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.
(Metallurgical Engineering)

(Revision: A.Y. 2021-22, Effective from: A.Y. 2022-23)

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Program Education Objectives (PEOs):

I. Graduate will have in-depth knowledge of Metallurgy and Materials Science aspects such as scientific principles of fabrication, phase transformations, mechanical treatment, heat treatment, structure-property correlations and service behavior of various types of materials necessary to formulate, solve and analyze critical engineering problems.

II. Graduate will be able to make a successful career in metallurgical and manufacturing industry, academics, research and development that meet the needs of Indian and multinational companies.

III. Graduate will be capable of solving unfamiliar problems through literature survey, deciding a suitable research methodology and conducting interdisciplinary/collaborative-multidisciplinary scientific research as per the need.

IV. Graduate will achieve the art of reflective learning, build hands-on experimental skills, and become familiar with modern engineering software tools and equipments and able to work independently or as a part of a team for successful project implementations in his/her professional life.

V. Graduate will acquire leadership qualities, techno-economical and social considerations, an aptitude for life-long learning, and get introduced to professional ethics and codes.

VI. Graduate will develop the ability to effectively communicate technical information in both written and oral form.

Program Outcomes (POs)

Engineering Graduates will be able to:

1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. **Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3. **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4. **Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5. **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

6. **The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

10. **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11. **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes (PSOs)

On completion of the B.Tech.(Metallurgical Engineering) degree, the graduates will be able to:

1. Design, develop and select new materials and processes to produce products with desired end properties, within optimum time and resources.
2. Apply modern software tools and quality control techniques to observe and understand the underlying mechanisms to perform structure - properties correlation, failure analysis, and provide solutions towards betterment of industry, R&D and society at large.

Correlation between the PEOs and the Pos

PO / PEO	1	2	3	4	5	6	7	8	9	10	11	12	PSO1	PSO 2
I	✓	✓	✓		✓		✓							✓
II	✓	✓	✓	✓	✓	✓	✓					✓		✓
III	✓	✓	✓	✓	✓	✓						✓	✓	
IV				✓	✓				✓	✓	✓	✓	✓	
V							✓		✓	✓	✓			✓
VI	✓	✓	✓					✓						✓

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

List of Abbreviations

Abbreviation	Title	No of courses	Credits	% of Credits
MLC	Mandatory Learning Course	1	0	0
SBC	Skill Based Course	1	8	27.59
PCC	Program Core Course	3	8	27.59
LC	Laboratory Course	2	2	6.90
IOC	Interdisciplinary Open Corse	1	2	6.90
DEC	Department Elective Course	3	9	31.02

Curriculum Structure

Final Year B. Tech (Metallurgical Engineering)

Scheme A

Semester VII

Sr. No.	Course Type	Course Code	Course Name	Teaching Scheme			Credits
				L	T	P	
1	MLC	ML-22001	Intellectual Property Rights	1	0	0	**0**
2	LLC		Liberal learning Course	1	0	0	**1**
3	IOC-II		Interdisciplinary Open Course-II	2	0	0	**2**
4	DEC	MT(DE)-22001 MT(DE)-22002 MT(DE)-22003 MT(DE)-22004	**Department Elective-II** • Nanomaterials and Nanotechnology • Powder Metallurgy • Electronic and Magnetic materials • Energy Materials	3	0	0	**3**
5	PCC1	MT-22001	Corrosion and Surface Protection	3	0	0	**3**
6	PCC2	MT-22002	Materials Joining	3	0	0	**3**
7	PCC3	MT-22003	Fatigue Creep and Fracture Mechanics	1	1	0	**2**
8	LC1	MT-22004	Corrosion and Surface Protection Laboratory	0	0	2	**1**
9	LC2	MT-22005	Materials Joining Laboratory	0	0	2	**1**
			Total Lectures-Tutorials-Practicals (L-T-P)	**14**	**1**	**4**	**16**
			Total Academic Engagement and Credits	**19**			**16**

Sr. No.	Semester	Minor Course	Honors Course	Lectures	Credits
1	VII	MT(MI)22001: Materials Joining	**Materials Engineering:** MT(HO)-22001:Phase Transformations in Materials **Process Metallurgy:** MT(HO)-22002: Advances in Iron and Steel Making	3	3

Final Year B. Tech (Metallurgical Engineering)

Scheme A

Semester VIII

Sr. No.	Course Type	Course Code	Course Name	Teaching Scheme			Credits
				L	T	P	
1	SBC	MT-22006	Major Project	0	0	16	**8**
2	DEC	 MT(DE)-22005 MT(DE)-22006 MT(DE)-22007 MT(DE)-22008	**Department Elective-III** • Surface Processing of Materials • Laser Materials Processing • Light Metals and Alloys • Design and Selection of Materials	3	0	0	**3**
3	DEC	 MT(DE)-22009 MT(DE)-22010 MT(DE)-22011 MT(DE)-22012	**Department Elective-IV** • Forging Technology • High Pressure Die Casting • Biomaterials • Modeling of Engineering Materials	3	0	0	**3**
			Total Lectures-Tutorials-Practicals (L-T-P)	**6**	**0**	**16**	**14**
			Total Academic Engagement and Credits	**22**			**14**

Sr. No.	Semester	Minor Course	Honors Course	Lectures	Credits
1	VIII	MT(MI)22002: High Pressure Die Casting	**Materials Engineering:** MT(HO)-22003: Noncrystalline Materials **Process Metallurgy:** MT(HO)-22004:High Temperature Corrosion	3	3

Curriculum Structure
Final Year B. Tech (Metallurgical Engineering)
Scheme B
Semester VII

Sr. No.	Course Type	Course Code	Course Name	Teaching Scheme			Credits
				L	T	P	
1	MLC	ML-22001	Intellectual Property Rights	1	0	0	0
2	LLC		Liberal Learning Course	1	0	0	1
3	IOC-II		Interdisciplinary Open Course-II	2	0	0	2
4	DEC	MT(DE)-22001 MT(DE)-22002 MT(DE)-22003 MT(DE)-22004	**Department Elective-II** • Nanomaterials and Nanotechnology • Powder Metallurgy • Electronic and Magnetic materials • Energy Materials	3	0	0	**3**
5	PCC	MT-22001	Corrosion and Surface Protection	3	0	0	3
6	PCC	MT-22002	Materials Joining	3	0	0	3
7	PCC	MT-22003	Fatigue Creep and Fracture Mechanics	1	1	0	2
8	LC	MT-22004	Corrosion and Surface Protection Lab	0	0	2	1
9	LC	MT-22005	Materials Joining Laboratory	0	0	2	1
			Total Lectures-Tutorials-Practicals (L-T-P)	**14**	**1**	**4**	**16**
			Total Academic Engagement and Credits	**19**			**16**

Sr. No.	Semester	Minor Course	Honors Course	Lectures	Credits
1	VII	MT(MI)22001 Materials Joining	**Materials Engineering:** MT(HO)-22001::Phase Transformations in Materials **Process Metallurgy:** MT(HO)-22002: Advances in Iron Steel Making	3	3

