# NATIONAL INSTITUTE OF TECHNOLOGY

# DURGAPUR

## CURRICULUM

## OF

### BACHELOR OF TECHNOLOGY IN METALLURGICAL AND MATERIALS ENGINEERING

## 2023 ONWARD UNDERGRADUATE ADMISSION BATCH

Curriculum

**V0:**

| | |
|---|---|
| First Year Curriculum Recommended by members of UGAC | 19.08.2023 |
| First Year Curriculum Approved by the Chairman, Senate | 19.08.2023 |
| First Year Curriculum & Syllabus ratified in the 71st Senate meeting (Item No. 71.5(b)) | 18.12.2023 |
| Entire Curriculum and Syllabus Recommended by UGAC | 09.12.2024 |
| Entire Curriculum and Syllabus Approved by the 73rd Senate (Item No. 73.8) | 23.03.2025 |

# DEPARTMENT OF METALLURGICAL AND MATERIALS ENGINEERING

## Program Name: Bachelor of Technology in Metallurgical and Materials Engineering

## DETAILED CURRICULUM

## OF

## B. TECH. in METALLURGICAL AND MATERIALS ENGINEERING

**L= Lecture hour/ week; T= Tutorial hour/ week; P= Sessional/ practical hour/ week**
**C= Subject credit point; H= Subject contact hour/ week.**

| Semester - I | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Sl. No** | **Code** | **Subject** | **L** | **T** | **P** | **C** | **H** |
| 1 | MAC01 | Mathematics - I | 3 | 1 | 0 | 4 | 4 |
| 2 | CSC01 | Computer Programming | 2 | 1 | 0 | 3 | 3 |
| 3 | XEC01 | Engineering Mechanics | 2 | 1 | 0 | 3 | 3 |
| 4 | XEC02 | Basic Electrical and Electronics Engineering | 3 | 0 | 0 | 3 | 3 |
| 5 | ESC01 | Ecology and Environment | 2 | 0 | 0 | 2 | 2 |
| 6 | CYC01 | Engineering Chemistry | 3 | 0 | 0 | 3 | 3 |
| 7 | CSS51 | Computing Programming Laboratory | 0 | 0 | 3 | 2 | 3 |
| 8 | XES52 | Basic Electrical and Electronics Engineering Laboratory | 0 | 0 | 3 | 2 | 3 |
| 9 | CYS51 | Engineering Chemistry Laboratory | 0 | 0 | 2 | 1 | 2 |
| **TOTAL** | | | **15** | **3** | **8** | **23** | **26** |
| **Semester - II** | | | | | | | |
| **Sl. No** | **Code** | **Subject** | **L** | **T** | **P** | **C** | **H** |
| 1 | MAC02 | Mathematics - II | 3 | 1 | 0 | 4 | 4 |
| 2 | CSC02 | Data Structure and Algorithms | 2 | 1 | 0 | 3 | 3 |
| 3 | PHC01 | Engineering Physics | 2 | 1 | 0 | 3 | 3 |
| 4 | HSC01 | Professional Communication | 2 | 0 | 2 | 3 | 4 |
| 5 | CSS52 | Data Structure and Algorithms Laboratory | 0 | 0 | 3 | 2 | 3 |
| 6 | XES51 | Engineering Graphics | 0 | 1 | 3 | 3 | 4 |
| 7 | PHS51 | Engineering Physics Laboratory | 0 | 0 | 2 | 1 | 2 |
| 8 | XXS51 | Extra Academic Activities | 0 | 0 | 2 | 1 | 2 |
| **TOTAL** | | | **9** | **4** | **12** | **20** | **25** |

| Semester - III | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Sl. No** | **Code** | **Subject** | **L** | **T** | **P** | **C** | **H** |
| 1 | MAC331 | Mathematics- III | 3 | 1 | 0 | 4 | 4 |
| 2 | MMC301 | Introduction to Metallurgy and Materials | 3 | 1 | 0 | 4 | 4 |
| 3 | MMC302 | Metallurgical Thermodynamics and Kinetics | 3 | 1 | 0 | 4 | 4 |
| 4 | MMC303 | Non - Ferrous Process Metallurgy | 3 | 1 | 0 | 4 | 4 |
| 5 | MMC304 | Computational Materials Science | 3 | 1 | 0 | 4 | 4 |
| 6 | MMS351 | Metallurgical Thermodynamics and Kinetics Laboratory | 0 | 0 | 3 | 2 | 3 |
| 7 | MMS352 | Mineral Beneficiation Laboratory | 0 | 0 | 3 | 2 | 3 |
| 8 | MMS353 | Computational Materials Science Laboratory | 0 | 0 | 3 | 2 | 3 |
| **TOTAL** | | | **15** | **5** | **9** | **26** | **29** |
| **Semester - IV** | | | | | | | |
| **Sl. No** | **Code** | **Subject** | **L** | **T** | **P** | **C** | **H** |
| 1 | MMC401 | Transport Phenomena in Metallurgical Processes | 3 | 1 | 0 | 4 | 4 |
| 2 | MMC402 | Phase Transformation and Phase Equilibria | 3 | 1 | 0 | 4 | 4 |
| 3 | MMC403 | Materials Characterization | 3 | 1 | 0 | 4 | 4 |
| 4 | MMC404 | Physics of Materials | 3 | 0 | 0 | 3 | 3 |
| 5 | MMC405 | Manufacturing Processes | 3 | 1 | 0 | 4 | 4 |
| 6 | MMS451 | Transport Phenomena Laboratory | 0 | 0 | 3 | 2 | 3 |
| 7 | MMS452 | Phase Transformation and Phase Equilibria Laboratory | 0 | 0 | 3 | 2 | 3 |
| 8 | MMS453 | Materials Characterization Laboratory | 0 | 0 | 3 | 2 | 3 |
| **TOTAL** | | | **15** | **4** | **9** | **25** | **28** |
| **Semester - V** | | | | | | | |
| **Sl. No** | **Code** | **Subject** | **L** | **T** | **P** | **C** | **H** |
| 1 | MMC501 | Modelling and Simulation of Metallurgical Processes | 3 | 1 | 0 | 4 | 4 |
| 2 | MMC502 | Engineering Materials and Heat Treatment | 3 | 1 | 0 | 4 | 4 |
| 3 | MMC503 | Mechanical Behaviour of Materials | 3 | 1 | 0 | 4 | 4 |
| 4 | MMC504 | Iron Making | 3 | 0 | 0 | 3 | 3 |
| 5 | MME510--- | Depth Elective - 1 | 3 | 0 | 0 | 3 | 3 |
| 6 | MMS551 | Manufacturing Processes Laboratory - I | 0 | 0 | 3 | 2 | 3 |
| 7 | MMS552 | Heat Treatment of Materials Laboratory | 0 | 0 | 3 | 2 | 3 |
| 8 | MMS553 | Mechanical Behaviour of Materials Laboratory | 0 | 0 | 3 | 2 | 3 |
| **TOTAL** | | | **15** | **3** | **9** | **24** | **27** |

| Semester - VI | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Sl. No** | **Code** | **Subject** | **L** | **T** | **P** | **C** | **H** |
| 1 | HSC631 | Economics and Management Accountancy | 3 | 0 | 0 | 3 | 3 |
| 2 | MMC601 | Mechanical Working of Materials | 3 | 1 | 0 | 4 | 4 |
| 3 | CSC631 | Artificial Intelligence (AI) and Machine Learning (ML) | 3 | 0 | 2 | 4 | 5 |
| 4 | MME610 -- | Depth Elective - 2 | 3 | 0 | 0 | 3 | 3 |
| 5 | MME610 -- | Depth Elective - 3 | 3 | 0 | 0 | 3 | 3 |
| 6 | MMS651 | Mechanical Working of Materials Laboratory | 0 | 0 | 3 | 2 | 3 |
| 7 | MMS652 | Manufacturing Processes Laboratory - II | 0 | 0 | 3 | 2 | 3 |
| **TOTAL** | | | **15** | **1** | **8** | **21** | **24** |
| **Semester - VII** | | | | | | | |
| **Sl. No** | **Code** | **Subject** | **L** | **T** | **P** | **C** | **H** |
| 1 | MSC731 | Principles of Management | 3 | 0 | 0 | 3 | 3 |
| 2 | MMC701 | Steel Making | 3 | 0 | 0 | 3 | 3 |
| 3 | MME710 -- | Depth Elective - 4 | 3 | 0 | 0 | 3 | 3 |
| 4 | MME710 -- | Depth Elective - 5 | 3 | 0 | 0 | 3 | 3 |
| 5 | YYO74* | Open Elective - 1 | 3 | 0 | 0 | 3 | 3 |
| 6 | MMS751 | Ferrous Process Metallurgy Laboratory | 0 | 0 | 3 | 2 | 3 |
| 7 | MMS752 | Materials Testing Laboratory | 0 | 0 | 3 | 2 | 3 |
| 8 | MMS753 | Summer Internship | 0 | 0 | 2 | 1 | 3 |
| 9 | MMS754 | Project – I | 0 | 0 | 3 | 1 | 3 |
| **TOTAL** | | | **15** | **0** | **11** | **21** | **27** |
| **Semester - VIII** | | | | | | | |
| **Sl. No** | **Code** | **Subject** | **L** | **T** | **P** | **C** | **H** |
| 1 | MMS851 | Project – II | 0 | 0 | 15 | 6 | 15 |
| 2 | MMS852 | Comprehensive Viva | 0 | 0 | 0 | 1 | 0 |
| **TOTAL** | | | **0** | **0** | **15** | **7** | **15** |

## CREDIT UNIT OF THE PROGRAM:

| **Semester** | I + II | III | IV | V | VI | VII | VIII | TOTAL |
|---|---|---|---|---|---|---|---|---|
| **Credit Unit** | 43 | 26 | 25 | 24 | 21 | 21 | 7 | 167 |

## List of Core Subjects:

| **Sl No** | **Core Subjects** | |
|---|---|---|
| 1 | MMC301 | Introduction to Metallurgy and Materials |
| 2 | MMC302 | Metallurgical Thermodynamics and Kinetics |
| 3 | MMC303 | Non - Ferrous Process Metallurgy |
| 4 | MMC304 | Computational Materials Science |
| 5 | MMC401 | Transport Phenomena in Metallurgical Processes |
| 6 | MMC402 | Phase Transformation and Phase Equilibria |
| 7 | MMC403 | Materials Characterization |
| 8 | MMC404 | Physics of Materials |
| 9 | MMC405 | Manufacturing Processes |
| 10 | MMC501 | Modelling and Simulation of Metallurgical Processes |
| 11 | MMC502 | Engineering Materials and Heat Treatment |
| 12 | MMC503 | Mechanical Behaviour of Materials |
| 13 | MMC504 | Iron Making |
| 14 | MMC601 | Mechanical Working of Materials |
| 15 | MMC701 | Steel Making |

## List of Subjects in Depth Elective – 1 to be offered in FIFTH SEMESTER

| CODE | DEPARTMENT OF METALLURGICAL AND MATERIALS ENGINEERING |
|---|---|
| MME510 | Functional Materials |
| MME511 | Energy Materials |
| MME512 | Alternative Routes of Iron Making |
| MME513 | Design and Selection of Engineering Materials |
| MME514 | Powder Metallurgy |

## List of Subjects in Depth Elective – 2 & 3 to be offered in SIXTH SEMESTER

| CODE | DEPARTMENT OF METALLURGICAL AND MATERIALS ENGINEERING |
|---|---|
| MME610 | Advanced Engineering Materials |
| MME611 | Energy and Environment in Metallurgical Industries |
| MME612 | Production of Ferroalloys |
| MME613 | Nano Science and Technology |
| MME614 | Ceramic Technology |
| MME615 | Solidification Phenomena |
| MME616 | Metal Joining Processes |
| MME617 | Experimental Techniques in Metallurgy |
| MME618 | Secondary Steel Making |
| MME619 | Coatings and Thin Film Technology |
| MME620 | Stainless Steel; Technologies and Applications |
| MME621 | Green Steel Making |
| MME622 | Metallurgical Waste Management |

## List of Subjects in Depth Elective – 4 & 5 to be offered in SEVENTH SEMESTER

| CODE | DEPARTMENT OF METALLURGICAL AND MATERIALS ENGINEERING |
|---|---|
| MME711 | Fatigue, Creep and Fracture |
| MME712 | Raw Materials Preparation for Iron and Steel Making |
| MME713 | Fuel, Furnace and Refractories |
| MME714 | Corrosion Engineering |
| MME715 | Metallurgical Process Design |
| MME716 | Composite Materials |
| MME717 | Advanced Material Processing |
| MME718 | High Temperature Materials |

## List of Non-Departmental Subjects:

MAC331- Mathematics- III
HSC631- Economics and Management Accountancy
CSC631- Artificial Intelligence (AI) and Machine Learning (ML)
MSC731- Principles of Management

## List of Sessional Subjects:

| Sl No | Laboratory | |
|---|---|---|
| 1 | MMS351 | Metallurgical Thermodynamics and Kinetics Laboratory |
| 2 | MMS352 | Mineral Beneficiation Laboratory |
| 3 | MMS353 | Computational Materials Science Laboratory |
| 4 | MMS451 | Transport Phenomena Laboratory |
| 5 | MMS452 | Phase Transformation and Phase Equilibria Laboratory |
| 6 | MMS453 | Material Characterization Laboratory |
| 7 | MMS551 | Manufacturing Processes Laboratory - I |
| 8 | MMS552 | Heat Treatment of Materials Laboratory |
| 9 | MMS553 | Mechanical Behaviour of Materials Laboratory |
| 10 | MMS651 | Mechanical Working of Materials Laboratory |
| 11 | MMS652 | Manufacturing Processes Laboratory - II |
| 12 | MMS751 | Ferrous Process Metallurgy Laboratory |
| 13 | MMS752 | Materials Testing Laboratory |

## FIRST SEMESTER

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

| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
|---|---|---|---|---|---|---|---|
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MAC01 | MATHEMATICS - I | PCR | 3 | 1 | 0 | 4 | 4 |
| Pre-requisites | | Basic concepts of function, limit, differentiation and integration. | | | | | |
| Course Outcomes | • CO1: learn the fundamentals of differential calculus of single and several variables.<br>• CO2: learn the basic concepts of convergence of infinite series.<br>• CO3: understand the basic concepts of integral calculus along with its various applications.<br>• CO4: acquire the theoretical knowledge of vector calculus and its engineering applications. | | | | | | |
| Topics Covered | **Functions of Single Variable:** Review of limit, continuity and differentiability. Mean value theorems: Rolle's Theorem, Lagrange's Mean Value Theorem (MVT), Cauchy's MVT, Taylor's theorem, Taylor's and Maclaurin's series. (8)<br>**Functions of several variables:** Limit, continuity and differentiability of functions of several variables, partial derivatives and their geometrical interpretation, derivatives of composite and implicit functions, derivatives of higher order and their commutativity, Homogeneous function, Euler's theorem and its converse, Exact differential, Jacobian, Taylor's & Maclaurin's series, Maxima and Minima, Necessary and sufficient condition for maxima and minima (no proof). (11)<br>**Sequences and Series:** Real sequences and their convergence, Series of positive terms, Necessary and sufficient condition for convergence, p-series, geometric series, Comparison test, D Alembert's ratio test, Cauchy's root test, Alternating series, Leibnitz's rule, Absolute and conditional convergence. (6)<br>**Integral Calculus:** Review of the idea of integration as a limit of a sum, Mean value theorems of integral calculus, Area and length in Cartesian and polar co-ordinates, Volume and surface area of solids of revolution in Cartesian and polar forms, Improper integrals and their convergence, Beta and Gamma functions. (12)<br>**Multiple Integrals:** Evaluation of double and triple integrals, Change of order of integration, Change to better coordinates, Area and volume by double integration, Volume by triple integration. (10)<br>**Vector Calculus:** Vector valued functions and its differentiability, Line integral, Surface integral, Volume integral, Gradient, Curl, Divergence, Green's theorem in the plane (including vector form), Stokes' theorem, Gauss's divergence theorem and their engineering applications. (9) | | | | | | |
| Text Books, and/or reference material | **Text Books:**<br>1. Kreyszig, E., Advanced Engineering Mathematics: 10th edition, Wiley India Edition, 2010.<br>2. Murray, D.A., Differential and Integral Calculus, FB & C Limited, 2018.<br>3. Marsden, J. E; Tromba, A. J.; Weinstein: Basic Multivariable Calculus, Springer, 2014.<br>4. Murray Spiegel, Schaum's Outline of Vector Analysis, .1980 ,Tata McGraw Hill Education<br>**Reference Books:**<br>1. Tom Apostal, Calculus-Vol-I & II, Wiley Student Edition, 2011.<br>2. Thomas and Finny: Calculus and Analytic Geometry, 11th Edition, Addison Wesley. | | | | | | |

| Course | COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MAC01 | CO1 | 2 | 3 | 2 | 3 | 1 | 1 | - | - | 1 | 1 | 1 | 2 |
| | CO2 | 2 | 3 | 2 | 3 | - | 1 | - | - | 1 | 1 | 2 | 2 |
| | CO3 | 2 | 3 | 2 | 3 | - | 1 | 1 | - | - | 2 | 2 | 2 |
| | CO4 | 3 | 3 | 2 | 3 | 1 | 1 | - | 1 | - | 2 | 1 | 2 |

**Correlation levels 1, 2 or 3 as defined below**:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
|---|---|---|---|---|---|---|---|
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| **CSC01** | **COMPUTER PROGRAMMING** | PCR | 2 | 1 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| Basic knowledge of computer. | | CT+MT+EA | | | | | |
| Course Outcomes | • CO1: To understand basics of computer programming, program flow, and programming constructs.<br>• CO2: Develop concepts on basic and complex data types, conditional and iterative statements.<br>• CO3: Exercise the concepts of user defined functions to solve real time problems.<br>• CO4: Inscribe C programs that use Pointers to access arrays, strings and functions.<br>• CO5: Exercise user defined data types including structures and unions to solve problems. | | | | | | |
| Topics Covered | **Introduction to C**: Phases of developing a running computer program in C. (2L)<br>Data types, size and values. Char, Unsigned and Signed data types. Number systems and representations. Constants, Overflow. (3L)<br>Data concepts in C: Constants, Variables, Expressions, Operators, and operator precedence in C. (2L)<br>Statements: Declarations, Input-Output Statements, Compound statements, Selection Statements. (2L)<br>Conditions, Logical operators, Precedences. Repetitive statements, While construct, Do-while Construct, For construct. (3L)<br>Arrays. Strings. Multidimensional arrays and matrices. (3L)<br>**Pointers:** Pointer variables. Declaring and dereferencing pointer variables. Pointer Arithmetic. Examples. Accessing arrays through pointers. Pointer types, Pointers and strings. String operations in C. (6L)<br>Dynamic memory allocation. (2L)<br>**Modular Programming:** Functions: The prototype declaration, Function definition. (3L)<br>Function call: Passing arguments to a function, by value, by reference. Scope of variable names. Recursive function calls, Tail recursion. (4L)<br>Sorting problem: Sorting in arrays with an example of Bubble sort. Sorting in strings. (3L)<br>Search problem: Linear search and binary search. (2L)<br>**More Data-types in C:** Structures in C: Motivation, examples, declaration, and use. Operations on structures. Passing structures as function arguments. type defining structures. (4L)<br>File input-output in C. Streams. Input, output and error streams. Opening, closing and reading from files. Programming for command line arguments. (3L) | | | | | | |
| Text Books, and/or reference material | **Text Books:**<br>1. P. Deitel, H. Deitel. C How to Program. Pearson Education India, 7th Ed.<br>2. B. W. Kernighan, Dennis M. Ritchie. The C Programming. Prentice Hall Software Series, 2nd Ed.<br>**Reference Books:**<br>1. P. Dey and M. Ghosh. Computer fundamentals and programming in C. Oxford press, 2013.<br>1. Y. Kanetkar. Let Us C. BPB Publications, Sixteenth edition, 2017. | | | | | | |

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

| Course | COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CSC01 | CO1 | 2 | 2 | 1 | - | 1 | 2 | - | - | - | - | - | - |
| | CO2 | 3 | 2 | 1 | - | 1 | 1 | 1 | - | - | - | - | - |
| | CO3 | 2 | 2 | 1 | - | - | 2 | - | - | - | - | - | - |
| | CO4 | 3 | 2 | 2 | - | - | 1 | - | - | - | - | - | - |
| | CO5 | 3 | 1 | 2 | - | 1 | 2 | - | - | - | - | - | - |

