 5th ed., ASM, Metals Park, 1987
- K. E. Thelning -Steel and its Heat Treatment Bofors Handbook, London Butterworths, 1975
- Keith Austin - Surface Engineering Hand Book, London : Kogan Page, 1998.

Department Elective-III

(MT(DE)-18008) Light Metals and alloys

Teaching Scheme:
Lectures : 3 Hrs/week

Examination Scheme:
T1 and T2: 20 Marks each
End-Sem Exam: 60 Marks

Course Outcomes:
At the end of course students will be able to

1. understand various routes of synthesis of light metals and alloys
2. understand the physical metallurgy of aluminium alloys
3. analyze the effect of microstructure on mechanical properties of various light metals and alloys and relate both the parameters to the recent trends in applications of light metals and alloys
4. understand the effect of alloying elements on microstructure, physical properties and mechanical properties of Magnesium alloys and Titanium alloys

Unit I: [7 **hrs**]
The light Metals: General introduction, production of aluminium, production of magnesium, production of titanium, usage and economics

Unit II: [**8 hrs**]
Cast Aluminum Alloys: Thermodynamics and kinetics of solidification, homogeneous and heterogeneous nucleation, dendritic growth, solid/liquid Interface stability, Heat flow, heat evolution, shrinkage, macro and micro segregation, Recent advances in processing: Semisolid processing (SSP), Thixographic processing, Designation, temper and characteristics of cast aluminum alloys, Al-Si alloys Al-Cu alloys, Al-Mg alloys, Al-Zn-Mg alloys

Unit III: [7 **hrs**]
Wrought Aluminium Alloys: Production of wrought alloys, Designation of alloys and tempers, Work hardening of aluminium and its alloys, Heat treatable and Non heat treatable alloys, Defect in wrought alloys, Joining methods, Special products-aircraft ,automotive, packaging etc alloys.

Unit IV: [7 **hrs**]
Physical Metallurgy of Aluminium alloys: Principles of age hardening, Aging Processes, Corrosion, Mechanical behavior, Microstructures of different Al -alloys

Unit V: [**7 hrs**]
Magnesium alloys: Introduction to alloying behavior, Melting and casting ,Alloy designation and tempers, Zirconium free and zirconium containing casting alloys, Wrought alloys, latest trends in applications of Mg alloy, Heat treatment ,applications

[**7 hrs**]

Unit VI:

Titanium alloys: Introduction, alpha alloys, alpha –beta alloys, beta alloys, fabrication, Heat treatments, Applications

Text Books:

- I.J.Polmear, Light Alloys, Butterworth Heinemann, Fourth Edition

Reference Books:

- Handbook of Aluminium –Part-I
- R.W.Heine, C.R.Loper, P.C.Rosenthal, Principles of Metal Casting ,Tata McGraw Hill edition1976
- Semisolid Processing of Alloys edited by Kirkwood.

Department Elective-III

(MT(DE)-18009) Laser Materials Processing

Teaching Scheme:
Lectures : 3 Hrs/week

Examination Scheme:
T1 and T2: 20 Marks each
End-Sem Exam: 60 Marks

Course Outcomes:
At the end of course students will be able to
1. utilize the knowledge of lasers to apply in industrial material processing.
2. analyze, interpret and present observations about laser processing parameters on the structure and properties of processed components.
3. understand the peripheral accessories used in Laser material processing

Unit I: **[6 hrs]**
Industrial lasers, construction, CO2 laser, Solid state lasers, Diode laser, Excimer laser, disc and fibre laser, Comparison of lasers.

Unit II: **[6 hrs]**
Interaction of lasers with materials, reflection, absorption, Laser beam optics and characteristics – wavelength, coherence, mode and beam diameter, polarization; effect of wavelength, temperature, surface films, angle of incidence, materials and surface roughness, Spot size, focus, lens doublets, depolarizers, collimator, metal optics, scanning systems, fiber delivery systems.

