Department of Metallurgical and Materials Engineering
Malaviya National Institute of Technology Jaipur

Structure of Proposed M.Tech. Program: Materials Engineering

The requirements of M.Tech. Programs as per the PG Regulations of MNIT Jaipur are:

(1) Minimum credits required to be earned are **61-65 (Table 2.1).**

(2) Minimum credits required to be earned in four different types of courses **(Table 2.2).**

(3) Semester-wise course structure **(Table 2.3)**

Table 2.1: Minimum credits to be earned during four semesters of M.Tech. Program

Semester	Courses	Total Credits
I	Taught Courses	18 – 22
II	Taught Courses	18 – 22
III	Dissertation, Seminar, Research Project	9 – 15
IV	Dissertation	9 – 15

Table 2.2: Minimum credits to be earned in four types of courses of M.Tech. Program

S.No.	Course Type	Min Credits to be earned
1	Taught Courses	18 – 22
2	Taught Courses	18 – 22
3	Dissertation, Seminar, Research Project	9 – 15
4	Dissertation	9 – 15

Table 2.3: Semester-wise course structure of proposed M.Tech. Programme (Materials Engineering)

First Semester

S. No.	Course Code	Course Title	Category	Type	Credit	L	T	P
1		Engineering Materials	PC	Theory	4	3	1	0
2		Characterization and Testing of Materials	PC	Theory	4	3	1	0
3		Physical Metallurgy	PC	Theory	4	3	1	0
4		Programme Elective - I	PE	Theory	3	3	0	0
5		Programme Elective - II	PE	Theory	3	3	0	0
6		Materials Processing Laboratory	PC	Laboratory	1	0	0	2
7		Characterization and Testing Laboratory	PC	Laboratory	1	0	0	2
				Total Credits	**20**			

Second Semester

S. No.	Course Code	Course Title	Category	Type	Credit	L	T	P
1		Theory of Metal Extraction	PC	Theory	4	3	1	0
2		Materials Manufacturing - I	PC	Theory	4	3	1	0
3		Materials Manufacturing - II	PC	Theory	4	3	1	0
4		Programme Elective - I	PE	Theory	3	3	0	0
5		Programme Elective - II	PE	Theory	3	3	0	0
6		Programme Elective - II	PE	Theory	3	3	0	0
				Total Credits	**21**			

PC: Programme Core**, PE:** Programme Elective

Third Semester

S. No.	Course Code	Course Title	Category	Type	Credit	L	T	P
1		Dissertation – I	PC	-	08	0	0	20
2		Seminar	PC	-	2	0	0	4
				Total Credits	**10**			

Fourth Semester

S. No.	Course Code	Course Title	Category	Type	Credit	L	T	P
1		Dissertation – II	PC	-	10	0	0	24
				Total Credits	**10**			

List of Programme Electives (PE) for First Semester								
S. No.	**Course Code**	**Course Title**	**Category**	**Type**	**Credit**	**L**	**T**	**P**
1		Nano Materials	PE-11	Theory	3	3	0	0
2		Electronics and Magnetic Materials	PE-12	Theory	3	3	0	0
3		Strategic Materials	PE-13	Theory	3	3	0	0
4		Computational Materials Engineering	PE-21	Theory	3	3	0	0
5		Surface Engineering	PE-22	Theory	3	3	0	0
6		Additive Manufacturing	PE-23	Theory	3	3	0	0

List of Programme Electives (PE) for Second Semester								
S. No.	**Course Code**	**Course Title**	**Category**	**Type**	**Credit**	**L**	**T**	**P**
1		Heat Treatment Practices	PE-11	Theory	3	3	0	0
2		Non-Destructive Testing and Evaluation	PE-12	Theory	3	3	0	0
3		Light Metals and Alloys	PE-13	Theory	3	3	0	0
4		Advanced Ceramics and Glasses	PE-14	Theory	3	3	0	0
5		Corrosion and its Prevention	PE-21	Theory	3	3	0	0
6		Fracture and Failure Analysis	PE-22	Theory	3	3	0	0
7		Biomaterials	PE-23	Theory	3	3	0	0
8		Advanced Composites	PE-24	Theory	3	3	0	0
9		Secondary Steel Making	PE-31	Theory	3	3	0	0
10		Sustainable Materials Management	PE-32	Theory	3	3	0	0
11		Processing and Properties of Polymers	PE-33	Theory	3	3	0	0
12		Emerging Materials	PE-34	Theory	3	3	0	0

Detailed Syllabi

Course Name	: **Engineering Materials**
Course code	:
Credits	: 4 (L - 3, T - 1, P - 0)
Course Type	: Programme Core
Prerequisites	: Basic Science

Course Objective (s)

- To provide knowledge and understanding about engineering materials (metals, polymers, ceramics and composites) and their applications

Course Outcome (s)

- Students will be able to acquire basic knowledge of various engineering materials and their applications
- Students will be able to understand fundamentals of material structure and its effect on properties.

Course Contents

Unit-1: Basic introduction and structure of materials: history of materials, classification of engineering materials: metals (ferrous, and non-ferrous), ceramics, polymers and composites. atomic structure, atomic bonding in solids: bonding forces and energies, primary bonding, secondary bonding, crystal structure and Bravias lattice, unit cell and miller indices, coordination number and packing fraction. Crystallographic directions and planes, imperfection in solids (point defects, line defects, surface defects, volume defects). Level of structures: macrostructure, microstructure, substructure, crystal structure, atomic structure, electronic structure, properties and applications of metals ***(No. of lectures - 16)***

Unit-2: Polymers: introduction, properties of polymers, polymerization, plastics as engineering materials, high temperature polymers, conductive polymers, liquid crystals, processing of polymers, injection moulding, applications of polymers. (***No. of lectures - 08)***

Unit-3: Ceramics: introduction, properties of ceramics (mechanical, thermal, chemical, electrical), classification of ceramics, dielectrics, semiconductors, ferroelectrics, processing of ceramics, applications of ceramics. ***(No. of lectures - 08)***

Unit-4: Composites: introduction, properties, classification, dispersion strengthened composites, particle strengthened composites, fibre strengthened composites, polymer matrix composites, metal matrix composites**,** applications of composites. ***(No. of lectures - 08)***

Text Books

1. Introduction to Materials Science, William D. Callister, John Wiley & Sons; 8th Edition, 2010
2. Introduction to Materials Science, V. Raghvan, Prentice Hall India Learning Private Limited, New Delhi, 6th Edition, 2015
3. Engineering Materials, A. K. Bhargava, Prentice Hall India Learning Private Limited, New Delhi, 2011
4. Engineering Materials – Properties and applications of Metal and Alloys, C.P. Sharma, Prentice- Hall of India Pvt. Ltd; 1st Edition, New Delhi, 2004

Online resources- https://nptel.ac.in

Course Name	: **Characterization and Testing of Materials**
Course code	:
Credits	: 4 (L - 3, T - 1, P - 0)
Course Type	: Programme Core
Prerequisites	: Basic Science and Physical Metallurgy

Course objective (s)

- To provide in-depth knowledge about different materials characterization techniques
- To make the students familiar with different mechanical property evaluation methods

Course outcome (s)

- Students will be able to understand the principles behind different characterization and sample preparation techniques
- Enable the students to use different characterization techniques to obtain desired information
- Students will be able to understand the theory behind different property evaluation techniques and their appropriate uses

Course Contents

Unit-1: X-ray and diffraction: basic theory/concept, absorption, x-ray diffraction techniques, interpretation of diffraction data, qualitative and quantitative phase analysis, analysis of particle size, residual stress/strain. X-ray fluorescence: origin, basic theory/concept, characterization of materials through x-ray fluorescence. ***(No. of lectures - 08)***

Unit-2: Optical microscopy: fundamentals of optics, optical microscope and its instrumental details, variants in the optical microscopes and image formation and phase contrast, polarized light, differential interference contrast, sample preparation and applications of optical microscopes. ***(No. of lectures - 04)***

Unit-3: Electron microscopy: TEM & SEM, construction, different components & their functions, aberration of electron lenses, image formation, magnification, resolution, depth of field & depth of focus etc. Bright field & dark field image, SAD diffraction, Kikuchi pattern, CBED. Elemental analysis through WDS, EDS, AES, & XPS: principle, application for analytical studies. thermal analysis techniques: thermogravimetric analysis (TGA), differential thermal analysis (DTA) and differential scanning calorimetry (DSC), the basis, instrumentation, data acquisition and interpretation of analytical results. ***(No. of lectures - 14)***