**Correlation levels 1, 2 or 3 as defined below**:

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

| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
|---|---|---|---|---|---|---|---|
| | | | Lecture (L) | Tutorial (T) | Practical (P)# | Total Hours | |
| **XEC01** | **ENGINEERING MECHANICS** | PCR | 2 | 1 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| | | CT+MT+EA | | | | | |
| Course Outcomes | • CO1: Acquire knowledge of mechanics and ability to draw free body diagrams.<br>• CO2: Apply knowledge of mechanics for solving special problems like truss and frame analysis.<br>• CO3: Ability to calculate centroid, moments of inertia for various shapes.<br>• CO4: Learn momentum and energy principles. | | | | | | |

| | |
|---|---|
| | • CO5: Knowledge on virtual Work Principle and its application |
| Topics Covered | Engineering Mechanics; measurement and SI units. [1]<br>Vectors and force as a vector; Resultant of a system of forces on a particle; free body diagram and conditions of equilibrium of a particle; problems on particles; equilibrium of particles in space. [2]<br>Resultant of a system of forces and couples on a rigid body; conditions of equilibrium of a rigid body; free body diagrams of rigid bodies subjected to different types of constraints; simple space problems of rigid bodies. [4]<br>Coefficients of static and kinetic friction; problems involving friction; theories of friction on square threaded power screw and flat belt. [5]<br>Simple trusses; analysis of trusses by method of joints and method of sections. [5]<br>Centre of gravity and centre of mass; centroids of lines, curves and areas; first moment of area; second moment of area; polar moment of inertia; radius of gyration of an area; parallel axis theorem; mass moment of inertia. [4]<br>Path, velocity, acceleration; rectilinear and curvilinear motion; motion of system of particles; introduction to the concept of plane kinematics of rigid bodies. [6]<br>Newton's second law of motion; dynamic equilibrium and D'Alembert's principle; linear momentum; angular momentum; rectilinear and curvilinear motion; principles of work–energy and impulse–momentum; impact of system of particles; introduction to the concept of plane kinetics of rigid bodies. [12]<br>Principle of Virtual Work, Solution of Problems on Mechanics using Principle of Virtual Work [3] |
| Text Books, and/or reference material | 1) S P Timoshenko and D H Young, Engineering Mechanics, 5th Edition<br>2) J L Meriam and L G Kraige, Engineering Mechanics, 5th Edition, Wiley India<br>3) F P Beer and E R Johnston, Vector Mechanics for Engineers<br>4) I H Shames, Engineering Mechanics |

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

| Course | COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| XEC01 | CO1 | 1 | - | - | - | - | - | - | - | - | - | - | 1 |
| | CO2 | 1 | 1 | 1 | 1 | - | - | - | - | - | - | - | 1 |
| | CO3 | 1 | 1 | - | - | - | - | - | - | - | - | - | 1 |
| | CO4 | 1 | 2 | - | - | - | - | - | - | - | - | - | 1 |
| | CO5 | - | 2 | 2 | 2 | 2 | 1 | - | - | - | 1 | - | 1 |

**Correlation levels 1, 2 or 3 as defined below**:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
|---|---|---|---|---|---|---|---|
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| **XEC02** | **Basic Electrical and Electronics Engineering** | PCR | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | | Course Assessment methods | | | | |
| (10+2) level mathematics and physics | | | CT+MT+EA | | | | |

| | |
|---|---|
| Course Outcomes | CO1: Learn the fundamentals of electric circuits and analyze the circuits using laws and network theorems.<br>CO2: Gain the knowledge about magnetic circuits, electromagnetism and the basics of generation of alternating voltage.<br>CO3: Understand the behaviour of single phase and poly-phase AC circuits.<br>CO4: Understand the fundamentals of semiconductor devices.<br>CO5: Analyze the design and characteristics of transistor-based electronic circuits.<br>CO6: Evaluate operational amplifier-based circuits and logic gates. |
| Topics Covered | 1. Introduction to Electrical systems, Fundamentals of Electric Circuits: Ohm's laws, Kirchhoff's laws, Independent and Dependent sources, Analysis of simple circuits. (4)<br>2. Network theorems (DC): Superposition Theorem, Thevenin's Theorem, Norton's Theorem, Maximum Power Transfer Theorem. (5)<br>3. Magnetic circuits: Review of fundamental laws of electromagnetic induction, Self and mutual inductances, Solution of magnetic circuits. (3)<br>4. Generation of alternating voltage and current, E.M.F. equation, Average and R.M.S. value, Phase and phase difference, Phasor representation of alternating quantity, Behaviour of AC circuits, Resonance in series and parallel R-L-C circuits. (6)<br>5. Poly-phase system, Advantages of 3-phase system, Generation of 3-phase voltages, Voltage, current and power in a star and delta connected systems, 3-phase balanced and unbalanced circuits. (3)<br>6. Semiconductor Devices: Construction, working and V-I characteristics of diode, Zener diode, Zener diode as a voltage regulator, LED. (6) |

| | |
|---|---|
| | 7. Transistors:Introduction to BJT, FET, MOSFET; CMOS, working principle, and V-I characteristics of Transistors, biasing of BJT circuits-fixed bias, emitter bias, feedback bias, voltage divider bias, transistor as an amplifier. (8)<br>8. Operational amplifier:Introduction, applications: inverting, non-inverting amplifier, unity follower, integrator, differentiator, summing circuit .(4)<br>9. Introduction of logic gates, memory: ROM, RAM. (3) |
| Text Books, and/or reference material | **TEXT BOOKS**<br>1. Electrical & Electronic Technology by Hughes, Pearson Education India.<br>2. Introduction Electronic Devices & Circuit Theory, 11/e, 2012, Pearson: Boylestad&Nashelsky.<br>3. Electronics: Fundamentals and Applications By D. Chattopadhyay, P. C. Rakshit; New Age Int. Publication.<br>**REFERENCE BOOKS**<br>1. Advanced Electrical Technology by H. Cotton, Reem Publication Pvt. Ltd.<br>2. Electrical Engineering fundamentals by Vincent Deltoro, Pearson Edu. India.<br>3. The Art of Electronics 3e, by Paul Horowitz, Winfield Hill.<br>4. Electronics - Circuits and Systems, Fourth Edition by Owen Bishop.<br>5. Electronics Fundamentals: Circuits, Devices & Applications (8e) by Thomas L. Floyd & David M. Buchla. |

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

| Course | COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| XEC02 | CO1 | 3 | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | CO2 | 3 | 3 | 3 | 3 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 |
| | CO3 | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 1 |
| | CO4 | 2 | 3 | 2 | 2 | - | 1 | - | - | - | - | - | 1 |
| | CO5 | 3 | 2 | 1 | 2 | 2 | 1 | - | - | 2 | - | - | 1 |
| | CO6 | 3 | 2 | 2 | 2 | 3 | - | - | - | 2 | - | - | 1 |

**Correlation levels 1, 2 or 3 as defined below**:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
|---|---|---|---|---|---|---|---|
| | | | Lecture (L) | Tutorial (T) | Practical (P)# | Total Hours | |
| **ESC01** | **Ecology and Environment** | PCR | 2 | 0 | 0 | 2 | 2 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| NIL | | CT+MT+EA | | | | | |
| Course Outcomes | • CO1: Understand the importance of environment and ecosystem.<br>• CO2: Understand the fundamental aspect of pollutant tracking and its implementation in natural and anthropogenic pollution of air and water system.<br>• CO3: Understand the scientific basis of local and as well as global issues.<br>• CO4: Apply of knowledge to develop sustainable solution. | | | | | | |
| Topics Covered | **UNIT – I: INTRODUCTION(2)**<br>Multidisciplinary nature of Environmental Studies: Definition, Scope, and Importance.<br><br>**UNIT–II: FUNDAMENTALS OF ECOLOGY (9)**<br>Definition, Components of Environment; Fundamentals of Ecology and Ecosystem; Components and Classification of Ecosystem; Energy flow in Ecosystem: Tropic level, Food Chain, Food Web, Ecological Pyramid; Biogeochemical cycles: Carbon, Nitrogen, Sulphur, Phosphorus, and Water Cycle; Biosphere and Biodiversity; Conservation.<br><br>**UNIT–III: FUNDAMENTALS OF ENVIRONMENT (10)**<br>**Environmental Pollution:** Air pollution, Water pollution, Soil pollution, Marine pollution, Noise pollution, Thermal pollution, Solid Wastes, and Natural hazards: Floods, earthquakes, cyclones, and landslides.<br>**Environmental Issues:** Climate change and global warming; acid rain; and ozone layer depletion.<br>**Environment Quality:** Ambient air quality standards, Water quality parameters and standards: pH, Turbidity, Hardness, Sulphate, Phosphates, Iron, Dissolved Oxygen, BOD, and COD.<br><br>**UNIT– IV: NATURAL RESOURCES (3)**<br>Mineral Resources, Energy Resources: Conventional and Non-Conventional.<br><br>**UNIT- V- GREEN TECHNOLOGY & ENVIRONMENTAL ETHICS (4)** | | | | | | |

| | |
|---|---|
| | Sustainability: Carbon Sequestration, Green building practices, Green computing; Carrying capacity; and Environment Protection Acts/laws. |
| Text Books, and/or reference material | 1. A Basic Course in Environmental Studies. Deswal & Deswal. Pub. Dhanpat Rai & Sons<br>2. Ecology. Odum. Pub. Oxford & IBH<br>3. Environmental Engineering. Peany et.al. Pub. McGraw Hill<br>4. A Text Book of Environmental Engg. Venugpal Rao. Pub. PHI<br>5. A Basic Course in Environmental Studies. Deswal & Deswal. Pub. Dhanpat Rai & Sons<br>6. Environmental Studies. Bharucha. Pub. University of Press<br>7. Environmental Chemistry and Pollution, S. S. Dara & D. D. Mishra, S. Chand Publishing |

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

| Course | COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ESC01 | CO1 | 3 | - | - | - | - | - | 2 | - | - | - | - | - |
| | CO2 | 1 | - | - | - | - | - | 2 | - | - | - | - | - |
| | CO3 | 2 | - | - | - | - | - | 2 | - | - | - | - | - |
| | CO4 | 1 | - | 3 | - | - | 2 | 1 | - | - | - | - | - |

**Correlation levels 1, 2 or 3 as defined below**:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
|---|---|---|---|---|---|---|---|
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| **CYC01** | **Engineering Chemistry** | PCR | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| None | | CT+MT+EA | | | | | |

**Course Outcomes**

- CO1: Students will get the knowledge of fundamentals as well industrial applications of polymer, petroleum products, organometallic compounds and others.
- CO2: Students will be able to elucidate the structure of different organic compounds and to analyze the structure-property correlation.
- CO3: Students will be aware on the role played by different metals in biological systems and also the ecological impact of metals.
- CO4: Students will be able to understand and analyzethermodynamical, kinetic as well as electrochemical aspects of chemical systems and apply the understanding in the technical field.

**Topics Covered**

**ORGANIC CHEMISTRY**

i. **Polymer chemistry and polymer engineering:** Fundamental concept on polymer chemistry; synthesis and application of important polymers, Rubber and plastic materials; vulcanization, structure-property correlation: Concept of Molecular weight of polymer, Glass transition temperature. Engineered polymer: Thermally stable, flame retardant, Conducting polymer. (5L)

ii. **Petroleum Engineering and oil refinery:** Origin of petroleum, separation principle and techniques of distillation of crude oil, thermal and catalytic cracking of petroleum, uses of different fractions, knocking, anti-knock compounds, octane number and cetane number. High octane and Aviation fuel. Bio-diesel. (3L)

iii. **Structure elucidation of organic compounds by modern spectroscopic methods:** Application of UV-Visible (Lambert-Beers law), concept of chromophore, auxochrome, hypso-, hyper-, bathochromic, red shift. FT-IR spectroscopy and Mass spectroscopy (including instrumentation). (4L)

**INORGANIC CHEMISTRY**

i. **Coordination Chemistry:** Crystal Field Theory of octahedral and tetrahedral complexes, colour and magnetic properties, LMCT, MLCT, IVCT. Isomerism and stereochemistry.(5L)

ii. **Bioinorganic Chemistry:** Metal ions in biological systems: Fe, Cu (2L)

iii. **Industrial applicationof Organometallic complexes:** π-acid ligands, stabilization of metal low oxidation state and 18 electron rules, metal carbonyls and nitrosyls, metal-alkene complexes, Various catalytic cycles of industrial importance. (4L)

iv. **Environmental Chemistry:** Metal toxicity (As, Hg, Pb and Cd) and its remediation (1L)

**PHYSICAL CHEMISTRY**

i. **Chemical Thermodynamics:** 2nd law of thermodynamics: Concept of thermodynamic engine (Carnotand reverse Carnot cycle), entropy, free energy. Temperature and pressure dependence of entropy and free energy. Change in phase: phase diagram of single component system. Cryogenics: Joule Thomson experiment. (5L)

ii. **Chemical Kinetics:**Rate expression of Reversible reaction, parallel reaction,and Consecutive reaction with proper examples. Temp effect on reaction rate.(3L)

| | |
|---|---|
| | iii. **Catalysis:** Types of catalysis, Rate expression for Catalysed reaction, Acid-base and Enzyme catalysis.(2L)<br>iv. **Electrochemistry:**EMF, Nernst Equation, Application of electrochemistry in chemical processes. Electrochemical cell, Fuel cell, Li-ion battery (3L). |
| Text Books, and/or reference material | Suggested Text Books:<br>(i) Physical Chemistry by P. Atkins, Oxford<br>(ii) A guidebook to mechanism in Organic chemistry: Peter Sykes; Pearson Edu.<br>(iii) Inorganic Chemistry Part-I & II, R. L. Dutta, The new book stall<br>Suggested Reference Books:<br>**Organic Chemistry**:<br>(i) Basic stereochemistry of organic molecules: S. Sengupta; Oxford University press<br>(ii) Engineering Chemistry: Wiley<br>(iii) Elementary Organic Spectroscopy: William Kemp, ELBS with Macmillan<br>**Inorganic Chemistry:**<br>(i) Inorganic Chemistry: Principle structure and reactivity, J. E. Huheey, E. A. Keiter and R. L. Keiter, Pearson Education<br>(ii) Bioinorganic Chemistry -- Inorganic Elements in the Chemistry of Life: An Introductionand Guide, 2nd Edition, Wolfgang Kaim, Brigitte Schwederski, Axel Klein.<br>(iii) Inorganic Chemistry Fourth Edition, Shriver & Atkins, Oxford<br>**Physical Chemistry:**<br>(i) Physical Chemistry by G.W Castellan<br>(ii) Physical Chemistry by P. C. Rakshit |

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

| Course | COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CYC 01 | CO1 | 1 | 2 | - | - | - | - | - | - | - | - | - | - |
| | CO2 | 1 | - | - | - | - | - | 2 | - | - | - | - | - |
| | CO3 | 1 | 2 | 1 | 1 | 1 | - | - | - | - | - | - | - |
| | CO4 | - | 1 | - | - | 2 | - | 1 | - | - | - | - | - |

**Correlation levels 1, 2 or 3 as defined below**:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
|---|---|---|---|---|---|---|---|
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| **CSS51** | **COMPUTER PROGRAMMING LABORATORY** | PCR | 0 | 0 | 3 | 3 | 2 |
| Pre-requisites | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| NIL | | CT+EA | | | | | |

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|---|---|
| Course Outcomes | CO1: To understand the principle of operators, loops and branching statements.<br>CO2: Implementation of function, recursion, arrays, and pointers based several types of assignments.<br>CO3: To detail out the operations of strings.<br>CO4: To understand structure and union.<br>CO5: Application of C-programming to solve various types of problems. |
| Topics Covered | **List of Experiments:**<br>1. Programs on expression evaluation.<br>2. Programs on conditional statements and branching<br>3. Programs on iterations/loops.<br>4. Applications of Arrays<br>5. Programs on basics of functions and pointers.<br>6. Programs on string using array and pointers.<br>7. Programs on recursion.<br>8. Programs on structures, union.<br>9. Programs on File Operations.<br>10. Case Studies. |
| Text Books, and/or reference material | **Text Books:**<br>1. Y. Kanetkar, "Let Us C", BPB Publications, Sixteenth edition, 2017.<br>2. B. S. Gottfried, "Programming with C", McGraw Hill Education, 4th Ed., 2018.<br>3. E. Balagurusamy, "Computing Fundamentals and C Programming", McGraw Hill Education; Second edition, 2017.<br>**Reference Books:**<br>1. P. Dey and M. Ghosh, “Computer fundamentals and programming in C”, Oxford press, 2013.<br>2. R. Thareja, “Computer fundamentals and programming in C”, Oxford press, 2013.<br>3. Schaum’s Outline, Programming with C. |

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

| Course | COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CSS51 | CO1 | 3 | 3 | 2 | - | - | 2 | - | - | - | - | - | - |
| | CO2 | 2 | 2 | 1 | - | - | 1 | - | - | - | - | - | - |
| | CO3 | 3 | 2 | 2 | - | - | 1 | - | - | - | - | - | - |
| | CO4 | 2 | 3 | 2 | - | - | 2 | 1 | - | - | - | - | - |
| | CO5 | 3 | 3 | 3 | - | 1 | 2 | 1 | - | - | - | - | - |

**Correlation levels 1, 2 or 3 as defined below**:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
|---|---|---|---|---|---|---|---|
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| **XES52** | **Basic Electrical and Electronics Laboratory** | PCR | 0 | 0 | 3 | 3 | 2 |
| Pre-requisites | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| NIL | | CT+EA | | | | | |

| | |
|---|---|
| Course Outcomes | CO1: Learn to analyse the electric circuits using network theorems.<br>CO2: Understand the characteristics of fluorescent lamp and compact fluorescent lamp.<br>CO3: Analyze the behaviour of single phase and three phase AC circuits.<br>CO4: Understand the application of electronics components, diode circuits as rectifier circuits and voltage regulators.<br>CO5: Evaluate and study the performance of the transistor as a switch.<br>CO6: Create inverting and non-inverting amplifier circuits using Op-Amp. |
| Labs Conducted. | 1. Verification of the network theorems (DC).<br>2. Study of the characteristics of fluorescent and compact fluorescent lamp.<br>3. Analysis of the three phase system for star and delta connected load.<br>4. Study of the series and parallel R-L-C circuit.<br>5. Identify and understand the use of different electronic and electrical instruments, various electronic components.<br>6. Study of half-wave and full-wave (bridge) rectifier with and without capacitor filter circuit. Zener diode as a voltage regulator.<br>7. Study the performance of a transistor as a switch through NOT gate.<br>8. Realization of Inverting and Non-inverting amplifier using Op-Amp. |
| Text Books, and/or reference material | **TEXT BOOK**<br>1. Handbook of Laboratory Experiments in Electronics and Electrical Engineering by A M Zungeru , J M Chuma, H U Ezea.<br>2. Experiments Manual for use with Electronic Principles (Engineering Technologies and the Trades) by Albert Paul MalvinoDr., David J. Bates, et al.<br>**REFERENCE BOOKS**<br>1. Laboratory Courses in Electrical Engineering (5th Edition) by S. G. Tarnekar, P. K. Kharbanda, S. B. Bodhke, S. D. Naik, D. J. Dahigaonkar (S. Chand Publications).<br>2. The Art of Electronics 3e, by Paul Horowitz, Winfield Hill.<br>3. Electronic Principles, by Albert Paul MalvinoDr. and David J. Bate. |

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

| Course | COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| XES52 | CO1 | 3 | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 2 | 2 | 2 | 3 |
| | CO2 | 3 | 3 | 2 | 3 | 3 | 3 | 1 | 1 | 2 | 2 | 2 | 3 |
| | CO3 | 3 | 3 | 2 | 3 | 3 | 2 | 1 | 1 | 2 | 2 | 2 | 3 |
| | CO4 | 3 | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 2 | 2 | 2 | 3 |
| | CO5 | 3 | 2 | 1 | 2 | 2 | 1 | - | - | 2 | - | - | - |
| | CO6 | 3 | 2 | 2 | 2 | 3 | - | - | - | 2 | - | - | - |
| | CO7 | 3 | 3 | 2 | 2 | - | - | - | - | 2 | - | - | - |