Unit III: **[6 hrs]**
Heat flow theory: one-dimensional model, stationary point source models, moving point source models, Keyhole model, models for flow and stress

Unit IV: **[6 hrs]**
Applications of lasers in industry: process, mechanism, laser requirements, variations, performance and practical solutions, capabilities, advantages and limitations. Laser cutting, Laser welding, Laser surface treatment, rapid prototyping, laser bending, laser cleaning. Process automation, online control

Unit V: **[6 hrs]**
Laser safety, standards, safety limits, laser classification

Text Books:
- William M. Steen, Laser Material Processing, Spinger Verlag; 4th edition

Reference Books:
- Metals Handbook, ASM, Metals Pak, OH 44073
- Powell J. CO2 Laser cutting, Carl Hanser Verlag, Munich
- Carlsaw H.S. and Jaeger J.C., Conduction of heat in solids, Oxford University Press

Department Elective-IV

(MT(DE)-18010) Forging Technology

Teaching Scheme:
Lectures : 3 Hrs/week

Examination Scheme:
T1 and T2: 20 Marks each
End-Sem Exam: 60 Marks

Course Outcomes:
At the end of course students will be able to

- develop in depth understanding of forging technology and how it is different from other forming technologies
- Correlate metallurgical factors and its influence on mechanical properties of forged products
- learn about various forging processes, design concepts, and materials suitability for forging and dies.

Unit 1 **6 hrs**
Brief review of metal shaping processes, such as casting, hot rolling, cold rolling. Strengthening mechanism. Influence of alloying.
Introduction to forging, classification of forging based on Process and Equipment, examples of forging products.

Unit 2 **6 hrs**
Metal flow in die forging, Grain flow and its control, Effect of non-uniform deformation, Factors influencing die-filling.

Unit 3 **6 hrs**
Principal Forging Processes – Upset, Cogging, Fullering, Edging, Coining, Heading, Drawing Out, Ring Rolling, Swaging etc.
Types of forging equipment, Furnaces, Lubrication System

Unit 4 **6 hrs**
Estimation of the amount of deformation and Load calculations in forging
Principles of Die forging Design

Unit 5 **6 hrs**
Die Manufacturing, Selection of Die-Materials
Selection of Materials for forging, Finishing Operations, Heat Treatment, Thermo-mechanical processing

Unit 6 **6 hrs**

Forging Defects, Testing/Inspection Methods – Destructive and non-destructive tests, Die failures, Root Cause Analysis

Reference Books/Articles:

- ASM Metals Handbook, Forming and Forging, Vol.14, ASM Internationals, Metals Park, Ohio, USA
- Forging Practices, G.G. Kamenschchikov, S. Koltun, V. Naumov, B. Chernobrovkin, Foreign Language Publication House, Moscow, Russia
- Forging Materials and Practices, A.M. Sabrof, F.W. Boulger, H.J. Henning, Reinhold Book Corporation, New York, USA
- Metals Forming Technology: Die Design and Forging, Alwyn Thomas, UK
- Metallurgy of ferrous forgings, American Iron and Steel Institute, Washington D.C., USA
- Principles of forging design, American Iron and Steel Institute, Washington D.C., USA

e-resources:

- www.dtic.mil/dtic/tr/fulltext/u2/460465.pdf
- http://www.sut.ac.th/engineering/Metal/pdf/Metform
- http://thelibraryofmanufacturing.com/forging.html#defects
- Ref: Suranaree University of Technology
- http://forgingmagazine.com/feature/what-causes-dies-fail
- http://www.dropforging.net/manufacturing-of-forging-dies.html
- http://www.gatonbrass.com/metal-forging-guide/

Department Elective-IV

(MT(DE)-18011) Advanced Ceramic Technology

Teaching Scheme:
Lectures : 3 Hrs/week

Examination Scheme:
T1 and T2: 20 Marks each
End-Sem Exam: 60 Marks

Course Outcomes:
At the end of course students will be able to

- get in depth knowledge of few of advanced ceramics covered here.
- understand the important properties and applications of ceramics
- analyze and solve the problems related to advanced ceramics covered here.
- pursue research on any of the topic covered here.