Unit-4: Hardness testing: various hardness tests, advantages and limitations of various hardness tests, microhardness testing. impact testing, tensile test and tensile curve analysis. ductile - brittle transition behavior and its significance. Fatigue and creep: introduction to fatigue, S-N curve, factors affecting fatigue. Creep: creep mechanisms, factors affecting creep. ***(No. of lectures - 14)***

Text Books

1. Elements of Diffraction, B D Cullity and S R Stock, 3rd Edition, Pearson, Noida, India, 2016.
2. X-ray Diffraction a Practical Approach, C. Suryanarayana and M. Grant Norton, Springer, 1998.
3. Electron Microscopy & Analysis, P.J. Goodhow, J. Humbreys & R. Beanland, Taylor & Francis Publ., 2000.
4. Transmission Electron Microscopy A Textbook for Materials Science, D.B. Williams and C.B. Carter, Springer, 2009.
5. Thermal Analysis of Materials, R.F. Speyer, Marcel Dekker Inc., New York, 1993
6. Mechanical Behavior of Materials, T.H Courtney, 2nd Edition, Waveland Press Inc., 2005.
7. Mechanical Metallurgy, G. E. Dieter, 3rd Edition, McGraw- Hill Book Company, 2017.

Online resources- https://nptel.ac.in

Course Name	: **Physical Metallurgy**
Course code	:
Credits	: 4 (L - 3, T - 1, P - 0)
Course Type	: Programme Core
Prerequisites	: Basic Science

Course objective (s)

- To provide knowledge on structure-property correlation in metals, phase diagrams and phase transformations

Course outcome (s)

- Students will be able to understand the role of crystal structure on material properties
- Develop the knowledge of students in phase diagrams, phase transformation and their significance
- Enable the students to access the effect of defects on properties of metals

Course Contents

Unit-1: Crystal Structure: space lattices and Bravais lattices, Miller indices of planes and directions, slip planes and slip directions. Bonding in solids: ionic, covalent, and metallic bonding. Defects in crystals, concept of plastic deformation. ***(No. of lectures - 10)***

Unit-2: Alloys and solid solutions: substitutional and interstitial solid solution, Hume-Rothery rules, intermetallic compounds, normal valency compounds, electron compounds, interstitial compounds. Binary phase diagrams: isomorphous, eutectic, peritectic, eutectoid, monotectic and syntectic systems, phase rule and lever rule. ***(No. of lectures - 10)***

Unit-3: Iron-Cementite Equilibrium diagrams and its applications, plain carbon and alloy steel, industrial applications of steels. Diffusion: Fick's first and second law of diffusion, atomic model of diffusion, grain boundary, surface and thermal diffusion, Kirkendall effect, interstitial diffusion. ***(No. of lectures - 10)***

Unit-4: Phase transformation: driving force, homogeneous and heterogeneous nucleation, growth kinetics. Solidification in isomorphous, eutectic and peritectic systems, cast structures and macro-segregation, dendritic solidification and constitutional supercooling, coring and micro-segregation. ***(No. of lectures - 10)***

Text Books

1. Physical Metallurgy Principles, R. Hill, E. Robert, R. Abbaschian, and L. Abbaschian. 4th Edition. Cengage Learning, 2009.
2. Introduction to Physical Metallurgy, S.H. Avner, McGraw Hill Education (India) Private Limited, 2017.
3. Materials Science and Engineering, V. Raghavan, 5th Edition, Prentice- Hall of India Pvt. Ltd., 2004.
4. Callister's Materials Science and Engineering, W.D. Callister, Wiley India (P) Ltd., 2007.
5. Physical Metallurgy, W.F. Hosford, 2nd Edition, Taylor & Francis, 2015
6. Physical Metallurgy, V. Singh, Standard Publishers, 2020.

Online resources- https://nptel.ac.in

Course Name	: **Materials Processing Laboratory**
Course code	:
Credits	: 1 (L - 0, T - 0, P - 2)
Course Type	: Programme Core
Prerequisites	: Basic Sciences

Course objective(s)

- To provide knowledge on various material manufacturing techniques.

Course outcome(s)

- Students will be familiarized with various powder metallurgy techniques.
- Students will be familiarized with various welding techniques.
- Students will be familiarized with various mechanical working techniques.
- Students will be familiarized with various foundry techniques.

Course Contents

1. To carry out sieve analysis of metal powders.
2. To determine the flow rate and apparent density of free-flowing metal powders using hall flow meter.
3. To determine the density and hardness of sintered powder metallurgy product.
4. To fabricate a butt joint using the oxy-acetylene gas welding (OAW) process.
5. To fabricate a lap joint using the shielded metal arc welding (SMAW) process.
6. To fabricate a joint using the resistance spot welding process.
7. To study the lathe machine and its various components, and prepare a tensile specimen on it.
8. To study the operation of forging hammer and determination of metal losses during forging.
9. To study the hot rolling process of mild steel.
10. To study the lathe machine and its various components, and prepare a tensile specimen on it.
11. To perform melting and casting of aluminium, and to study the effect of degasifier and grain refiner on microstructure.
12. To prepare a metal object through centrifugal casting and to study its microstructure.

Reference Material:

1. Materials processing laboratory manual.

Course Name	: **Characterization and Testing Laboratory**
Course code	:
Credits	: 1 (L - 0, T - 0, P - 2)
Course Type	: Programme Core
Prerequisites	: Basic Sciences

Course objective(s)

- To provide knowledge on various material characterization and testing techniques.

Course outcome(s)

- Students will be able to understand the working principle of various microscopy techniques.
- Students will gain knowledge on the working principle of various mechanical testing techniques.
- Data analysis of various advanced characterization techniques like, XRD, DSC, Dilatometer, SEM, will be known by the students.

Course Contents

1. To study an optical microscope, types of optical microscope, resolution, magnification, limitations, etc.
2. To study the metallographic sample preparation techniques for microstructural characterization.
3. To carryout microstructural examination of ferrous and non-ferrous systems (grain size measurements, phase analysis, inclusions rating, etc.).
4. X-ray diffraction and its applications in materials characterization (Miller indexing of XRD pattern).
5. To carry out microstructural characterization using scanning electron microscopy techniques and EDS analysis.
6. To determine the coefficient of thermal expansion of the given material using dilatometer.
7. To determine the phase transformation temperatures using differential scanning calorimeter (DSC).
8. To study and compare different hardness techniques - Brinell, Rockwell and Vickers's Hardness tests.
9. To determine the tensile and impact properties of different class of materials - steel, aluminum and cast-iron specimen.
10. To carryout quenching and tempering of steel.
11. To perform Jominy end quench test for accessing the hardenability of steel.
12. To study and measure the corrosion behaviour of different ferrous and non-ferrous materials.

Reference Material:

1. Materials characterization laboratory manual.

Course Name	: **Nano Materials**
Course code	:
Credits	: 3 (L - 3, T - 0, P - 0)
Course Type	: Programme Elective
Prerequisites	: Basic Science

Course objective(s)

- To provide the scientific principles of nanomaterials and technology
- To make the student aware of the importance of nonmaterial technology in present technological world

Course outcome(s)

- Students will get knowledge on the applications of nanomaterials and nanotechnology
- Make the students understand the scientific principles of nanomaterials and technology
- Make the students aware of different characterization techniques to evaluate nanomaterials

Course Contents

Unit-1: Introduction to nanomaterials: nature inspired nanomaterials and historical nanomaterials, classification of nanomaterials, length scales, surface area/volume ratio of micron to nanoscale materials. Properties of nanomaterials: effect of particle size on thermal properties, electrical properties, mechanical properties, magnetic properties, optical properties and chemical sensitivity. Nanowires, nanoclusters, nanobelts, quantum dots/wells. Polymer/metal/ceramic matrix nanocomposites. ***(No. of lectures -12)***

Unit-2: Synthesis of nanomaterials: top-down and bottom-up approaches, top-down approaches: lithography, mechanical alloying, severe plastic deformation, sonication, 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. synthesis, purification, properties and applications of carbon nanotubes (CNT). ***(No. of lectures - 12)***

Unit-3: 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. Applications and challenges of nanomaterials: nanofluids, hydrogen storage, solar energy, antibacterial coating, self- cleaning coating, nanotextiles, biomedical field, water treatment, automotive sector, catalysts. Challenges of nanomaterials, risks and toxicity from metallic and oxide nanoparticles, recent advances in nanoscience and nanotechnology. ***(No. of lectures - 12)***

Text Books

1. Nanomaterials, Nanotechnologies and Design: An Introduction for Engineers and Architects, M.F. Ashby, B. Heinemann, 2009.
2. Nanomaterials and Nanocomposites: Synthesis, Properties, Characterization Techniques and Applications, R.K Goyal, CRC Press, 2017.
3. Textbook of Nanoscience and Nanotechnology, B.S. Murty, P. Shankar, B. Raj, B.B. Rath, J. Murday, Springer-Verlag Berlin, Co-publication with Universities Press (India) Pvt. Ltd., 1st Ed., 2013
4. Introduction to nanoscience and nanotechnology, G.L. Hornyak, H.F. Tibbals, J. Dutta, CRC Press, 2013
5. Introduction to Nanotechnology, Charles P. Poole, Jr. and F.J. Owens, Wiley, 2003.