Final Year B. Tech (Metallurgical Engineering)

Scheme B

Semester VIII

Sr. No.	Course Type	Course Code	Course Name	Teaching Scheme			Credits
				L	T	P	
1	SBC	MT-22007	Major Project with Industry/Corporate/Academia	0	0	16	8
2	SLC	MT-22008	Massive Open Online Course -I (Students have to select any one MOOC course from the list of Department Elective-III* and IV**)	3	0	0	3
3	SLC	MT-22009	Massive Open Online Course -II (Students have to select any one MOOC course from the list of Department Elective-III* and IV**)	3	0	0	3
			Total Lectures-Tutorials-Practicals (L-T-P)	**6**	**0**	**16**	**14**
			Total Academic Engagement and Credits	**22**			**14**

***Department Elective-III**	****Department Elective-IV**
• Surface Processing of Materials • Laser Materials Processing • Light Metals and Alloys • Design and Selection of Materials	• Forging Technology • High Pressure Die Casting • Biomaterials • Modeling of Engineering Materials

Sr. No.	Semester	Minor Course	Honors Course	Lectures	Credits
1	VIII	MT(MI)22002: High Pressure Die Casting	**Materials Engineering:** MT(HO)-22003: Noncrystalline Materials **Process Metallurgy:** MT(HO)-2200:High Temperature Corrosion	3	3

[ML-22001] Intellectual Property Rights

Teaching Scheme | **Examination Scheme**
Lectures: 1 hr/week | Audit Course

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Infer that tomorrow's world will be ruled by ideas, concept, and creativity
2. Gather knowledge about Intellectual Property Rights which is important for students of engineering in particular as they are tomorrow's technocrats and creator of new technology.
3. Discover how IPR are regarded as a source of national wealth and mark of an economic leadership in context of global market scenario.
4. Study the national & International IP system.Evaluate
5. Summarize that it is an incentive for further research work and investment in R & D, leading to creation of new and better products and generation of economic and social benefits.

Unit 1 **(2 hrs)**

Introduction to the concepts Property and Intellectual Property:
Nature and importance of Intellectual Property Rights, Objectives of understanding Intellectual Property Rights

Unit 2 **(4 hrs)**

Understanding the types of Intellectual Property Rights:
Patents, Designs, Trademarks (Registered and unregistered trademarks) Copyright, Traditional Knowledge, Geographical Indications, Trade Secrets, Idea Patenting, (Case Studies)

Unit 3 **(3 hrs)**

New Developments in IPR:
Process of Patenting and Development: technological research, innovation, patenting, development…,International Scenario: WIPO, TRIPs

Unit 4 **(3 hrs)**

Indian Patent Office and its Administration
Administration of Patent System – Patenting under Indian Patent Act,Patenting under PCT

Unit 5 **(3 hrs)**

Patent Rights and its Scope, Licensing and transfer of technology,
Patent information and database. Provisional and Non Provisional Patent Application and

Specification

Reference Book:

- Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd ,2007
- Mayall, "Industrial Design", Mc Graw Hill
- Niebel, "Product Design" Mc Graw Hill
- Asimov, " Introduction to Design", Prentice Hall
- Robert P. Merges, Peter S. Menell, Mark A. Lemley," Intellectual Property in New Technological Age"
- T. Ramappa, S. Chand, "Intellectual Property Rights under WTO"

[MT(DE)-22001] Nanomaterials and Nanotechnology

Teaching Scheme	**Examination Scheme**
Lectures: 3 hrs./week	Test I - 20 Marks
	Test II - 20 Marks
	End Sem Exam - 60 marks

Course Outcomes:

At the end of the course, students will demonstrate the ability 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 and know characterization of nanomaterials using x-ray diffraction, laser particle size analyzer, transmission electron microscope (TEM) etc.
5. understand the theoretical concepts of about the applications of nanomaterials in structural, electronics, optical, magnetic, and bio-medical fields, nanocomposites etc.

Unit 1 **(6 hrs)**

Introduction to nanomaterials and nanotechnology: 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, phase transformation, mechanical properties, magnetic properties, optical properties, wear resistance and chemical sensitivity. Examples of inspiration from the Nature and ancient history

Unit 2 **(6 hrs)**

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, combustion method

Unit 3 **(6 hrs)**

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, combustion method.

Unit 4 **(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, Thermal analyser.

Unit 5 **(6 hrs)**

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

Unit 6 **(6 hrs)**

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

Textbooks:

- Rajendra Kumar Goyal," Nanomaterials and nanocomposites: Synthesis, Properties, Characterization Techniques and Applications" 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 Book:

- 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, "Handbook of Nanotechnology",3rd Revision, 2010, Springer-Verlag Publication 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)

[MT(DE)-22002] Powder Metallurgy

Teaching Scheme
Lectures: 3 hrs./week

Examination Scheme
Test I - 20 Marks
Test II - 20 Marks
End Sem Exam - 60 marks

Course Outcomes:
At the end of the course, students will demonstrate the ability to:

1. Identify various powder manufacturing processes
2. Explain effect of particle size and shape on compressibility of powders and its sinterability
3. Apply various characterization techniques for phase transformation and properties
4. Analyze sinterability of powders and processing variables
5. Evaluate structure-property of sintered products
6. Design alloy and process cycle for the materials

Unit 1 **(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; ASTM/MPIF standards

Unit 2 **(6 hrs)**

Production of Metal Powders: Introduction to Mechanical Processes: Machining, Crushing, Milling, Shotting Graining, Atomization; Physico-Chemical Processes: Condensation, Thermal Decomposition, Reduction, Electrodeposition, Precipitation from Aqueous Solution, Intergranular Corrosion. Electrometallurgy of high purity powders, Mechanical alloying.

Unit 3 **(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 Compaction and extrusion of powders, Powder Forging, Metal Injection Molding- feedstock preparation

Unit 4 **(6 hrs)**

Sintering Furnaces, Furnace Atmospheres, Types of Sintering processes, Different Mechanisms of Sintering, Liquid Phase Sintering and Activated Sintering, Sinter hardening, Sinterability of ferrous and Al, Cu, Cr, contacts materials, precious metals, diamond cutting tools, HSS tools and carbide tools, magnetic materials; sintering stages of MIM compacts.

Unit 5 **(6 hrs)**

High Entropy alloys: thermodynamics principles in designing of alloys; hard facing alloys for thermal coating /cladding/weld overlay; Powders for additive manufacturing of Engineering and biomedical components, and Secondary operations such as surface hardening treatment, Heat treatment and microstructural transformations, machinability.

