UNIVERSITY OF HYDERABAD

SCHOOL OF ENGINEERING SCIENCES AND TECHNOLOGY

Syllabus

Semester - 1

1. **Course title: Principles of Engineering and Sustainability**

Code: MT101

Credits: 4

Syllabus:

Unit 1: Introduction: What is science, engineering and technology. History of engineering and key contributions of engineering across different disciplines. What engineers do?

Unit 2: Building blocks of engineering: Understanding engineering through simple machines and devices – Inclined plane, wedge, screw, levers, pulley, wheel and axle, gear and piston

Unit 3: Engineering problem solving: Basic steps in engineering problem solving. Need-Know-How-Solve approach. Select case studies of problem solving covering various engineering disciplines. Fermi problems.

Unit 4: Engineering design and practice: Fundamental principles of engineering design. Steps in engineering design. Select case studies of the design process covering various engineering disciplines. Dimensional analysis and units. Standards and codes.

Unit 5: Sustainability: Industrial revolution 1.0-4.0 and its impact on environment. Climate change, Greenhouse effect, Renewable energy, Significance of sustainable technology. Quantification of sustainability by sustainability index. Life cycle analysis. Determining total energy consumption.

2. **Course title: Engineering Mathematics-1**

Code: BS101

Credits: 3

Syllabus:

Unit-1:

Partial derivations, chain rule, differentiation of implicit functions, exact differentials. Maxima and Minima points, Methods of Lagrange multipliers. Differentiation under Integral sign, Jacobians and transformations of coordinates.

Unit-2:

Ordinary differential equations(ODEs): Basic concepts. Geometric meaning of y'=f(x,y). Direction fields, Euler's method, separable ODEs. Exact ODEs. Integrating factors, Linear ODEs. Bernoulli equation. Population dynamics, Orthogonal trajectories. Homogenous Linear ODEs with constant coefficients. Differential operators. Modelling of free osciallations of a Mass-Spring systems, Euler- Cauchy equations. Wronskian, Non-homogenous ODEs, solution by variation of parameters. Power series method for solution of ODEs: Legendre's equation, Legendre polynomials, Bessel's equation, Bessel's functions jn(x) and yn(x). Gamma function.

Unit-3:

Linear algebra: Matrics and determinants, Gauss elimination, Linear independence. Rank of a matric. Vector space. Solutions of Linear systems and concepts of existence, uniqueness, determinants. Carmer's rule, Gauss-Jordan elimination. The matrix eigenvalue problem. Determining Eigenvalues and eigenvectors, symmetric, Skew-symmetric, and orthogonal matrices. Eigenbases. Diagonalization. Quadratic forms. Cayley – Hamilton Theorem (without proof)

Unit-4:

Vector calculus: vector and scalar functions and their fields. Derivatives, curves. Arc length. Curvature, Torsion, gradient of a scalar field. Directional derivative, divergence of a vector field, curl of a vector field, line integrals, path independence of line integrals, double integrals. Green's theorem in the plane, surfaces for surface integrals, surface integrals, triple integrals, Stokes theorem, Divergence theorem of Guass.

3. **Course title: Engineering Physics-I**

Code: BS103

Credits: 3

Syllabus:

Unit 1: Classical mechanics
Kinematics and dynamics of particles and rigid bodies. Conservation laws. Concept of work, energy, and power, linear momentum and impulse. Rotational motion and moment of inertia. Select examples of application in engineering systems

Unit 2: Mechanics of deformable bodies
Concept of stress, strain, strain energy. Elasticity, Hooke's law, plasticity. Select examples of applications of these concepts in material selection for structural applications such as bridges

Unit 3: Thermodynamics – Basic terms and first law
Scope, State, State properties, Temperature, Heat capacity, Internal energy, The first law of thermodynamics, Limitation of the first law

Unit 4: Thermodynamics – Basic concepts and second law
Reversible & Irreversible processes, Isothermal & adiabatic processes, Path quantities, Engine, Exergy, Entropy, Clausius inequality, The second law, Statistical Interpretation of Entropy, Types of entropy

Unit 4: Quantum mechanics:

Wave-particle duality and de Broglie hypothesis. Heisenberg's uncertainty principle. Schrödinger equation Particle in a box model. Applications in quantum computing.

4. **Course title: Basic Engineering Laboratory-1**

Code: ES105

Credits: 2

Syllabus:

Module 1-Electrical Lab

1. Fundamentals of electrical circuitry and safety: A practical approach
2. Single switch and light bulb connection and wiring
3. Two-Way switch and wiring
4. Building an extension box with multiple switches and sockets
5. Basic residential wiring with multiple loads

Module 2-Electronics Lab

1. Basics of electronic components and wiring with a bread board
2. Voltage and current division in series and parallel circuits
3. Building logic gates using switches
4. Understanding the working principle of transistors in simple circuits
5. Building a water level indicator using IC555

Module 3 -Computer Lab

Computer hardware

5. **Course title: Problem Solving and Programming**

Code: CS101

Credits: 3

Syllabus:

Unit 1:

Problems And Problem Instances, Generalization and Special Cases, Types of Computational Problems, Classification of Problems, Analysis of Problems, Solution Approaches, Algorithm Development, Analysis of Algorithm, Efficiency, Correctness, Data Representation, Role of Data Structures in Problem Solving, Problem-Solving Steps (Understand the Problem, Plan, Execute, and Review), Breaking the Problem into Subproblems, Input/Output Specification, Input Validation, Pre and Post Conditions.

Unit 2:

Structured Programming Concepts: Sequence (Input/Output/Assignment), Selection (If, If-Else) And Repetition (For, While, Do-While) Statements, Control Structure Stacking and Nesting. Different Kinds of Repetitions: Entry Controlled, Exit Controlled, Counter Controlled, Definite, Indefinite and Sentinel-Controlled Repetitions. Pseudocode and Flowcharts. Definition And Characteristics of Algorithms, Standard Algorithm Format.