**Correlation levels 1, 2 or 3 as defined below**:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
|---|---|---|---|---|---|---|---|
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| **CYS51** | **CHEMISTRY LABORATORY** | PCR | 0 | 0 | 2 | 2 | 1 |
| Pre-requisites | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| None | | CT+EA | | | | | |
| Course Outcomes | • CO1: To learn basic analytical techniques useful for engg applications.<br>• CO2: Synthesis and characterization methods of few organic, inorganic and polymer compounds of industrial importance.<br>• CO3: Learn chromatographic separation methods.<br>• CO4: Applications of spectroscopic measurements. | | | | | | |
| Topics Covered | 1. Experiments based on pH metry: Determination of dissociation constant of weak acids by pH meter.<br>2. Experiments based on conductivity measurement: Determination of amount of HCl by conductometric titration with NaOH.<br>3. Estimation of metal ion: Estimation of $Fe^{2+}$ by permangnomentry<br>4. Estimation of metal ion: Determ. of total hardness of water by EDTA titration.<br>5. Synthesis and characterization of inorganic complexes: e. g. $Mn(acac)_3$, $Fe(acac)_3$, cis-bis(glycinato)copper (II) monohydrate and their characterization by m. p. , FTIR etc.<br>6. Synthesis and charact. of organic compounds: e.g.Dibenzylideneacetone.<br>7. Synthesis of polymer: polymethylmethacrylate<br>8. Verification of Beer-Lamberts law and determination of amount of iron present in a supplied solution.<br>9. Chromatography: Separation of two amino acids by paper chromatography<br>10. Determination of saponification value of fat/ vegetable oil | | | | | | |
| | Suggested Text Books:<br>1. Vogel's Quantitative Chemical Analysis (6th Edition) Prentice Hall<br>2. Advanced Physical Chemistry Experiments: By Gurtu&Gurtu<br>3. Comprehensive Practical Organic Chemistry: Qualitative Analysis By V. K. Ahluwalia and S. Dhingra<br>Suggested Reference Books:<br>1. Practical Chemistry By R.C. Bhattacharya<br>2. Selected experiments in Physical Chemistry By N. G. Mukherjee | | | | | | |

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

| Course | COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CYS51 | CO1 | 2 | 1 | - | 1 | - | - | - | - | - | - | - | - |
| | CO2 | - | 1 | - | 1 | 1 | 2 | - | - | - | - | - | - |
| | CO3 | 2 | - | - | 1 | 1 | - | - | - | - | - | - | - |
| | CO4 | - | 1 | - | 1 | 1 | - | - | - | - | - | - | - |

**Correlation levels 1, 2 or 3 as defined below**:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

# SECOND SEMESTER

| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
|---|---|---|---|---|---|---|---|
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| **MAC02** | **MATHEMATICS - II** | PCR | 3 | 1 | 0 | 4 | 4 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| Basic concepts of set theory, differential equations, and probability. | | CT+MT+EA | | | | | |

| | |
|---|---|
| Course Outcomes | • CO1: learn the basic concepts of linear algebra and be able to apply the same to solve various engineering problems.<br>• CO2: understand fundamentals of ordinary differential equations and their applications.<br>• CO3: acquire the theoretical knowledge of Fourier Series, Fourier & Laplace transforms, and learn about their applications.<br>• CO4: learn the basic concepts of probability theory. |
| Topics Covered | **Introduction to Algebraic structures:** Group, subgroup, ring, subring, integral domain, and field. (3)<br>**Linear Algebra:** Vector spaces over field, linear dependence and independence of vectors, linear span of a set of vectors, basis and dimension of finite dimensional vector space, elementary row/column operations, rank of a matrix, solutions of system of linear (homogeneous and non-homogeneous) equations, eigenvalues and eigenvectors, characteristic polynomials, Cayley-Hamilton theorem (without proof), Diagonalization of matrices. (15)<br>**Ordinary Differential Equations (ODE):** Review of first order ODE, Picard's theorem (Statement Only), ODE of first order and of the first degree (exact ODE, rules for finding integrating factors), ODE of first order and of the higher degree (ODE solvable for x, solvable for y; Clairaut's equation, singular solution), homogeneous and non-homogeneous linear ODE with constant coefficients and variable coefficients (Euler–Cauchy type), linear dependence of solutions, Wronskian determinant, Solution of simultaneous ODEs $(dx/P = dy/Q = dz/R;\ dx/dt = ax + by,\ dy/dt = cx + dy)$, properties of nonlinear ODEs, phase plane analysis. (18)<br>**Fourier series:** Piecewise smooth and periodic functions, Fourier series of a function in an interval, Dirichlet conditions, Convergence of Fourier series, Fourier sine and cosine series, Complex form of Fourier series. (4)<br>**Fourier Transforms:** Fourier Integral Theorem (statement only), Different forms of Fourier Integrals, Fourier Transform and its inversion formula, Properties of Fourier Transform, Convolution. (7)<br>**Laplace Transforms:** Laplace transforms and its Properties, Inverse Laplace transforms, Convolution theorem, Applications to ODE. (4)<br>**Probability:** Random variables and probability distributions (discrete and continuous), Binomial, Poisson, Uniform and Normal distributions. (5) |
| Text Books, and/or reference material | **Text Books:**<br>1. Kreyszig, E., Advanced Engineering Mathematics: 10th edition, Wiley India Edition (2010).<br>2. Strang, G., Linear algebra and its applications (4th Edition), Thomson (2006).<br>3. Murray, D.A., Introductory Course in Differential Equations, Khosla Publishing House (2021).<br>4. Debnath, L., Integral Transforms and Their Applications, CRC Press (1995).<br>5. Baisnab, A.P., Jas, M., Elements of Probability and Statistics, McGraw Hill Education (2017).<br>**Reference Books:**<br>1. Kumaresan, S., Linear algebra - A Geometric approach, ChaukhambaAuriyantaliya (2017).<br>2. Ross, S.L., Differential Equations, 3rd Edition, Wiley Student Edition (2017).<br>3. Shivamoggi, A., Integral Transforms for Engineers, PHI (2003).<br>4. Grinstead, C.M., Snell, J.L., Introduction to probability, American Mathematical Society (2012). |

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

| Course | COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MAC02** | CO1 | 3 | 3 | 2 | 1 | 2 | - | 2 | - | - | - | 1 | 2 |
| | CO2 | 3 | 3 | 2 | 2 | 2 | - | 2 | - | - | 1 | - | 2 |
| | CO3 | 3 | 3 | 2 | 2 | 3 | 1 | 1 | - | 1 | 1 | 1 | 2 |
| | CO4 | 3 | 2 | 1 | 3 | 2 | 1 | 1 | 1 | 1 | - | - | 2 |

**Correlation levels 1, 2 or 3 as defined below**:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
|---|---|---|---|---|---|---|---|
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| **CSC02** | Data Structure and Algorithms | PCR | 2 | 1 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| CSC01 (Computer Programming) | | CA+ MT + ET **[**CA: 15%, MT: 25%, ET: 60%**]** | | | | | |

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|---|---|
| Course Outcomes | • CO1: Understanding the fundamental concepts of abstract data types, data structures, algorithms and time complexity analysis of algorithms.<br>• CO2: Implementation of different abstract data types (array, linked list, stack, queue, tree, graph).<br>• CO3: Implementation of different sorting and searching techniques along with their performance evaluation.<br>• CO4: Analysis of the suitability/compatibility of different data structures based on the types of applications.<br>• CO5: Design and development of algorithms for real-life applications. |
| Topics Covered | **Introduction:** Abstract Data Type (ADT), Data Structures, Concept of static and dynamic memory allocation, Algorithm, Analysis of time and space complexity of algorithms, Asymptotic notations: Big Oh, Big Omega and Big Theta notations, Impact of data structure on the performance of an algorithm. (6L)<br>**Array:** Array as an ADT, Single and multi-dimensional array, Memory representation (row major and column major) of array, Address calculation for array elements. (2L)<br>**Linked list:** Linked list as an ADT, Memory allocation and deallocation for a linked list, Linked list versus array, Types of linked lists: singly linked list, doubly linked list and circular linked list, Operations on linked list: creation, display, insertion and deletion (in different positions), Concatenation, Searching, Sorting, Applications of linked list: Representations and operations on polynomials, sparse matrices, etc., Array vs. Linked List. (6L) |
| | **Stack:** Stack as an ADT, Push and pop operations on stacks, Array implementation of stack, Linked list implementation of stack, Applications of stack: Recursion, Function call, Evaluation of postfix expression using stack, Conversion of infix to postfix using stack. (5L)<br>**Queue:** Queue as an ADT, Enqueue and dequeue operations, Array implementation of queue, Limitation of array implementation, Circular queue, Linked list implementation of queue, Priority queue. (4L)<br>**Binary Tree:** Binary Tree, Definition and properties, Representation of binary tree in memory: linked representation, array representation, Binary tree traversal (Preorder, Inorder and Postorder), Binary search tree, Heap (8L)<br>**Searching Algorithms:** Linear search and binary search. (2L)<br>Sorting Algorithms: Selection sort, Insertion sort, Quick sort, and Merge sort. (5L)<br>**Graphs Algorithms:** Graph representation using Adjacency matrix and Adjacency list, Breadth First Search and Depth First Search algorithms. (4L) |
| Text Books, and/or reference material | **Text Books:**<br>1. R. F. Gilberg and B. A. Forouzan, "Data Structures: A pseudocode approach with C", 2nd Edition, CENGAGE Learning.<br>2. A. V. Aho, J. D. Ullman and J. E. Hopcroft, “Data Structures and Algorithms”, Addition Wesley.<br>3. Lipschutz, “Data Structures (Schaum’s Outline Series)”, Tata Mcgraw Hill.<br>4. E. Horowitz, S. Sahni, S. Anderson-Freed, “Fundamentals of Data Structures in C”, Universities Press; Second edition (2008).<br>**Reference Books:**<br>1. Y. Langsam, M. J. Augenstein and A. N. Tanenbaum, "Data Structures using C and C++", Pearson, 2006.<br>2. Knuth, Donald E. The Art of Computer Programming. 3rd ed. Vols 1&2. Reading, MA: Addison-Wesley, 1997. ISBN: 0201896834. ISBN: 0201896842. ISBN: 0201896850.<br>3. Kleinberg and Eva Tardos. Algorithm Design. Addison-Wesley 2005 ISBN-13: 978-0321295354. |

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

| Course | COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CSC02 | CO1 | 3 | - | 1 | 1 | 1 | - | - | - | - | - | - | - |
| | CO2 | 3 | 2 | 1 | 2 | 2 | - | - | - | - | - | - | 1 |
| | CO3 | 3 | 2 | 1 | 2 | 2 | - | - | - | - | - | - | 1 |
| | CO4 | 3 | 3 | 2 | 3 | 3 | - | - | - | - | - | - | 1 |
| | CO5 | 3 | 3 | 3 | 3 | 3 | - | - | - | - | - | - | 2 |

**Correlation levels 1, 2 or 3 as defined below**:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
|---|---|---|---|---|---|---|---|
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| **PHC01** | **Engineering Physics** | **PCR** | **2** | **1** | **0** | **3** | **3** |
| **Pre-requisites:** | | Course Assessment methods: (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| NIL | | CT+MT+EA | | | | | |
| Course Outcomes | • CO1: To realize and apply the fundamental concepts of physics such as superposition principle, simple harmonic motion to real world problems.<br>• CO2: Learn about the quantum phenomenon of subatomic particles and its applications to the practical field.<br>• CO3: Gain an integrative overview and applications of fundamental optical phenomena such as interference, diffraction and polarization.<br>• CO4: Acquire basic knowledge related to the working mechanism of lasers and signal propagation through optical fibers. | | | | | | |
| Topics Covered | **Harmonic Oscillations** - Linear superposition principle, Superposition of two perpendicular oscillations having same and different frequencies and phases, Free, Damped and Forced vibrations, Equation of motion, Amplitude resonance, Velocity resonance, Quality factor, sharpness of resonance, [8]<br>**Wave Motion**: Longitudinal waves, Transverse waves, Wave equation, phase velocity and group velocity, Maxwell's equations, Electro-magnetic waves in free space. [3]<br>**Introductory Quantum Mechanics** - Inadequacy of classical mechanics, Blackbody radiation, Planck's quantum hypothesis, de Broglie's hypothesis, Heisenberg's uncertainty principle and applications, Schrodinger's wave equation and applications to simple problems: Particle in a one-dimensional box, Simple harmonic oscillator, Tunnelling effect. [8]<br>**Interference & Diffraction** - Huygens' principle, Young's experiment, Superposition of waves, Conditions of sustained Interference, Concepts of coherent sources, Interference by division of wavefront, Interference by division of amplitude with examples, The Michelson interferometer and some problems; Fraunhofer diffraction, Single slit, Multiple slits, Resolving power of grating. [13]<br>**Polarisation** - Polarisation, Qualitative discussion on Plane, Circularly and elliptically polarized light, Malus law, Brewster's law, Double refraction (birefringence) - Ordinary and extra-ordinary rays, Optic axis etc.; Polaroid, Nicol prism, Retardation plates and analysis of polarized lights. [5]<br>**Laser and Optical Fiber** - Spontaneous and stimulated emission of radiation, Population inversion, Einstein's A & B co-efficient, Optical resonator and pumping methods, He-Ne laser. Optical Fibre– Core and cladding, Total internal reflection, Calculation of numerical aperture and acceptance angle, Applications. [5] | | | | | | |
| **Text Books, and/or reference material** | **TEXT BOOKS**:<br>1. The Physics of Vibrations and Waves, H. John Pain, Willy and Sons<br>2. A Text Book of Oscillations and Waves, M. Goswami and S. Sahoo, Scitech Publications<br>3. Engineering Physics, H. K. Malik and A. K. Singh, McGraw-Hill.<br><br>**REFERENCE BOOKS**:<br>1. Vibrations and Waves in Physics, Iain G. Main, Cambridge University Press<br>2. Quantum Physics, R. Eisberg and R. Resnick, John Wiley and Sons<br>3. Fundamental of Optics, Jankins and White, McGraw-Hill<br>4. Optics, A. K. Ghatak, Tata McGraw-Hill<br>5. Waves and Oscillations, N. K. Bajaj, Tata McGraw-Hill<br>6. Lasers and Non-linear Optics, B. B. Laud, New Age International Pvt Lt | | | | | | |

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

| Course | COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PHC01 | CO1 | 3 | 2 | 1 | 1 | 1 | - | - | 1 | - | - | - | 1 |
| | CO2 | 3 | 2 | - | 2 | - | - | - | - | - | - | - | 1 |
| | CO3 | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | - | 1 | 1 |
| | CO4 | 3 | 2 | 2 | 2 | 1 | 1 | 1 | - | 1 | - | 1 | 1 |

**Correlation levels 1, 2 or 3 as defined below**:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
|---|---|---|---|---|---|---|---|
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| **HSC01** | **Professional Communication** | PCR | 2 | 0 | 2 | 4 | 3 |
| **Pre-requisites** | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| None | | CT+EA | | | | | |

| | |
|---|---|
| **Course Outcomes** | • CO1: Learners will acquire linguistic proficiency in terms of improvement in their listening, speaking, reading, and writing skills.<br>• CO2: Learners will acquire better communicative ability.<br>• CO3: The course will help learners improve their social connectivity skill. |
| **Topics Covered** | Vocabulary<br>1. Word Formation, Use of Prefixes and Suffixes (1)<br>2. Synonyms, Antonyms (1)<br>3. Prefixes and Suffixes from Foreign Languages, Words from Foreign Languages (1)<br>4. Abbreviations and Acronyms (1)<br>5. Technical Vocabulary (1)<br>Grammar<br>1. Identifying Common Errors in Articles and Prepositions (1)<br>2. Common Errors in Noun-Pronoun Agreement and Subject-Verb Agreement (1)<br>3. Misplaced Modifiers and Tenses (1)<br>4. Redundancies and Clichés (1)<br>Reading<br>1. Reading and Its Importance, Techniques of Effective Reading (1)<br>2. Improving Comprehension Skills, Techniques for Good Comprehension (1)<br>3. Skimming and Scanning (1)<br>4. Comprehension, Intensive and Extensive Reading (2)<br>Writing<br>1. Sentence Structures, Phrases and Clauses, Punctuation (2)<br>2. Organising Principles of Paragraphs (2)<br>3. Formal Letters, Letters of Complaint, Requisition Letters, Job Application, and Résumé (2)<br>4. Nature and Style of Sensible Writing, Defining, Describing, Classifying, Providing Examples and Evidence (2)<br>5. Essay Writing (2)<br>6. Précis Writing (2)<br>7. Report Writing (2)<br>Oral Communication<br>1. Listening Comprehension (4)<br>2. Pronunciation, Intonation, Stress, and Rhythm (4)<br>3. Communication at the Workplace (4)<br>4. Everyday Conversation (4)<br>5. Group Discussion (4)<br>6. Interviews (4)<br>7. Formal Presentations (4) |
| **Text Books, and/or reference material** | **Text Book:**<br>1. English for Engineers –Sudharshana & Savitha (Cambridge UP)<br>**Reference Books:**<br>2. *English*—Kulbhushan Kumar (Khanna Book Publishing)<br>3. *Remedial English Grammar*—F. T. Wood (Macmillan) |

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

| Course | COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **HSC01** | **CO1** | 1 | -- | -- | 1 | -- | 1 | -- | 1 | 2 | 3 | 1 | -- |
| | **CO2** | 1 | -- | -- | 1 | -- | 2 | -- | 2 | 2 | 3 | 2 | -- |
| | **CO3** | -- | -- | -- | 1 | -- | 3 | -- | 3 | 3 | 3 | 2 | -- |

**Correlation levels 1, 2 or 3 as defined below**:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
|---|---|---|---|---|---|---|---|
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| **CSS52** | **DATA STRUCTURES AND ALGORITHMS LABORATORY** | PCR | 0 | 0 | 3 | 3 | 2 |
| Pre-requisites | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| NIL | | CT+EA | | | | | |

| | |
|---|---|
| Course Outcomes | CO1: Understanding the suitability and compatibility of array and linked list implementations for different application problems.<br>CO2: Understanding the concept of abstract data types from real-life scenarios and their implementation in computing system.<br>CO3: Identify, design and implementation of stack, queue, binary tree, and graph as applicable for given problem.<br>CO4: Implementation of different searching and sorting techniques using appropriate data structures and perform efficiency analysis.<br>CO5: Create efficient algorithms for real-life applications. |
| Topics Covered | **List of Experiments:**<br>1. Application of arrays using dynamic memory allocation.<br>2. Implementation and Applications of linked lists.<br>3. Implementation of stack, and applications of stack.<br>4. Implementation of queue, applications of queue: Priority queue.<br>5. Implementation of Binary tree, Binary tree traversal: Preorder, Inorder and Postorder traversal.<br>6. Implementation of binary search tree and operations on it.<br>7. Implementation of linear search, binary search (recursive, non-recursive).<br>8. Implementation of different sorting algorithms.<br>9. Implementation of graph algorithms: Breadth first search, Depth first search.<br>10. Case Studies. |
| Text Books, and/or reference material | **Text Books:**<br>1. S. Lipschutz, “Data Structures (Schaum’s Outline Series)”, McGraw Hill Education; First edition (2017).<br>2. E. Horowitz, S. Sahni, S. Anderson-Freed, “Fundamentals of Data Structures in C”, Universities Press; Second edition (2008).<br>3. E. Balagurusamy, "Programming in ANSI C", McGraw Hill Education India Private Limited, Seventh edition (2017).<br>**Reference Books:**<br>1. B. S. Gottfried, "Programming with C", McGraw Hill Education, 4th Ed. (2018). |

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

| Course | COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CSS52 | CO1 | - | 1 | 1 | 1 | - | - | - | - | - | - | - | - |
| | CO2 | - | 1 | 1 | 3 | - | - | - | - | - | - | - | - |
| | CO3 | 2 | 2 | 3 | 2 | 1 | - | - | - | - | - | - | - |
| | CO4 | 2 | 2 | 2 | 1 | 1 | - | - | - | - | - | - | - |
| | CO5 | 3 | 3 | 3 | 3 | 3 | - | 1 | 1 | - | - | 1 | 2 |