Unit 6 **(6 hrs)**

Sustainable process and circular economy: extraction of metal powders, recycle and reuse of wastes, Case studies on Bearing Materials, Tool Materials, Ferrites, Cermet, Friction Materials, Medical and Dental Applications, Nuclear and Automotive Applications

Textbooks:

- Anish Upadhyaya and G S Upadhyaya, "- Powder Metallurgy Technology", University Press, 2011.
- Randall M German, "Powder Metallurgy and Particulate Materials Processing" MPIF, 2005

Reference Book:

- Powder Metallurgy, ASM Handbook,Vol.7,1984.
- Randall M German, "Sintering Theory and Practices", John Wiley and Sons,1996

[MT(DE)-22003] Electronic and Magnetic Materials

Teaching Scheme
Lectures: 3 hrs./week

Examination Scheme
Test I - 20 Marks
Test II - 20 Marks
End Sem Exam - 60 marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Identify and explain the basic principles of various electronic and magnetic materials.
2. Apply various laws and relations to evaluate the suitability of various electronic and magnetic materials for a particular application.
3. Analyze the effect of process parameters on the structure - property relationship of electrical engineering materials.
4. Engineer the synthesis-structure property relationship for the electronic materials according to recent commercial applications.

Unit 1 **(6 hrs)**

Electrical and Thermal Conduction In Solid metal and conduction by electrons, Resistivity and its Temperature dependence, Thermal Conductivity, Thermal Resistance Temperature coefficient of Resistivity, Impurity Effect, Resistivity Mixture Rule, Skin Effect. Electrical Conductivity of Non -Metals: Ionic Crystals and Glasses, Semiconductors, Solar Radiation Fundamentals

Unit 2 **(6 hrs)**

Semiconductors, Extrinsic, Intrinsic, Recombination and Generation in Semiconductors, Semiconductor Devices, Compound Semiconductor, Metal Semiconductor contacts, Microelectronic Devices Such as LED, CMOS, MOSFETS, BPT etc, Manufacturing Methods and Applications, Si wafer Manufacturing, Solar Cell Device and Quantum Efficiency Calculations

Unit 3 **(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 4 **(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, Magnetoelectric materials, Multiferroicity.

Unit 5 **(6 hrs)**

Optical Properties of Materials: Light and Electromagnetic Spectrum, Refraction, Absorption, Transmission and Reflection of Light, Luminescence, Laser, Optical Spectral bands, Basic optical laws and definitions, Optical fibers Modes and configurations, Fiber materials and fabrication, Optical Anisotropy, Electrooptic Effect, Electro-optic Ceramics, Antireflection Coating on Solar Cell.

Unit 6 **(6 hrs)**

Dielectric Materials and Insulation: Polarization, Relative Permitivity, Polarization Mechanisms, Dielectric Constant, Dielectric Loss, Capacitors and Insulators, Piezoelectric, Ferro Electric and Pyroelectric Materials, Supercapacitors.

Textbooks:

- 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.
- Robert Pierret, "Advanced Semiconductor Fundamentals", Vol.6 (Modular Series on Solid State Devices, Vol 6), 1987, Pearson Publication.
- S. M. Sze, Physics of Semiconductor Devices, 2006, Wiley Publication.

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.," Handbook of Magnetic Materials", Amsterdam: Elsevier, Volume 15, First Edition December 2003.

[MT(DE)-22004] Energy Materials

Teaching Scheme
Lectures: 3 hrs./week

Examination Scheme
Test I - 20 Marks
Test II - 20 Marks
End Sem Exam - 60 marks

Course Outcomes:
At the end of the course, students will demonstrate the ability to:

1. Identify methods for manufacturing process for materials
2. Explain the effect of processing parameters on material manufacturing
3. Apply thermodynamic and kinetic principles on development of materials
4. Analyze material processing system for recycle, reuse and circular economy
5. Evaluate sustainability of process on energy and carbon foot print
6. Design energy management system for storage, generation and conservation

Unit 1 **(6 hrs)**
Nuclear Materials: Materials Specifications for fuel, cladding, moderator, coolant, shield, pressure vessel; Materials selection influenced by the need for a low capture cross-section for neutrons. Nuclear metallurgy; Structures and properties of materials with special relevance for nuclear power generation: uranium and other actinides, beryllium, zirconium, graphite. Recycle and waste management and disposal. environmental impact; safety.

Unit 2 **(6 hrs)**
Hydrogen: production of hydrogen, green, blue and grey hydrogen; Hydrogen Storage alloys; thermodynamics and kinetics; fuel cell, applications in material processing, carbon footprint; safety and environmental impact; sustainability of process.

Unit 3 **(6 hrs)**
Rare earth metals**:** Types of raw materials, Extraction process such as fluorides/chlorides/metallothermic reduction and other processes, applications of these metals in ferrous and nonferrous and corresponding phase diagrams and physical metallurgy of alloys, safety and environmental impacts; sustainable process, recycle and reuse of waste; mass and energy management and reduction of carbon footprint.

Unit 4 **(6 hrs)**
Rare earth metals (La, Nd, Ce, Pr and others): Phase diagrams and physical metallurgy of alloys, processing techniques for magnetic and electronic magnetic materials; thermo-physical, electrical and magnetic and mechanical properties. Extraction techniques for Palladium and Platinum as catalyst in clean energy applications. Application of Ruthenium.

Unit 5 **(6 hrs)**

Solar Energy materials: raw materials; Extraction processes, properties of materials, applications in semiconductor for renewal energy. Thermoelectric materials; manufacturing techniques; Figure of merit. Seebeck and Peltier effect; Harvesting of waste heat; Hybrid energy systems; Application of thermoelectric to metallurgical processes.

Unit 6 **(6 hrs)**

Metal/nonmetals: production techniques; power to weight density; clean energy fuel vs fossil fuel; materials for batteries and power generation; recycle and environmental impact; Current trends in clean energy materials / graphene / ceramic-based systems and their applications.

Textbooks:

- C.K.Gupta," Materials in Nuclear Energy Applications", CRC Press, 1st Edition 1989
- M. Shamsuddin , "Physical Chemistry of Metallurgical Processes",2020

Reference Book:

- Konstantin. I. Popov, Stojan S. Djokic and Branimir N. Grgur, Fundamental Aspects of Electrometallurgy

[MT-22001] Corrosion and Surface Protection

Teaching Scheme
Lectures: 3 hrs./week

Examination Scheme
Test I - 20 Marks
Test II - 20 Marks
End Sem Exam - 60 marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Remember and understand concepts and fundamentals in corrosion.
2. Apply knowledge of material selection for different corrosive environments.
3. Apply knowledge of corrosion prevention methods, testing methods & standards
4. Analyze and establish correlation between thermodynamic and corrosion
5. Evaluate numericals and problems.
6. Create new material and corrosion prevention methods to mitigate corrosion

Unit 1 **(7 hrs)**

Importance of corrosion, Thermodynamics and Kinetics of Electrode Processes, Free energy concept, Nernst"s Equation, Emf Series, anodic and cathodic reactions, electrochemical cell analogy, Determination of corrosion tendency of metal. Pourbiax Diagram for Metal Water

System, Applications and Limitations, Concept of Over-Potential, Polarization Curves, Evan"s Corrosion Diagram, mixed potential theory, Kinetics Of Passivity and Transpassivity.