C Language: Introduction To Programming Languages, Different Generations of Programming Languages. Typed Vs Typeless Programming Languages, History of C Language, An Empty C Program. C Language Counterparts For Input (scanf()), Output (printf()) Statements, Assignment, Arithmetic, Relational and Logical Operators. C statements for If, If-Else, For, While, Do-While Statements. Data Types. Translating Pseudocode/Algorithm to C Program. Incremental Compilation and Testing of The C Program. Simple Problems Involving Input, Output, Assignment Statement, Selection and Repetition Statements. Good Coding Practices.

Unit 3:

Problems Involving Iteration and Nesting: Displaying Different Patterns and Shapes Using Symbols and Numbers, Generating Arithmetic and Geometric Progression, Fibonacci and Other Sequences, Approximate Values For π, Sin(x), Cos(x), Etc. Using Taylor Series.

Unit 4:

Problems on Numbers: Extracting Digits of a Number (Left to Right and Right to Left), Palindrome, Prime Number, Prime Factors, Amicable Number, Perfect Number, Armstrong Number, Factorial, Converting Number from One Base to Another. Statistics (Maximum, Minimum, Sum and Average) on a Sequence of Numbers which are Read using Sentinel-Controlled Repetition using only a few Variables.

C Language: else-if Ladder, switch Case, Increment/Decrement Operators, break and continue Statements.

Unit 5:

Modular Programming, Top-Down and Bottom-Up Approaches to Problem Solving. Recursion. Problems on Arrays: Reading and Writing of Array Elements, Maximum, Minimum, Sum, Average, Median and Mode. Sequential And Binary Search. Any one Sorting Algorithm. Matrix Operations.

C Language: Function Definition and Declaration (Prototype), Role of Return Statement, One Dimensional and Two-Dimensional Arrays. String Functions. Other Operators, Operator Precedence and Associativity. Debugging.

6. **Course title: Problem Solving and Programming Laboratory**

Code: CS103

Credits: 2

Syllabus:

Exercises corresponding to the topics in the theory course, **Problem Solving and Programming.**

7. **Course title: English**

Code: HS101

Credits: 3

Syllabus:

Unit 1: Humour in Communication

- Understand the power of humour in building rapport and creating a positive work environment.
- Analyse the use of humour in daily communication, readings, technical writing and presentations.
- Explore cultural nuances and sensitivities around humour.

Unit 2: Gender Sensitization and Inclusive Communication

- Develop awareness of gender equality and inclusivity in the engineering field.
- Identify and challenge gender stereotypes in engineering workplaces.
- Practice using inclusive language and communication strategies.

Unit 3: Digital Readership and Critical Thinking

- Develop critical thinking skills to evaluate online information effectively.
- Identify credible sources for technical research.
- Practice effective research techniques for engineering topics.
- Observe the post-pandemic digital readership and its challenges

Unit 4: Art, Literature and the Engineer's Perspective

- Broaden perspectives and foster creativity through the lens of art and literature.
- Analyse the portrayal of engineers in various literary works.
- Explore the intersection of technology and art in modern society.
- Discuss the ethical implications of technological advancements.

Unit 5: Life and its Teachings: Emotional Intelligence and Well-being

- Develop emotional intelligence skills for personal and professional well-being.
- Discuss ethical dilemmas faced by engineers in real-world scenarios.
- Explore the impact of technology on society and individual well-being.
- Practice mindfulness and stress management techniques.

Semester - 2

1. **Course title: Introduction to Materials Engineering**

Code: MT102

Credits: 3

Syllabus:

Unit 1: Introduction: Definition and scope of materials engineering, Classification of materials: metals, ceramics, polymers, composites, Importance of materials in engineering applications

Unit 2: Structure and Bonding: Basic concepts of atomic structure, types of chemical bonds, crystal structure and unit cells, crystal Imperfections: point defects, planar and volumetric defects

Unit 3: Properties of materials: Overview of physical, mechanical, thermal, optical, electrical and magnetic properties. Select engineering examples that utilize these properties

Unit 4: Phase diagrams and phase transformation: Foundational aspects of phase diagrams, binary phase diagrams, solidification, precipitation, diffusional and martensitic phase transformation.

Unit 5: Materials Processing techniques: Introduction to casting, forming, welding and heat treatment

Unit 6: Processing-structure-property relationships: Select case studies showcasing the relationship between processing, structure, and property.

2. **Course title: Engineering Mathematics-2**

Code: BS108

Credits: 3

Syllabus:

Unit 1: Complex Analysis: Complex Numbers and Their Geometric Representation, Polar Form of Complex Numbers. Powers and Roots, Derivative. Analytic Function, Cauchy–Riemann Equations. Laplace's Equation, Exponential Function, Trigonometric and Hyperbolic Functions. Euler's Formula, de'Moivre's theorem, Logarithm. General Power. Principal Value. Singularities and Zeros. Infinity, Line Integral in the Complex Plane, Cauchy's Integral Theorem, Cauchy's Integral Formula, Derivatives of Analytic Functions, Taylor and Maclaurin Series.

Unit 2: Probability and Statistics: Probability concepts - sample space, events, probability rules. Discrete and continuous probability distributions - binomial, normal etc. Statistical measures - mean, variance, standard deviation. Statistical inference and hypothesis testing. Applications of probability and statistics in engineering - reliability, quality control and risk analysis.

Unit 3: Integral Transformations: Laplace Transforms: Definitions and existence (without proof), properties, First Shifting Theorem (s-Shifting), Transforms of Derivatives and Integrals and ODEs, Convolution. Integral Equations, Differentiation and Integration of Transforms. Solution of ODEs with Variable Coefficients, Solution of Systems of ODEs. Inverse Laplace transform and its properties. Fourier Analysis: Fourier Series, Arbitrary Period. Even and Odd Functions. Half-Range Expansions, Fourier Integral, Fourier Cosine and Sine Transforms, Fourier Transform. Usage of F ODEs. Inverse Fourier transform and its properties.

Unit 4: PDEs and Applications: : Basic Concepts of PDEs. Modeling: Vibrating String, Wave Equation. Solution by Separating Variables. Use of Fourier Series. D'Alembert's Solution of the Wave Equation. Characteristics. Modeling: Heat Flow from a Body in Space. Heat Equation: Solution by Fourier Series. Steady Two-Dimensional Heat Problems.