**Correlation levels 1, 2 or 3 as defined below**:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
|---|---|---|---|---|---|---|---|
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| **XES51** | **ENGINEERING GRAPHICS** | PCR | 1 | 0 | 3 | 4 | 2.5 |
| Pre-requisites | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| NIL | | CT+EA | | | | | |

| | |
|---|---|
| Course Outcomes | • CO1: Ability of mental visualization of different objects<br>• CO2: Theoretical knowledge of orthographic projection to solve problems on one/two/three dimensional objects<br>• CO3: Able to read/interpret industrial drawing and to communicate with relevant people |
| Topics Covered | Graphics as language of communication; technical drawing tools and their up-keep; types of lines; construction of geometrical figures; lettering and dimensioning. [6]<br>Construction and use of scales; construction of curves of engineering importance such as curves of conic section; spirals, cycloids, involutes and different loci of points; use of equations for drawing some curves. [9] |

| | |
|---|---|
| | Descriptive geometry: necessity and importance of orthographic projection; horizontal and vertical reference planes; coordinate of points; orthographic projection of points and lines situated in different quadrants, viz. 1st, 2nd, 3rd and 4th quadrants; traces of lines. First angle and third angle projection of lines and planes; views from top, front and left (or right); true length and true inclination of lines with planes of projections; primary auxiliary projection of points, lines and planes; auxiliary plan and auxiliary elevation. [9]<br>Projection of simple regular solids, viz. prisms, cubes, cylinders, pyramids, cones, tetrahedrons, spheres, hemi-spheres etc. [6]<br>Section of solids; section by perpendicular planes; sectional views; true shapes of sections. [6]<br>Dimensional techniques; international and national standards (ISO and BIS). [3]<br>Freehand graphics. [3] |
| Text and/or reference material | 1)… Engineering Drawing and Graphics – K Venugopal<br>2)… Engineering Drawing – N D Bhat<br>3)… Practical Geometry and Engineering Graphics – W Abbott |

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

| Course | COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| XES51 | CO1 | 1 | - | - | - | - | - | - | - | - | - | - | - |
| | CO2 | 1 | 1 | - | - | - | - | - | - | - | - | - | - |
| | CO3 | 1 | - | 1 | - | - | - | - | - | - | - | - | - |

**Correlation levels 1, 2 or 3 as defined below**:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
|---|---|---|---|---|---|---|---|
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| PHS51 | Physics Laboratory | PCR | 0 | 0 | 2 | 2 | 1 |

| Pre-requisites | Course Assessment methods: (Continuous evaluation (CE) and end assessment (EA)) |
|---|---|
| NIL | CE+EA |
| **Course Outcomes** | CO1: To realize and apply different techniques for measuring refractive indices of different materials.<br>CO2: To realize different types of waveforms in electrical signals using CRO.<br>CO3: To understand charging and discharging mechanism of a capacitor.<br>CO4: To understand interference, diffraction and polarization related optical phenomena.<br>CO5: To acquire basic knowledge of light propagation through fibers. |
| **Topics Covered** | 1. Find the refractive index of a liquid by a travelling microscope.<br>2. Determine the refractive index of the material of prism using spectrometer.<br>3. Determination of amplitude and frequency of electrical signals by oscilloscope.<br>4. To study the characteristics of RC circuits.<br>5. To study Brewster's law/Malus' law using laser light.<br>6. To study the diffraction of light by a grating.<br>7. To study the interference of light by Newton's ring apparatus.<br>8. To determine numerical aperture of optical fiber.<br>9. Determination of Planck constant. |
| **Text and/or reference material** | **SUGGESTED BOOKS**:<br>1) A Text Book on Practical Physics – K. G. Mazumdar and B. Ghosh<br>2) Practical Physics – Worsnop and Flint |

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

| Course | COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PHS51 | CO1 | 3 | 2 | 1 | - | - | - | - | - | 2 | 1 | - | 1 |
| | CO2 | 3 | 2 | 1 | - | - | 1 | - | - | 2 | 1 | - | 1 |
| | CO3 | 3 | 1 | - | - | - | - | - | - | 2 | 1 | - | 1 |
| | CO4 | 3 | 2 | - | 1 | - | 1 | 1 | - | 2 | 1 | - | 1 |
| | CO5 | 3 | 2 | 1 | - | 1 | 1 | 1 | - | 2 | 1 | - | 1 |

**Correlation levels 1, 2 or 3 as defined below**:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
|---|---|---|---|---|---|---|---|
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| XXS51 | Extra Academic Activities | PCR | 0 | 0 | 2 | 2 | 1 |

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

**Course Outcomes**

- CO1: Social Interaction through the medium of sports
- CO2: Team building and self defence

**Topics Covered**

**YOGA**

- Introduction of Yoga- Suryanamaskar. 1L
- Sitting Posture / Asanas – Padmasana, Vajrasana, ArdhaKurmasana, Ustrasana, Janusirshasana, Gomukhasana, Bhadrasana. 7L
- Mudra- Gyana Mudra, Chin Mudra. 1L
- Laying Posture/ Asana-PavanaMukhtasana, UttanaPadasana, Sarpasana, Bhujangasana (Cobra Pose), EkaPadaSalabhasana, Dhanurasana, Chakrasana, Viparitkarani, ArdhaHalasana (Half Plough Pose), Naukasana (Boat Posture), Shavasana (Relaxing Pose) ,Makarasana. 7L
- Meditation-Om Chant. 1L
- Standing Posture / Asana-Tadasana (Mountain Pose), Vrikshana (Tree Pose), ArdhaChandrasana, Padahastasana, ArdhaChakrasana (Half Wheel Posture). 5L
- Pranayama-Deep Breathing, AnulomVilom, Shitali, Bhramari. 5L
- Kriya- Kapalbhati 1L

**TAEKWONDO**

- Introduction About Taekwondo- Meaning Of Taekwondo, Korean Language Of Dress, Fighting Area, Punch, Block, Kicks Etc. 1L
- Stance- Ready Stance, Walking Stance, Front Stance, Back Stance. 2L
- Punch Technique- Front Fist Punch, Double Fist Punch, With Stance Etc. Blocks- Upper Blocks, Middle Block, Side Block, Suto Etc. 4L
- Foot Technique- Standing Kick, Front Kick, Doliyo, Back Kick Etc. 6L
- Poomsae (Forms)- Jang, Yi Jang. 6L
- Self Defense Technique- Self Defense from Arms, Fist and Punch. 4L
- Sparring (Kyorugi)- One Step Sparring 2L
- Combination Technique- Combined Kick And Punch. 2L
- Project Work 1L

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

| Course | COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| XXS51 | CO1 | - | - | - | - | - | 2 | - | - | 2 | - | - | 1 |
| | CO2 | - | - | - | - | - | - | - | 2 | 3 | - | - | 1 |

**Correlation levels 1, 2 or 3 as defined below**:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

# THIRD SEMESTER

<table>
<tr><td colspan="8">Department of Mathematics</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MAC331</td><td>MATHEMATICS-III</td><td>PCR</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Basic knowledge of topics included in MAC01 & MAC02</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: Acquire the idea about mathematical formulations of phenomena in physics and engineering.<br>• CO2: To understand the common numerical methods to obtain the approximate solutions for the intractable mathematical problems.<br>• CO3: To understand the basics of complex analysis and its role in modern mathematics and applied contexts.<br>• CO4: To understand the optimization methods and algorithms developed for solving various types of optimization problems.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Partial Differential Equations (PDE): Formation of PDEs; Lagrange method for solution of first order quasilinear PDE; Charpit method for first order nonlinear PDE; Homogenous and Nonhomogeneous linear PDE with constant coefficients: Complimentary Function, Particular integral; Classification of second order linear PDE and canonical forms; Initial & Boundary Value Problems involving one dimensional wave equation, one dimensional heat equation and two dimensional Laplace equation. [14]<br><br>Numerical Methods: Significant digits, Errors; Difference operators; Newton's Forward, Backward and Lagrange's interpolation formulae; Numerical solutions of nonlinear algebraic/transcendental equations by Bisection and Newton-Raphson methods; Trapezoidal and Simpson's 1/3 rule for numerical integration; Euler's method and modified Eular's methods for solving first order differential equations. [14]<br><br>Complex Analysis: Functions of complex variable, Limit, Continuity and Derivative; Analytic function; Harmonic function; Conformal transformation and Bilinear transformation; Complex integration; Cauchy's integral theorem; Cauchy's integral formula; Taylor's theorem, Laurent's theorem (Statement only); Singular points and residues; Cauchy's residue theorem. [17]<br><br>Optimization:<br>Mathematical Preliminaries: Hyperplanes and Linear Varieties; Convex Sets, Polytopes and Polyhedra. [2]<br><br>Linear Programming Problem (LPP): Introduction; Formulation of linear programming problem (LPP); Graphical method for its solution; Standard form of LPP; Basic feasible solutions; Simplex Method for solving LPP. [9]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:<br>1. An Elementary Course in Partial Differential Equations-T. Amarnath<br>2. Numerical Methods for scientific & Engineering Computation- M.K.Jain, S.R.K. Iyengar & R.K. Jain.<br>3. Foundations of Complex Analysis- S. Ponnuswami<br>4. Operations Research Principles and Practices- Ravindran, Phillips, Solberg<br>5. Advanced Engineering Mathematics- E. Kreyszig<br>Reference Books:<br>1. Complex Analysis-L. V. Ahfors<br>2. Elements of partial differential equations- I. N. Sneddon<br>3. Operations Research- H. A. Taha</td></tr>
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<table>
<tr><td colspan="8">DepartmentofMetallurgical andMaterialsEngineering</td></tr>
<tr><td rowspan="2">CourseCode</td><td rowspan="2">Titleofthe course</td><td rowspan="2">Program Core(PCR) / Electives(PEL)</td><td colspan="4">TotalNumber of contacthours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MMC301</td><td>Introduction toMetallurgyand Materials</td><td>PCR</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))</td></tr>
<tr><td colspan="2">PHC01: EngineeringPhysics</td><td colspan="6">CT+MT+EA</td></tr>
<tr><td>CourseOutcomes</td><td colspan="7">I. Tocorrelateatomic structure,periodictable,elementalproperties, chemical bondingandmaterial properties.<br>II. To interpretcrystal structure in view oftranslationalperiodicityandsymmetry and as well as to introspect different kinds of defects in a crystal.<br>III. To study the binary phase diagrams and a brief introduction to different engineering materials.</td></tr>
<tr><td>TopicsCovered</td><td colspan="7">Atomic Structure and chemical Bonding: Quantum mechanical approach, Schrödingerwaveequation,wavefunction,Quantumstate, Periodic Table, electronicconfigurationand atomic structure. Bonding in solids, different types of bonds, Bond energy, effect ofbondingonmaterialproperties. (10)<br>Structure of Solids: The crystalline and the noncrystalline states – Metals and Alloys,Ceramics,semiconductorsandpolymers;Crystalstructure– conceptoflatticeandcrystal,Translationalperiodicityandsymmetry,crystalsystems,spacelattice,representationofatomicposition,latticedirectionsandlatticeplanesincubicandhexagonalsystems;atomicpacking,voidsinFCC,BCCandHCPcrystals;crystalimperfections– point defect, line defect, surface defect and volume defect; equilibriumconcentrationof pointdefect. (12)<br>Solidificationof metalsandalloysincludingRapidSolidificationTechnology. (6)<br>Phasediagrams:Thephaserule,singlecomponentsystem.Binaryphasediagramswith referenceto afewimportantmetallicsystems. (6)<br>Corrosionandoxidationofmaterials:Theprinciplesofcorrosion;Protectionagainstcorrosion;Mechanismofoxidation; Oxidationresistant materials. (6)<br>IntroductiontoMaterials(Classification,SelectionandApplications):MetalsandAlloys, Intermetallics,Polymers,GlassesandCeramics,CompositeMaterials,nano-crystalline materials. (10)</td></tr>
<tr><td>Text Books,and/orreferencematerial</td><td colspan="7">Text Books:<br>1. Materials Science and Engineering: A first course – V. Raghavan, PHI Learning Pvt.Ltd., 2004.<br>2. IntroductiontoMetallurgy-A.H.Cottrell,Arnold,1968.<br>3. Structure and Properties of Engineering Materials – R. M. Brick, A. W.Pense and R. B.Gordon.<br>4. The Structure and properties of Materials ( I – IV) – R.M. Rose, L. A. Shepard and J.Wulff.<br>5. Introductiontosolids-L.V.Azaroff,TataMcGraw-Hill,1990.<br>6. Crystallographyappliedtosolid statephysics-A. R.Verma,O.N. Srivastava,Wiley,1982.</td></tr>
</table>

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | - | 2 | 2 | 1 | - | 2 | 3 | 3 | 2 | 3 |
| **CO2** | 2 | 3 | 3 | 2 | 3 | - | 2 | 2 | 2 | 3 | 3 | 3 |
| **CO3** | 3 | 3 | 3 | 2 | 2 | 1 | 3 | 1 | 2 | 3 | 3 | 3 |

**Correlation levels 1, 2 or 3 as defined below:**

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

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MMC302 | Metallurgical Thermodynamics and Kinetics | PCR | 3 | 1 | 0 | 4 | 4 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| CYC01: Engineering Chemistry | | CT+MT+EA | | | | | |
| Course Outcomes | CO1: Acquire the knowledge of thermodynamic laws to apply in metallurgical processes and materials.<br>CO2: Identify the feasibility of metallurgical processes and reactions.<br>CO3: Learn to analyze the kinetics of metallurgical processes and design the alloy systems by applying the concepts of thermodynamics. | | | | | | |
| Topics Covered | Definitions, behaviour of gasses, vapours and gaseous moisture, materials balances in metallurgical processes. (4)<br>First law of thermodynamics, Heat and work changes in reversible processes, Concept of Heat Capacity, Enthalpy energy balance in metallurgical processes, Reversible adiabatic process. (4)<br>The Carnot cycle, concept of entropy, Entropy changes in reversible, irreversible processes and universe, Clausius inequality, Combined statement of first and second law, Entropy change for irreversible chemical reactions. (6)<br>Helmholtz free energy and the Gibbs free energy, Free-energy equations in differential form, Thermodynamic potentials, The Maxwell relations, Criteria of equilibrium and spontaneity (or irreversibility), The Gibbs-Helmholtz equation, Third law of thermodynamics. (6)<br>Concept of chemical potential, Chemical potential of oxygen, partial molar quantities, Integral molar quantities, Raoult's law and Henry's law, Alternative standard states,Sievert's law, Mixing function, Excess function, Regular solution, concept of interaction parameter. (13)<br>Fugacity, Activity, standard state, equilibrium constant, Van't Hoff reaction isotherm,LeChatelier's Principle, Free-energy Charts and Ellingham diagrams, Gas-solid reaction, Van't Hoff equation, Sigma Function (Σ), Clausius-Clapeyron Equation, Trouton's Rule. (8)<br>Types of electrochemical cells, Laws of electrolysis, determination of thermodynamics quantities using reversible electrochemical cells, Electrochemical cell based on solid electrolytes. (3)<br>Types of reaction, Order of reaction, Determination of order and rate constant of a reaction, Reactions involve in solids – nucleation and growth kinetics (J-M equation), Gas-solid reaction kinetics. (6) | | | | | | |
| Text Books, and/or reference material | Suggested Text Books:<br>1. Introduction to Metallurgical Thermodynamics – David R Gaskell. 2. Metallurgical<br>2. Textbook of Materials and Metallurgical Thermodynamics –A. Ghosh<br>3. Thermochemistry – O. Kubaschewski, E LL Evans and C B Alcock<br><br>Suggested Reference Books:<br>1. Stoichometry and thermodynamics of Metallurgical processes - Y K Rao.<br>2. Problems in Metallurgical Thermodynamics and Kinetics – G S Upadhyay and R K Dube.<br>3. Chemical Kinetics - Keith Laidler. | | | | | | |

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO2** | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO3** | 1 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Correlation levels 1, 2 or 3 as defined below:**

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

<table>
<tr><td colspan="7">Department of Metallurgical and Materials Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MMC303</td><td>Non Ferrous Process Metallurgy</td><td>PCR</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="4">Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))</td></tr>
<tr><td colspan="3">CYC-01: Engineering Chemistry</td><td colspan="4">CT+MT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="6">• CO1: Understand fundamentals and unit operations of Mineral Beneficiation (MB).<br>• CO2: Acquire knowledge of Non-ferrous metal production<br>• CO3: Analyze the problems and its solution in non-ferrous metal production industrial applications</td></tr>
<tr><td>Topics Covered</td><td colspan="6">Sources of nonferrous metals (Sources in land and sea, exploration methods, nonferrous metals wealth in India) (2)<br>Methods of Comminution: Primary Crusher, Secondary Crusher, Tertiary Crusher , Screening (3)<br>Methods of Beneficiation: Magnetic Separator, Electric separator, WilfreyTable ,Froth Floatation (3)<br>Principles of metals extraction, (Thermodynamic principles, homogeneous and heterogeneous reactions, Ellingham diagrams, kinetic principles, electro-chemistry) (8)<br>General methods of extraction, (Pyro-metallurgy – calcinations, roasting (predominance area diagram) and smelting, Hydrometallurgy – leaching, solvent extraction, ion exchange, precipitation, and electrometallurgy – electrolysis and electro-refining) (6)<br>General methods of refining, (Basic approaches, preparation of pure compounds, purification of crude metal produced in bulk) (2)<br>Extraction of metals from oxide sources, (Basic approaches and special features of specific extraction processes, extraction of metals such as Mg, Al, Cr, Sn, Li) (8)<br>Extraction of metals from sulphide ores, (Pyro-metallurgy and hydro-metallurgy of sulphides, production of metals such as Cu, Pb, Zn, Ni etc.) (8)<br>Extraction of metals from halides, (Production of halides and refining methods, production of reactive and reactor metals. Methods of extraction of metals such as Ti, Ur) (3)<br>Production of precious metals (Methods applied for Au, Ag and Pt.) (3)</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="6"><u>Suggested Text Books:</u><br>1. Extraction of nonferrous metals, H.S. Ray, R.Sridhar and K.P. Abraham Affiliated East West Press Pvt Ltd., New Delhi (2007).<br>2. H.S. Ray and A. Ghosh, Principles of extractive metallurgy,Wiley Eastern Ltd., New Delhi (1991)<br>3. Alfred Richard Burkin, The Production of Aluminium and Alumina, Vol. 20,<br>4. A. K. Biswas and W. G. Davenport, Extractive Metallurgy of Copper, (Published by Pergamon Press, Sydney, Australia)<br><u>Suggested Reference Books:</u><br>1. W.H. Dennis, Extractive Metallurgy, Philosophical Library,New York (1965)<br>2. F. Habashi, Principles of Extractive Metallurgy, Vol.1, Gordon and Breach, New York (1969).<br>3. T. Rosenqvist, Principles of Extractive Metallurgy, McGraw Hill, New York (1983).<br>4. J.L. Bray, Nonferrous production metallurgy, Wiley, NewYork(1954).</td></tr>
</table>

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

| PO / CO | **PO1** | **PO2** | **PO3** | **PO4** | **PO5** | **PO6** | **PO7** | **PO8** | **PO9** | **PO10** | **PO11** | **PO12** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 |
| **CO2** | 3 | 3 | 2 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 3 |
| **CO3** | 3 | 3 | 3 | 3 | 2 | 1 | 2 | 1 | 3 | 1 | 1 | 2 |