Online resources- https://nptel.ac.in

Course Name	: **Electronics and Magnetic Materials**
Course code	:
Credits	: 3 (L - 3, T - 0, P - 0)
Course Type	: Programme Elective
Prerequisites	: Basic Science

Course objective (s)

- To familiarize the students with the knowledge of different electronic and magnetic materials, their properties and uses

Course outcome (s)

- Students will understand the electronic and magnetic properties of materials
- Students will learn about various characterization techniques used to evaluate electronic and magnetic materials
- Make the students understand the construction and working principles of different devices comprising of electronic and magnetic materials

Course Contents

Unit-1: Introduction: the electron, problems with classical description, wave-particle duality, De Broglie theorem, Bohr model for hydrogen, Born postulate, Schrödinger's equation in solving the wave equation, particle a 1-D box & quantum tunneling, electrons in a periodic potential, Bloch waves, energy (E) versus wave vector (k) dispersion plots, energy bands, Brillouin zones, Fermi Dirac/Bose-Einstein/Boltzmann statistics, density of states, population density, effective mass. ***(No. of lectures -09)***

Unit-2: Electronic properties: classical conductivity, quantum description of conductivity, effect of alloying in metals, intrinsic and extrinsic semiconductor properties, Fermi level and Hall effect in semiconductors. Electronic materials: devices (diode, zener diode, bipolar transistor, FETs, MOSFETS, Ohmic/Schottky junctions), conductive polymers, ionic conductors, superconductors. ***(No. of lectures - 09)***

Unit-3: Magnetic properties: introduction to magnetism, magnetic order, dipolar fields, anisotropy, types of magnetism (ferro-, para-, ferri-, dia- and antiferro-magnetism), susceptibility, quantum description of magnetism, magnet design. ***(No. of lectures – 09)***

Unit-4: Magnetic Materials: biomagnetism and magnetic nano-particles, biomedical application, magnetic imaging and microscopy, permanent magnets and soft magnets, interfacial and surface effects, magnetic heterostructures, spintronics and magnetic recording. ***(No. of lectures - 09)***

Text Books

1. Electronic Properties of Materials, R.E. Hummel, 4th Edition, Springer-Verlag, 2013
2. Magnetism and Magnetic Materials, J.M.D. Coey, Cambridge University Press, 2012
3. Materials Science and Engineering, W.D. Callister, Wiley India (P) Ltd., 2007.

Online resources- https://nptel.ac.in

Course Name	: **Strategic Materials**
Course code	:
Credits	: 3 (L - 3, T - 0, P - 0)
Course Type	: Programme Elective
Prerequisites	: Basic Science

Course objective (s)

- To introduce the materials that are used for the strategic applications like, space, defence and sustainable energy sectors
- To make the students aware about strategic materials, their processing, specifications and different standards.

Course outcome (s)

- The student will be able to know about the material that is being used for strategic applications.
- The student will be made aware about the processing of these materials**.**
- The student will be able to know the standard and practices followed in these industries**.**

Course Contents

Unit-1: Strategic materials: an overview and its importance, mineral chemistry, important materials like aluminium alloys, special steel alloys, titanium alloys, tungsten alloys, superalloys, composites and ceramics, essential uses of strategic materials ***(No. of lectures -09)***

Unit-2: Introduction to Rare Earth Elements (REE), significance of REE, global REE deposits and mining processes, India and REEs, REEs on the critical list ***(No. of lectures - 06)***

Unit-3: Graphene, germanane, stanene, metamaterials, 3D printing technology, molybdenum disulphide, new solar cells, shape memory alloys, smart materials, self-healing artificial material, boron, aluminium and magnesium (BAM), ceramic alloy, ceramic matrix composites (CMC). ***(No. of lectures - 09)***

Unit-4: Nuclear material**:** brief outlines of essential requirements of metals for nuclear energy programs - structural, fissile, moderator and control, materials for canning, control rods, moderators, coolants, pressure vessels, heat exchanging tubing, and shielding, materials selection. extraction of uranium, thorium, zirconium, beryllium and plutonium and their processing. Indian reactors and atomic energy programmes.

(No. of Lectures - 12)

Text Books

1. Strategic Materials: A Resource Challenge for India, A. Lele, P. Bhardwaj.
2. Strategic And Critical Materials, L.H. Bullis, J.E. Mielke, L.H. Bullis.
3. Strategic Materials and National Strength, N. Harry
4. Developments in Strategic Materials; H.T. Lin, K. Koumoto, W.M. Kriven, D.P. Norton, E. Garcia, I.E. Reimanis, T.Ohji, and A.Wereszczak.
5. Extraction and Metallurgy of Uranium, Thorium and Beryllium. R.G. Hill, N.A. Bellamy. Pergamon Press, 1963.
6. Uranium Production Technology, C.D. Harigton and A.D. Ruchle. Van Nostrand Publication. Krieger Publishing Company; 1st edition, 1959.

Online resources- https://nptel.ac.in

Course Name	: **Computational Materials Engineering**
Course code	:
Credits	: 3 (L - 3, T - 0, P - 0)
Course Type	: Programme Elective
Prerequisites	: Basic Science

Course objective (s)

- To introduce modelling and computational techniques in the context of materials engineering

Course outcome (s)

- Students will understand materials modelling and simulation using the first-principle calculations at various length scales
- Make the students understand applications of materials modelling using computational techniques

Course Contents

Unit-1: Introduction and fundamentals: basic idea behind modeling and simulation, fundamentals and solution of differential equations, applications of materials modelling and simulation. ***(No. of lectures -06)***

Unit-2: Simulation techniques at the nano-micro scale: Monte Carlo simulation and integration: introduction and fundamentals, random walk simulation, molecular dynamics: introduction and fundamentals, examples of Monte Carlo simulation and molecular dynamics simulations in materials engineering.

(No. of lectures - 10)

Unit-3: Simulation techniques at the micro-meso scale, discrete dislocation statics and dynamics, introduction and fundamentals, linear elasticity theory for crystal plasticity, dislocation statics, dislocation dynamics. Phase field modelling: introduction and fundamentals. ***(No. of lectures - 10)***

Unit-4: Simulation techniques at the meso-macro scale: finite element and difference methods at the meso-macroscale: introduction and fundamentals, polycrystal elasticity and plasticity models: introduction and fundamentals, constitutive models for polycrystals. ***(No. of lectures - 10)***

Text Books

1. Physical Foundations of Materials Science, G. Gottstein, Springer Berlin Heidelberg, 2004.
2. Computational Materials Science, The Simulation of Materials Microstructure and Properties, D. Raabe, Wiley, 1998.
3. Introduction to Computational Materials Science, R. Lesar, Material Research Society, Cambridge University Press, 2018.
4. Numerical Methods for Engineers, S.K. Gupta, New Age International (P) Limited, New Delhi, 1998.