3. **Course title: Engineering Physics-2**

Code: BS104

Credits: 3

Syllabus:

Unit 1 Optics: Wave motion: types of waves and their properties. Wave equation. Concepts of reflection and refraction and applications in lenses, and mirrors. Basics of interference and diffraction of light. Select examples of application of these concepts in the area of acoustics, optics including fiber optics and lasers.

Unit 2: Electricity and magnetism: Review of basic concepts of electric charge, electric fields, and Gauss's law. Electric potential, capacitance, and dielectrics. Electric current, resistance, and Ohm's law. Magnetic fields, magnetic forces, and Ampere's law. Electromagnetic induction and Faraday's law. Select examples of application of these concepts in design of circuits, motors, generators, etc.

Unit 3: Semiconductors: Crystal structure, Energy bands, carrier concentration at thermal equilibrium, Intrinsic and extrinsic semiconductors, donors and acceptors, n and p type semiconductors, energy-band gap, carrier transport phenomena, Hall's effect, pn junction diode, rectifier

Unit 4: Nuclear physics: Basic concepts in atomic and nuclear physics- atomic structure, radioactivity, and nuclear reactions. Applications in nuclear engineering and medical field.

4. **Course title: UHV-II**

Code:

Credits: 3

Syllabus:

Module 1 – Introduction to Value Education

- Understanding Value Education
- Self-exploration as the Process for Value Education
- Continuous Happiness and Prosperity – the Basic Human Aspirations and their Fulfilment
- Right Understanding, Relationship and Physical Facility
- Happiness and Prosperity – Current Scenario
- Method to Fulfil the Basic Human Aspirations

Module 2 – Harmony in the Human Being

- Understanding Human being as the Co-existence of the Self and the Body
- Distinguishing between the Needs of the Self and the Body
- The Body as an Instrument of the Self
- Understanding Harmony in the Self
- Harmony of the Self with the Body
- Programme to Ensure self-regulation and Health

Module 3 – Harmony in the Family and Society

- Harmony in the Family – the Basic Unit of Human Interaction
- 'Trust' – the Foundational Value in Relationship
- 'Respect' – as the Right Evaluation
- Values in Human-to-Human Relationship

- Understanding Harmony in the Society
- Vision for the Universal Human Order

Module 4 – Harmony in the Nature (Existence)

- Understanding Harmony in the Nature
- Interconnectedness, self-regulation and Mutual Fulfilment among the Four Orders of Nature
- Realizing Existence as Co-existence at All Levels
- The Holistic Perception of Harmony in Existence

Module 5 – Implications of the Holistic Understanding – a Look at Professional Ethics

- Basis for Universal Human Values
- Definitiveness of (Ethical) Human Conduct
- Professional Ethics in the light of Right Understanding
- A Basis for Humanistic Education, Humanistic Constitution and Universal Human Order
- Holistic Technologies, Production Systems and Management Models- Typical Case Studies
- Strategies for Transition towards Value-based Life and Profession

5. **Course title: Basic Engineering Laboratory-2**

Code: E106

Credits: 2

Syllabus:

Module 1: Mechanical engineering

- Mechanical measurements
- Filing, cutting, basic shape fitting, drilling and tapping.

Module 2: Materials engineering

- Identification of different engineering materials by their physical appearance, colour, weight in proportion to approximate size.
- Estimation of density of different engineering materials by adopting theoretical calculations and Archimedes principle.
- Sample preparation for metallographic examination: Cutting, grinding, mounting press operation, hot mounting, cold mounting, emery paper polishing, wet-polishing (fine polishing) and chemical etching.

6. **Course title: Engineering Chemistry**

Code: BS106

Credits: 3

Syllabus:

Unit 1: Atomic structure and bonding: Historical development of atomic theory. Structure of atoms. Electronic configuration and periodic trends. Chemical bonding: ionic, covalent, and metallic bonds and their relation to material properties. Effect of chemical bonding on physical properties – melting points, thermal expansion, Young's modulus and strength of solids, surface energy etc.

Unit 2: Behaviours of electrons in crystals – Free electrons, electrons in potential well, electrons in periodic field of a crystal, energy bands in crystal, reciprocal lattice, DOS, population density, energy bands in materials

Unit 3: Thermodynamics and Chemical Equilibrium: Combined laws of thermodynamics; Need and origin of new state properties: enthalpy, entropy, and Gibbs free energy; Chemical equilibrium.

Unit 4: Chemical Kinetics: Scope of kinetics against thermodynamics; Activation energy; Driving force; Rate of chemical reactions and transformations.

Unit 5: Electrochemistry: Galvanic cells and standard electrode potential. Nernst equation and its applications in predicting cell potential. Corrosion: mechanisms, types, and prevention methods. Introduction to batteries.

Unit 6: Engineering materials (and synthesis techniques): Polymers (classification, properties, and applications in engineering). Ceramics (types, properties, and applications). Composites (types, properties, and applications).

7. **Course title: Engineering Drawing**

Code: ES104

Credits: 3

Syllabus:

Unit 1: Introduction to engineering drawing: Introduction to the field of engineering graphics and its applications in various engineering disciplines. Importance of engineering drawings in the design and manufacturing process. Introduction CAD software. Engineering lettering and dimensioning practices according to standards.

Unit 2: Basic Geometrical Constructions: Lines, angles, and their classifications. Construction of triangles, quadrilaterals, and other polygons. Methods for construction of circles and tangents, ellipses and parabolas. Using CAD software to implement the same.

Unit 3: Orthographic Projection: Principles of orthographic projection (first-angle and third-angle projections).Drawing projections of points, lines, and planes in various orientations. Relationship between views and true lengths and angles. Projections of simple solids (prisms, pyramids, cylinders, cones).

Unit 4: Sections of Solids: Methods for representing sections of solids in orthographic drawings. True shapes of sections obtained by cutting planes. Applications in visualizing internal features and designing components.

Unit 5: Isometric Projection: Introduction to isometric projection as a pictorial representation. Isometric axes and scaling principles. Drawing isometric views of simple solids from orthographic projections using CAD software. Conversion between isometric and orthographic projections.