Unit I: [7 **hrs**]
Dielectric materials, Basic Theory, Polarization (electronic, Ionic, dipolar, space charge), Dielectric constant and Loss, High-Q materials, high-ε_r materials, Capacitors and insulators, Frequency dependence of ε_r & tan δ, Temperature dependence of ε_r, resonant frequency; and tan δ, AC impedance & its measurement, ac conductivity, Debye equations, Dielectric Breakdown, factor affecting dielectric constant and loss

Unit II: [7 **hrs**]
Piezoelectric and ferroelectric materials, Crystallographic Considerations, Structural origin of the ferroelectric state, Hysteresis, Ferroelectric domains, Antiferroelectric Ceramics, Piezoelectric figures of merit (piezoelectric strain constant d, the piezoelectric voltage constant g, the electromechanical coupling factor k, the mechanical quality factor QM, and the acoustic impedance Z), Piezoelectric materials (Single Crystals, Polycrystalline Materials), Morphotropic phase boundary, Relaxor Ferroelectrics, Piezoelectric Devices such as pressure sensors, resonators/filters and actuators

Unit III: [7 **hrs**]
Ceramics for energy and environment technologies: Basic theory of Electrical and Ionic Conductivity in solids, fast ion conductors (FICs)/ solid electrolytes, Nernst-Einstein relationship, fuel cell : currently used materials: electrolytes, cathodes, anodes, interconnects, lithium and high energy batteries, production process of Li-ion battery , gas sensor and catalytic support, Ceramics in Electrochemical cells : Sodium sulphate cell (with β – alumina), Joncher's power law, Arrhenius equation, Activation energy.

Unit IV: [7 **hrs**]
Magnetic Ceramics : Spinel Ferrites , Hexagonal Ferrites , Garnet , Processing , Single crystal ferrite , Applications . Critical parameters, Powder synthesis

Unit V: [**7 hrs**]

Bioceramics: Structure of typical human bone, ceramics for artificial bone, requirement for artificial material to bond to living bone, apatite formation, Tissue attachment mechanism, Bio- active materials, nearly inert crystalline ceramics, bioceramic implants for hip and knee prosthesis; hydroxyapatite related ceramics/composites; porous ceramics, bioactive glass and glass ceramics, Bioactive cements, calcium phosphate ceramics, carbon base implant materials, ceramics for dental applications.

Unit VI: [**7 hrs**]

Glass and glass-ceramics: Definition of glass, Basic concepts of glass structure, theory of glass formation, Batch materials and minor ingredients and their functions, Elementary concept of glass manufacturing process, Different types of glasses. Application of glasses, Glass ceramics-controlled devitrification of a glass & fabrication, advantages of glass ceramic formation, properties and applications, Low temperature co-fired glass ceramics.

Text Books:

- M.W. Barsoum, Fundamentals of Ceramics,
- C. Barry Carter, M.Grant Norton, Ceramic Materials- Science and Engineering
- Physical Ceramics for Engineers - Van Vlack

Reference Books:

- Shigeyuki Somiya (Editor-in-Chief), Handbook of Advanced Ceramics, VOLUME II Processing and their Applications, Elsevier Academic Press, London, UK, 2003
- R.C. Buchanan, Ceramic Materials for Electronics, Processing, Properties and Applications
- S. Kumar: Hand book of ceramics ; Vol – I & II

Department Elective-IV

(MT(DE)-18012) Secondary Steel Making

Teaching Scheme:
Lectures : 3 Hrs/week

Examination Scheme:
T1 and T2: 20 Marks each
End-Sem Exam: 60 Marks

Course Outcomes:
At the end of course students will be able to
1. analyze effect of dissolved gases on soundness of casting
2. apply laws of thermodynamics and kinetics for producing clean steel
3. design process route for economical production of steel

Unit I: [8 **hrs**]
Ladle preparation & preheating for secondary steel operations, refractories required to withstand the temperatures, advances in refractories for improved life.

Unit II: [7 **hrs**]
Transport phenomena during taping of liquid steel- estimation of gas absorption during tapping. importance of slag free tapping.

Unit III: [7 **hrs**]
Thermodynamics & kinetics of deoxidation. types & selection of deoxidizers, metallurgical & thermodynamic conditions for good desulphurization and synthetic slag. wire injection techniques for increased efficiency of deoxidation &desulphurization. practical aspects in handling of liquid steel and safety precautions to be adopted in industry.