Online resources- https://nptel.ac.in

Course Name	: **Surface Engineering**
Course code	:
Credits	: 3 (L - 3, T - 0, P - 0)
Course Type	: Programme Elective
Prerequisites	: Basic Science

Course objective (s)

- To establish a fundamental understanding of materials and their roles in surface selection for target applications
- To introduce the concept of surface engineering and its importance

Course outcome (s)

- Students will be able to analyze the factors responsible for surface damage by corrosion and wear mechanisms
- Make the students understand different surface protection techniques
- Students will learn about different surface characterization techniques to access surface properties

Course Contents

Unit-1: Introduction: general introduction to surface and bulk, microstructure, properties, interfaces, defects, importance of substrate, current status of surface engineering, introduction to tribology, surface degradation by wear and corrosion. Surface degradation by wear: friction, wear, lubrication, roles of friction and lubrication, categories of wear, wear and lubrication mechanisms, wear and lubrication mode, an overview of lubrication. Surface degradation by corrosion: corrosion mechanisms, oxidation and related concepts, the interaction between wear and corrosion. ***(No. of lectures -12)***

Unit-2: Surface coating processes: gaseous state processes – chemical vapor deposition, physical vapor deposition, ion and laser beam- assisted deposition and surface treatment. Solution state processes – chemical solution deposition, electrochemical deposition, sol- gel processing, plasma electrolysis. Molten and semi-molten processes – laser surface treatment, thermal spraying, welding. Surface hardening treatment.

(No. of lectures - 12)

Unit-3: Surface characterizations: coating characteristics: surface, thickness, adhesion, morphology, composition, wettability, residual stress. Property characterization and evaluation: roughness, thickness, microhardness and nanoindentation, tribological evaluation, visual and metallurgical examinations, optical and electron microscopy. Industrial applications: sliding bearings, rolling contact bearings, gears, tools for cutting, tool forming, erosion and scratch- resistant surfaces, and magnetic recording devices. ***(No. of lectures - 12)***

Text Books

1. Coatings Tribology: Properties, Mechanisms, Techniques, and Applications in Surface Engineering, K. Holmberg and A. Matthews, Elsevier, UK, 2009.
2. Corrosion Engineering, M.G. Fontana, Tata McGraw- Hill, 3rd edition. 2008.
3. Principles and Prevention of Corrosion, D.A. Jones, Prentice- Hall, 1996.

Online resources- https://nptel.ac.in

Course Name	: **Additive Manufacturing**
Course code	:
Credits	: 3 (L - 3, T - 0, P - 0)
Course Type	: Programme Elective
Prerequisites	: Basic Science

Course objective(s)

- To educate students with fundamental and advanced knowledge in the field of additive manufacturing technology

Course outcome(s)

- Understand the working principles and process parameters of additive manufacturing processes.
- Distinguish different additive manufacturing processes and suggest suitable methods for building a particular component
- Design and develop a working model using additive manufacturing processes.

Course Contents

Unit-1: Introduction to additive manufacturing (AM), steps in AM, classification and advantages of AM, material types for AM. Additive manufacturing methods: vat photo-polymerization, material jetting: material extrusion, binder jetting, sheet lamination, powder bed fusion. Direct energy deposition: discuss on process mechanism, process parameters, advantages, limitations, applications, recent advances. Other similar processes: thermal spray direct writing, beam deposition, liquid phase deposition, hybrid techniques.

(No. of lectures - 12)

Unit 2: AM equipment and sub-systems: laser, electron beam, and arc-based AM processes, their mechanism, process parameters, advantages, limitations, applications, and recent advances. Beam, material feeding and job manipulation system: laser beam scanning, laser optics, fibre delivery system, job manipulation, electron beam manipulation, process chambers, sensors, material feeding systems, co-axial and lateral nozzles, powder spreading, multi-material spreading. ***(No. of lectures - 8)***

Unit 3: Additive manufacturing materials: types of materials, polymer, metals, ceramics, recent advances in materials, forms of raw materials, support materials, powder production techniques, and powder characterization. Post-processing: support material removal, surface texture improvement, accuracy improvement, aesthetic improvement, preparation for use as a pattern, property enhancements using non-thermal and thermal techniques. ***(No. of lectures - 12)***

Unit 4: Guidelines for process selection: selection methods for a part, challenges of selection, example system for preliminary selection, process planning and control. ***(No. of lectures - 4)***

Text Books

1. Additive manufacturing: principles, technologies and applications, C.P Paul, A.N Junoop, McGraw-Hill, 2021
2. Additive manufacturing, A. Bandyopadhyay, S. Bose, CRC Press Taylor & Francis Group, 2020.
3. Additive manufacturing technologies: 3D printing, Rapid Prototyping, and Direct Digital Manufacturing, I. Gibson, D.W Rosen, B. Stucker, Springer, 2015.
4. 3D printing and additive manufacturing: principles & applications, C.C. Kai, L.K. Fai, World Scientific, 2015.
5. Rapid prototyping: laser- based and other technologies, P.K.V. Vinod and W. Ma, Springer, 2004.

Online resources- https://nptel.ac.in

Course Name	: **Theory of Metal Extraction**
Course code	:
Credits	: 4 (L - 3, T - 1, P - 0)
Course Type	: Programme Core
Prerequisites	: Basic Science

Course Objective (s)

- To provide knowledge and understanding on ores & minerals, their processing, and extraction of ferrous and important non-ferrous metals.

Course Outcome (s)

- Students will be able to acquire basic knowledge about various physicochemical principles involved in iron making and the working principle of blast furnace.
- Students will gain understanding on different pyrometallurgical, hydrometallurgical and electro-metallurgical methods used for extraction of non- ferrous metals (Al, Cu, Zn, and Pb).
- Students will be able to identify suitable processes of metal extraction depending on the type of non-ferrous metals to be extracted.

Course Contents

Unit-1-The sources of metals, minerals and ores, primary metal production plants in India (ferrous and non-ferrous metals). Introduction to unit processes in pyrometallurgy, hydrometallurgy and electrometallurgy. ***(No. of Lectures: 06)***

Unit-2 Raw materials required for iron making, agglomeration techniques, physical chemistry of iron making process, theory and practice of iron making in blast furnace including gas cleaning and hot blast stoves, modern trends in the blast furnace. ***(No. of Lectures: 14)***

Unit-2- Aluminium Extraction: Bayer process for alumina production, Hall-Heroult process, electrolytic refining of aluminium, alternatives to Bayer process and Hall-Heroult Process, advances in the extraction of aluminium, methods of treating low grade ores. Aluminium production in India. ***(No. of Lectures: 06)***

Unit-3- Pyrometallurgical processes for copper extraction: roasting, matte smelting, converting and refining processes and their physico-chemical aspects. Hydrometallurgical process for copper extraction. recovery of copper from copper slag. treatment of refractory copper ores. newer processes in the extraction of copper. Copper production in India. ***(No. of Lectures: 06)***

Unit-4 Occurrence of lead and zinc ores, pyrometallurgical and hydrometallurgical processes for lead and zinc production and their physico-chemical aspects. Refining of lead and zinc and recovery of by-products. Modern methods for lead and zinc extraction and their production in India. ***(No. of lectures - 08)***

Text Books

1. Principles of extractive metallurgy, H.S. Ray and A. Ghosh, New Age International Publishers, 2018.
2. Iron making and steelmaking: theory and practice, A. Ghosh, and A. Chatterjee, PHI Learning (P) Ltd., 2008.
3. A first course in iron and steel making, D. Mazumdar, Universities Press (P) Ltd., 2015.
4. Extraction of Non- ferrous Metals, H. S. Ray, R. Sridhar and K. P. Abraham, Affiliated East West Press (P) Ltd., 2015.
5. Extractive Metallurgy of Non- ferrous Metals, R. Raghvan, Vijay Nicole Publication, 2016.
6. Principles of Extractive Metallurgy, T. Rosenquist, Techbooks, 1991

Online resources- https://nptel.ac.in

Course Name	: **Materials Manufacturing - I**
Course code	:
Credits	: 4 (L - 3, T - 1, P - 0)
Course Type	: Programme Core
Prerequisites	: Physical Metallurgy

Course objective(s)

- To provide in-depth knowledge about foundry materials and processes
- To develop understanding on metal powder production, characterization and processing

Course outcome(s)

- Students will get familiarize with different materials used in foundry industries
- Make the students understand different molding processes and casting defects
- Students will be able to understand different powder production and processing techniques

Course Contents

Unit-1: Introduction to foundry technology: significance, advantages and disadvantages. Patterns: functions, requirements, classification, materials and allowances. Molding sand: properties and ingredients. Cores: functions, requirements, types and core boxes. Gating system: objectives, parts, design of gating system, types of gates and parameters affecting function of riser. ***(No. of lectures - 8)***