Semester - 3

1. **Course title: Principles of Mechanical Metallurgy**

Code: MT203

Credits: 3

Syllabus:

Structure of Materials: Atomic structure, chemical bond, crystalline — amorphous — quasi-crystalline materials, crystal structure, single crystal/polycrystalline materials, Ceramics, polymers, composites, lattice defects.

Elasticity: Deformation modes, Stress & strain (including hydrostatic and deviatoric components), atomic interaction, Hooke's law, elastic strain energy, Isotropy & Anisotropy, Young's modulus, shear modulus and bulk modulus, Temperature dependence of young's modulus.

Plasticity: Engineering strain & True strain, types of stress-strain diagram, Analysis of stress-strain diagram. Yield criteria and their application, flow rules and hardening, Theoretical strength, types of dislocations, the stress field of a dislocation, dislocation movement (glissile/sessile), slip system; Deformation by Slip vs. Twinning; Slip by dislocation movement; Critical resolved shear stress for slip; Deformation of single crystals; Stacking faults; Strain hardening. Critical Resolved Shear Stress (CRSS), Taylor factor. Shear fracture, cleavage fracture, fracture criteria

Materials testing: The Hardness Test, Hardness (scratch / rebound / indentation methods), Brinell/Rockwell/Vickers/Knoop procedures, Macro-micro and nano-indentation. The Tension Test; Engineering Stress-Strain Curve; True- Stress-True-Strain; Instability in Tension; Stress Distribution at the neck; Ductility Measurement in Tension; Test of Strain Rate on Flow Properties; Effect of Temperature on Flow Properties; Yield point phenomenon, Dynamic Strain Ageing etc.

Strengthening Mechanisms: Strengthening from grain boundaries; Yield-point phenomenon; Strain aging; Solid solution strengthening; Deformation of two-phase systems; Strengthening from fine particles; Fiber strengthening; Strengthening due to point defects; Cold-worked structures

Introduction to Fatigue, Creep & Fracture: Fundamentals, types of loading, time scale effects, temperature effects, S-N curve, Creep curve etc. Fracture definition, modes/types.

Suggested Reading:

1. Mechanical Metallurgy by George E. Dieter, 3rd Edition, Mc Graw-Hill Education, 2013.

2. Mechanical Behaviour of Materials by Thomas H. Courtney, 2nd Edition, Waveland Pr Inc, 2005.

2. **Course title: Semiconductor Materials and Devices**

Code: MT205

Credits: 3

Syllabus:

Unit –1 Semiconductor Materials

Fundamentals of semiconductor and compound semiconductor materials and their structures, bonding, defects and properties, Band gap & energy band diagram.

Unit – 2 PN Junction Diode And Application

Metals-semiconductors junction, PN junction diode and IV characteristics, Electrical break down in PN junction diode- Zenner breakdown, Avalanche breakdown, Applications of breakdown diodes, Tunnel diode, Schottky barrier diode, ohmic contact

Unit –3 Transistors, Mesfet And Mosfet

PnP and NpN transistors, CE, CB and CC configurations, IV characteristics, Transistors Ebers–Moll model and h- parameters, Junctions and metal- semiconductor filed-effect transistors (MESFETs), principle of operation, IV characteristics, Metal-oxide- field effect transistors (MOSFETs), Principle of operation, CV characteristics, Circuits models for MESFETs and MOSFETs.

Unit –4 Latest Semiconductor Devices

Fundamentals of Sensors, Solar cells, and Micro-Electro-Mechanical Systems (MEMS).

3. **Course title: Physical Metallurgy**

Code: MT215

Credits: 4

Syllabus:

Unit 1: Basic terms and Phase Diagrams

Microstructure; Phase: crystal structure, composition, chemical order; Morphology; Phase diagrams: Unary and binary: phase equilibria, solubility, tie line, lever rule; Transformations in phase diagrams: Solidification, reaction and precipitation; Experimental construction of phase diagram: cooling curve method

Tutorial: Exercises on connecting microstructure to phase diagrams: identification of types of phases, solubility, chemical order, phase transformations, phase compositions and fractions.

Unit 2: Thermodynamics of phase diagrams

Gibbs energy; Solution thermodynamics: chemical potential, activity, partial quantities; Thermodynamic underpinning of phase diagrams: Gibbs energy vs composition plots; Gibbs phase rule

Tutorial: Exercises on connecting Gibbs energy-composition diagrams to phase diagrams

Unit 3: Diffusion and Kinetics - introduction

Scope of kinetics against thermodynamics; Uphill and downhill diffusion; Driving force for diffusion; Interfacial energy

Unit 4: Phase transformation mechanisms and overall kinetics - introduction

Diffusional transformations: Nucleation and growth; Diffusionless (martensite) transformation; Overall transformation kinetics: TTT and CCT diagrams

Unit 5: Steels and heat treatment practices

Iron-iron carbide diagram; Ferrite and austenite stabilizers; Introduction to heat treatments: Annealing, Normalizing, Hardening, and Ageing.

Reference:

Physical Metallurgy: Principles and Practice, V. Raghavan, 2012, PHI Learning

Phase Transformations in Metals and Alloys, D. A. Porter, K. E. Easterling, M. Y. Sherif, 2021, CRC Press

Physical Metallurgy Principles, R. Abbaschian, L. Abbaschian, R. E. Reed-Hill, 2009, Cengage Learning

Heat Treatment: Principles and Techniques, C. P Sharma, A. Sharma, T.V Rajan, 2023,

4. **Course title: Functional Behavior of Materials**

Code: **MT211**

Credits: 3

Syllabus:

Unit 1: Introduction: Atomic structure, electronic configuration, periodic table, bonding forces and energies, ionic bonding, covalent bonding, metallic bonding, van der waals bonding, hydrogen bonding, dipole bonding;

Unit 2: Fundamentals of Electron Theory: Energy bands in crystals, electrons in a crystal, Fermi energy and surface, Fermi distribution function, density of states, population density, density of states function within a band, consequence of band model;