**Correlation levels 1, 2 or 3 as defined below:**

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

<table>
<tr><td colspan="8">Department of Metallurgical & Materials Engineering</td></tr>
<tr><td rowspan="2">Course code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MMC304</td><td>Computational Materials Science</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))</td></tr>
<tr><td colspan="3">Nil</td><td colspan="5">CT+MT+EA</td></tr>
<tr><td>Course outcomes</td><td colspan="7">CO1: To understand the different methodologies of materials modelling and simulation<br>CO2: To explore materials structure, properties, and behaviour under externally imposed variables<br>CO3: To design materials for different applications</td></tr>
<tr><td>Topics covered</td><td colspan="7">1. Introduction: Overview of different modeling approaches; aims and scopes; concept of multiscale modeling and simulation; significance of materials modeling and simulation. [4 h]<br>2. Atomistic Modeling and Simulation: Classical Newtonian mechanics; overview of molecular dynamics (MD) simulation and its field of applicability; statistical mechanics principles; N-body problem; ensembles and ergodicity; interatomic potentials; initialization and thermal equilibration; boundary conditions; force calculation; potential energy cut-off and truncation schemes; integration algorithms with their relative merits and demerits; thermostatting; barostatting; evaluation of different physical, mechanical, structural, thermodynamic, and transport properties of materials using MD simulation technique; illustration of equilibrium MD and non-equilibrium MD techniques; MD exercises with LAMMPS; overview of probability theory based Monte Carlo (MC) simulation and its field of applicability; Metropolis algorithm; Kawasaki dynamics; kinetic Monte Carlo method; simulation of phase evolution and phase transformation using Monte Carlo method. [16 h]<br>3. Mesoscale Stochastic Simulation: Overview; Brownian dynamics; modeling diffusion of a particle in a fluid medium. [4 h]<br>4. Continuum Modeling and Simulation: Overview; Outline of continuum modeling using FEM technique; Discretization; Element types; Interpolation functions; Continuity; Finding the element properties using direct approach and Galerkin method; Assembling the element properties to obtain the system equations; Imposing the boundary conditions; solving the system equations; Convergence analysis; illustration of solving structural mechanics and heat transfer problems using FEM simulation. [20 h]<br>5. Multiscale Approaches: Overview and examples; bridging the scale gaps between different simulation levels; simultaneous integration of models; sequential integration of models (hierarchical approach); illustration of coupled MD-FEM model and coupled MD-stochastic model. [4 h]</td></tr>
<tr><td>Text books, and/or reference materials</td><td colspan="7">• Understanding Molecular Simulation: D. Frenkel and B. Smit, Academic Press, 2002<br>• The Art of Molecular Dynamics Simulation: D.C. Rapaport, Cambridge University Press, 2004<br>• Statistical Mechanics: Donald A. Mcquarrie, Harper Row, 1976<br>• Handbook of Materials Modeling: Ed.: Sydney Yip, Springer, 2005<br>• Monte Carlo Methods in Statistical Physics, M.E.J. Newman and G.T. Barkema, Clarendon Press, 1999<br>• An Introduction to the Finite Element Method, J.N. Reddy, Mc-Graw Hill, 2006</td></tr>
</table>

**CO-PO Mapping**

| POs / COs | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 3 | 3 | 3 | 1 | 3 | | | | 1 | 1 | | 3 |
| **2** | 3 | 3 | 3 | 2 | 3 | 2 | 1 | | 1 | 1 | | 3 |
| **3** | 3 | 3 | 3 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 3 |

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MMS351 | Metallurgical Thermodynamics and Kinetics Lab | PCR | 0 | 0 | 3 | 3 | 2 |
| Pre-requisites | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| NIL | | CT+EA | | | | | |
| Course Outcomes | CO1: Ability to acquire experimental data and learn to process it<br>CO2: Learn to estimate the thermodynamic parameters from experiments<br>CO3: Apply knowledge of kinetics to identify the mechanism of a reaction and calculate the rate constant and activation energy. | | | | | | |
| Topics Covered | Experiment 1: Non-Isothermal Decomposition of pure Calcium Carbonate (3)<br>Experiment 2: Oxidation kinetics of copper at elevated temperature (12)<br>Experiment 3: Oxidation kinetics of mild steel at elevated temperature (12)<br>Experiment 4: Determination of partial molar volume (3)<br>Experiment 5: Determination of the stability of the oxide using Ellingham diagram. (3)<br>Experiment 6: Study the reducibility of iron ore to evaluate the degree of reduction.(3) | | | | | | |
| Text Books, and/or reference material | Suggested Text Books:<br>1. Introduction to Metallurgical Thermodynamics – David R Gaskell. 2. Metallurgical<br>2. Textbook of Materials and Metallurgical Thermodynamics –A. Ghosh<br>3. Thermochemistry – O. Kubaschewski, E LL Evans and C B Alcock<br><br>Suggested Reference Books:<br>1. Stoichometry and thermodynamics of Metallurgical processes - Y K Rao.<br>2. Problems in Metallurgical Thermodynamics and Kinetics – G S Upadhyay and R K Dube.<br>3. Chemical Kinetics - Keith Laidler. | | | | | | |

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO2** | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Correlation levels 1, 2 or 3 as defined below:**

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

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MMS352 | Mineral Beneficiation Laboratory | PCR | 0 | 0 | 3 | 3 | 2 |
| Pre-requisites | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| MMC303: Non- Ferrous Process Metallurgy | | CT+EA | | | | | |
| Course Outcomes | • CO1: Correlate crushing of a material with different crushers<br>• CO2: Separation of fines from different fraction and measuring efficiency<br>• CO3: Separation of sulphide ores by froth floatation unit | | | | | | |
| Topics Covered | Experiment-1: Crushing of material in Jaw crusher followed by Roll Crusher<br>Experiment-2: Crushing the product of Roll Crusher in ball Mill<br>Experiment-3: Sieve shaking of the fines generated from Ball Mill<br>Experiment-4: Separation of Micro fines in a Cyclone Separator<br>Experiment-5: Froth Floatation<br>Experiment-6: Jigging<br>Experiment-7: Magnetic separation of metallic fines<br>Experiment-8: Separation of Material in a double-decker screen. | | | | | | |
| Text Books, and/or reference material | Suggested Text Books:<br>1. Extraction of nonferrous metals, H.S. Ray, R.Sridhar and K.P. Abraham Affiliated East West Press Pvt Ltd., New Delhi (2007).<br>2. W.H. Dennis, Extractive Metallurgy, Philosophical Library, New York (1965)<br>Suggested Reference Books:<br>1. F. Habashi, Principles of Extractive Metallurgy, Vol.1, Gordon and Breach, New York | | | | | | |

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

| PO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| **CO2** | 3 | 3 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| **CO3** | 3 | 3 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |

**Correlation levels 1, 2 or 3 as defined below:**

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

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course code | Title of the course | Program Core (PCR) / Elective (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total hours | |
| MMS353 | Computational Materials Science Lab. | PCR | 0 | 0 | 3 | 3 | 2 |
| Pre-requisites | | Course assessment methods (continuous (CT) and end assessment (EA)) | | | | | |
| Nil | | CT+EA | | | | | |
| Developer | | Dr. Madan Mohan Ghosh | | | | | |
| Course outcomes | CO1: To know about different modelling techniques applicable to structural materials<br>CO2: Design of materials at the microscale level on the basis of atomistic and mesoscale simulations<br>CO3: Design of materials at the macroscale level on the basis of FEM and multiscale simulations | | | | | | |

| | |
|---|---|
| Topics covered | 1) Determination of melting point and heat of fusion of a material using both equilibrium and non-equilibrium MD simulations [6 h]<br>2) Determination of lattice parameter and cohesive energy of a crystalline material using equilibrium MD method [3 h]<br>3) Determination of thermal expansion coefficient of a crystalline material using MD technique [3 h]<br>4) MD based tensile and compressive modelling of a material and evaluation of strength and ductility properties [3 h]<br>5) MD modelling and simulation for crack propagation of a material [3 h]<br>6) MD based nanoindentation modelling and simulation of a material [3 h]<br>7) Evaluation of thermal conductivity of a material by MD simulation [3 h]<br>8) Studying phase evolution of a binary alloy using MC simulations with different boundary conditions [3 h]<br>9) Studying Brownian motion of a nanoparticle in a nanofluid by mesoscale stochastic simulation [3 h]<br>10) FEM based tensile and compressive modelling and simulations of a material [3 h]<br>11) Multiscale modelling and simulations for extracting mechanical properties of a nanocomposite [3 h] |
| Text books and/or reference materials | • Understanding Molecular Simulation*: D. Frenkel and B. Smit*, Academic Press, 2002<br>• The Art of Molecular Dynamics Simulation: *D.C. Rapaport*, Cambridge University Press, 2004<br>• Statistical Mechanics: *Donald A. Mcquarrie*, Harper Row, 1976<br>• Handbook of Materials Modeling: Ed.: *Sydney Yip*, Springer, 2005<br>• Monte Carlo Methods in Statistical Physics, *M.E.J. Newman and G.T. Barkema*, Clarendon Press, 1999<br>• An Introduction to the Finite Element Method, *J.N. Reddy*, Mc-Graw Hill, 2006 |

## CO-PO Mapping

| POs / COs | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 3 | 3 | 3 | 1 | 2 | 1 | 1 | | 2 | 1 | 1 | 3 |
| **2** | 3 | 3 | 3 | 1 | 2 | | | | 2 | 1 | 1 | 3 |
| **3** | 3 | 3 | 3 | 1 | 2 | | | 1 | 2 | 1 | 1 | 3 |

# FOURTH SEMESTER

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MMC401 | Transport Phenomena in Metallurgical Processes | PCR | 3 | 1 | 0 | 4 | 4 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT), and end assessment (EA)) | | | | | |
| XEC-01: Engineering Mechanics | | CT+MT+EA | | | | | |
| Course Outcomes | CO1: Understand the fundamentals of fluid flow and momentum conservation<br>CO2: Understand different modes of heat transfer and mass transfer.<br>CO3: Ability to solve industry oriented problems involving heat, mass, and momentum transfer. | | | | | | |
| Topics Covered | Introduction, Continuum hypothesis, fluid statics. (3)<br>Fluid flow: Newton's law of viscosity, Non-newtonian fluids. (5)<br>Continuity equation, Navier-Stokes equations, Laminar flow. (6)<br>Turbulence and experimental correlations, the concept of friction factor. (3)<br>Flow through porous media, fluidized bed, Concept of Hydraulic Radius, Ergun equation. EX: centrifugal casting, bottom gating system. (6)<br>Modes of heat transfer, Industrial examples, Fundamental law and Subsidiary law (3)<br>Concept of thermal resistance and overall heat transfer coefficient, Differential equation of heat conduction. (3)<br>Conduction-convection system, Moving fins, Application in estimating heat losses from furnaces, Two dimensional steady state heat conduction. (3)<br>Lumped heat capacity analysis, Time constant and response time of temperature measuring instruments, Heisler's charts, application in heat treatment and solidification. (4)<br>Concept of the boundary layer, correlation for external flow and internal flow, continuous casting cooling system, heat losses from hot surfaces. (3)<br>View factor between surfaces, radiation heat transfer in furnace enclosures, reactors in used in materials processing, radiation shields Case studies involving multimode heat transfer in materials processing. (5)<br>Fick's Laws of diffusion, advection due to diffusion, case of evaporation of liquid through a column, Analogy between mass and heat transfer, mass transfer coefficient, application in gas-solid reactions such as oxidation, reduction etc. (7) | | | | | | |
| Text Books, and/or reference material | Suggested Text Books:<br>4. Rate Phenomena In process metallurgy – J. Szekely and N.J. Themelis<br>5. Transport Phenomena in Metallurgy – G.H. Geiger and D.R.Poirier<br>Suggested Reference Books:<br>4. Heat Transfer– J.P. Holman<br>5. Heat and Mass Transfer – F. P. Incropera and D. P. DeWitt<br>6. Transport Phenomena – R. B. Bird, W. E. Stewart and E. N. Lightfoot | | | | | | |

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO2** | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Correlation levels 1, 2 or 3 as defined below:**

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

| DepartmentofMetallurgical andMaterialsEngineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| CourseCode | Titleofthe course | Program Core(PCR) / Electives(PEL) | TotalNumber of contacthours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MMC402 | PhaseTransformation andPhase Equilibria | PCR | 3 | 1 | 0 | 4 | 4 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| MMC301:Introduction to MetallurgyandMaterials | | CT+MT+EA | | | | | |
| CourseOutcomes | I. To understand and interpret Free energy-composition diagram and origin of phase diagrams.<br>II. A detailed understanding on diffusion in solid and solidstatephasetransformationsinsteel.<br>III. To understand the fundamentals of solidification in order to apply it in Foundry industry. | | | | | | |
| TopicsCovered | Introduction: Basic concepts about Stability of Phases and equilibrium; Types of PhaseTransformations,Orderoftransformations. (5 hrs)<br>Phase Equilibria: Thermodynamics of phase changes, phase diagrams and equilibria inrelationtoFreeenergy-compositiondiagrams;Interpretationofphasediagrams,determination and calculations; Solid-liquid Miscibility gap; invariant reaction. Principlesofternaryphasediagram,Examplesofafewmetallicandceramicphasediagrams. (6 hrs)<br>Diffusion:Phenomenologicalequationofdiffusion,Chemicalpotentialgradient,Fick's first law of diffusion, diffusion coefficient (diffusivity), representation of diffusion flux interms of chemical potential gradient; Nernst-Einstein Equation, Diffusion in ideal solutionand in solutions with positive and negative deviation; Uphill diffusion, determination ofdiffusion coefficient (diffusivity) for ideal binary solid solution in terms of jump frequencyand jump distance, atomic mechanism of diffusion,Expression of diffusion coefficient(diffusivity) for self diffusion in pure metal or diffusion in substitutional solid solutionthrough vacancy mechanism and in interstitial solid solution; Steady state diffusion andtransientdiffusion;Fick'ssecondlawofdiffusion;determinationofselfdiffusioncoefficient by radioactive method; solution of Fick's second law: analysis of carburizinganddecarburizingprocesses;solutionofFick'ssecondlawforvariablediffusivity:Boltzmann-Matano analysis, Matano interface, determination of diffusivity as a function of concentration;Diffusioninsubstitutionalsolidsolution:Kirkendalleffect,Darken'sanalysis. (10hrs)<br>Liquid-SolidPhaseTransformation:PrinciplesofSolidificationinmetalsandalloys:thermodynamicsinvolved,eutecticandperitecticSolidification,Homogeneousandheterogeneousnucleation,Mechanismsofgrowth.RapidSolidificationProcessing. (8 hrs)<br>Solid State Phase Transformations: Nucleation and growth Kinetics, homogeneous andheterogeneoustransformation,Precipitation:Coherency,agehardening,particleCoarsening;Ostwaldripening,Order-disordertransformation,spinodaldecomposition,massive transformations. (8hrs)<br>Solid State Phase Transformations in steel: Reconstructive and displacive transformations;Pearlitic transformation: mechanism and kinetics: Johnson-Mehl equation, morphology ofpearlite; Bainitic transformation: mechanism and kinetics; morphology of upper bainite and lowerbainite;Martensitictransformation:Mechanism-diffusionlessdisplacivenature; morphologyofhigh carbonand lowcarbon martensite. (8hrs) | | | | | | | |
| Text Books, and/or reference material | Text Books:<br>1.Phasetransformationsinmetalsandalloys-D.A.PotterandK.E.Easterling,CRCPress, 1992. 2.TransformationsinMetals, P.G.Shewmon, Mc-GrawHill, 1969.<br>3. Introductionto PhysicalMetallurgy– S. N. Avner, TataMcGrawHill, 1997.<br>4.Physical Metallurgy–PeterHaasen,CambridgeUniversityPress, 1996.<br>5.PhysicalMetallurgyPrinciples,R.E.Reed-HillandR.Abbaschian,3rded,PWS-Kent Publishing,1992.<br>6.PhysicalMetallurgyforEngineers–A. G.Guy,Addison-WesleyPub.Co.,1962.<br>7.ModernPhysicalMetallurgy,R.E.Smallman,Butterworths,1963. | | | | | | | |

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 2 | 2 | 1 | - | 1 | - | 3 | - | - | 3 |
| **CO2** | 3 | 3 | 3 | 3 | 2 | - | 2 | - | 2 | 1 | 2 | 2 |
| **CO3** | 3 | 3 | 3 | - | 3 | 3 | 3 | 2 | 3 | 2 | 2 | 2 |

**Correlation levels 1, 2 or 3 as defined below:**

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MMC403 | Materials Characterization | PCR | 3 | 1 | 0 | 4 | 4 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| MMC-301: Introduction to Metallurgy and Materials | | CT+MT+EA | | | | | |
| Course Outcomes | I. Learn fundamentals of X-ray diffraction, electron microscopy and other characterization techniques.<br>II. Understand X-ray diffraction, electron microscopy and other characterization techniques in detail.<br>III. Identify the crystal structure and index the diffraction patterns of different phases to meet contemporary needs (including tutorials) and learn different applications in characterization techniques. | | | | | | |
| Topics Covered | **X-Ray Diffraction:**<br>X-ray basics: Production of X-ray; The continuous and characteristic spectrum; Absorption; Filters. 4h<br>Elementary Crystallography: Overview the basics of crystallography; real and reciprocal lattice. 2h<br>X-ray diffraction: Bragg's Law; Ewald sphere construction; Diffraction methods–Laue method, rotating crystal methods, powder methods; Diffractometers; diffraction under non ideal condition. 6h<br>Intensity of diffracted beams: Structure factor calculations and other factors; Extinction rules. 4h<br>Application of X-ray diffraction: Crystal structure determination; Precise lattice parameter measurements; Phase diagram determination, Chemical analysis by diffraction, residual stress determination, particle size determination. 10h<br><br>**Electron Microscopy:** Basics; Resolution and depth of field of a microscope; Aberrations in a microscope; Specimen beam interaction; Interaction volume; Construction, modes of operation and application of Scanning electron microscope; Different contrast formation; Effect of different operational variables on the resolution and depth of field of a SEM; Specimen preparation; EDS and WDS. Elements of transmission electron microscopy. 14h<br><br>**Thermal Analysis:** Different thermal analysis techniques. 4h | | | | | | |
| Text Books, and/or reference material | Text Books:<br>1. "Elements of X-Ray Diffraction", by B.D. Cullity, Addision Wesley Publishing Co., Massachusetts, 1968.<br>2. "X-ray diffraction-a practical approach", by C. Suryanarayana and M. Grant Norton, Springer, 1998.<br><br>3. "X-ray Diffraction: Its Theory and Applications", by S. K. Chatterjee, Prentice-Hall of India Pvt. Limited,2004.<br><br>*4. "Electron Microscopy in the Study of Materials"*, by *P.J. Grundy and G.A. Jones*, Arnold, London, 1976.<br><br>5. "Transmission Electron Microscopy: A Textbook for Materials Science (4 Vol set)", by David B. Williams and C. Barry Carter, 2nd ed., Springer, 2009.<br><br>6. "Electron Microscopy and Analysis", by Peter J. Goodhew, John Humphreys and Richard Beanland, Third Edition, CRC Press, 2000. | | | | | | |

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

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

| CO ↓ | PO → | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| I | 3 | 1 | 1 | 1 | | 1 | 1 | 1 | 1 | 1 | | 2 |
| II | 3 | 2 | | 2 | 1 | 1 | | 1 | 1 | 2 | 1 | 2 |
| III | 2 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |

**Correlation levels 1, 2 or 3 as defined below:**

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

<table>
<tr><td colspan="7">Department of Metallurgical and Materials Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MMC404</td><td>Physics of materials</td><td>PCR</td><td>3</td><td></td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))</td></tr>
<tr><td colspan="2">PHC01: Engineering Physics,<br>CYC01: Engineering Chemistry<br>MMC302: Metallurgical Thermodynamics and Kinetics</td><td colspan="5">CT+MT+EA</td></tr>
<tr><td colspan="2">Developer</td><td colspan="5">Dr Barna Roy</td></tr>
<tr><td>Course Outcomes</td><td colspan="6">CO1: Material properties and free electron theory<br>CO2: Improvement of free electron theory through quantum mechanics<br>CO3: Combining crystal structure with free electron theory and quantum mechanics; Using the model to describe the specific materials properties.</td></tr>
<tr><td>Topics Covered</td><td colspan="6">1. Introduction- Electron Theory: Free electron theory: Classical electron theory, quantum free electron theory; Properties of materials; Thermal expansion; Thermal conductivity; AC and DC conductivity (Electrical conductivity); Wiedemann-Franz Law; Ideal and free electron gas; Large system; Maxwell-Boltzmann statistics.<br>[12 h]<br>2. Particles- Classical and Quantum; History of quantum mechanics; Drude Sommerfeld model; Fermi Dirac statistics; Anisotropy, periodic potential and density of states; Fermi energy, surface and temperature; Bose-Einstein statistics.<br>[12 h]<br>3. Reciprocal space; Diffraction; Wigner Seitz cells; Brillouin zones; Critical wave velocity; Band Theory/Zone theory of solids.<br>[12 h]<br>4. Semiconductor; Magnetic materials; Optoelectronic materials; Superconductivity; Nano-materials; Summary.<br>[12 h]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="6">Text Books:<br>1. Introduction to electronic properties of materials by David Jiles - (Chapman and Hall, 1994)<br>2. Introduction to the Modern Theory of Metals by Alan Cottrell - (Ashgate Publishing Company, 1988)<br>3. Materials Science and Engineering An Introduction; William D. Callister, Jr; John Wiley & Sons, Inc., 2003.</td></tr>
</table>