Unit-2: Molding/casting processes: sand molding (green, dry, floor, pit, cement bonded core sand), shell molding, CO_2 mold casting, investment casting, ceramic molding, plaster molding. Permanent mold casting: centrifugal casting, gravity die-casting and pressure die casting. Solidification of castings: nucleation and growth phenomena, metal mold vs. sand mold, pure metal vs. alloy solidification and effect of grain refiner. Casting defects: causes and remedies. ***(No. of lectures - 12)***

Unit-3: Introduction to powder metallurgy: significance, advantages and disadvantages, methods of powder production and general principles involved in mechanical, chemical, atomization and electrolytic methods of metal and alloy powder production. Powder characterization: chemical composition, microstructure, size and size distribution, shape, surface area, flow rate, apparent, tap density and compressibility. Powder processing: mechanical alloying of powders involving high energy mechanical milling, parameters affecting mechanical milling, heat treatment of powders, powder compaction techniques. ***(No. of lectures - 10)***

Unit-4: Hot consolidation techniques: sintering, stages of sintering and bonding mechanisms involved, liquid phase sintering, solid state sintering, spark plasma sintering, reactive sintering, sintering furnaces, sintering atmospheres, pressurized sintering, hot pressing, powder compact extrusion and forging, hot isostatic pressing (HIP), sinter- HIP process, powder compact rolling, powder injection molding, additive manufacturing.

(No. of lectures - 10)

Text Books

1. Principles of Metal Casting, R.W. Heine, C.R. Loper, P.C. Rosenthal, Tata McGraw Hill, 2017.
2. Principles of foundry Technology, P.L. Jain, Tata McGraw Hill Co. Ltd., New Delhi, 2003.
3. Powder Metallurgy, K. Sinha, Dhanpat Rai Publications, New Delhi, 2nd edition, 2016.
4. Powder Metallurgy for Engg. (Brighton), R.H.T. Dixon & A. Clayton –Machinery Publishing, 2011.
5. Powder Metallurgy, P.C. Angelo & R. Subramanian, PHI Learning Pvt. Ltd., 2008.
6. ASM Hand Book, Vol. 15, Casting, 2008.
7. ASM Hand Book, Vol. 7, Powder Metallurgy, 2015.

Online resources- https://nptel.ac.in

Course Name	: **Materials Manufacturing - II**
Course code	:
Credits	: 4 (L - 3, T - 1, P - 0)
Course Type	: Programme Core
Prerequisites	: Physical Metallurgy

Course objective (s)

- To provide knowledge about different type of welding processes
- To develop understanding on different metal working practices used in industries

Course outcome (s)

- Students will get familiarize with different welding techniques along with soldering and brazing.
- Students will understand the responses of materials to welding.
- Students will impart knowledge about different mechanical working techniques.

Course Contents

Unit-1: Introduction to welding: Fusion welding processes: gas welding, thermit welding, arc welding (SMAW, GTAW, GMAW, SAW), plasma arc welding, laser beam welding and electron beam welding. Solid state welding processes: friction welding, friction-stir welding, diffusion bonding, explosive welding, ultrasonic welding, and resistance welding. Hybrid and sustainable welding processes. Surface cladding. Brazing and soldering. ***(No. of lectures-10)***

Unit-2: Responses of materials to welding: structure of the welded joint, solidification modes, welding stresses and distortion, heat treatment of parent metals and welds, solidification cracking, reheat cracking, welding defects and detection techniques. ***(No. of lectures-06)***

Unit-3: Introduction to mechanical working: principles and classification. Forging: classification of forging operations, variables associated with forging, forging equipment and forging defects. Rolling: classification of rolling mill, terminology in rolling, variables in rolling, roll bite conditions, roll pass design, types of passes, rolling of blooms, billets, slabs, rods, rails, sheets and structural sections, rolling defects, microstructural changes. ***(No. of lectures-10)***

Unit-4: Extrusion: classification of extrusion processes, variables in extrusion, flow of metal during extrusion, extrusion equipment, hydrostatic extrusion, defects in extrusion, microstructural changes. Drawing and forming: mechanism of drawing, variables in wiredrawing, defects in rod and wire products. Sheet metal forming: classification of forming operations, forming limit curve, defects and remedies. Manufacturing of seamless and welded tubes, rail road wheels, high energy rate forming, hydroforming, severe plastic deformation techniques like, equal channel angular extrusion, high pressure torsion, accumulative roll bonding. ***(No. of lectures-14)***

Text Books

1. Mechanical Metallurgy, G. E. Dieter, McGraw- Hill Book Company, 2017
2. Manufacturing Technology, P.N. Rao, McGraw Hill Education, 2018
3. Manufacturing Engineering and Technology, Serope Kalpakjian & Steven R. Schmid, Pearson Education, 2018
4. Welding Engineering and Technology, R.S. Parmar, 3rd Edition, Khanna Publishers, 2013.
5. Welding: Principles and Application, L. Jeffus, 8th Edition, Delmar Cengage Learning, 2016.
6. Welding Metallurgy, S. Kou, 2nd Edition, Wiley and Sons, 2005.

Online resources- https://nptel.ac.in

Course Name	: **Heat Treatment Practices**
Course code	:
Credits	: 3 (L - 3, T - 0, P - 0)
Course Type	: Programme Elective
Prerequisites	: Physical Metallurgy

Course objective(s)

- To make the students aware of the importance of different heat treatment techniques

Course outcome(s)

- Students will understand the microstructure evolution during heat treatment.
- Students will be able to sketch the heat treatment routes to control the microstructure.
- Make the students aware of different phase transformations in ferrous and non-ferrous metals.

Course Contents

Unit-1: Furnaces, basics of heat treatment, review on different types of heat treatment techniques, heat treatment process variables, the effect of heating and cooling on properties of steel, quenching technology, high-pressure gas quenching, applications of vacuum oil quenching. ***(No. of Lectures: 10)***

Unit-2: Recovery, recrystallization, and grain growth, TTT curves, and CCT diagram and its significance to heat treatment. microstructure evolution during austenite decomposition, microstructure evolution during reheating, strengthening mechanisms in steel. ***(No. of Lectures: 07)***

Unit-3: Hardness and hardenability of steels and methods of determination, case hardening processes for steels (induction hardening, carburizing, nitriding, boronizing, carbonitriding), thermo-mechanical treatments, precipitation hardening (Maraging steel, PH stainless steel, Al-Cu based alloys), vacuum treatments, vacuum carburizing. ***(No. of Lectures: 07)***

Unit-4: Heat treatment of special steels like high-speed steels, maraging steels, spring steels, ball bearing steels, stainless steels heat treatment defects and remedial measures. Heat treatment of some important non-ferrous metals such as aluminium, titanium, nickel, etc. ***(No. of lectures - 12)***

Text Books

1. Heat Treatment: Principles, T. V. Rajan, C. P. Sharma, A. Sharma, Prentice Hall of India Pvt. Ltd., New Delhi,1994.
2. Heat Treatment of Steels, S. K. Mandal, McGraw Hill Education (NOIDA, India), 2017.
3. Heat treatment of Metals, V. Singh, Standard Publisher Distributors, 1998.
4. Physical Metallurgy: Principles and Practice, V. Raghvan, 3rd edition, Prentice Hall of India Publishing, 2015.

Online resources- https://nptel.ac.in

Course Name	: **Non-Destructive Testing and Evaluation**
Course code	:
Credits	: 3 (L - 3, T - 0, P - 0)
Course Type	: Programme Elective
Prerequisites	: Basic Science

Course objective(s)

- To introduce the concept of non-destructive testing (NDT) among the students and teach them the working principles.
- To make awareness on how NDT techniques shall be applied for inspecting materials in accordance with industry specifications and standards.

Course outcome(s)

- Students will be able to identify appropriate NDT techniques as per requirement.
- Students will understand various process parameters and control the NDT process for the desired output parameters.
- Students will identify the internal flaws in the material by NDT and take measures to eliminate them.