Unit 3: Electrical and Dielectric Properties: Electrical conduction, electronic and ionic conduction, band structure in solids, conduction in terms of band structure and atomic bonding model, electrical resistivity of metals, intrinsic and extrinsic semiconduction, electrical conduction in ionic ceramics and polymers, dielectric behavior – capacitance, types of polarization, frequency dependence of dielectric constant, dielectric strength, ferroelectricity, piezoelectricity;

Unit 4: Magnetic Properties: Basic concepts, diamagnetism and paramagnetism, ferromagnetism, antiferro- and ferrimagnetism, influence of temperature on magnetic behavior, domains and hysteresis, magnetic anisotropy, soft magnetic materials, hard magnetic materials, magnetic storage, superconductivity;

Unit 5: Thermal Properties: Heat capacity, thermal expansion, thermal conductivity, thermal stress/shock;

Unit 6: Optical Properties: Basic concepts, electromagnetic radiation, light interaction with solids, atomic and electronic interactions, refraction, reflection, absorption, transmission, optical birefringence, color, opacity and translucency in insulators, luminescence, photoconductivity, lasers;

Suggested Books:

1. Materials Science and Engineering, William D Callister, Jr.
2. Electronic Properties of Material, Rolf E. Hummel.
3. Materials Science for Engineers, James F. Shackelford.
4. Science and Engineering of Materials, Askeland.
5. Introduction to Solid State Physics, C. Kittel.
6. Elements of Materials Science and Engineering, Van Vlack and H. Lawrence.

5. **Course title: Physical Metallurgy Laboratory**

Code: MT217

Credits: 2

Syllabus:

1. Understanding the working principle of optical microscope and its construction details, operation as well as applications in the field of materials characterization.
2. Understanding the working principle of heat treatment furnace, its construction details and various sub-systems including the thermocouple, temperature controllers, different tools for sample loading un-loading as well as safety measures to be adopted during heat treatment of materials.
3. Understanding the Iron and Iron-carbide phase diagram. Annealing, Normalizing, and Hardening experiments on plain carbon steel followed by examination of the corresponding microstructure.
4. Sample preparation and microstructure examination of non-ferrous materials such as Aluminium, Copper and Nickel.

6. **Course title: Skill Development Laboratory**

Code: IE209

Credits: 2

Syllabus:

(a) <u>MIT App Inventor (a no-code platform)</u>

Exercise#1: Tip Calculator App

Exercise#2: Flashlight App (Toggle Image)
Exercise#3: Soundboard App
Exercise#4: Daily Quote App
Exercise#5: Pedometer Step Counter

(b) <u>Web app development exercises(no-code) using Figma or Canva</u>

Exercise#6: Personal Portfolio Web App (Figma/Canva)
Exercise#7: E-Commerce Product Page (Figma)
Exercise#8: Login & Sign-Up UI (Figma)
Exercise#9: Food Delivery App Dashboard (Figma)

(c) <u>Data visualization exercises using Flourish, Excel, and GenAI-based tools (like Copilot in Excel or ChatGPT + charts plugins).</u>

Exercise#10: Interactive World Map: Population or Internet Users
Exercise#11: Animated Bar Chart Race: GDP Growth or Medal Counts
Exercise#12: Excel Dashboard: Sales or Attendance Tracker
Exercise#13: GenAI Chat-to-Chart: Visualize Survey or CSV Data
Exercise#14: Storytelling with Multiple Visuals: Compare City AQI

<u>Semester - 4</u>

1. **Course title: Creativity and Innovation**

Code:

Credits: 3

Syllabus:

Module 1 (Theoretical underpinning of creative practices and innovation):

Overview of stages in creative practices and stages in innovation; Importance of thoroughly understanding a problem; Methods for defining a problem with examples; Overview of important techniques to generate new ideas: Attribute listening, Brainstorming, etc; Conceptual blocks and barriers for innovation;

Module 2 (Practical implementation):

Hand on training in various stages of innovation; Implementation of ideas to build products or services; Common issues in implementation of the ideas; practical guidelines with examples

2. **Course title: Diffusion, Kinetics and Phase Transformations (ME)**

Code: MT204

Credits: 3

Syllabus:

Unit 1:
Atomic theory of diffusion; Activation energy for diffusion; Fick's first law: Interstitial diffusion; Diffusion constant; Effect of temperature on diffusion; Fick's second law

Unit 2:
Solution to diffusion Equations: case studies of homogenization and carburization; Substitutional diffusion; Kirkendall effect; Types of diffusivities; Thermodynamic factor; High diffusivity paths

Unit 3:
Interfacial energy; Types of interfaces; Gibbs-Thomson effect; Equilibrium in polycrystalline material; Grain growth: non-glissile interface (thermally activated); Annealing stages: Recovery, Recrystallization, Grain Growth; Glissile interface motion;

Unit 4:
Nucleation rate; Diffusion-controlled and interface-controlled growth; Homogeneous transformations: Spinodal and binodal decomposition; ordering; massive transformation; diffusionless transformations: martensite transformation; displacive transformation; summary of transformations.

Unit 5:
Discontinuous precipitation; eutectoid transformation; T0 concept; Ostwald ripening; Order of transformations; Overall transformation kinetics; Johnson-Mehl-Avrami equation; Dendritic solidification: thermal and constitutional supercooling; cast structures;

Text books:

- Phase Transformations in Metals and Alloys, D. A. Porter, K. E. Easterling, M. Y. Sherif, 2021, CRC Press

- Physical Metallurgy Principles, R. Abbaschian, L. Abbaschian, R. E. Reed-Hill, 2009, Cengage Learning
- Hillert, Mats. Phase equilibria, phase diagrams and phase transformations: their thermodynamic basis., 2007, Cambridge university press
- Physical Metallurgy: Principles and Practice, V. Raghavan, 2012, PHI Learning

3. **Course title: Mechanical Behaviour of Engineering Materials**

Code:

Credits: 4

Syllabus:

Dislocation theory: Edge, screw and mixed dislocations, source and multiplication of dislocations, stress fields around dislocations; Partial dislocations, dislocation interactions and reactions, Peach-Koehler force.