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

| PO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| **CO2** | 3 | 3 | 2 | 3 | 1 | 1 | 2 | 1 | 3 | 3 | 1 | 2 |
| **CO3** | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |

**Correlation levels 1, 2 or 3 as defined below:**

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

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MMC405 | Manufacturing Processes | PCR | 3 | 1 | 0 | 4 | 4 |
| Pre-requisites | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| MMC-302: Metallurgical Thermodynamics and Kinetics | | CT+EA | | | | | |
| Course Outcomes | • To understand different Manufacturing Processes<br>• Ability to design casting techniques and the basics of Welding Metallurgy<br>• To have ability to have a practical concept of manufacturing objects. | | | | | | |
| Topics Covered | Introduction to casting as a shaping technique; Characteristic and effects of sand, binders and additives; Different types of Moulding and Machine moulding; Special casting techniques (12)<br>Design of Gating and Risering of casting; Solidification (5)<br>Melting furnace- cupola, rotary furnace, induction furnace; Defects in casting and their remedy; Metallurgy of cast iron, Aluminium and copper based alloy. (12)<br>Joining: Physics of welding, Process of different welding, common welding processes of shielded metal arc welding, gas metal arc welding, gas tungsten arc welding and submerged arc welding; Welding metallurgy, problems associated with welding of steels and aluminium alloys, defects in welded joints. (14)<br>Historical perspective of Powder Metallurgy; Reasons for using Powder Metallurgy; The Future of Powder Metallurgy; Powder Fabrication: Different powder fabrication techniques; Powder Characterization: Experimental methods for measuring particle size, shape, distribution, surface area; Significance of true, apparent and tap densities of powders; Flow rate of powders and its significance; compressibility and green strength; Powder Handling: Powder Packing; Mixing and Blending; Mixing with Binders and Lubricants; Powder Lubrication; Compaction: Phenomenology of Powder Compaction; Conventional Compaction; Fundamentals of Compaction; Influence of Material and Powder Characteristics; Sintering: Sintering fundamentals; Full Density Processing. (14) | | | | | | |
| Text Books, and/or reference material | Text Books:<br>1. O. P. Khanna: Foundry technology, 17th Edition, DhanpatRai Publications, 2011.<br>2. Rajender Singh: Introduction to Basic Manufacturing Processes & Workshop Technology, New Age International (P) Limited, Publishers, 2006.<br>3. R. A. Flinn: Fundamentals of Metal Casting, Addison-Wesley; Underlining edition,<br>4. Powder Metallurgy – AUpadhyaya and G S Upadhyaya.<br>5. Powder metallurgy: principles and applications- Fritz V. Lenel<br>Reference Books:<br>1. P. L. Jain: Principles of Foundry Technology, 5th Edition, Tata Mcgraw Hill Education Private, 2009.<br>2. M. C. Flemings: Solidification processing, McGraw-Hill, 1974.<br>3. Metals Handbook, Casting, vol. 15, 10th Edition, ASM International, Materials Park, Ohio, USA, 1998. | | | | | | |

**MMC 501** **Mapping of CO (Course Outcome) and PO (Programme Outcome)**

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 2 | 2 | 2 | 2 | 1 | 2 | 3 | 1 | 1 | 3 | 1 |
| **CO2** | 1 | 1 | 2 | 1 | 3 | 2 | 2 | 3 | 2 | 2 | 2 | 1 |
| **CO3** | 1 | 2 | 1 | 1 | 3 | 2 | 2 | 3 | 1 | 1 | 2 | 1 |

**Correlation levels 1, 2 or 3 as defined below:**

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

<table>
<tr><td colspan="8">Department of Metallurgical and Materials Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MMS451</td><td>Transport Phenomena Lab</td><td>PCR</td><td>0</td><td>0</td><td>3</td><td>3</td><td>2</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">NIL</td><td colspan="5">CT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: Identify the nature of flow.<br>CO2: Determine the value of the coefficient of discharge for flow meters.<br>CO3: Evaluate the thermal conductivity and diffusivity for a particular system.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Experiment 1: Measurement of Reynold’s Number<br>Experiment 2: Measurement of total energy across various points in a fluid flow system; verification of Bernoulli’s theorem<br>Experiment 3: Measurement of coefficient discharge through a venturimeter.<br>Experiment 4: Measurement of coefficient discharge through an orificemeter.<br>Experiment 5: Measurement of pressure drop through a packed bed<br>Experiment 6: Measurement of coefficient of Pitot Tube and point velocity at different points across the flow<br>Experiment 7: Determination of Stefan – Boltzmann Constant<br>Experiment 8: Measurement of thermal Conductivity of Metal Rod<br>Experiment 9: Study the molecular diffusion of vapors in air</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Suggested Text Books:<br>6. Fundamentals of Momentum, Heat, and Mass Transfer by Welty, Wicks, Wilson, and Rorrer<br>7. Transport Phenomena – R. Byron Bird, Warren E. Stewart, Edwin N.<br><br>Suggested Reference Books:<br>7. An Introduction to Transport Phenomena in Materials Engineering – D. R. Gaskell,<br>8. A Textbook on Heat Transfer –S. P. Sukhatme</td></tr>
</table>

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO2** | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 3 | 2 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Correlation levels 1, 2 or 3 as defined below:**

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

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<tr><td rowspan="2">CourseCode</td><td rowspan="2">Titleofthe course</td><td rowspan="2">Program Core(PCR) / Electives(PEL)</td><td colspan="4">TotalNumber of contacthours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MMS452</td><td>PhaseTransformation and Phase Equilibria Laboratory</td><td>PCR</td><td>0</td><td>0</td><td>6</td><td>6</td><td>1.5</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">CourseAssessmentmethods(Continuous(CT)andendassessment(EA))</td></tr>
<tr><td colspan="3">Nil</td><td colspan="5">CT+EA</td></tr>
<tr><td>CourseOutcomes</td><td colspan="7">I. To introspect phase equilibria and phase transformation in steels of varying carbon content through investigation of microstructure in correlation to iron-carbon diagram.<br>II. To investigate microstructures of different cast irons in correlation to associated phase equilibria and phase transformation.<br>III. To understandtheapplication ofleverrule andphaserule.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">(i) Experiment1:Investigationsofthe microstructuresof pure metals(Fe,Cu,Zn,Al)<br>(ii)Investigationofthemicrostructuresofcarbonsteelscontaining~0.2%C,~0.4%C, ~0.6%C,~0.8%C,~1.0%C,incorrelationwithphaseequilibriainFe-Csystem(Iron–Carbonphasediagram).<br>Experiment2(PartI):Microstructureof0.2wt.%C steel (4hours)<br>Experiment3(PartII):Microstructure of 0.4wt.%Csteel (4hours)<br>Experiment4 (PartIII): Microstructure of0.6wt.% Csteel (4hours)<br>Experiment5(PartIV):Microstructure of0.8wt.% Csteel (4hours)<br>Experiment6 (PartV):Microstructureof1.0 wt.% Csteel (4hours)<br>(iii) With regard to Fe-C-Si phase equilibria, investigation of the microstructure of differenttypes of cast irons, viz. White Cast iron, Grey Cast iron, Spheroidal (Nodular) graphite castironandMalleablecast iron.<br>Experiment8 (PartI): MicrostructureofWhite Castiron (4hours)<br>Experiment9(PartII):Microstructure ofGreyCastiron (4 hours)Experiment10(PartIII):MicrostructureofSpheroidal(Nodular)graphitecastiron (4hours)<br>Experiment11(PartIV):Microstructure ofMalleable castiron (4hours)<br>(iv) Experiment 12: Study of the precipitation hardening process in Duralumin (Al-4.5%Cualloy) (3 hours)<br>(v) Experiment 13: ApplicationofLeverRule. (3 hours)<br>(vi)Experiment14:ApplicationofPhaseRuletodifferenttypesofbinaryphasediagrams.(3 hours)</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Textbook:<br>1. Phasetransformationsinmetalsandalloys-D.A. Potter andK.E. Easterling,CRCPress, 1992.2. Introductionto PhysicalMetallurgy– S. N. Avner,Tata McGrawHill, 1997.<br>3.PhysicalMetallurgyPrinciples, R.E.Reed-HillandR.Abbaschian,3rded,PWS-Kent Publishing,1992.<br>4.ModernPhysicalMetallurgy,R.E.Smallman,Butterworths,1963.</td></tr>
</table>

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 1 | - | 3 | 2 | 2 | 1 | 3 | 2 | 2 | 2 |
| **CO2** | 3 | 2 | 1 | - | 3 | 2 | 2 | 1 | 3 | 2 | 2 | 2 |
| **CO3** | 3 | 3 | 3 | 1 | 1 | - | - | - | 3 | - | - | 2 |

**Correlation levels 1, 2 or 3 as defined below:**

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

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MMS453 | Materials Characterization Laboratory | PCR | 0 | 0 | 3 | 3 | 2 |
| Pre-requisites | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| MMC-301: Introduction to Metallurgy and Materials | | CT+EA | | | | | |

| | |
|---|---|
| Course Outcomes | I. Learn fundamentals and operational aspects of X-ray diffraction, electron microscopy and other characterization techniques.<br>II. In-hand identification of the crystal structure and indexing of diffraction patterns of different phases to meet contemporary needs.<br>III. Data analysis and report writing of various experiments. |
| Topics Covered | **List of Experiments**<br>1. Indexing the X-ray diffraction (XRD) pattern of different phases.<br>(a). Indexing the XRD pattern of BCC structure.<br>(b) Indexing the XRD pattern of FCC structure.<br>(c) Indexing the XRD pattern of HCP structure.<br>(d) Indexing the XRD pattern containing a mixture of BCC and FCC phase.<br>2. Precise lattice parameter determination.<br>3. X-ray diffraction of powders to show the effect of powder size on peak broadening.<br>4. Microstructural and Fractographic study by SEM.<br>5. Indexing of SADP<br>6. Precipitation kinetics study of age hardenable Al alloy |
| Text Books, and/or reference material | Text Books:<br>1. "Elements of X-Ray Diffraction", by B.D. Cullity, Addision Wesley Publishing Co., Massachusetts, 1968.<br>2. "X-ray diffraction-a practical approach", by C. Suryanarayana and M. Grant Norton, Springer, 1998.<br>**3. "X-ray Diffraction: Its Theory and Applications", by S. K. Chatterjee, Prentice-Hall of India Pvt. Limited,2004.**<br>*4. "Electron Microscopy in the Study of Materials"*, by *P.J. Grundy and G.A. Jones*, Arnold, London, 1976.<br>**5. "Transmission Electron Microscopy: A Textbook for Materials Science (4 Vol set)", by David B.** Williams **and C. Barry** Carter**, 2nd ed., Springer, 2009.**<br>**6. "Electron Microscopy and Analysis", by Peter J. Goodhew, John Humphreys and Richard Beanland, Third Edition, CRC Press, 2000.** |

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

| CO ↓ | PO → | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| I | 3 | 1 | 1 | 1 | | | 1 | 1 | 2 | 1 | | 1 |
| II | 3 | 3 | 3 | 3 | 1 | 2 | 1 | 2 | 3 | 2 | 2 | 2 |
| III | 2 | 3 | 1 | 2 | 2 | | 1 | 2 | 3 | 3 | 1 | 2 |

**Correlation levels 1, 2 or 3 as defined below:**

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

# FIFTH SEMESTER

<table>
<tr><td colspan="8">Department of Metallurgical and Materials Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MMC501</td><td>Modelling and Simulation of Metallurgical Processes</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))</td></tr>
<tr><td colspan="3">MMC401: Transport Phenomena in Metallurgical Processes</td><td colspan="5">CT+MT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To Learn fundamentals of Modelling.<br>CO2: To Identify the nature of engineering problems and solving by numerical methods<br>CO3: To Build physical and mathematical models to describe the complex physical phenomena pertaining to the real world.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Review of Fluid Flow, heat transfer and Mass Transfer, Type of Models, Advantages of Mathematical Model, Types of Mathematical model, Method of prediction, Modeling vs. experimentation, nature of coordinates. (4)<br>Classification of partial differential equations, Elliptic, Parabolic, and Hyperbolic Equations, Initial and Boundary Conditions, Initial Value and Boundary Value Problems, Substantial derivative, Concept of grid points, cell and mesh, methods of discretization, Types of cells and mesh, Basic approach in solving a problem. (4)<br>Central, Forward, and Backward difference expressions for a uniform grid, Central difference expression for a nonuniform grid, Numerical errors, Accuracy of solution: optimum step size, grid Independence test. (4)<br>Application heat of conduction and diffusion, one dimensional steady state problem, Method of solution: Gaussian elimination, Tri-diagonal matrix algorithm (TDMA), Gauss-Seidel iterative method, the concept of Relaxation factor, optimization of Relaxation factor, Two-dimensional steady state problem, Block iterative methods, There-dimensional steady state problem, Transient one dimensional problem, Euler method, Crank-Nicolson method, Pure Implicit method, Accuracy of Euler, Crank-Nicolson and Pure Implicit method, stability, Von Neumann stability analysis, Two-dimensional transient, Alternative Direction Implicit method, Problem in cylindrical and spherical geometry, Non-axissymmetric problem, Transient conduction in composite media, Treatment of nonlinearity in conduction and diffusion, irregular geometry, Diffusive- convective system with Flow, Met lab codes. (24)<br>Phase Change Problems: Mathematical Formulation of Phase Change Problems, Variable Time Step Approach for Single-Phase solidification, Variable Time Step Approach for two-Phase solidification, Enthalpy Method. (5)<br>Physical modeling: Introduction, dimensional analysis, similarity criteria, modeling of steel making processes. (7)<br>Case studies. (4)</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7"><u>Suggested Text Books:</u><br>1. Finite difference Method in heat transfer- M. N. Ozisik<br>2. Computational Fluid dynamics and heat transfer – P.S. Ghoshdastidar<br>3. Modeling of Steelmaking Processes – D. Mazumdar and James W. Evans<br><br><u>Suggested Reference Books:</u><br>1. Getting Started with MATLAB 7: A Quick Introduction for Scientists and Engineers– R. Pratap.<br>2. Numerical Methods for Engineers - D. Vaughan Griffiths and I.M. Smith.</td></tr>
</table>

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO2** | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 3 | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Correlation levels 1, 2 or 3 as defined below:**
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<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MMC 502</td><td>Engineering Materials and Heat Treatment</td><td>PCR</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT), mid-term (MT), and end assessment (EA))</td></tr>
<tr><td colspan="3">PHC 01 Engineering Physics<br>MMC 402 Phase Transformation and Phase Equilibria</td><td colspan="5">CT+MT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: To understand the basic principle behind the heat treatment of metals and alloys in terms of solid-state phase transformation<br>• CO2: To acquire basic knowledge to change the physical and mechanical properties after different heat treatments of materials<br>• CO3: To learn different heat treatment processes that have some commercial applications</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Objectives and Principles of Heat Treatment on Engineering Materials. Introduction to Various Classes of Engineering Materials: Factors Affecting Selection of Engineering Materials- Service requirements, fabrication requirements, and economic requirements. Study of the industrially important of steels, their mechanical and thermal treatment and uses: Plain carbon steels. Conventional low carbon steels, Mild steels, dual-phase steels, and alloy steels. [6 hours]<br>Phase Transformation on heating, Forming of austenite, Kinetics of formation of austenite, Nucleation sites in eutectoid steels, Austenitic grain size, Grain growth, Importance of grain size [4 hours]<br>Annealing – Stress relieving, recrystallization annealing, full annealing, partial annealing, diffusion annealing, Spheroidizing, Normalizing, Hardening, and Tempering, [4 hours]<br>Method of plotting, Types of TTT diagram, Critical cooling rate, Effect of alloying elements on TTT diagram, Applications, Continuous cooling transformation diagram, Pearlitic transformation: Mechanism, Kinetics, Effect of alloying elements on transformation, Interlameller spacing, Bainitic transformation: Mechanism, Characteristics, Bainitic structure. Diffusion less transformation: Mechanism, Kinetics, Ms - Mf temperatures, Athermal& isothermal martensites, Effect of applied stress on transformation, Habit planes, Bain distortion model / crystallographic theory of martensitic transformation, Retained austenite, Martensitic transformation in non-ferrous systems. [8 hours]<br>Hardenability: Significance, Grossman method, Critical and ideal critical diameter, Jominy End Quench method, Effect of grain size and composition, Residual stresses, Quench cracking. Factors affecting hardenability, Quenchants: Characteristics of quenchants, Different quenching media, Mechanism of quenching. [4 hours]<br>Principles involved in surface hardening, Induction and flame hardening methods and application of selective hardening, Laser hardening, Case carburizing (solid, liquid, and gaseous), Cyaniding, Carbonitriding, Nitriding, Plasma nitriding, etc., [6 hours]<br>Special heat treatment processes: Thermomechanical treatment, Austempering, Martempering, Ausforming, Patenting, Sub-zero treatment etc., Thermo-Mechanical treatments. [4 hours]<br>Design for heat treatment of alloy steels, tool steels, dies steels, stainless steels (concerning carbide precipitation and sigma phase formation), cast irons and non-ferrous alloys. – specific examples,<br>Heat treatment of aluminum alloys, titanium alloys, and copper alloys, Concept of age-hardening.<br>Heat treatment furnaces- their temperature and atmosphere control, Defects in heat-treated parts, Causes for the defects in heat-treated parts, and remedies.<br>[8 hours]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7"><u>Suggested Text Books:</u><br>1. An Introduction to Physical Metallurgy – S. N. Avner, McGraw-Hill Book Company.<br>2. ASM Metals Hand Book – Vol. IX, ASM International Materials Society.<br>3. Principles of the Heat Treatment of Plain Carbon and Low Alloy Steels, Charlie R. Brooks, ASM international, 1996.<br>4. Structure and properties of materials – J Wulff and other. Vols. I–IV. Wiley Eastern pub Ltd. New Delhi<br><u>Suggested Reference Books:</u><br>5. Principles of Heat Treatment – R. C. Sharma, New Age International (P) Ltd.<br>6. Heat Treatment of Metals – V. Singh (Standard Publication Distributors) New Delhi</td></tr>
</table>

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 3 |
| **CO2** | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 3 |
| **CO3** | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 3 |