Unit IV: [7 **hrs**]
Specific stirring power of igp and types of porous plugs stoke's law for floatation of oxide inclusions. exogenous & endogenous inclusions. modification of inclusion morphology. thermodynamics of degassing of liquid steel. tank degassing vs circulatory degassing. stream degassing for vacuum teeming of ingots. performance indicies for clean steel.

Unit V: [**7 hrs**]
Principles of ESR & VAR.Aadvantages over traditional secondary steel making vs costs involved.

Text Books:

- Ahindra Ghosh & Amit Chatterjee - Iron and Steel Making – Theory & Practice, PHI Leasing Private Ltd.,2012
- Dipak Mazumdar- A First Course in Iron and Steel Making, Universities Press(India) Pvt. Ltd.
- Ahindra Ghosh - Secondary Steel Making: Principles & Applications, CRC Press.

Reference Books:

- Sham Suddic, Physical Chemistry of Metallurgical Processes, TMS Publication, 2017

Department Elective-IV
(MT(DE)-18013) Modeling of Engineering Materials

Teaching Scheme:
Lectures : 3 Hrs/week

Examination Scheme:
T1 and T2: 20 Marks each
End-Sem Exam: 60 Marks

Course Outcomes:
At the end of course students will be able to
1. understand the basics of modeling and computational simulation in materials science and engineering
2. find approximate solutions to the problems and to interpret and visualize the solutions
3. apply Monte Carlo and Molecular Dynamics Methods to solve materials problem
4. apply neural networks for material modeling

Unit I: **[6 hrs]**
Introduction of modeling:
Setting up of mathematical model, Simple linear model, Non-linear model and breakdown of analytical solutions, Integrated Computational Materials Engineering (ICME), macroscale, mesoscale, microscale, nanoscale and electronic scale

Unit II: **[6 hrs]**
Introduction to Material Modeling:
General aspects of materials modeling, modeling regimes, multiscale modeling, constructing a model, the early chemists' models, the modern model, the modeling of alloys

Unit III: **[6 hrs]**
Model based on Metallurgical Thermodynamics:
The thermodynamic functions, models of solutions, ideal solution, regular solutions, computation of phase diagrams, Quasichemical solution models, introduction to phase field modeling,

Unit IV: **[6 hrs]**
Monte Carlo and Molecular Dynamics Methods:
Thermodynamics and Statistical Mechanics of Atomistic Simulations, Role of Computer Simulations, Monte Carlo Methods, Markov Process, The Metropolis MC method, Accelerating the MC Method, Molecular Dynamics Methods, The Molecular Dynamics Algorithm

Unit V: **[6 hrs]**
Finite Elements Methods:
Stiffness Matrix Formulation, Single Spring, Spring in a System of Springs, System of

Two Springs, Minimizing Potential Energy, Element Attributes, Applications of FEM to thermal analysis and stress analysis

Unit VI: [6 hrs]

Application of neural networks to material modeling:

Physical and empirical models, linear regression, neural networks, overfitting, miscellany, Gaussian distributions, straight line in a Bayesian framework, application to sold state transformations in steel

Text Books

- C. Lakshman Rao and A.P. Deshpande, Modelling of Engineering Materials, Wiley, 2014
- Z.H. Barber, Introduction to Materials Modeling, Maney Publishing, London, 2005

Reference Books

- Harry Bhadeshia and Robert Honeycombe, Steels: Microstructure and Properties, 4^{th} Edition, Butterworth-Heinemann, 2017
- Chapra, S.C. & Canale, R. P.,Numerical Methods for Engineers, Tata McGraw Hill Publication (5th Edition)
- Janssens, Raabe, Kozeschnik, Miodownik, Nestler, Computational Materials Engineering: An Introduction to Microstructure Evolution, Academic Press, 2007
- G.J. Schmitz and U. Prahl, Integrative Computational Materials Engineering: Concepts and Applications of a Modular Simulation Platform, Wiley

Courses for B. Tech Minor (Metallurgical Engineering)

(MT-   ) Failure Analysis of Engineering Materials

Teaching Scheme:	**Examination Scheme:**
Lectures : 3 Hrs/week	T1 and T2: 20 Marks each
	End-Sem Exam: 60 Marks

Course Outcomes:

At the end of course students will be able to

1. understand techniques and stages of failure analysis.
2. understand the fundamentals of fracture mechanics
3. analyse elevated temperature and environmentally induced failures
4. understand the reasons behind failures of various engineering components like shaft, bearing etc.