Course Contents

Unit-1: Introduction - need for inspection, types of the inspection system, quality of inspection, reliability of defect detection, and benefits of NDT examination. ***(No. of Lectures: 05)***

Unit-2: Visual inspection - basic principles, physical aids used for visual inspection and applications, liquid penetrant inspection: physical principles, procedures of testing, penetrant testing materials, penetrant testing methods, applications and limitations. Magnetic particle testing - principle of MPT, magnetization techniques, procedure used for testing a component, equipment used for MPT. Eddy current testing: basic principles, techniques used for ECT, applications and limitations. ***(No. of Lectures: 12)***

Unit-3: Radiography - basic principles, electromagnetic radiation sources, effect of radiation in film, radiographic imaging, inspection techniques, micro-computed tomography, applications and limitations. ultrasonic testing - basic principles of sound beam, ultrasonic transducers, type of display, inspection methods A, B and C scanning modes, identification of defects, immersion testing, applications and limitations.

(No. of Lectures: 11)

Unit-4: Acoustic emission testing (AET) - principles, technique, instrumentation and applications, miscellaneous tests, reliability in NDT, statistical methods for quality control. leak testing - basic principles and application. ***(No. of Lectures: 08)***

Text Books

1. Practical Non-Destructive Testing, B. Raj, T. J. Kumar and M Thavasimuthu, ASM Intl, 2nd edition, 2002.
2. Testing of Metallic Materials, A.V.K. Suryanarayana, PHI, New Delhi, 2007.
3. Non-Destructive Testing, B. Hull and V. John, Springer, New York, 1st edition, 1988.
4. Introduction to Physical Metallurgy, S. H. Avner, McGraw-Hill Inc., US, 2nd edition, 1974.

Online resources- https://nptel.ac.in

Course Name	: **Light Metals and Alloys**
Course code	:
Credits	: 3 (L - 3, T - 0, P - 0)
Course Type	: Programme Elective
Prerequisites	: Basic Science and Physical Metallurgy

Course objective(s)

- To impart knowledge on processing, microstructure and properties of various important light metals and alloys being used by mankind today.

Course outcome(s)

- Students will understand the importance of light metals and alloys.
- Students will correlate the processing, properties and applications of Al and its alloys.
- Students will distinguish the processing, properties and applications of Mg & Ti and their alloys.
- Students will understand the processing and properties of Be and Li alloys.

Course Contents

Unit-1: General introduction, production, processing, and properties of light metals and alloys, applications. ***(No. of Lectures: 05)***

Unit-2: Physical and mechanical metallurgy of aluminium and aluminium alloys, nomenclature of Al alloys, classification of aluminium alloys, wrought and cast aluminium alloys, work hardening, annealing and age hardening of aluminium alloys. ***(No. of Lectures: 08)***

Unit-3: Physical and mechanical metallurgy of magnesium and magnesium alloys, alloying behaviour, classification, deformation behaviour, effect of crystallographic texture on properties. Physical and mechanical metallurgy of titanium and titanium alloys, classification of titanium alloys, α alloys, α/β alloys, β alloys, titanium aluminides. ***(No. of Lectures: 16)***

Unit-4: Beryllium and Li alloys, rapid solidification, metallic glasses, quasicrystals, mechanical alloying, future aspects and challenges. ***(No. of Lectures: 07)***

Text Books

1. Light alloys: From Traditional Alloys to Nanocrystals, I. J. Polmear, 4th edition, Elsevier, 2006.
2. Physical Foundations of Materials Science, G. Gottstein, 1st edition, Springer, 2004.
3. Engineering Materials and Processes: Titanium, G. Lütjering and J. Williams, 2nd edition, Springer, 2007.
4. Magnesium Alloys and Technology, K. U. Kainer, 1st edition, Wiley, 2003.
5. ASM Handbook, Volume 2A: Aluminium Science and Technology, 2020.
6. ASM Handbook, Volume 2: Properties and Selection: Nonferrous Alloys and Special Purpose Materials, 2020.

Online resources- https://nptel.ac.in

Course Name	: **Advanced Ceramics and Glasses**
Course code	:
Credits	: 3 (L - 3, T - 0, P - 0)
Course Type	: Programme Elective
Prerequisites	: Basic Science and Engineering Materials

Course objective(s)

- To provide the basic knowledge of the processing and design of ceramic materials, glass, glass-ceramic materials, and binders in terms of both science and engineering.

Course outcome(s)

- Students will identify technically important ceramic and glass materials.
- Students will understand the basics of the properties of ceramic and glass materials.
- Students will be able to infer a material with the required properties using characterization techniques.

Course Contents

Unit-1: Introduction to ceramic structures, point defect equilibria in ceramics, novel processing techniques for ceramic powders, deformation behaviour, and toughening of ceramics. ***(No. of Lectures: 08)***

Unit-2: Refractories, structural ceramics, ceramic cutting tools, ceramic coatings, wear components, high strength, and high-temperature components, ceramics for sensors, advanced functional ceramics, advanced ceramics for strategic applications. ***(No. of Lectures: 10)***

Unit-3: Glassy State, kinetic and thermodynamic criteria for glass formation, nucleation and crystal growth in glasses, nucleation through micro miscibility, nucleating agents, properties and applications of glass-ceramics, use of Na_2O-SiO_2 and Na_2OCaO- SiO_2 phase diagrams in glass manufacture, types and properties of glasses. ***(No. of Lectures: 10)***

Unit-4: Thermal endurance of glass, toughening of glasses, strength and fracture behavior of glass, surface tension, effect of temperature and composition on the physical properties of glasses, defects in glass. ***(No. of Lectures: 08)***

Text Books

1. Fundamentals of ceramics, M. W. Barsoum, 2nd edition, CRC Press, 2020.
2. Ceramic Processing, M. N. Rahaman, 2nd edition, CRC Press, 2017.
3. Materials Characterization Techniques, S. Zhang, L. Li and A. Kumar, CRC Press, 2008.
4. Introduction to Ceramics, 2nd edition, W. David Kingery, H. K. Bowen, Donald R. Uhlmann, Wiley, 1976.

Online resources- https://nptel.ac.in

Course Name	: **Corrosion and its Prevention**
Course code	:
Credits	: 3 (L - 3, T - 0, P - 0)
Course Type	: Programme Elective
Prerequisites	: Basic Science

Course objective(s)

- To provide the basic knowledge of different forms of corrosion its prevention techniques.

Course outcome(s)

- Students will understand about the mechanisms and causes of different forms of corrosion.
- Students will understand about corrosion of materials and its prevention techniques & propose materials with better corrosion resistance in specific environments.
- Students will be able to select inhibitors and coating materials which can sustain in adverse conditions by eliminating/reducing corrosion in particular condition.

Course Contents

Unit-1: Relevance and importance of corrosion studies, costs of corrosion, expressions for corrosion rate. ***(No. of Lectures: 02)***

Unit-2: Electrochemical and thermodynamic principles of corrosion, electrode kinetics, its application to experimental observations, activation, and concentration polarization, graphical representation of kinetic data, determination of E_{corr} and I_{corr} from potentio-dynamic polarization curve, passivity & electrochemical behaviour of active-passive metals and alloys. ***(No. of Lectures: 14)***

Unit-3: Different forms of corrosion: uniform, galvanic, intergranular, pitting, crevice, dealloying, stress corrosion cracking, corrosion fatigue, hydrogen embrittlement, high temperature corrosion. Corrosion prevention: selection of proper materials, development of suitable alloys, design improvement, modification of environment, cathodic and anodic protection, corrosion and its prevention, coating. ***(No. of Lectures: 16)***

Unit-4: Case studies related to combatting corrosion in industries. ***(No. of Lectures: 04)***

Text Books

1. Corrosion: Vol. I & II, L.L. Shrier, R.A. Jarmon and G.T. Bursteir, Butterworth & Heinemann publications, Great Britain, 1994.
2. Corrosion Science and Technology, D. Talbot and J. Talbot, CRC Press, London, 2019.
3. Corrosion Engineering, M.G. Fontana, Tata McGraw-Hill, 3rd Ed. (seventh reprint), 2008.
4. Principles and Prevention of Corrosion, D.A. Jones, Prentice-Hall, 1996.

Online resources- https://nptel.ac.in

Course Name	: **Fracture and Failure Analysis**
Course code	:
Credits	: 3 (L - 3, T - 0, P - 0)
Course Type	: Programme Elective
Prerequisites	: Physical Metallurgy

Course objective(s)

- To develop an in-depth understanding of the fundamentals of fracture mechanics and their historical prospects.
- To familiarize the students with various tools used to characterize the fracture behaviour of materials.