**Correlation levels 1, 2 or 3 as defined below:**

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

<table>
<tr><td colspan="8">Department of Metallurgical and Materials Engineering</td></tr>
<tr><td rowspan="2">Course code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program core (PCR) / Elective (PEL)</td><td colspan="4">Total number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MMC503</td><td>Mechanical Behaviour of Materials</td><td>PCR</td><td>3</td><td>1</td><td>0</td><td>4</td><td>4</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))</td></tr>
<tr><td colspan="2">MMC301 Introduction to Metallurgy and Materials</td><td colspan="6">CT+MT+EA</td></tr>
<tr><td colspan="2">Developer</td><td colspan="6">Dr. Madan Mohan Ghosh and Dr. Manab Mallik</td></tr>
<tr><td>Course outcomes</td><td colspan="7">CO1: To understand the fundamental concepts of plastic deformation of materials<br>CO2: To know about various lattice defects and the roles played by these defects in plastic deformation and strengthening of materials<br>CO3: To correlate the fundamentals ideas of deformation and strengthening with the observations in materials testing and mechanical processing</td></tr>
<tr><td>Topics covered</td><td colspan="7">1) Introduction to plastic deformation and evaluation of the mechanical properties: Concept of stresses and strains, engineering stress and strain, true stress and strain, different types of loading for bulk deformation, slow strain rate deformation, evaluation of mechanical properties of materials by tensile and compression testing, stress-strain response of different materials - elastic region, yield point, plastic deformation, necking and fracture, effects of strain rate and temperature on stress-strain response of materials, superplastic behavior, evaluation of shear stress - shear strain curve from torsion testing, deformation and fracture of materials under impact loading, ductile to brittle transition, elementary concept of fatigue deformation and fracture, elementary concept of creep deformation and fracture, localized deformation at surface and indentation hardness, different methods of hardness measurement. [24 h]<br>2) Mechanisms of plastic deformation and strengthening: Plastic deformation by slip, slip system, slip line, slip band, critical resolved shear stress (CRSS) of a material, theoretical shear strength, defects/imperfections in crystals, classification of defects, thermodynamics of defects, geometry of dislocations, Burgers vector, Burgers circuit, various types of dislocations, dislocation glide, Peierls stress, partial dislocations and stacking faults, cross slip, dislocation climb, intersection of dislocations, jogs and kinks in dislocation, force on a dislocation, line tension of a dislocation, dislocation generation - Frank-Read and grain boundary sources, stress and strain field around dislocations, strain energy of a dislocation, dislocation interactions, forces between dislocations, polygonization, dislocation movement and strain rate, deformation behavior of single crystals - flow curve and strain hardening/work hardening mechanisms of single crystals, deformation behavior of polycrystalline aggregates, plastic deformation by twinning, interaction between dislocations and interstitial atoms - yield point phenomena and strain ageing, dislocation phenomena involved in fatigue and fracture, Hall-Petch and other hardening mechanisms of polycrystalline aggregates, grain size effect, Hall-Petch breakdown, strengthening due to fine particles, fiber strengthening, solid solution strengthening, strengthening due to point defects, plastic deformation of two-phase aggregates, cold-worked structure of polycrystalline materials, annealing of cold-worked polycrystalline materials, Bauschinger effect, preferred orientation. [24 h]</td></tr>
<tr><td>Text books, and/or reference materials</td><td colspan="7">• Mechanical Metallurgy, SI Metric Edition, George E. Dieter, McGraw-Hill Book Company (UK) Limited, 1988<br>• Mechanical Behavior of Materials, William F. Hosford, Cambridge University Press, New York, 2005<br>• Mechanical Behavior of Materials, Second Edition, Marc A. Meyers and Krishan K. Chawla, Cambridge University Press, New York, 2009<br>• Mechanical Behavior of Materials, Second Edition, Thomas H. Courtney, Waveland Press, Inc., Illinois, 2005<br>• The Plastic Deformation of Metals, R.W.K. Honeycombe, Edward Arnold, 1968<br>• Dislocations and Plastic Flow in Crystals, A.H. Cottrell,Clarendon Press, 1965</td></tr>
</table>

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

| COs | POs | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **PO1** | **PO2** | **PO3** | **PO4** | **PO5** | **PO6** | **PO7** | **PO8** | **PO9** | **PO10** | **PO11** | **PO12** |
| **CO1** | 3 | 3 | 2 | 2 | 3 | 1 | 1 | | 1 | 1 | 2 | 2 |
| **CO2** | 3 | 3 | 1 | 1 | 1 | | | | 1 | 1 | 1 | 1 |
| **CO3** | 3 | 3 | 3 | 3 | 3 | 1 | | 1 | 1 | 2 | 3 | 2 |

**Correlation levels 1, 2 or 3 as defined below:**

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

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MMC504 | Iron Making | PCR | 3 | 1 | 0 | 4 | 4 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| MMC-301: Metallurgical Thermodynamics and Kinetics | | CT+MT+EA | | | | | |
| Course Outcomes | • CO1: Understand fundamentals of physico-chemical principles of blast furnace iron making.<br>• CO2: Understand the design & operational aspects of blast furnace technology.<br>• CO3: Understand the development in alternative iron making processes. | | | | | | |
| Topics Covered | History of Iron Making Pig Iron production in India. (2)<br>Raw Materials – Valuation and preparation of raw materials (6)<br>Methods of Agglomeration: sintering, pelletizing. (6)<br>Testing of raw materials. (2)<br>Design and construction of the blast furnace. (2)<br>Theory and practice of pig iron making – charge distribution, burden calculation. mass balance (4)<br>Physico-chemical aspects of blast furnace reactions, Blast furnace slags. Operating line (6)<br>Developments in blast furnace practice. Blast furnace irregularities. (4)<br>Blast furnace accessories: blowers, stoves, gas cleaning plants. (4)<br>Alternative methods of Iron making. (4)<br>Manufacture of ferro alloys. (2)<br>Environmental considerations in iron making. (1) | | | | | | |
| Text Books, and/or reference material | Suggested Text Books:<br>1. A Text Book on Modern Iron Making - R. H. Tupkary (new edition)<br>2. Principles of Iron Making - A. K. Biswas.<br>3. Ghosh, A. and Chatterjee, A., Principles and Practices in Iron and Steel making, Prentice Hall of India, New Delhi, 2008<br>Suggested Reference Books:<br>1. Manufacture of Iron & Steel. Vol. I.- G. B. Bashforth. | | | | | | |

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

| PO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| **CO2** | 3 | 3 | 2 | 3 | 1 | 1 | 2 | 1 | 3 | 3 | 1 | 2 |
| **CO3** | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |

**Correlation levels 1, 2 or 3 as defined below:**

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

## Depth Elective – 1

| DepartmentofMetallurgical andMaterialsEngineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Titleofthe course | Program Core(PCR) / Electives(PEL) | TotalNumber of contacthours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MME510 | Functional Materials | PEL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | CourseAssessmentmethods(Continuous(CT)andendassessment(EA)) | | | | | |
| MMC-301:Introductionto MetallurgyandMaterials | | CT+MT+EA | | | | | |
| CourseOutcomes | CO1: Learn thebasic materials properties like thermal, electrical, magnetic and optical etc.<br>CO2: Different types of functional materials – Electrical, magnetic, thermal and optical materials, energy materials, biomaterials etc.<br>CO3: Designing different types of functional materials, problemsand applications. | | | | | | |
| TopicsCovered | Fundamentals of atomic structure- chemical bonding-crystal structure-property correlation; classification of different functional materials<br>[2 hours]<br><br>Introduction to thermal properties and thermal materials<br>[5 hours]<br>Introduction to electrical properties and electrical materials<br>[5 hours]<br>Introduction to magnetic properties and magnetic materials<br>[5 hours]<br>Introduction to optical properties and optical materials<br>[5 hours]<br><br>Thermoelectric materials and devices, Inorganic and organic photovoltaic materials, Materials for hydrogen energy/storage, Materials for electrochemical energy storage<br>[8 hours]<br><br>Biomaterials, Shape memory and Super-elastic alloys, Piezoelectric Materials, Conducting Polymers, Magnetostrictive materials<br>[8 hour]<br><br>Nanomaterials, Metal foams, Nanofluids, Carbon nanotubes, Hybrid nanocomposites, Nanoporous materials, Nano coatings<br>[2 hours] | | | | | | |
| Text Books, and/or reference material | Text Books:<br>1.MaterialsScienceandEngineeringAnIntroduction–WilliamD.Callister,Jr.,John Wiley&Sons,Inc., 2007<br>2.Materials;Engineering,Science,ProcessingandDesign–MichaelAshby,Hugh Shercliffand DavidCebon<br>3.IntroductiontoMagnetic Materials–B. D.Cullity and C.D. Graham | | | | | | |

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 2 | 2 | 1 | | 2 | 2 | 2 | 2 | 2 | 2 |
| **CO2** | 1 | 2 | 2 | 3 | 3 | 2 | 3 | 2 | 2 | 3 | 3 | 3 |
| **CO3** | 2 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 2 | 2 | 3 | 3 |

**Correlation levels 1, 2 or 3 as defined below:**

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

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MME511 | Energy Materials | PEL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| NIL | | CT+MT+EA | | | | | |
| Course Outcomes | • CO1: Basics of different types of alternative energy sources and technologies.<br>• CO2: Fundamentals of different types of materials utilized for different energy technologies.<br>• CO2: To train the students to select and design specific materials for specific energy technology. | | | | | | |
| Topics Covered | **Introduction:** General introduction to current earth climate and it's problems. Need for search of alternative energy sources. **[2]**<br>**Thermoelectric materials:** Thermoelectric materials and devices. **[4] Photovoltaic materials:** Inorganic and organic photovoltaic materials. **[8]**<br>**Materials for hydrogen energy:** Hydrogen production, transportation, storage, and use; hydrogen storage – compressed storage, liquid state storage, solid state storage, metal hydrides, complex and chemical hydrides. **[10]**<br>**Materials for electrochemical energy storage:** Electrochemical Reactions; Electrochemical Energy Storage Systems, Batteries and Supercapacitors **[6]**<br>**Fuel cells:** Introduction, different types, SOFC, Bio fuel cells **[5]**<br>**Other energy technologies and materials:** Nuclear, geothermal, hydro and wind **[5]** | | | | | | |
| Text Books, and/or reference material | **Text Books:**<br>1. Materials for Sustainable Energy Applications: Conversion, Storage, Transmission, and Consumption, David Munoz-Rojas and Xavier Moya (Editors), CRC Press, 2016.<br>**Reference Books:**<br>1. Fundamental studies connected with electrochemical energy storage; by E.Buck; Washington, DC: NASA (1975)<br>2. Electrochemical Supercapacitors; by B. E. Conway; Kluwer Academic/Plenum; New York (1999)<br>3. Handbook of Hydrogen Storage - New Materials for Future Energy Storage - by M Hirscher, 2010, Wiley-VCH<br>4. Fuel cells: from fundamentals to applications; by Supramaniam Srinivasan; Springer Science + Business Media; New York (2006) | | | | | | |

| Department of Metallurgical & Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MME512 | Alternative Routes of Iron Making | PCR | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| MMC-302:Metallurgical Thermodynamics and Kinetics<br>MMC-404: Iron Making, | | CT+MT+EA | | | | | |
| Course Outcomes | • CO1: Apply the thermodynamic knowledge to understand the fundamentals of direct reduction and smelting reduction of iron oxides<br>• CO2: Acquire the knowledge of reaction mechanism and the process technology of alternative routes of iron making<br>• CO3: Learn to analyze raw materials requirements for different processes | | | | | | |
| Topics Covered | Ironmaking and environment 4R principles, Steel facts, Blast furnace iron making technology and its limitation, Objectives of alternative routes of ironmaking [6]<br>Classifications of alternative routes, direct reduction and smelting reduction technology, classifications of DR processes, Characterization of DRI - % of Metallization and Degree of Reduction, Fundamentals of reduction of iron oxides, Discussion of Fe-C-O system, Equilibrium gas composition calculation with temperature for different oxides of iron, Raw materials characterization techniques – Chemical, physical and physicochemical characterization [12]<br>Gas based direct reduction processes – Midrex and HyL, principles and operation [4]<br>Coal based direct reduction process, Rotary kiln – principles and operation, process analysis, Accretion formation – mechanism, factors affecting it. Comparative analysis of SL/RN, CODIR, ACCAR, TDR, JSW, DRC. Rotary Hearth Furnace - Principles and features, various RHF based processes – INMETCO, FASTMET, COMET, SIDCOMET. [8] | | | | | | |

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|---|---|
| | Fluidized bed reactor – FINMET and FINNEX process. Application of DRI, DRI statistics [2]<br>Introduction to smelting reduction, Fundamentals of Smelting reduction, Factors affecting smelting – Postcombustion ratio, Prereduction degree, Coal chemistry, Classifications of smelting reduction, Corex process - principles and operation, raw materials requirement, Environmental aspect [4]<br>Moden technologies: Itmk3 process, Hisarna process - Fundamentals and Features of the process and nugget, Environmental aspects. Basic mechanism, Product quality, Advantages [4]<br>Environmentally friendly Breakthrough technologies, Iron production by electrolysis, Hydrogen production technologies, Hydrogen based process technologies - HPR process and its fundamentals, [4]<br>Case studies. [6] |
| Text Books, and/or reference material | Suggested Text Books:<br>1. Alternative routes of iron making, Arabinda Sarangi and Bidyapati Sarangi, PHI learning<br>2. Beyond the Blast Furnace, Amit Chatterjee, CRC Press<br>3. Alternative Methods of Ironmaking, S. K. Dutta, S CHAND & Company Limited<br>4. Sponge Iron Production by Direct Reduction of Iron Oxide, Amit Chatterjee, PHI learning<br>5. Metallics for Steelmaking Production and Use, Amit Chatterjee and Banshidhar Pandey<br>6. Hot Metal Production by Smelting Reduction of Iron Oxide, Amit Chatterjee<br>Suggested Reference Books:<br>1. B. F. Ironmaking Principles -A.K Biswas<br>2. Direct Reduced Iron – Stephansion&Smailer<br>3. Modern Iron Making – R. H. Tupkery<br>4. Physical Chemistry of Iron & Steel manufacture – C. Bodsworth. |

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO2** | 3 | 3 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 3 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 |

**Correlation levels 1, 2 or 3 as defined below:**

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

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MME513 | Design and Selection of Engineering Materials | PEL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| MMC503: Mechanical Behaviour of Materials | | CT+MT+EA | | | | | |
| Course Outcomes | CO1: To understand the criteria and the importance of the selection of materials<br>CO2: To distinguish different design criteria for manufacturing process.CO3: To understand the relationship between the requirements of the materials for design, selection, processing and its applications. | | | | | | |

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| Topics Covered | Overview of Materials Selection and Design: The Importance of Materials Selection, Relation to Design, Product Analysis, Activities of Product Development, Case Examples of Product Development Stages, Product Development Activities for Piston-Cylinder Liner, Product Development Activities for New Automotive Brake Pad, and Development of Automotive Fuel Tank. (6)<br><br>Mechanical Failure of Materials: Mechanical Failure, Failure Due to Fracture, Factors Affecting the Fracture of a Material, Griffith Crack Theory and Fracture Toughness, Failure Due to Fatigue, Prevention of Fatigue Failure, Failure Due to Creep, Failure Due to Corrosion, Failure Due to Wear, Failure Analysis of an Electric Disconnector: Case Study (6)<br>Design Phases: Factors Influence Engineering Design, Major Phases of Design, Design Tool and Material Data, Design Reviews, Design Codes, Specification and Standards, Probabilistic Approach in Design, Factor of Safety and De-Rating Factors, Case Study on Automotive Brake Pad (6)<br>Materials Properties and Design: Materials Properties and Design, Design Under Different Conditions: Surface Finish Factor, Size Factor, Reliability Factor, Operating Temperature Factor, Loading Factor, Stress Concentration Factor, Service Environment Factor, Manufacturing Process Factor, Designs Against Fatigue Load, Design for Automotive Intake Manifold: A Case Study (6)<br>Materials Selection Process: Events in Materials Selection Process, Materials Performance Requirement: Functional Requirements, Manufacturing Requirements: Reliability Requirements Sustainable Requirement, Development of Different Solutions: Creativity Phase, Screening Phase, Quantitative Methods of Materials Selection: Cost Per Unit Property Method, Weighted Properties Method, Digital Logic Approach, Ashby Method, Application of Digital Logic Method: Material Selection for Automotive Brake Disc: Case Study 1, Material Selection for Automotive Piston: Case Study, Optimum Material Selection, Material Selection for a Cylindrical Shaft: Case Study, Screening of Candidate Materials. (8) Knowledge-based expert system (KBS) in Materials Selection: Expert System Components Facts: Rule-Based Reasoning, Database; Inference Engine, Architecture and Elements in Expert System, Benefits of Knowledge Based System, KBS for Optimum Selection of Materials: Case Study1, KBS for Optimum Selection of Materials: Case Study 2, KBS for Optimum Selection of Materials: Case Study 3: Analytic Hierarchy Process; Materials Selection for Automotive Dashboard, KBS for Optimum Selection of Materials: Case Study 4: KBS for Material Selection for Boat Components. (8) |
| Text Books, and/or reference material | 9. Michael F. Ashby, Materials Selection in Mechanical Design, Fourth edition, Elsevier.<br>10. Gerhard Pahl, W. Beitz,and Jorg Feldhusen, Engineering Design: A Systematic Approach, Springer.<br>11. George E. Dieter and Linda C. Schmidt, Engineering Design, Fourth Edition, McGraw-Hill.<br>12. Md Abdul Maleque and MohdSapuanSalit, Materials Selection and Design, Springer.<br>13. Avelino J. Gonzalez and Douglas D. Dankel, The Engineering of Knowledge-Based Systems: Theory and Practice, Prentice-Hall, Inc., United States.<br>14. Materials Selection and Design, Volume 20 of ASM Handbook, ASM International. |

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO2** | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 1 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Correlation levels 1, 2 or 3 as defined below:**

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

| Department of Metallurgical & Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MME514 | Powder Metallurgy | PEL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| MMC-301: Introduction to Metallurgy and Materials | | CT+MT+EA | | | | | |
| Developer | | Dr. Manab Mallik | | | | | |

| | |
|---|---|
| Course Outcomes | CO1: Learn science and technological aspects of the Powder Metallurgy Techniques.<br>CO2: The contemporary need can be met by the ability to analyze the industrial processes.<br>CO3: Solve problems of near net shape fabrication of powder metallurgy parts and explore powder-processing-property relationship |
| Topics Covered | **Introduction:** Historical perspective of Powder Metallurgy; The Future of Powder Metallurgy. [4 hours]<br>**Fabrication of Powders:** Basics methods, Mechanical fabrication techniques; Electrolytic fabrication techniques, Chemical fabrication techniques, Atomization techniques. Production of Ferrous powders [8 hours]<br>**Powder Characterization:** Experimental methods for measuring particle size, shape, distribution, surface area; Significance of true, apparent and tap densities of powders; Flow rate; compressibility and green strength; Characteristics of common ferrous powders [6 hours]<br>**Mixing and Blending:** Dry Mixing, wet mixing; Powder Lubrication [4 hours]<br>**Compaction:** Injection Molding; Fundamentals of Compaction; Influence of Material and Powder Characteristics on compaction. [6 hours]<br>**Sintering Behavior:** Sintering fundamentals; Sintering Theory; Mixed Powder Sintering; Liquid Phase Sintering; Sintering Atmosphere, Sintering Furnaces; Full Density Processing. [8 hours]<br>**Finishing Operations:** Machining; Heat Treatments; Surface Treatments [4 hours]<br>**Applications:** Competitive Processes; Examples of Powder Metallurgy Applications and Properties. [4 hours] |
| Text Books, and/or reference material | TEXT BOOKS:<br>1. Powder Metallurgy – A Upadhyaya and G S Upadhyaya.<br>2. Powder Metallurgy Science – R. M. German, 2nd Edition, MPIF, 1994<br>REFERENCE BOOKS:<br>1. Powder metallurgy: principles and applications, Fritz V. Lenel, Metal Powder Industries Federation, 1980<br>2. Powder Metallurgy Technology, Cambridge International Science Publishing, 2002 |

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | | 3 | 1 | 1 |
| **CO2** | 3 | 3 | 1 | 1 | 1 | 2 | 3 | | 1 | 1 | 1 | 1 |
| **CO3** | 3 | 3 | 2 | 1 | 2 | 1 | 2 | 1 | 3 | 1 | 2 | 3 |

**Correlation levels 1, 2 or 3 as defined below:**

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

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MMS551 | Manufacturing Processes Laboratory - I | PCR | 0 | 0 | 3 | 3 | 1.5 |
| Pre-requisites | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| Nil | | CT+EA | | | | | |
| Course Outcomes | • To understand the basic of metal Casting and the techniques of welding.<br>• To understand casting and welding defects and methods of elimination.<br>• To understand the microstructures of three different zones of a welded portion. | | | | | | |
| Topics Covered | Experiment-1: Determination of various properties of sand -clay -water mixture<br>Experiment-2 : Design and preparation of green sand mould with various gating system<br>Experiment-3 : Melting and Casting of Aluminum in green sand mould<br>Experiment-4 : Welding of Butt -Joint by MMAW<br>Experiment-5 : Determination of various defects by NDT of weld Joint<br>Experiment-6 : Observation of Microstructure of welded joint | | | | | | |

| | |
|---|---|
| | Experiment-7 : Welding of Butt -Joint by TIG<br>Experiment -8 : Comparison weld by 2 different Routes. |
| Text Books, and/or reference material | Text Books:<br>1. O. P. Khanna: Foundry technology, 17th Edition, Dhanpat Rai Publications,2011<br>2. P. L. Jain: Principles of Foundry Technology, 5th Edition, Tata Mcgraw Hill Education Private, 2009. |