Tension-Compression asymmetry: Reasons and implications; Mitigation strategies, Bauschinger effect.

Fatigue: Stress cycles; The S-N curve; Statistical nature of fatigue; Effect of mean stress on fatigue; Cyclic stress-strain curve; Low-cycle fatigue, High-cycle fatigue, thermal fatigue, fretting fatigue; Strain-life equation; Structural features of fatigue.

Creep: High temperature behaviour of materials; Larson-Miller parameter, Zener-Hollomon parameter, Time-dependent mechanical behaviour; Creep curve; Stress-Rupture test; Structural changes during creep; Mechanisms of creep deformation, Superplasticity.

Fracture mechanics: Stress concentration factor, testing of notched specimens, introduction to fracture mechanics, fracture modes, linear-elastic fracture mechanics, Elastic - plastic fracture mechanics, Crack tip opening displacement, Griffith theory, J-integral, R-curve. Environmental effects on deformation, Hydrogen embrittlement, Irradiation effects of nuclear engineering importance, Stress corrosion cracking, Ductile-brittle transition etc.

Mechanical behaviour at small length scales: Definition and introduction to length scales, feature size vs component size, hierarchical structures, classification and importance. Dislocation pile-up breakdown, Inverse Hall-Petch effect, grain boundary dislocation sources and sinks, grain-boundary sliding, rotation and coalescence, shear bands.

Suggested Reading:

1. Mechanical behaviour of materials, M. A. Meyers and K. K. Chawla, Second Edition, Cambridge University Press (2009).
2. Deformation and Fracture Mechanics of Engineering Materials, R. W. Hertzberg, R. P.Vinci, J. L. Hertzberg, Fifth Edition, John Wiley & Sons (2012).
3. K. V. Rajulapati and C. C. Koch, “Nanocrystalline Materials: Mechanical Properties”, Reference Module in Materials Science and Materials Engineering (Encyclopaedia of Materials), Elsevier, 2016.

4. Several recent scientific and review articles (Intimated and circulated during lectures).

4. **Course title: Principles of Extractive Metallurgy**

Code:

Credits: 3

Syllabus:

Unit 1
Topic: Mineral beneficiation. Scope of mineral beneficiation; Unit process; Comminution techniques; Size classification; Flotation, Gravity and other methods of mineral beneficiation; Agglomeration: Sintering, Pelletizing and Briquetting.

Unit 2
Topic: Basics of Metal Extraction. Categories of the routes of metal extraction and refining; Pyrometallurgy principles: Smelting, Thermodynamics of Reduction – Equilibrium constant and Ellingham diagram

Unit 3
Topic: Electrometallurgy and Hydrometallurgy. Basics of electrolysis, Electrolysis for Extraction; Pourbaix diagrams; Leaching, Purification and Recovery.

Unit 4:
Ore treatment: Calcination, Roasting; Extraction of iron: Introduction to blast furnace method

Unit 5:
Extraction of aluminium, copper and titanium; Material balance and Energy balance in extraction.

References:
Principles of Extractive Metallurgy, H.S. Ray and A. Ghosh (1992), Wiley-Blackwell
Suggested reference books
Mineral Beneficiation, A Concise Basic Course, D V Subbarao, CRC Press, 2011
The Extraction and Refining of Metals, C. Bodsworth, CRC Press (1994)
Extractive Metallurgy 1: Basic Thermodynamics and Kinetics, Alain Vignes (ISTE Ltd.,)
Extractive Metallurgy 2: Metallurgical Reaction Processes, Alain Vignes (ISTE Ltd.,)
Extractive Metallurgy 3: Processing Operations and Routes, Alain Vignes (ISTE Ltd.,)
Topics in non-ferrous extractive metallurgy, Burkin, Wiley-Blackwell (1980)
The Extraction and Refining of Metals, C. Bodsworth, CRC Press (1994)

5. **Course title: Phase Transformations Laboratory**

Code:

Credits: 2

Syllabus:

1. Homogenization – Elimination of chemical inhomogeneity in a segregated microstructure
2. Al - precipitation aging 2xxx *or* 6xxx series – Solutioning (T0)

3. Al - precipitation aging 2xxx *or* 6xxx series – Artificial aging (T6)
4. Ni-base superalloy aging – Gamma prime precipitates formation
5. Eutectoid transformation (lamellar) – Steel *or* Eutectic transformation (divorced) – Al-Si alloy
6. TGA for parabolic growth rate constant determination – oxidation of a metal
7. DTA for melting point determination of a metal
8. DSC for determination of heat of transformation on melting of a metal (first order transformation)

Glass transition (Second order transformation)

6. **Course title: Mechanical Testing Laboratory**

Code:

Credits: 2

Syllabus:

i. Rebound Hardness – a. Steel Ball b. Tennis Ball c. Cricket Ball
ii. Scratch Hardness
iii. Indentation-Based Hardness
    a. Macroindentation
    b. Microindentation
    c. Nanoindentation
iv. Tensile Test
v. Compression Test
vi. 3-point bending Test
vii. Realisation of the Yield Point Phenomenon
viii. Understanding Tension – compression asymmetry
ix. Determination of Superplasticity
x. Fatigue Testing.

7. **Course title: Transport Phenomena**

Code:

Credits: 3

Syllabus:

Unit 1

Mathematical foundations of transport phenomena, introduction to subscript notation & tensors, Control volume formulation and concept of balance

Unit 2

Navier-Stokes equations, exact solutions for simple geometries; Friction factors, empirical relations in fluid flow

Unit 3

Application of fluid flow solutions to materials processing; Governing equations for heat transfer, problem statements; Exact solutions for heat transfer problems; Empirical correlations, heat transfer coupled with fluid flow; Mass balance equations, governing equations

Unit 4

Diffusive mass transfer, exact solutions for simple geometries; Solute transfer during phase change

Unit 5

Convective mass transfer correlations, Similarity across transport phenomena

References

1) Transport phenomena, 2nd Edition: R. Byron Bird, Warren E. Stewart and Edwin N Lightfoot; John Wiley & Sons

2) Fundamentals of Momentum, Heat and Mass Transfer, 4th Edition: James R. Welty, Charles E. Wicks, Robert E. Wilson and Gregory Rorrer; John Wiley & Sons

3) Transport phenomena in materials processing : D.R. Poirier and G.H. Geiger, TMS

4) Introduction to Fluid Mechanics, 5th Edition: Robert W. Fox & Alan T. McDonald: John Wiley & Sons

5) Basic Transport Phenomena in Materials Engineering: Manabu Iguchi, Olusegun J. Ilegbusi; Springer

6) Mass Transport in Solids and Fluids: David S. Wilkinson; Cambridge University Press.