Unit I: [6 **hrs**]

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

Unit II: [6 **hrs**]

Classification of fatigue and fracture modes, Distortion failure-Mechanism and types, stress system related single fracture of ductile and brittle material, stress verses strength relations in metallic materials, residual stress in engineering components, ductile and brittle fractures, fatigue fracture.

Unit III: [6 **hrs**]

Fundamentals of fracture mechanics**,** Factors affecting fracture mechanics, linear elastic fracture mechanics, elastic-plastic fracture mechanics, Factors affecting facture toughness, fracture toughness testing, fracture mechanics approach to failure

Unit IV: [6 **hrs**]

Casting/ welding related failure**,** Effect of non-metallic inclusions, segregation and dissolved gas on mechanical properties. Metallurgical failure in cast products and weldments.

Corrosion related failure, Corrosion failures, Life cycle of metals, basic nature of corrosion; type of corrosion(galvanic, crevice corrosion, pitting, stress corrosion, etc.), intercrystalline and transcrystalline corrosion in engineering components. Corrosion fatigue. Practical examples and case studies.

[6 **hrs**]

Unit V:

Elevated temperature failure, Creep Mechanism, Elevated temperature fatigue, thermal fatigue, metallurgical instabilities.

Environmentally induced failures. Wear related failure: wear type, contact stress fatigue prevention methods. Subsurface origin and surface origin fatigue; Sub-case origin, cavitation fatigue.

Unit VI: [6 **hrs**]

Case studies on failure of shaft, bearing, etc., failure of mechanical fasteners, failure in pressure vessels, Failure in welded structure, failure of gears, advanced experimental techniques in failure analysis.

Text Book:

- J.S. Collins, Failure of Materials In Mechanical Design, A Wiley Interscience Publication, 1993

Reference Books:

- Ross Bob, Investigating Mechanical Failures, Chapman & Hall, 1995
- G.E. Dieter, Mechanical Metallurgy, McGraw- Hill Education Pvt Ltd, New Delhi (India), 2016.
- ASM Hand Book Vol 19: Fatigue and Fracture, ASM International ,USA, 1996.

Courses for B.Tech Honors (Metallurgical Engineering)

(MT-   ) Amorphous materials

Teaching Scheme:	**Examination Scheme:**
Lectures : 3 Hrs/week	T1 and T2: 20 Marks each
	End-Sem Exam: 60 Marks

Course Outcomes:

At the end of course students will be able to

1. establish the conditions leading to the formation of amorphous materials
2. select and design the process for fabrication of glasses and glass ceramics
3. utilize various characterization techniques for establishing the structure – property correlation

Unit I: [6 **hrs**]

Network structure of various oxide glasses, Stevel's parameters and kinetic criterion of glass formation, Role of oxides in glass composition

Unit II: [6 **hrs**]

Melting, refining and forming of glasses, Viscoelastic behaviour of glasses and physical and mechanical properties, chemical durability of glasses

Unit III: [6 **hrs**]

Thermal, electrical and optical properties of glasses, heat treatment in glasses, Coloured and photosensitive glasses

Unit IV: [6 **hrs**]

Glass fibre technology, Glass-ceramics: Preparation, structure, properties and applications

Unit V: [**6 hrs**]

Characterization of glasses and glass – ceramics: Composition and structure analysis, microscopic techniques, thermal analysis

Unit VI: [**6 hrs**]

Preparation of metallic glasses by rapid solidification, Synthesis of amorphous alloys by mechanical alloying, Properties and applications of amorphous alloys, Microcrystalline and nanocrystalline materials.