Unit 2 **(7 hrs)**

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

Unit 3 **(7 hrs)**

Principles of Corrosion Protection, Materials selection, Modification/Alteration of environment, Design, Corrosion Inhibitors, Cathodic protection, Anodic protection, Protective Coating

Unit 4 **(7 hrs)**

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

Unit 5 **(4 hrs)**

Corrosion Testing by Physical and Electrochemical Methods. Specimen Preparation, Exposure Technique salt spray, cyclic corrosion test, weatherometer, Weight loss by immersion test, Corrosion Rate Measurements by Electrochemical method. Intergranular Corrosion of austenitic stainless steel, A Few case studies

Unit 6 **(4 hrs)**

Standard: Use of ASTM standards like G-8, G-5, G-1, A262 etc. NACE standards / their equivalents, Equivalents IS.

Textbooks:

- 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 Book:

- D.A. Jones, "Principals and Prevention of Corrosion", 2nd intl. Ed., Prentice Hall International Singapore, 1995.
- L.L. Shreir, "Corrosion Volume I & II" , Butterworths Publication, 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-22002] Materials Joining

Teaching Scheme
Lectures: 3 hrs./week

Examination Scheme
Test I - 20 Marks
Test II - 20 Marks
End Sem Exam - 60 marks

Course Outcomes:
At the end of the course, students will demonstrate the ability to:

1. apply knowledge of mathematics, science, and engineering.
2. design and conduct experiments, as well as to analyze and interpret data.
3. identify, formulate, and solve engineering problems related to welding
4. have skills to communicate effectively
5. use the techniques, skills, and modern engineering tools necessary for engineering practice.
6. select and design welding materials, processes and inspection techniques based on application, fabrication and service conditions.
7. identify the defects in welded joints and perform the failures analysis and report in professional manner

Unit 1 **(6 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 2 **(6 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 3 **(6 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 4 **(6 hrs)**

Chemical Reactions in Welding, Gas-Metal, Slag-Metal Reactions, Metal Evaporation, Residual Stresses, Distortion, Fatigue of Welded Joints.

Unit 5 **(6 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 6 **(6 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.

Textbooks:

- 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 Hoboken 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 Book:

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

[MT22003] Fatigue, Creep and Fracture Mechanics

Teaching Scheme	**Examination Scheme**
Lecture: 1 hrs./week	Test I - 20 Marks
Tutorial:1hr./week	Test II - 20 Marks
	End Sem Exam - 60 marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Identify failure modes and analyze the reasons of failures of the components in service.

2. Understand macro and microscopic aspects of fracture mechanisms
3. Understand significance of the failure analysis techniques.
4. Understand fracture mechanics approach

Unit 1 **(6 hrs)**

An atomic view of fracture, Theoretical cleavage strength, Griffith's theory of fracture, Strain energy release rate, Plastic zone ahead of a crack tip, plain strain fracture toughness (K_{IC}), Crack Tip Opening Displacement, Strength of materials vs. fracture mechanics approach to engineering design.

Unit 2 **(6 hrs)**

Types of fracture, Fracture Mechanisms in Metals: Ductile Fracture - Void Nucleation, Growth and Coalescence, Brittle fracture- cleavage initiation and fracture, Combined fracture modes, Inter granular fracture, Ductile - Brittle Transition, Alloy design for fracture resistance.

Unit 3 **(6 hrs)**

Fatigue: Low cycle fatigue, Effect of mean stress and metallurgical factors on fatigue life, Micro structural aspects of fatigue failure, Cumulative fatigue damage estimation, Use of fracture mechanics to study fatigue crack propagation, Methods for improving fatigue life.

Unit 4 **(6 hrs)**

Creep: Temperature - stress- strain relations, Creep life estimation, Deformation mechanism maps, Creep fracture micro mechanisms, Creep- fatigue interactions, Alloy design for creep resistance.

Unit 5 **(6 hrs)**

Stress systems related to single load fracture of ductile and brittle metals, residual stresses, distortion , wear ,electrochemical and high temperature corrosion failures.

Unit 6 **(6 hrs)**

Failure case studies- shafts and gears, bearings, mechanical fasteners, welded and cast structures, failure analysis methodology and techniques.

Textbooks:

- Donald J. Wulpi, "Understanding How components fail", Third Edition ASM International, USA. ISBN : 978- 1-62708- 014 - 9, 2013
- Dieter, G.E., "Mechanical Metallurgy", Third Edition, McGraw- Hill Education Pvt Ltd,

New Delhi (India), 2017, ISBN:978-1259064791

Reference Book:

- T. L. Anderson, " Fracture Mechanics: Fundamentals and Applications", Third Edition, CRC Press, USA, 2005 , ISBN : 978-1-4200-5821-5 (eBook - PDF)
- Metals Hand Book, Vol 11, "Failure Analysis and Prevention", ASM International 1996, **ISBN: 978-1-62708-293-8**
- Proceedings of the Indian Academy of Sciences, Engineering Sciences, Vol 3 (12) Part 4 Dec 1980 and Vol 4 (13) Part1,April 1981 Published by The Indian Academy of Sciences, Bangalore, India

(MT-22004) Corrosion and Surface Protection Laboratory

Teaching Scheme
Practical: 2 hrs./week

Examination Scheme
Term work - 50 Marks
Oral – 50 Marks

Course Outcomes:
At the end of the laboratory work, students will demonstrate the ability to:

1. Remember and understand concepts and fundamentals in corrosion.
2. Apply knowledge of theory to conduct actual practical independently.
3. Analyze and interpret results obtained in experiments
4. Evaluate numericals and problems.
5. Create new material and corrosion prevention methods to mitigate corrosion

List of Experiments:
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);Stress corrosion cracking of Mg/Mg alloys in NaCl exposed at different time
11. Polarization and Electrochemical Impedance Study
12. Characterization by optical, SEM, XRD method

13. Effect of machining on microstructure and corrosion behaviour

(MT-22005)Materials Joining Laboratory

Teaching Scheme
Practical: 2 hrs./week

Examination Scheme
Term work - 50 Marks
Orall – 50 Marks

Course Outcomes:
At the end of the laboratory work, students will demonstrate the ability to:

1. apply knowledge of mathematics, science, and engineering.
2. understand how to design and conduct experiments, as well as to analyze and interpret data.
3. identify, formulate, and solve engineering problems related to welding
4. communicate effectively
5. select and design welding materials, processes and inspection techniques based on application, fabrication and service conditions.
6. identify the defects in welded joints and perform the failures analysis and report in professional manner

List of Experiments:
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

Course for B.Tech Honors (Materials Engineering)
[MT(HO)-22001] Phase Transformation in Materials

Teaching Scheme
Lectures: 3 hrs./week

Examination Scheme
Test I - 20 Marks
Test II - 20 Marks
End Sem Exam - 60 marks

Course Outcomes:

At the end of the laboratory work, students will demonstrate the ability to:

1. utilize the knowledge to understand how desired properties in materials for industrial application can be achieved through effective phase transformation in materials
2. develop new materials through research and development activities.
3. analyze, interpret the phase transformation data to design effective heat treatment cycles
4. design and selection of materials for fulfilling the objectives of functional requirements

Unit 1 **(6 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 2 **(6 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,. factor affecting diffusion, role of vacancy, crystal structures, dislocation and strength of materials, plastic flow, Kirkendall effect

Unit 3 **(6 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. advantages of austempering, phase transformation in HAZ & sensitization due to welding.