Course outcome(s)

- Students will understand fracture and failure modes and their significance in materials evaluation.
- Students will be able to analyze the crack behaviour in different loading conditions.
- Students will understand the practical aspect of failure analysis.

Course Contents

Unit-1: Basic Concepts in fracture mechanics - the geometry of stress and strain, elastic deformation, plastic, and elastoplastic deformation, the concept of catastrophic failure, brittle fracture, Griffiths theory, ductile fracture, probabilistic aspects of fracture mechanics. ***(No. of Lectures: 08)***

Unit-2: Mechanics of fracture- static loading - elastic fields – analytical solutions yielding near a crack front – Irwin's approximation-plastic zone size- Dugdaale model – J integral and its relation to crack opening displacement, strain energy release and stress intensity factor, evaluation of fracture toughness of different materials: size effect and control. ***(No. of Lectures: 08)***

Unit-3: Failure analysis of fatigue fracture - fundamental sources of failures- deficiency in design, empirical relation describing crack growth by fatigue – life calculations for a given load amplitude-effects of changing the load spectrum-effects of environment, microstructural analysis of fatigue failures, some case studies in the analysis of fatigue failures. ***(No. of Lectures: 08)***

Unit-4: Failure analysis of creep rupture - fracture at elevated temperature: time-dependent mechanical behavior, stress rupture, microstructural changes during creep, mechanism of creep deformation and creep deformation maps, prediction of time to rupture, creep-fatigue interaction, some case studies in the analysis of creep failures. failure analysis of corrosion and wear: failure due to erosion and corrosion.

(No. of Lectures: 12)

Text Books

1. Analysis of Metallurgical Failures, Colangelo, V.J., Heiser, F.A., John Wiley & Sons, Singapore, 2012.
2. Strength and Fracture of Engineering Solids, Felbeck, David K., Atkins, Anthony G., Prentice Hall, Inc., Englewood Cliffs, 2008.
3. Mechanical Metallurgy, Dieter, George E., Jr; McGraw Hill Book Co., New York. 2017.
4. Failure Analysis- Case Histories and Methodology, Naumann, F.K., ASM, Metals Park, Ohio. 2020.
5. Failure and its Prevention, American Society for Metals, Metals Handbook, 8th edition., Vol. 10, ASM, Metals Park, Ohio. 2001.
6. Fundamentals of Fracture Mechanics, Knott, J.E., Butterworths, London. 2003.

Online resources- https://nptel.ac.in

Course Name	: **Biomaterials**
Course code	:
Credits	: 3 (L - 3, T - 0, P - 0)
Course Type	: Programme Elective
Prerequisites	: Basic Sciences

Course objective(s)

- To familiarize the students with different metals, ceramics, polymers and nanomaterials characteristics as biomaterials.
- To develop an in- depth understanding on the concept of biocompatibility and the methods for biomaterials testing.

Course outcome(s)

- Students will understand common use of biomaterials as metals, ceramics and polymers and its chemical structure, properties, and morphology.
- Students will be able to identify significant gap required to overcome challenges and further development in metallic and ceramic materials, polymeric materials.
- Students will understand the testing standards applied for biomaterials.

Course Contents

Unit-1: Introduction to biomaterials: introduction, historical developments, impact of biomaterials, biological tissue, implants, safety and efficacy testing. Bulk properties and surface properties of materials, characterization methods of surface properties of biomaterials. ***(No. of Lectures - 04)***

Unit 2: Metallic and ceramic materials: metallic implants – stainless steels, Co-based alloys, Ti-based alloys, shape memory alloy, nanostructure metallic implants, degradation and corrosion, ceramics – carbon, alumina, yttria based zirconia, resorbable ceramics, bioactive ceramics, nanostructured bio ceramics.

(No. of Lectures - 10)

Unit 3: Polymeric materials: polymers as biomaterials, biodegradable polymers, bio-polymers: collagen, elastin and chitin. Soft tissue application, medical textiles. Materials for ophthalmology: contact lens, intraocular lens. Membranes for plasma separation and blood oxygenation. Biological functional materials, grafts and other materials. ***(No. of Lectures - 10)***

Unit 4: Testing of biomaterials: biocompatibility, blood compatibility and tissue compatibility tests, toxicity tests, sensitization, carcinogenicity, mutagenicity and special tests, in-vitro and in-vivo testing. Sterilization of implants and devices: ETO, gamma radiation, autoclaving, effects of sterilization. Application of biomaterials: cardiovascular applications, dental implants, adhesives and sealants, ophthalmologic applications, orthopedic applications, drug delivery system, sutures, bioelectrodes, biomedical sensors and biosensors. Materials used in medicine: metals, polymers, hydrogels, bioresorbable and biodegradable materials. ***(No. of Lectures - 12)***

Text Books

1. Biomaterials, Second Edition, Sujata V. Bhatt, Narosa Publishing House, 2005.
2. Functional Materials: Preparation, Processing and Applications, S Banerjee and A. K. Tyagi, 1st Edition, Elsevier, USA, 2012.
3. Biomaterials Science: An Introduction to Materials in Medicine, Schoen, F.J. Ratner, B.D. Hoffman, A.S. Lemons, J.E. Netherlands: Elsevier Science, 2004.
4. The Biomedical Engineering Handbook, Bronzino, J.D., CRC Press, Germany, 2000.

Online resources- https://nptel.ac.in

Course Name	: **Advanced Composites**
Course code	:
Credits	: 3 (L - 3, T - 0, P - 0)
Course Type	: Programme Elective
Prerequisites	: Basic Sciences and Engineering Materials

Course objective(s)

- To familiarize and equip students with basic knowledge about composite materials.

Course outcome(s)

- Students will understand various basic concepts related to composite materials.
- Students will be able to identify various fabrication processes of composite materials.
- Students will be able to find out ways to reuse the composite materials after their service life is over.

Course Contents

Unit-1: Overview- introduction and importance of composite materials over other materials. ***(No. of Lectures: 04)***

Unit-2: Reinforcements- role of reinforcements. Types of reinforcement: fibers, particulates, and whiskers. Types of fibers: glass, carbon, boron, organic and ceramic fibers, comparison of fibers, and non-oxide particulates (SiC and WC). Interfaces- wettability, the effect of surface roughness, crystallographic nature of the interface, interactions at the interface, type of bonding (mechanical, physical, and chemical) at the interface, role of interfaces. ***(No. of Lectures: 12)***

Unit-3: Classification and strengthening of composite- classification of composites based on matrices, types and orientation of fibers. Micromechanics: strengthening by fibers or particulates, mechanism of deformation in fiber reinforced composites, the influence of fiber length, its orientation, and volume fraction on composite properties. mechanisms of toughening in composites. ***(No. of Lectures: 10)***

Unit-4: Processing, properties, and applications– metal matrix composites, polymer matrix composites, ceramic matrix composites, nanocomposites, merits and demerits of nanocomposites compared to composites. ***(No. of Lectures: 10)***

Text Books

1. Composite Materials: Properties, Non-destructive testing and Repair, M.M. Schwartz, Prentice Hall, New Jersey, 1996
2. Composite Materials – Science & Engineering, K.K. Chawla., Springer-Veslag, New York, 3rd Ed, 2012
3. Industrial Materials: Polymers, Ceramics and Composites, D.A. Colling and T. Vasilos, vol. 2, Prentice Hall, N. Jersey, 1995.
4. Composite Materials: Engineering and Science, F.L. Matthews and R.D. Rawlings, Chapman and Hall, London, 1994.

Online resources- https://nptel.ac.in

Course Name	: **Secondary Steel Making**
Course code	:
Credits	: 3 (L - 3, T - 0, P - 0)
Course Type	: Programme Elective
Prerequisites	: Basic Sciences and Steel Making

Course objective(s)

- To teach the students about the importance, theories and practices of producing secondary steel.