Text Books:

- J.E. Shelby, Introduction to Glass Science and Technology, 2^{nd} Edition, Royal Society of Chemistry, Cambridge, 2005
- R.H. Doremus, Glass Science, 2^{nd} Edition, John Wiley and Sons, New York, 1994
- J. Zarzycki, Glasses and Amorpjous Materials Vol. 9 (Materials Science and Technology: A Comprehensive Treatment), Wiley VCH, New York, 1991

Reference Books:

- A.K. Varshneya, Fundamentals of Inorganic Glasses, 1^{st} Edition, Academic Press, London, 1994
- Paul, Chemistry of Glasses, 1^{st} Edition, Springer, Amsterdam, 1982
- Suryanarayan and A. Inoue, Bulk Metallic Glasses, 1^{st} Edition, CRC Press, Boca Raton, 2011
- E.L. Bourhis, Glass: Mechanics and Technology, 1^{st} Edition, Wiley VCH, Darmstadt, 2008
- H. Bach and D. Krause, Analysis of the Composition and Structure of Glass and Glass

Courses for B.Tech Honors (Metallurgical Engineering)

(MT-) High Temperature Corrosion

Teaching Scheme:
Lectures : 3 Hrs/week

Examination Scheme:
T1 and T2: 20 Marks each
End-Sem Exam: 60 Marks

Course Outcomes:
At the end of course students will be able to

- Understand thermodynamics approach to predict possibility of high temperature oxidation
- Understand oxidation kinetics and solve design problems.
- Understand hot corrosion mechanisms and their practical significance.
- Understand alloy design principles for high temperature corrosion resistance, selection of coating systems and materials for high temperature service.

Unit1 [6 **hrs**]

Thermodynamics Fundamentals_: Free Energy - the driving force behind oxidation, Variation of the Gibbs free energy with pressure and temperature, Variation of the Gibbs free energy with composition, Gibbs Free energy change and the equilibrium constant,Chemical Potential: An alternative approach to find driving force behind oxidation, Oxidation Thermodynamics, Construction and use of Richardson Jeffes diagram, Limitations of the diagram.

Unit 2 [6 **hrs**]

Oxide film formation and kinetics: Adsorption of oxygen, lateral growth of oxide nuclei and thin film formation, Thin film growth, Pilling – Bedworth ratio and its significance , Oxidation kinetics, Linear growth, Logarithmic and Inverse logarithmic growth, Wagner's experiment theory of parabolic growth.

Unit3 [6 **hrs**]

Defect structure of the metal oxides and oxidation of metals and alloys : Defect notations, Defect structures in stoichiometric oxides and in non stoichiometric oxides, Amorphous oxides and Transport mechanisms, Oxidation of - Nickel, Zinc, Aluminum, Iron and Cobalt and their alloys ,Internal and selective oxidation, Decarburization.

Unit 4 [6 **hrs**]

Oxidation in sulphur and carbon and reaction of metals in mixed environment:
Reactions with sulphur and carbon, Air- water vaopur and air- carbon dioxide systems,
Iron- oxygen- sulphur system factors affecting penetration of protective scales

Unit 5 [6 **hrs**]
Hot Corrosion : Degradation sequence, Initial stage and propagation modes, Basic and Acid Fluxing and sulphidation

Unit 6 [6 **hrs**]
Materials for High temperature service , Coatings and Atmosphere control: Super alloys, Intermetallics, Ceramics, Diffusion coatings, Pack Aluminizing, Overlay coatings, Thermal barrier coatings, Prevention of oxide layer formation, Protective atmospheres, Monitoring and control.

Text books

- Neil Birks, Gerald H. Meier and Freed S. Pettit: Introduction to the High Temperature Oxidation of Metals, Second Edition , 2006, Cambridge University Press, Cambridge, U.K. , 2006 **(ISBN 978- 0- 521-48042-0**)

- A.S. Khanna: High Temperature Oxidation and Corrosion, ASM International ,Materials Park Ohio, USA, 2004 **(ISBN 0-87170-762-4)**

Reference book

- David Young : High Temperature Oxidation and Corrosion of Metals, Elsevier Corrosion Series , Elsevier Publications , Oxford, U.K, 2008 **(ISBN 978--0-08-044587-8**)