Unit 4 **(6 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. Structure – properties correlation with specific examples of various ferrous alloys, pearlite, spheroidised and martensite phases with reference to supercooling, critical nucleus size and TTT diagram, influence of prior normalized and spheroidized strcucture on the final hardened & tempered microstructure, effect of retained austenite on the finished components like bearings.

Unit 5 **(6 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 6 **(6 hrs)**

Precipitation hardening: Structural changes, Mechanism and integration of reactions, example of Al-alloy application in aircraft, automobiles, carbide precipitation leading to sensitization of stainless steels and inter-granular corrosion, EFS structure in tool steels. 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 Ternary diagrams of alloy & Oxide system – examples practical applications refractory, ceramics and slags.

Textbooks:

- William D. Callisters, Jr., "Materials Science and Engineering, An introduction", by 7th Edition, John Wiley & Sons, Inc, 2011.
- David A. Porter, Kenneth E. Easterling, and Mohamed Y. Sherif, "Phase Transformation in Metals and Alloys" CRC Press, 3rd Ed. (Indian reprint), 2009.

Reference Book:

- V. Raghavan," Solid State Phase Transformations" Prentice-Hall of India (P) Ltd., N. Delhi, 1987.
- R. E. Smallman and R.J. Bishop," Modern Physical Metallurgy and Materials Enginering", 6th Edition, Butterworth Heinemann, 1999.
- P. Cotterill & P. R. Mould, "Recovery Recrystallization & Grain Growth in Metals Surrey, University Press
- Cahn, Haasen,"Physical Metallurgy, North Holland Physics Publication

Course for B.Tech Honors (Process Metallurgy)
[MT(HO)-22002] Advances in Iron and Steel Making

Teaching Scheme
Lectures: 3 hrs./week

Examination Scheme
Test I - 20 Marks
Test II - 20 Marks
End Sem Exam - 60 marks

Course Outcomes:

At the end of the laboratory work, students will demonstrate the ability to:

1. Design alloy chemistry for manufacturing/procurement of desired composition of the steel as per the specification.
2. Decide raw materials quality and sequence of refining for making clean steel.
3. Control the cost of the steel by careful selection of the raw materials and other necessary ingredients required for steel manufacturing.
4. Understand metallurgical benefits of ingot and continuous cast products.
5. Devise ways for energy conservation and environmental pollution.

Unit 1 **(6 hrs)**

Raw Materials for Steel making, Refractories, Scrap, Fluxes, Sponge Iron production, Electric Furnace

Unit 2 **(6 hrs)**

Steel Making, Construction, Operation, Transformer Rating, Primary and Secondary Circuit, Power Factor, Thermal efficiency of the furnace.

Unit 3 **(6 hrs)**

Ladle Metallurgy: Construction and Operation of LRF, Principle of Steel making and Refining Technology,

Unit 4 **(6 hrs)**

Gases removal, Deoxidation of Steel and Non-Metallic inclusions, Role of Slag Composition on Quality of Steel, Processes-AOD, VOD& VD.

Unit 5 **(6 hrs)**

Continuous Casting M/Cs Operation and Construction, bloom, Billet, Slab and Thin strip Caster, primary and Secondary Cooling, Process parameters of the caster. Ingot Casting: Types of Moulds, Defects in Cast Product,

Unit 6 **(6 hrs)**

Electromagnetic Stirring (EMS) for Quality improvement, Types of EMS, Selection Advantages, and Disadvantages. Dust generation from Furnaces and environmental impacts

Textbooks:

- Dr.R.H.Tupkari, "Introduction to Modern Steel Making" Khanna Publishers

Reference Book:

- V. Kudrin, " Steel Making" , Mir. Publisher
- Edneral, "Electrometallurgy-I "
- J.J.Moore,, "Continuous Casting Vol-III
- Irving W.R,"Continuous Casting of Steel"

Semester VIII

[MT(DE)-22005] Surface Processing of Materials

Teaching Scheme
Lectures: 3 hrs./week

Examination Scheme
Test I - 20 Marks
Test II - 20 Marks
End Sem Exam - 60 marks

Course Outcomes:

At the end of the laboratory work, students will demonstrate the ability to:

1. Remember and understand concepts and fundamentals in surface processing of materials.
2. Apply knowledge of surface engineering for development of useful property.
3. Analyze and establish correlation between surface engineering and functional properties
4. Evaluate numericals and problems.
5. Create new surface coating methods to improve performance

Unit 1 **(6 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 2 **(6 hrs)**

Various methods of surface modifications such as: Physical Vapor Deposition, Chemical Vapor Deposition (Chromium, Nickel, Titanium, Copper etc.), Electrochemical and spark discharge processes.

Unit 3 **(6 hrs)**

Various methods of surface modifications such as: Ion Implantation method, Coatings for high temperature performance, Thermal barrier coating ,Plasma coating methods , Advanced electron beam techniques, Laser surface processing

Unit 4 **(6 hrs)**

Solar induced surface transformation of materials (SISTM) in surface processing of materials and compared with other direct energy methods such as Ions, Laser, Electron beam and Thin film deposition. Organic and Powder coatings, Coating on plastics.

Unit 5 **(6 hrs)**

Applications of these methods in the fields like Mechanical, Metallurgical engineering, optical, electronics and surgical instruments, medicine and biotechnology

Unit 6 **(6 hrs)**

Testing methods and Techniques for evaluation and characterization. Coating thickness measurement, Adhesion testing methods: Bend test, tape test, pull-off adhesion test. Microhardness test. Optical microscopy, scanning electron microscopy, X-ray diffraction

Textbooks:

- 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 Book:

- 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.

[MT(DE)-22006] Laser Materials Processing

Teaching Scheme
Lectures: 3 hrs./week

Examination Scheme
Test I - 20 Marks
Test II - 20 Marks
End Sem Exam - 60 marks

Course Outcomes:

At the end of the laboratory work, students will demonstrate the ability to:

1. utilize the knowledge of lasers to apply in industries and research organizations for material processing.
2. analyze, interpret and present observations about laser processing parameters on the structure and properties of processed components.
3. demonstrate the ability to function in engineering industries and science laboratory teams, as well as on multidisciplinary projects.
4. have the confidence to apply laser engineering solutions in global and societal contexts

Unit 1 **(7 hrs)**

Industrial lasers, construction, CO_2 laser, Solid state lasers, Diode laser, Excimer laser, disc and fibre laser, Comparison of lasers.