Semester - 5

1. **Course title: Materials Processing – 1**

Code:

Credits: 3

Syllabus:

Unit -1

Introduction to evolution of engineering materials and their classification. Applications of engineering materials including defence and civilian sectors (power generation bio-medical industries etc.)

Unit -2

Critical assessment and selection of materials processing techniques- evolution of microstructure - mechanical and functional properties.

Unit -3

Melting, solidification, nucleation and crystal growth. Formation of phases, dendrites, poly crystalline (equiaxed / columnar) and single crystal structures in materials.

Unit -4

Shaping of materials through melting and solidification. Metal casting, principles of foundry technology (sand casting, permanent mould casting, investment casting, casting defects and remedial methods)

Unit -5

Solid state processing of materials through plastic deformation (forging, rolling and extrusion), machining and joining (welding, brazing etc).

Unit -6

The concepts of innovative thermal and thermomechanical treatments for the advanced engineering materials.

References:

P. L. Jain, Principles of Foundry Technology, 1984

G. E. Dieter, Mechanical Metallurgy, 1988

P. Rao, Manufacturing Technology: Foundry, Forming and Welding, 2008

R.S. Parmar, Welding Processes and Technology, 1996

A. Ghosh and A.K. Mallik, Manufacturing Science, 1986

2. **Course title: Materials Characterization – 1**

Code:

Credits: 3

Syllabus:

Unit 1: Fundamentals of Crystallography

Structure and Microstructure; Basic crystallography; Crystal Structures; Point groups and space groups; Pole figures and inverse pole figures

Unit 2: Fundamental concepts for characterization

Scattering, interference and diffraction (including Bragg's law); Grains and Grain boundaries; Residual stress; Probes used in different techniques; Magnification, contrast and focus in microscopy; Interaction of electrons and X-rays with matter

Unit 3: X-ray diffraction (XRD)

Generation of X-rays; Different types of X-ray sources; Geometries for XRD; Origin of diffraction for single crystal, polycrystal and amorphous materials; Laue method; Analysis of XRD patterns of single phase and multiphase materials; Measurement of full width at half maximum; Peak intensity in an XRD pattern; Estimation of crystallite size; Measurement of residual stress; XRD patterns of films and coatings (glancing incidence XRD); brief introduction to small angle x-ray scattering (SAXS)

Unit 4: Optical and Electron Microscopy

Optical microscopy; Electron sources; Collimation of an electron beam; Introduction to Scanning Electron Microscopy and Transmission Electron Microscopy; Instrumentation for SEM and TEM; Modes of Imaging; Guidelines to obtain good images

Unit 5: Electron Diffraction and Energy Dispersive Spectroscopy

Introductory SAED; Diffraction in an SEM and EBSD; Analysis of EBSD patterns; Specimen preparation; Basics of Energy Dispersive Spectroscopy (EDS) and Wavelength Dispersive Spectroscopy WDS)

References:

1. Handouts and presentations distributed in class
2. Elements of X-ray Diffraction by B.D. Cullity
3. H. P. Klug, L. E. Alexander, X-ray diffraction procedures for polycrystalline and amorphous materials, John Wiley & Sons, New York, 1974.
4. J. I. Goldstein et al., Scanning Electron Microscopy and X-ray Microanalysis (2018) 4th edition
5. D. B. Williams, C. B. Carter, Transmission Electron Microscopy (4 volumes), Springer, USA, 2009.

3. **Material Processing Lab – 1**

Code:

Credits: 3

Syllabus:

1. Classification of Materials manufacturing processing in metals and alloys (Melting, Casting, Forming, Heat treatment, Metal joining)
2. Melting & alloy preparation
3. Casting
4. Metal forming
5. Heat treatment
6. Metal joining
7. Testing and characterization
8. Structure-property correlations during processing

4. **Materials Characterization Lab – 1**

Code:

Credits: 3

Syllabus:

- **XRD**
  - Phase identification of single-phase alloy in XRD - peak indexing method
  - Phase identification of dual phase alloy in XRD – single phase
  - Lattice parameter determination in XRD – single phase
  - Determination of average crystallite size measurement for single phase material: Scherrer equation method for crystallite size (coherent diffracting domain within a grain)
  - Strain measurement – Cold worked vs Annealed - Williamson Hall method
  - XRD patterns for amorphous materials / thin films
- **SEM**
  - SEM- SE imaging – topological contrast
  - SEM-BSE imaging - phase contrast for dual phase
  - SEM- Analysis of multilayer thin film cross section for thickness determination
  - SEM-EDS: (i) area EDS overall composition, (ii) point EDS – individual phase composition
- **TEM**
  - Imaging / Diffraction

5. **Corrosion Engineering**

Code:

Credits: 4

Syllabus:

Unit 1: Fundamentals of Corrosion

- Introduction: Definition, economic, safety, and environmental impact of corrosion.
- Electrochemical Principles: Principles of metallic corrosion, electrochemical cells, Anode/Cathode reactions, the Electromotive Force (EMF) series, and Nernst equation.
- Thermodynamics & Kinetics: Gibbs free energy, Pourbaix diagrams (potential-pH diagrams), exchange current density, polarization (activation, concentration, and resistance), and Evans diagrams.

Unit 2: Forms of Corrosion

- Classification: Uniform corrosion, Galvanic corrosion, Pitting corrosion, Crevice corrosion, Intergranular corrosion, Dealloying (selective leaching), Erosion-corrosion, and Environmentally Assisted Cracking (Stress Corrosion Cracking, Hydrogen Embrittlement, Corrosion Fatigue).