Course outcome(s)

- Students will understand the importance and different theories of secondary refining of steel.
- Students will be able to understand the concept of different secondary steel making processes.
- Various advances carried out in the field of secondary steel making will be known to the students

Course Contents

Unit-1: Basic principles of steelmaking - Raw material, theory of slags, mechanism of removal of common impurities like Si, C, Mn, P and S. Slag-metal and gas-metal reactions in steel making, importance of secondary steel making. ***(No. of Lectures: 12)***

Unit-2: Concept of cleanliness of steels - inclusion in steels- its different types and genesis, dissolved gasses, tramp and residual elements in steels and their effect on steel properties. ***(No. of Lectures: 04)***

Unit-3: Secondary steel making principles and practices - objectives and techniques adopted in secondary steel making, ladle metallurgy, inert gas stirring and its merits, ladle furnace, principles of deoxidation, desulphurization and inclusion control, injection metallurgy and its usefulness, ladle refining technique with synthetic slag practice, vacuum degassing of steel and related processes. ***(No. of Lectures: 12)***

Unit-4: Refining of steel by remelting under vacuum - CEVAM process, principles of ESR & VAR processes ladle metallurgy as secondary refining process - Vacuum arc degassing, ASEA-SKF process, production of stainless steel through VOD, AOD and CLU processes. Recent advances in secondary steel making. ***(No. of Lectures: 08)***

Text Books

1. Secondary Steelmaking: Principles & Applications, A. Ghosh, CRC Press, 2001.
2. Iron Making and Steelmaking: Theory and Practice, A. Ghosh, and A. Chatterjee, PHI Learning (P) Ltd., 2008.
3. A first course in Iron and Steel Making, D. Mazumdar, Universities Press (P) Ltd., 2015.
4. Steel Making, A. K. Chakrabarti, PHI Learning (P) Ltd., 2007

Online resources- https://nptel.ac.in

Course Name	: **Sustainable Materials Management**
Course code	:
Credits	: 3 (L - 3, T - 0, P - 0)
Course Type	: Programme Elective
Prerequisites	: Basic Sciences

Course objective(s)

- To provide background and details of the energy resources and various waste management techniques applied in metallurgical engineering industries.

Course outcome(s)

- Students will gain knowledge about different energy resources used in metallurgical industries and the need for its conservation.
- Students will be able to analyze the root cause of the pollution in ferrous and non-ferrous metallurgical industries and their negative effects.
- Students will be able to understand the working principles of waste (solid and liquid) management techniques in metallurgical industries.

Course Contents

Unit-1: Energy resources: non-renewable and renewable, Indian energy resources. use of energy in metallurgical industries, energy conservation in metallurgical industries with examples of non-ferrous metals and iron & steel making. ***(No. of Lectures: 06)***

Unit-2: Sources and types of pollutants (wastes) from metallurgical industries. Gaseous emissions: control of SPM, hazardous gases, viz. sulphur dioxide, fluorides, nitrogen oxides. Concept of hydrogen embrittlement. Greenhouse gases: greenhouse effect, global warming potential, Kyoto protocol, carbon trading.

(No. of lectures - 06)

Unit-3: Meteorological factors influencing air pollution, control of air pollution by equipment. cleaner production (pollution control) in metallurgical industries, iron and steel and non-ferrous metals (Cu, Al, Zn, and Pb), pollution control in ferrous and non- ferrous foundries, introduction to need of environmental management. ***(No. of lectures - 12)***

Unit-4: Liquid effluents: treatment of waste water with examples from metal industries. Solid wastes: types, disposal and utilization of red mud and spent pot lining, iron and steel slags. Impact of pollutants on human health. management of radioactive wastes, e-waste, noise pollution and thermal pollution.

(No. of Lectures: 12)

Text Books

1. Energy and Environmental Management in Metallurgical Industries, R.C. Gupta, PHI Learning (P) Ltd., 2012.
2. Energy in Mineral and Metallurgical Industries, H.S. Ray. B.P. Singh, S. Bhattcharya, V.N. Misra, Allied Publishers (P) Ltd., 2005.
3. Environmental Pollution Control Engineering, C.S. Rao, New Age International Publishers, 2018.
4. Basic Environmental Technology: Water Supply, Waste Management and Pollution Control, J.A. Nathanson, Pearson Prentice Hall India, 2014.
5. Dust and Fume Generation in the Iron and Steel Industry, S. Andonyev, O. Filipyev, Y. Nadler, Central Books Ltd, 1977.

Online resources- https://nptel.ac.in

Course Name	: **Processing and Properties of Polymers**
Course code	:
Credits	: 3 (L - 3, T - 0, P - 0)
Course Type	: Programme Elective
Prerequisites	: Basic Sciences and Engineering Materials

Course objective(s)

- Acquire the knowledge about structures, properties, processing and applications of engineering polymers.

Course outcome(s)

- Students will knowledge about different types of polymers.
- Students will be able to correlate the structure, properties and applications of polymers.

Course Contents

Unit-1: Introduction to polymers - thermoplastics, thermosets, high-performance polymers, liquid crystal polymers, polymer blends and alloys, shape memory polymers, thermoplastic elastomers, thermoset elastomers, molecular weight distributions, roles of additives, and glass transition temperature.

(No. of Lectures: 08)

Unit-2: Factors affecting properties - effect of chemical composition, types of bonds, structures, and degree of crystallinity on the mechanical, thermal, electrical, barrier, and rheological properties of polymers. effect of molecular weight, crosslinking, fillers, and additives on transition temperatures. ***(No. of Lectures: 08)***

Unit-3: Processing techniques - injection molding, special injection molding processes (multi-component injection molding, coinjection molding, gas-assisted injection molding, injection-compression molding, reaction injection molding, liquid silicone rubber injection molding), extrusion, blow molding, rotational molding, thermoforming, calendering, foaming. ***(No. of Lectures: 10)***

Unit-4: Additive manufacturing techniques - stereo lithography, fused filament fabrication, selective laser sintering, other 3D printing techniques, etc. Characterization techniques: melt flow index, limiting oxygen indexer, thermogravimetry analyzer, differential scanning calorimetry, dynamic mechanical analyzer.

(No. of Lectures: 10)

Text Books

1. Introduction to Plastics Engineering, V.K. Stokes, John Wiley & Sons Ltd, UK, 2020.
2. Plastics Engineering, R. J Crawford and P.J Martin. 4th Edition, Elsevier, UK. 2020.
3. Material Science of Polymers for Engineers, T.A. Oswald and G. Menges., 3rd Edition, Hanser Publications, Cincinnati, USA, 2012.

Online resources- https://nptel.ac.in

Course Name	: **Emerging Materials**
Course code	:
Credits	: 3 (L - 3, T - 0, P - 0)
Course Type	: Programme Elective
Prerequisites	: Basic Sciences and Engineering Materials

Course objective(s)

- To introduce the engineering materials whose use is increasing at an accelerated rate in multi-functional areas.

Course outcome(s)

- Students will acquire knowledge on emerging materials like, carbon nanotubes, fullerenes, graphene, shape memory alloy, Li, Ni, Cr, etc.
- Students will become familiar with their sources, processing and application.
- To describe the materials used for cryogenic, nuclear and space applications.

Course Contents

Unit-1: Introduction to emerging materials, driving force behind them (application), variation in material uses over time. Classification of materials: conductor, semiconductor, insulator, superconductor, molybdenum disulphide, new solar cells, shape memory alloys, self-healing artificial material.

(No. of lectures - 08)

Unit-2: Carbon based materials: carbon allotropes (basic), new carbon structures, carbon nanotube (CNT), single wall carbon nanotubes (SWCNT), multi-wall carbon nanotubes (MWCNT), carbon fiber. Graphene science: introduction of graphene, graphene reinforced composites, application of nanostructured graphene, applications and limitations. High entropy alloys. ***(No. of lectures - 08)***

Unit-3: Sources, extraction, uses and limitations of Li, Ni and Co. Other advanced materials: high-temperature material, bulletproof material, amorphous materials, nano quasicrystals, Battery materials, new generation photo-voltaic materials. ***(No. of lectures - 10)***

Unit-4: Aluminium alloys, magnesium alloys and titanium alloys; metallurgical aspects, mechanical properties and applications. development of super alloys-iron base, nickel base and cobalt base - properties and their applications; materials for cryogenic service, MXenes material, materials in nuclear field, materials used in space and defense. ***(No. of lectures - 10)***

Text Books

1. Emerging Materials for Energy Conversion and Storage, K.Y. Cheong, Elsevier, 2018.
2. Emerging Materials for Environment Protection and Renewable Energy, S. Ameen, H.S. Shin, M.S. Akhtar, Nova Publication, 2018.
3. Emerging Materials and Technologies, B.I. Kharissov, Taylor and Francic.

Online resources- https://nptel.ac.in