Unit 2 **(8 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 3 **(7 hrs)**

Heat flow theory: one-dimensional model, stationary point source models, moving point source models, Keyhole model, models for flow and stress

Unit 4 **(7 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 5 **(7 hrs)**

Laser safety, standards, safety limits, laser classification

Textbooks:

- William M. Steen, " Laser Material Processing", Spinger International edition, ISBN: 978-81-8128-880-6, 2008

Reference Book:

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

[MT(DE)-22007] Light Metals and Alloys

Teaching Scheme
Lectures: 3 hrs./week

Examination Scheme
Test I - 20 Marks
Test II - 20 Marks
End Sem Exam - 60 marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Identify methods for manufacturing process for metal and its alloys
2. Explain the effect of processing parameters solidification / casting/ deformation behavior
3. Apply thermodynamics and kinetic principles on degree of recovery of metals and its alloys.
4. Analyze metallurgical soundness of resultant products and process
5. Evaluate sustainability of process, mass, energy and waste management

Unit 1 **(6 hrs)**

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,

Unit 2 **(6 hrs)**

Aluminum and its alloys: Extraction process, melting and solidification, phase diagrams and physical metallurgy of alloys; Alloy designing and its designation and alloying elements, latest trends in applications of Al alloy, heat treatment; mechanical processing- rolling, extrusion.

Unit 3 **(6 hrs)**

Magnesium and its alloys: Extraction process, melting and solidification, phase diagrams and physical metallurgy of alloys; Alloy designing and its designation, latest trends in applications of Mg alloy, heat treatment; mechanical processing- rolling, extrusion,

Unit 4 **(6 hrs)**

Titanium and its alloys**:** Extraction process, phase diagrams and physical metallurgy of alloys; Alloy designing and its designation, latest trends in applications of Ti alloy, heat treatment

Unit 5 **(6 hrs)**

Lithium Metal and its alloys: Extraction process, melting and solidification, phase diagrams and physical metallurgy of alloys; Alloy designing and its designation, safety, and environmental impacts; sustainable process, recycle and reuse of waste; energy management and reduction of carbon footprint.

Unit 6 **(6 hrs)**

Calcium and Sodium Metal and its alloys: Extraction process, melting and solidification, phase diagrams and physical metallurgy of alloys; Recycling of EV batteries.energy materials

Textbooks:

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

Reference Book:

- Handbook of Aluminium –Part-I
- R.W. Heine, C.R.Loper, P.C.Rosenthal," Principles of Metal Casting ,Tata McGraw Hill Edition ,1976
- Kirkwood, "Semisolid Processing of Alloys"
- M. Samsuddin, "Physical Chemistry of Metallurgical Processes" TMS, 2016

[MT(DE)-22008] Design and Selection of Materials

Teaching Scheme
Lectures: 3 hrs./week

Examination Scheme
Test I - 20 Marks
Test II - 20 Marks
End Sem Exam - 60 marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. utilize the knowledge to design and manufacture numerous machines and structures for industrial applications
2. understand the techniques to identify right kind of material and process to satisfy all functional requirements to develop superior and efficient machines
3. gain knowledge regarding the scientific methodology with multidisciplinary approach involving a strong team with effective communication and knowledge sharing understanding

Unit 1 **(6 hrs)**

Materials in Design, Evolution of Engineering Materials, Design process, Types of design,

Design flow chart- tools and material data, Interaction between Function, attributes, Standards grades & properties,, Material domain, screening, ranking, supporting information, cost & availability Material, Shape and Process establishing design strategy, failure analysis & case studies, alternative materials

Unit 2 (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

Some important tests like, Hardness, tensile, bend, creep, fatigue, Erichsen cupping, wear, DBTT, IGC, fracture toughness, surface roughness, bearing life test, rollingcontact fatigue, ultrasonic test, magnetic particle test, ceramic & refractory tests - spalling, softening temperature, pyrometric cone equivalent, porosity etc - standards applicable all tests (ASTM, DIN etc)

Unit 3 (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, Material index, strength / weight ratio computer aided selection, structural index; Case studies:, flywheel, springs, elastic hinges, seals, pressure vessels, passive solar heating, gears, precision devices, bearings, rock drill bits, turbine blades, high temperature turbine blades, heat exchangers, airframes, ship structures, jaw crusher, rock drill bits, engines and power generation, automobile structures, special materials :Ti –alloys, Graphene, superalloys, stainless steels for nuclear application

Unit 4 (6 hrs)

Materials Substitution, Pugh Method, concurrent engineering design, Cost–Benefit Analysis, Cost basis for selection, causes of failure in service- bearings, crankshafts, gears, shaft, ships& pipelines at sub-zero regions Specifications, quality and process control, Selection for static strength, toughness, stiffness, fatigue strength, creep, corrosion resistance, wear resistance, sub-zero temperature applications, orthopedic, material databases

Unit 5 (6 hrs)

Process selection, ranking processes, cost, computer based process selection, Case studies: fan, pressure vessel, optical table, cast tables, manifold jacket, vibration tables, ladle hook, jaw crusher, antiaircraft gun, high tension lines, spark plug insulator, heat sink, crash barrier for highways / bridges, ceramics for crockeries, tiles electronics applications, & refractory bricks for furnaces etc, concept of material – process compatibility - examples, HPDC, powder method for very high melting point materials, Process selection criteria, ranking processes, cost, computer based process selection, Case studies: fan, pressure vessel, optical table, cast tables, manifold jacket, spark plug insulator

Unit 6 **(6 hrs)**

Selection under multiple constraints, conflicting objectives, penalty-functions, exchange constants,. To explain the advantages and the critical aspects of strategy formation for materials & process selection with respect to design and construction of machines of the modern age, where good performance, long life, low cost, use of exotic materials, safety and cutting edge technology are the important factors in the process of design and selection of materials.

Textbooks:

- Michael F. Ashby, "Materials Selection in Mechanical Design", Fifth edition, Elsevier, 2016
- J. Charles, F.A.A. Crane, J. A.G. Furness, "Selection and Use of Engineering Materials", third edition, Butterworth-Heinemann, 2006

Reference Book:

- 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(DE)-22009] Forging Technology

Teaching Scheme
Lectures: 3 hrs./week

Examination Scheme
Test I - 20 Marks
Test II - 20 Marks
End Sem Exam - 60 marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. develop in depth understanding of forging technology and how it is different from other forming technologies.
2. learn metallurgical factors and its influence on mechanical properties of forged products
3. 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

Textbooks:

- G.G. Kamenschchikov, S. Koltun, V. Naumov, B. Chernobrovkin, "Forging Practices", Foreign Language Publication House, Moscow, Russia
- A.M. Sabrof, F.W. Boulger, H.J. Henning, "Forging Materials and Practices", Reinhold Book Corporation, New York, USA

Reference Book:

- ASM Metals Handbook, Forming and Forging, Vol.14, ASM Internationals, Metals Park, Ohio, USA
- Alwyn Thomas, " Metals Forming Technology: Die Design and Forging" , UK
- Metallurgy of ferrous forgings, American Iron & Steel Institute, Washington DC, USA
- Principles of forging design, American Iron & Steel Institute, Washington DC, USA

[MT(DE)-22010] High Pressure Die Casting

Teaching Scheme
Lectures: 3 hrs./week

Examination Scheme
Test I - 20 Marks
Test II - 20 Marks
End Sem Exam - 60 marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Establish correlation between process parameters to resultant die casting.
2. Solve numerical problems related to die casting design
3. Understand concepts and process capabilities of casting
4. Know pre-treatment and post heat treatments of die castings
5. Analyze die casting defects and their remedial measures.