Unit 3: Corrosion Testing & Monitoring

- Laboratory Methods: Weight loss measurements, electrochemical impedance spectroscopy (EIS), potentiodynamic polarization, and scratch tests.

- Field Monitoring: Corrosion coupons, electrical resistance probes, and linear polarization resistance (LPR).
- Standards: Introduction to ASTM and NACE standards for corrosion testing.

Unit 4: Corrosion Control and Prevention

- Material Selection: Thermodynamic stability, alloy development, and passivity.

- Design Considerations: Geometric design to avoid crevices, drainage, and galvanic isolation.
- Protective Coatings: Metallic, inorganic, and organic coatings (paints, polymers, inhibitors).
- Cathodic and Anodic Protection: Principles of Sacrificial Anodes (Galvanic Protection) and Impressed Current Cathodic Protection (ICCP).

Unit 5: Industrial Applications and Case Studies

- Environment-Specific Corrosion: Atmospheric, soil, seawater, and high-temperature oxidation/sulfidation

- Industrial Case Studies: Corrosion issues in oil and gas pipelines, power plants (boilers/condensers), and automotive industries.
- Risk-Based Inspection (RBI) & Asset Integrity: Basic introduction to managing aging infrastructure and life-cycle costing.

Practical Exposure

1. Potentiostatic Polarization Study: Determining the corrosion rate of a mild steel specimen in a salt solution.
2. Galvanic Corrosion Setup: Observing potential differences between dissimilar metals.
3. Coating Performance Test: Evaluating the adhesion and durability of common industrial protective coatings.
4. AI enhanced Real Time Monitoring of Corrosion

References

- Corrosion Engineering by M.G. Fontana and N.D. Greene.
- Principles and Prevention of Corrosion by Denny A. Jones; Uhlig's Corrosion Handbook.
- Software/Tools: Exposure to basic electrochemical software for analyzing polarization data (e.g., EC-Lab or open-source equivalents).

6. **Physics of Materials – 1**

Code:

Credits: 4

Syllabus:

- Properties of materials, thermal expansion
- DC and AC techniques to measure electronic conductivity, free electron gas,
- Drude model for electronic conductivity and for thermal conductivity; Successes and Limitations of the Drude model –
- The Wiedemann Franz Law; Statistical Mechanics, Maxwell-Boltzmann statistics; history of quantum mechanics; Drude
- Sommerfeld model, Fermi-Dirac Statistics; Confinement and quantization; calculating density of available states for electrons;
- Fermi Energy, Fermi Surface, Fermi Temperature; Reciprocal space ; Wigner seitz cells Brillouin zones;
- Calculating allowed and forbidden energy levels; Description of tight binding approximation, impact of inter atomic spacing on band gaps.
- Comparison of free electron approximation and tight binding approximation. Efect of pressure on band gaps;
- Direct Band gap, indirect Band gap semiconductors; Magnetic properties; Electron compounds/Hume Rothery phases.
- Phonons, Optoelectronic properties;
- Superconductivity, Bose-Einstein Statistics;
- Physics of nano scale materials.

References:

- SWAYAM-NPTEL course content and references.

7. **Industrial Engineering & Operations Research**

Code:

Credits: 3

Syllabus:

- Definition of Industrial Engineering and Operations Research, Production Planning and Control, aggregate production planning, Product design (functional, aesthetic and human factors aspects), Job, batch, and flow production methods (Not much mathematics in this week; only covering basic concepts)

- Work study including ergonomics, Time and motion study, Inventory management: a brief introduction to Lean Manufacturing, JIT, MRP, MRP-II and digital supply chain management
- Total Quality Management (TQM), Statistical Process Control, Acceptance Sampling, six sigma
- Forecasting, Scheduling (only heuristic methods), Assignment problem (only Hungarian method)
- Line balancing, Breakeven analysis, A comparative exposure to Industry 4.0 and Industry 5.0
- Application of big data, analytics, Internet of Things in manufacturing, Smart factories, Digital Model, Digital Shadow and Digital twins (Contents will be descriptive only for providing exposure and indicating the application in industries; each of these topics need dedicated study of several hours. Here, the purpose is to provide directions to students. One small case study will be provided.)
- Linear programming, Graphical method, Simplex method
- Dual problem, Concept of unit worth of resource, Discussion on some exercise problems
- Transportation problems, unbalanced and degenerate transportation problems
- Network models: CPM and PERT
- Queuing theory: applications and definition of terms, exponential and Poisson distribution, Little's law, single-server model, multiple-server model
- Simple deterministic and probabilistic inventory models

References:
SWAYAM-NPTEL course content and references.

8. Numerical Methods for Engineers

Code:

Credits: 4

Syllabus:

- Introduction & Approximations Motivation and Applications Accuracy and precision; Truncation and round-off errors; Binary Number System; Error propagation
- Linear Systems and Equations Matrix representation; Cramer's rule; Gauss Elimination; Matrix Inversion; LU Decomposition;
- Linear Systems and Equations Iterative Methods; Relaxation Methods; Eigen Values
- Algebraic Equations: Bracketing Methods Introduction to Algebraic Equations Bracketing methods: Bisection, Reguli-Falsi;
- Algebraic Equations: Open Methods Secant; Fixed point iteration; Newton-Raphson; Multivariate Newton's method
- Numerical Differentiation Numerical differentiation; error analysis; higher order formulae
- Integration and Integral Equations Trapezoidal rules; Simpson's rules; Quadrature
- Regression Linear regression; Least squares; Total Least Squares;
- Interpolation and Curve Fitting Interpolation; Newton's Difference Formulae; Cubic Splines
- ODEs: Initial Value Problems Introduction to ODE-IVP Euler's methods; Runge-Kutta methods; Predictor-corrector methods;
- ODE-IVP (Part-2) Extension to multi-variable systems; Adaptive step size; Stiff ODEs
- ODEs: Boundary Value Problems Shooting method; Finite differences; Over/Under Relaxation (SOR)

References:
SWAYAM-NPTEL course content and references.