Unit 1 **(6 hrs)**

Introduction. Evolution of die-casting processes. Permanent mold casting. Die-casting of low melting metals and alloys, Zinc and lead alloys. Die-casting of aluminum alloys. Hot-chamber and cold-chamber pressure die casting methods. Low pressures die casting developments. General advantages and limitations of high-pressure die-casting methods

Unit 2 **(6 hrs)**

High pressure die-casting machines. Plate type and toggle type machines. Range of pressures and capacities of HPDC machines. PQ2 analysis of machine capacity. Basic process and pressure-time cycles. Hydraulic systems. General control systems in HPDC machines.

Unit 3 **(6 hrs)**

Alloys for HPDC method. Zinc alloys. Aluminum alloys. Alloys with short and long melting temperature ranges. Hot shortness and related solidification problems. Common Aluminum die-casting alloys.

Unit 4 **(6 hrs**

Melting methods and melt quality problems in aluminum alloys, charge calculation for alloy preparation, raw materials, quality, cost of production and energy consumption Scrap, ingots, master alloys, degassing agents and other additives. Gas content measurement. Densitometry for casting quality. Analytical methods for routine heat quality records. Basic factors in the process of solidification in metallic molds. Solidification: Controlled solidification Microstructure Development, etc., Inspection/Quality Check: mechanical/ Microstructural/ physical/ Chemical properties, NDT etc.

Unit 5 **(6 hrs)**

Dies for High pressure die-casting processes. Common alloys for HPDC dies and their heat-treatment. CAD systems for HPDC die design. Provision of cooling channels, inserts and supports in die-design. Die-coats and die-casting consumables

Unit 6 **(6 hrs)**

High Integrity Die Castings. Advanced methods for high integrity and quality aluminum pressure die- castings. Squeeze casting, Semi-solid casting methods, Rheo-casting, vacuum die casting systems. Design and simulation of High Pressure Die Casting process.

Textbooks:

- Degarmo, E. Paul; Black, J T.; Kohser, Ronald A., "Materials and Processes in Manufacturing", (9th ed.), Wiley(2003), ISBN 0-471-65653-4.
- Andresen, Bill, "Die Casting Engineering", New York: Marcel Dekker, (2005) ISBN 978-0-8247-5935-3.
- Alan Kaye and Arthur Street, "Die Casting Metallurgy", Butterworths Monographs in Materials, 1982.
- Davis, J. (1995), "Tool Materials, Materials Park: ASM International", ISBN 978-0-87170-545-7.

Reference Book:

- ASM Metals Handbook, 9th Edition, Vol 15: Casting, 2008, Metals Park, Ohio, U.S.A.
- Brevick, Jerald; Mount-Campbell, Clark; Mobley, Carroll, "Energy Consumption of Die Casting Operations (PDF), Ohio State University. 2004
- North American Die Casting Association, Arlington Heights, Illinois IL 60004, USA.: Publications and Handbooks, 2015.

[MT(DE)-22011] Biomaterials

Teaching Scheme
Lectures: 3 hrs./week

Examination Scheme
Test I - 20 Marks
Test II - 20 Marks
End Sem Exam - 60 marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Define and demonstrate basic knowledge and understanding of the biomaterials
2. Able to classify the biomaterials and understand its properties
3. Selection and application of suitable biomaterials
4. Analyse and evaluate biocompatibility tests and other properties of the biomaterials

for the intended application
5. Choose application areas of the various biomaterials and their limitations and recommendations

Unit 1 **(6 hrs)**

Introduction to Biomaterials: Social, Environmental & Ethical Issue,Building Blocks of the Human Body, Fundamentals of Human Biology and Anatomy Interactions of materials with the human body

Unit 2 **(6 hrs)**

Classification of biomaterials with applicable standards Properties of biomaterials: mechanical properties (Hardness, yield strength, ductility toughness, elongation); tribological (friction, wear, lubricity); physical (electrical, optical, magnetic, thermal); morphology and texture, chemical and biological properties. Criteria for selection of biomaterials for specific medical applications, Structure and property relationships of different classes of biomaterials

Unit 3 **(6 hrs)**

Tissue-Biomaterial Interactions, General Concepts of biocompatibility, Testing of biomaterials: Evaluation of biocompatibility(ISO10993), and other properties of biomaterials; in vitro and in vivo tests; preclinical and clinical trials or tests, Classification of medical devices as per USFDA, EMDR, CDSCO

Unit 4 **(6 hrs)**

Corrosion (metallic biomaterials) Applicable standards, biodegradation, simulated body fluids and their effect on biodegradation, short- and long-term interaction with body, prevention of corrosion in biomaterials to improve properties and corrosion resistance of biomaterials.

Unit 5 **(6 hrs)**

Processing of biomaterials, applicable advanced technologies for processing
Biomaterial application in: Soft & hard Tissue Replacement Joints: Orthopedic implants, Spinal implants, ,Dental Restorations, and Implants, Ocular materials, ocular materials, Applicable standards, and case studies of some of the applications

Unit 6 **(6 hrs)**

Blood Interfacing Implants and Applications: Vascular Grafts, Heart Valves, Artificial Organs Stents, and Assist Devices Tissue Engineering Materials and Regeneration: Scaffolds materials, types, properties, and applications, Controlled Release Systems: Drug delivery carriers, biomaterials for Targeted Delivery, Applicable standards, case studies of some of the applications

Textbooks:

- Vasif Hasirci , Nesrin Hasirci, "Fundamentals of Biomaterials" , Springer

Reference Book:

- Buddy D. Ratner, Allan S. Hoffman, Frederick J. Schoen, Jack E. Lemons, "Biomaterials Science: An Introduction to Materials in Medicine", 4^{th}Edition, Academic press, UK.
- Fredrick H. Silver," Biomaterials, Medical Devices & Tissue Engineering: An integrated approach", 1994, Chapman & Hall, UK.
- B.Basu, D.Katti and Ashokkumar, "Advanced Boimaterials: Fundamentals, Processing and Applications", John Wiley and Sons, USA
- Jonathan Black, "Biological performance of Materials : Fundamentals of Biocomaptibilty" Marcel Dekker

[MT(DE)-22012] Modeling of Engineering Materials

Teaching Scheme
Lectures: 3 hrs./week

Examination Scheme
Test I - 20 Marks
Test II - 20 Marks
End Sem Exam - 60 marks

Course Outcomes:
At the end of the course, students will demonstrate the ability to:

1. understand the basics of modeling and computational simulation in materials science and engineering
2. study different tools such as matlab/scilab/spreadsheet for solving mathematical problems in materials and their processing
3. find approximate solutions to the problems, to interpret and visualize the solutions

Unit 1 **(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 2 **(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 3 **(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 4 **(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 5 **(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 6 **(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

Textbooks:

- 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 Book:

- Harry Bhadeshia and Robert Honeycombe*, "*Steels: Microstructure and Properties", 4th 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

[MT-22006/MT-22007] Major Project

Teaching Scheme
Practical : 16 hrs./week

Examination Scheme
Term Work - 50 Marks
Oral – 50 Marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to

1. demonstrate their knowledge in science and engineering.
2. perform experiments independently in metallurgy, characterize and can propose proper material and/or process selection.
3. to function on engineering and science laboratory in teams, as well as on multidisciplinary projects. Students understand professional and social responsibilities.
4. Prove the ability to present the findings in a written report or oral presentation

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 semesters and at the end of semester .In the final stage, it will be externally evaluated on the basis of oral/seminar talk.

Course for B.Tech Honors (Materials Engineering)
[MT(HO)-22003] Non-Crystalline Materials

Teaching Scheme	**Examination Scheme**
Lectures: 3 hrs./week	Test I - 20 Marks
	Test II - 20 Marks
	End Sem Exam - 60 marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. Establish conditions which lead to formation of amorphous and crystalline materials.
2. Develop correlations between structure and properties.
3. Select and design composition for the development of glasses and glass-ceramics required for various applications.
4. Design processes for the forming of glasses.

Unit 1 **(6 hrs)**

Introduction to Glasses: Importance of glasses in human life, Global and Indian glass production status, A brief history of glass making,Various definitions of glass, Structural and kinetic theories of glass formation, Factors affecting glass formation, Determination of glass forming

Unit 2 **(6 hrs)**

Structure of Glasses and their Melting: Factors affecting the structure of glasses, Glass formation rules, Structure of: Silicate glasses and their variants, borate glasses and their variants, chalcogenide glasses in terms of characteristic Qn units, bridging and non-bridging oxygen and number of tetrahedra, Essential agents required in glass melting, Mechanism of batch melting, Fining of and homogenization of melts, Chemical analysis of prepared glasses

Unit 3 **(6 hrs)**

Viscoelastic Behaviour and Glass Technology: Temperature dependence of viscosity of glasses, Concept of working range, Viscosity measurement techniques, Viscoelastic behaviour, Maxwell Model, Fragility of the melt, Composition dependence of viscosity, Glass Technology: Gob feeder process, Container processes, Danner process, Float glass process, Processes for production of toughened glasses, Fibre glass production processes

Unit 4 **(6 hrs)**

Properties of Glasses: Density, Thermal expansion behaviour, Transport properties: Diffusion, chemical durability and ionic conductivity, Mechanical properties: theoretical vs. practical strength, Factors affecting crack propagation, Thermal shock resistance, Strengthening, Simultaneous action of stress and environment, Optical properties: bulk properties (refraction and optical dispersion), Optical effects associated with colour, Other effects (photosensitivity, photochromism, electrochromism, light scattering etc.)

Unit 5 **(6 hrs)**

Glass-ceramics: Need for glass-ceramics, Composition selection to produce glass-ceramics, Heat treatment cycle to produce glass-ceramics, Role of various constituents, Phase and microstructure analysis, Electrical, thermal and mechanical behaviour of glass-ceramics, Comparative study of composition and properties of commercial glasses and glass-ceramics for applications such as window, container, solar, labware, electrical, substrate, sealing etc.

Unit 6 **(6 hrs)**

Bioglasses and Metallic glasses: Need for biomaterials, Advantages of bioglass over other biomaterials, Composition and properties of clinically used bioactive systems, Interfacial reactions in bioactive implants, Metallic glasses: Departure from equilibrium, Criteria for formation of bulk metallic glasses (BMGs), Processes for producing BMGs, Properties and applications of BMGs

Textbooks:

- James E. Shelby," Introduction to Glass Science and Technology", 3rd Edition, Royal Society of Chemistry, London, 2020
- Arun K. Varshneya and John C. Mauro," Fundamentals of Inorganic Glasses", 3rd Edition, Elsevier, Amsterdam, 2019

Reference Book:

- H. Scholze," Glass: Nature, Structure and Properties", Springer-Verlag, New York, 1991.
- J. Zarzycki, " Glasses and the Vitreous State", Cambridge Univ. Press, 1991.
- S.J. Schneider Jr., "Ceramics and Glasses" , Engineered Materials Handbook, Vol. 4, ASM International, Ohio, 1991.

Course for B.Tech Honors (Process Metallurgy)
[MT(HO)-22004] High Temperature Corrosion

Teaching Scheme
Lectures: 3 hrs./week

Examination Scheme
Test I - 20 Marks
Test II - 20 Marks
End Sem Exam - 60 marks

Course Outcomes:

At the end of the course, students will demonstrate the ability to:

1. establish correlation between thermodynamic and high temperature corrosion.
2. solve numerical based on high temperature corrosion.
3. understand concepts and fundamentals in high temperature corrosion.
4. knowledge of material selection for different corrosive environments and knowledge of corrosion prevention methods.

Unit 1 **(6 hrs)**

Introduction to high Temperature corrosion & oxidation of Metals and Alloys, Thermodynamics & Ellingham diagram, vapour species diagram, Isothermal stability diagram, Rate Laws, Kinetics and Mechanics.

Unit 2 **(6 hrs)**

Wagner's parabolic law of Oxidation. Derivation and Limitations, Role of Diffusion and Defect structure of oxides in Oxidation, multiple scale formation & cracking.

Unit 3 **(6 hrs)**

Forms of Corrosion with Special reference to External and Internal Oxidation.

Unit 4 **(6 hrs)**

Stress Corrosion cracking, hydrogen Embrittlement, Corrosion Fatigue, Liquid Metal Embrittlement, Hot Corrosion, Corrosion in Mixed Gaseous Environment.

Unit 5 **(6 hrs)**

Prevention of Corrosion, Material Selection and Design, Alteration of Environment, Inhibition, Metallic and Ceramic Paints, Coatings, Special Treatment.

Unit 6 **(6 hrs)**

High temp. Materials: super alloys, inter metallic, ceramics.

Textbooks:

- Fundamentals of Corrosion- Scully

Reference Book:

- R. Aris, "Mathematical Modelling Techniques", Pitman, London 1978.
- Kofstadt ," Oxidation of Metals"
- N.Birks and Meir, "High Temperature Oxidation of Metals and Alloys"
- Riedel H., "Fracture of High Temp.", Springer-Verlag, Berlin ,1987.
- J.M.West "Basic Corrosion & Oxidation", 2nd Ed. Ellis Harwood Publication, 1986.
- ASM Metals H.B., Vol. 13, ASM international, Metals park, Ohio, 1986