**MMS 551** **Mapping of CO (Course Outcome) and PO (Programme Outcome)**

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 2 | 2 | 2 | 2 | 1 | 2 | 3 | 1 | 1 | 3 | 1 |
| **CO2** | 1 | 1 | 2 | 1 | 3 | 2 | 3 | 3 | 2 | 2 | 2 | 2 |
| **CO3** | 1 | 2 | 1 | 1 | 3 | 2 | 2 | 3 | 1 | 3 | 3 | 1 |

**Correlation levels 1, 2 or 3 as defined below**:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MMS 552 | Heat treatment of Materials Laboratory | PCR | 0 | 0 | 3 | 3 | 2 |
| Pre-requisites | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| Phase Transformation and Phase Equilibria (MMC 402) | | CT+EA | | | | | |
| Course Outcomes | CO1: To learn fundamental of change in microstructure, hardness and mechanical properties with different cooling rate, cooling medium and temperature<br>CO2: To understand the change in surface structure and property with chemical treatment<br>CO3: To get an overall idea on a microstructure and assessment of hardness and mechanical property of steel under various industrial cooling condition. | | | | | | |
| Topics Covered | Acquaintance with Furnaces and their Operation [3 hours]<br>Annealing, normalizing, hardening, and tempering treatments of plain carbon steels [12 hours]<br>Influence of underheating and overheating on microstructure and properties [3 hours]<br>Jominy End Quench Test [3 hours]<br>Determination of critical diameter of Steel by trial hardening method. [6 hours]<br>Pack Carburizing of steels, Post-carburizing heat treatment, Measurement of case depth. [6 hours | | | | | | |
| Text Books, and/or reference material | Suggested Text Books:<br>1. Principles of the Heat Treatment of Plain Carbon and Low Alloy Steels, Charlie R. Brooks, ASM international, 1996.<br>2. ASM Metals Hand Book – Vol. IX, ASM International Materials Society.<br>Suggested Reference Books:<br>1. Principles of Heat Treatment – R. C. Sharma, New Age International (P) Ltd.<br>2. Heat Treatment of Metals – V. Singh (Standard Publication Distributors) New Delhi | | | | | | |

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 1 | 3 | 3 | 1 | 1 | 1 | 2 | 1 | 3 | 3 |
| | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO2** | 3 | 3 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | 3 | 3 |
| **CO3** | 3 | 3 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 3 | 3 |

**Correlation levels 1, 2 or 3 as defined below:**
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

<table>
<tr><td colspan="7">Department of Metallurgical and Materials Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MMS553</td><td>Mechanical Behavior of Materials Laboratory</td><td>PCR</td><td>0</td><td>0</td><td>3</td><td>3</td><td>2</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="4">Course Assessment methods (Continuous (CT) and end assessment (EA))</td></tr>
<tr><td colspan="3">XEC01Engineering Mechanics; MMC301Introduction to Metallurgy and Materials</td><td colspan="4">CT+EA</td></tr>
<tr><td colspan="3">Developer</td><td colspan="4">Dr. Madan Mohan Ghosh and Dr. Manab Mallik</td></tr>
<tr><td>Course Outcomes</td><td colspan="6">CO1: To know about the method of tension, compression, torsion, impact, hardness testing<br>CO2: To analyze the results of different mechanical testing and interpret the mechanical behaviour of the materials<br>CO3: To correlate structure with the mechanical properties under different conditions of deformation</td></tr>
<tr><td>Topics Covered</td><td colspan="6">1) Studying the stress-strain behavior of different materials under tension.<br>2) Studying the effect of strain rate on the stress-strain behavior of materials.<br>3) Determination of the Youngs modulus by tension tests<br>4) Studying the stress-strain behavior of different materials under compression and evaluate strength and ductility properties.<br>5) Studying the localized deformation at surface of metallic materials by various hardness testing methods [3]<br>6) Evaluation of shear stress - shear strain plot of ductile metals and alloys from torsion testing and determination of useful mechanical properties [6]<br>7) Studying materials behavior under impact loading by Charpy V-notch testing [3]<br>8) Demonstration on fatigue test of a material using rotating beam fatigue testing machine.<br>9) Determination of fracture toughness by three point bend tests on single edge notch bend tests, and observation of fracture surfaces.<br>10) Determination of flexural modulus and strength of a brittle material using three point bend test</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="6">• Mechanical Metallurgy, SI Metric Edition, George E. Dieter, McGraw-Hill Book Company (UK) Limited, 1988<br>• Mechanical Behavior of Materials, William F. Hosford, Cambridge University Press, New York, 2005<br>• Mechanical Behavior of Materials, Second Edition, Marc A. Meyers and Krishan K. Chawla, Cambridge University Press, New York, 2009</td></tr>
</table>

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

| Course | COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MMS553** | CO1 | 3 | 3 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | - | 1 | 1 |
| | CO2 | 3 | 3 | 1 | 1 | 2 | 3 | 1 | 1 | 1 | - | - | - |
| | CO3 | 3 | 2 | 1 | 3 | 3 | 2 | 1 | 1 | 1 | 1 | - | 2 |

**Correlation levels 1, 2 or 3 as defined below**:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

# SIXTH SEMESTER

| DepartmentofHumanitiesandSocialSciences | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Titleofthecourse | ProgramCore (PCR) / Electives(PEL) | TotalNumberofcontacthours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| HSC631 | Economicsand Management Accountancy | PCR | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | CourseAssessmentmethods(Continuous(CT),mid-term(MT)andendassessment (EA)) | | | | | |
| NIL | | CT+MT+EA | | | | | |

**Course Outcomes**

- Learnerswillbeabletoreviewbasiceconomicprinciples.
- Learners will be introduced to the basic capital appraisal methods used for carrying out economic analysis of different alternatives of engineering projects or works.
- Learnerswillgainagoodknowledgeoffinancialaccounting,enablingthemprepare,analyseand interpretfinancialstatementsfortakinginformeddecisions.

**Topics Covered**

**PART 1: Economics**

**GroupA:Microeconomics**

| Sl.No. | Name | L | T | P | Cr | H |
|---|---|---|---|---|---|---|
| Unit 1: | Economics: Basic Concepts | 2 | 0 | 0 | 2 | 2 |
| Unit 2: | TheoryofConsumerBehaviour | 3 | 0 | 0 | 3 | 3 |
| Unit 3: | TheoryofProduction,CostandFirms | 3 | 0 | 0 | 3 | 3 |
| Unit 4: | AnalysesofMarketStructures:PerfectCompetition | 3 | 0 | 0 | 3 | 3 |
| Unit 5: | Monopoly Market | 2 | 0 | 0 | 2 | 2 |
| Unit 6: | GeneralEquilibrium&WelfareEconomics | 2 | 0 | 0 | 2 | 2 |
| | **TOTAL** | **15** | **0** | **0** | **15** | **15** |

**GroupB:Macroeconomics**

| Sl.No. | Name | L | T | P | Cr | H |
|---|---|---|---|---|---|---|
| Unit 1: | IntroductiontoMacroeconomicTheory | 2 | 0 | 0 | 2 | 2 |
| Unit 2: | NationalIncomeAccounting | 3 | 0 | 0 | 3 | 3 |
| Unit 3: | DeterminationofEquilibriumLevelofIncome | 4 | 0 | 0 | 4 | 4 |
| Unit 4: | Money,InterestandIncome | 2 | 0 | 0 | 2 | 2 |
| Unit 5: | InflationandUnemployment | 2 | 0 | 0 | 2 | 2 |
| Unit 6: | Output,PriceandEmployment | 2 | 0 | 0 | 2 | 2 |
| | **TOTAL** | **15** | **0** | **0** | **15** | **15** |

**PART2:ManagementAccountancy**

| Sl.No. | Name | L | T | P | Cr | H |
|---|---|---|---|---|---|---|
| Unit 1: | **IntroductiontoAccounting**: Accounting Environment of Business; Objectives of Accounting; Accounting Equations for Financial Statements.BooksofAccounting:Journal,Ledger, | 3 | 0 | 0 | 3 | 3 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Cashbook. | | | | | |
| | Unit2: | **FinancialStatementPreparationandAnalysis:** Preparationof TrialBalance, Trading, Profit&Loss accountandBalanceSheet.Casestudydiscussion. | 5 | 0 | 0 | 5 | 5 |
| | Unit3: | **FinancialRatioAnalysis:** Common Size Statements; Computation of Financial Ratios;InterpretationandanalysisofFinancialRatios withthehelpofcasestudies. | 4 | 0 | 0 | 4 | 4 |
| | | **TOTAL** | **12** | **0** | **0** | **12** | **12** |

| | |
|---|---|
| Text Books, and/or reference material | **PART1:Economics**<br>**GroupA:Microeconomics**<br>1. Koutsoyiannis:ModernMicroeconomics<br>2. MaddalaandMiller:Microeconomics<br>3. AnindyaSen:Microeconomics:TheoryandApplications<br>4. Pindyck&Rubenfeld:Microeconomics<br><br>**GroupB:Microeconomics**<br>1. W.H.Branson:Macroeconomics–TheoryandPolicy(2nded)<br>2. N.G.Mankiw:Macroeconomics, WorthPublishers<br>3. DornbushandFisher:MacroeconomicTheory<br>4. SoumyenSikder:PrinciplesofMacroeconomics<br><br>**PART2:ManagementAccountancy**<br>1. Gupta,R.L.andRadhaswamy,M:FinancialAccounting;S.Chand&Sons<br>2. AshokeBanerjee:FinancialAccounting;ExcelBooks<br>3. Maheshwari:IntroductiontoAccounting;VikasPublishing<br>4. Shukla,MC,GrewalTSandGupta,SC:AdvancedAccounts;S.Chand&Co. |

CO-POMAPPINGofEconomicsandManagementAccountancy(HSC631)

| CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | - | - | 2 | 1 | - | 1 | 3 | - | - | - | - | - |
| CO2 | - | 1 | - | 1 | - | - | - | - | - | 2 | 1 | - |
| CO3 | - | - | - | 1 | - | - | - | - | - | 2 | 3 | - |

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course code | Title of the course | Program Core (PCR) / Elective (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MMC601 | Mechanical Working of Materials | PCR | 3 | 1 | 0 | 4 | 4 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| MMC503: Mechanical Behaviour of Materials | | CT+MT+EA | | | | | |
| Developer | | Dr. Madan Mohan Ghosh and Dr. Manab Mallik | | | | | |

| | |
|---|---|
| Course Outcomes | CO1: To understand the mechanics of metal forming processes<br>CO2: To know about tools and techniques of different metal forming processes<br>CO3: To understand the parameters which are needed to be controlled for increasing quality and productivity of different metal forming operations |
| Topics covered | **1) Introduction:** Overview, objectives of mechanical working or plastic deformation of materials, classification of plastic deformation processes, mechanics of mechanical working of materials, influence of friction and lubrication in mechanical working processes, workability. [3 h]<br>**2) Theory of Elasticity:** Description of stress and strain at a point within a loaded body, stress tensor, principal stresses under 3D state of stress, concept of Mohr's circle construction and its implications under 3D state of stress, hydrostatic and deviator components of stress, elastic stress - strain relations, strain energy. [8 h]<br>**3) Theory of Plasticity:** Yielding criteria for ductile metals, yield locus, yield surface, plastic stress - strain relations, plane strain condition of plastic deformation, stress analysis under plane strain condition of plastic deformation using slip line - field theory. [6 h]<br>**4) Rolling:** Classification of rolling processes, forces and geometrical relationships in rolling, angle of bite, neutral point, theories of cold rolling and hot rolling, calculation of rolling load, torque and horse power, maximum allowable back tension in cold rolling, variables controlling rolling process, common defects in rolled products and their remedies. [10 h]<br>**5) Forging:** Classification of forging processes, open-die forging, closed-die forging, stress distribution in open-die forging, calculation of forging load, common forging defects. [8 h]<br>**6) Extrusion:** Classification of extrusion processes, analysis of extrusion process, hot extrusion, cold extrusion, deformation, lubrication and defects in extrusion processes, hydrostatic extrusion, extrusion for producing tubes. [3 h]<br>**7) Drawing:** Different types of drawing processes, analysis of wire drawing and tube drawing, limit of drawability, residual stresses in drawn products. [3 h]<br>**8) Sheet - Metal Forming:** Various sheet-metal forming processes, stretch forming, deep drawing, limiting draw ratio, forming limit criteria, defects in sheet-formed products. [7 h] |
| Text books, and/or reference materials | • Mechanical Metallurgy, SI Metric Edition, *George E. Dieter,* McGraw-Hill Book Company, London, 1988<br>• Principles of Industrial Metal Working Processes, *G.W. Rowe,*CBS Publishers & Distributors, New Delhi, 2005<br>• Metal Forming: Mechanics and Metallurgy, 3rd Edition, *William F. Hosford and Robert M. Caddell,* Cambridge University Press, New York, 2007<br>• The Rolling of Strip, Sheet and Plate, 2nd Edition, *E.C. Larke,* Chapman and Hall, Ltd., London, 1963<br>• The Extrusion of Metals, 2nd Edition, *C.E. Pearson and R.N. Parkins,* John Wiley & Sons, Inc., New York, 1960<br>• Wire Technology, 1st Edition, *Roger Wright,*Butterworth-Heinemann, 2010<br>• Metal Forming: Processes and Analysis, *B. Avitzur,* McGraw-Hill Book Company, New York, 1968<br>• Mechanical Working of Metals: Theory and Practice, *J.N. Harris,* Pergamon Press, 1983<br>• Principles of Metal Working, *Surender Kumar,* Oxford & IBH Publishing Company, 1985<br>• An Introduction to Plasticity, *G.C. Spencer,* Chapman & Hall, London, 1968 |

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

| POs<br>COs | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 3 | 3 | 3 | 3 | 2 | 1 | 1 | | 1 | 1 | | 2 |
| **2** | 3 | 2 | 2 | 2 | 3 | 2 | 2 | | 2 | 1 | | 2 |
| **3** | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 1 | 1 | 1 | 1 | 2 |

**Correlation levels 1, 2 or 3 as defined below**:

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

## Depth Elective – 2 & 3

<table>
<tr><td colspan="8">Department of Metallurgical and Materials Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MME 610</td><td>Advanced Engineering Materials</td><td>PCL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))</td></tr>
<tr><td colspan="2">MMC 302 Introduction to Metallurgy and Materials<br>MMC 502: Engineering Materials and Heat Treatment</td><td colspan="6">CT+MT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To learn the basic fundamentals of different advanced engineering materials<br>CO2: To understand the microstructure - properties correlation for various advanced engineering materials<br>CO3: To learn the latest developments in materials technology and application of new advanced materials</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Fundamentals of atomic structure- chemical bonding, crystal structure. Introduction to Various Classes of advanced Engineering Materials: Selection of advanced Engineering Materials, Microstructure - Properties correlation in Advanced Engineering Materials, [4 hours]<br>Development Strategy of advanced high strength steels (AHSS): Concept of Multiphase Sstructure, Classification of AHSS, Strengthening mechanism of AHSS steels, Processing, properties and application of DP steels, HSLA steels, TRIP, TWIP and Q&P Steels. [6 hours]<br><br>Sstrengthening mechanism of Materials, Effect of alloying elements, Aluminium alloys, Al-Li alloy, Pprocessing of Al alloys. Rapid solidification process for alloys, Ti base alloys, Al base composites. [4 hours]<br><br>High temperature materials: Materials available for high-temperature and low temperature applications, Structure, Processing, mechanical behaviour and oxidation resistance of Stainless Steels, Ni- and Co-Based Super alloys, Processing, Properties and Applications of Super alloys. Intermetallics - Aluminides and Silicides, Carbon-Carbon and Ceramic Composites. [6 hours]<br>Shape memory and Superelastic alloys: shape memory effect, thermodynamic aspects and micromechanism of martensitic transformation, Stress induced martensitic, transformation and super-elasticity, Ni-Ti and Ni-Al based alloys and their applications. [6 hours]<br>Nanomaterials, Smart materials, Metal foams, Nanofluids, Carbon nanotubes, Metal Hydride, Hybrid nanocomposites, Nanoporous materials, Nano coatings. Bulk Metallic Glass: Criteria for glass formation and stability, Examples and mechanical behavior<br>[6 hours]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7"><u>Suggested Text Books:</u><br>1. An Introduction to Physical Metallurgy – S. N. Avner, McGraw-Hill Book Company.<br>2. Structure and properties of materials – J Wulff and other. Vols. I–IV. Wiley Eastern pub Ltd. New Delhi<br>3. Materials Science and Engineering An Introduction – William D. Callister, Jr., John Wiley & Sons, Inc., 2007<br>4. Introduction to Magnetic Materials – B. D. Cullity and C. D. GrahamMetallurgy for Engineers – E C Rollason<br>5. Physical Metallurgy – Vijendra Singh.<br><u>Suggested Reference Books:</u><br>1. Physical Metallurgy of Engineering Materials by N. R. petty, Allen Unwin (1968)<br>2. Light Alloys: Metallurgy of the light Metals by I. J. Polmser-Edwaraedannord.<br>3. The Super alloys by C. T. Sims and W. C. Hegel –Wily-Interscience.</td></tr>
</table>

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 2 | 2 |
| **CO2** | 3 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 3 |
| **CO3** | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 3 |

**Correlation levels 1, 2 or 3 as defined below:**
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MME-611 | Energy and environment in metallurgical industries | PEL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| MMC404: Iron Making<br>MMC504: Steel Making | | CT+MT+EA | | | | | |
| Course Outcomes | CO1: Understand the concept of utilization of energy and environmental degradation in metallurgical processes.<br>CO2: Acquire knowledge of minimization of energy requirements and methods of controlling pollution in metallurgical processes.<br>CO3: Application of knowledge to prevent energy loss and to minimize waste generation in metallurgical industries | | | | | | |
| Topics Covered | **UNIT I:** Energy: (14 hrs)<br>Energy resources: non-renewable and renewable, Indian energy resources. Use of energy in metal production, process fuel equivalent. Conservation of energy in metallurgical industries with examples of aluminium, iron & steel making. Hydrogen energy: characteristics, production, storage and utilization in metal industries.<br>**Biomass:** types of biomass, wood char as reductant in iron making.<br>**UNIT II:**(25 hrs)<br>Environment: Sources and types of pollutants (wastes) from metal / minerals industries. Gaseous emissions: control of SPM, hazardous gases, viz. sulphur dioxide, fluorides, nitrogen oxides. Greenhouse gases: Greenhouse effect, global warming potential, Kyoto protocol, carbon trading. Emission and control from, iron & steelmaking and aluminium smelting. Liquid effluents: treatment of waste water, with examples from metal industries. Solid wastes: types, disposal and utilization of slime, red mud and spent pot lining, iron and steel slags. Impact of pollutants on human health, management of radioactive wastes,e-waste, noise pollution, thermal pollution. | | | | | | |
| Text Books, and/or reference material | **Text Books:**<br>1. R.C.Gupta: Energy and Environmental Management in Metallurgical Industries, PHI Learning<br>2. H.S.Ray. B.P.Singh, S.Bhattcharya, V.N.Misra,. Energy in Mineral and Metallurgical Industries, Allied Publisher<br>3. C.S.Rao: Environmental Pollution Control Engineering, Wiley Eastern Ltd.<br>4. J.A.Nathanson: Basic Environmental Technology, prentice-Hall India<br>**Reference Books:**<br>1. R.C. Gupta(ed.): Proc. Environmental Management in Metallurgical Industries(EMMI-2000),Allied Publishers<br>2. R.C. Gupta(ed.): Proc. Environmental Management in Metallurgical Industries(EMMI-2010),Allied Publishers<br>3. Fathi Habashi: Pollution Problems in Mineral and Metallurgical Industries, Metallurgie Extractive Quebec.<br>4. H.S.Peavy et al.: Environmental Engineering, McGraw Hill | | | | | | |

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

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 |
| **CO2** | 3 | 1 | 1 | 1 | 1 | 2 | 3 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 3 | 3 | 2 | 2 | 2 | 3 | 3 | 1 | 1 | 3 | 3 | 3 |
| **CO4** | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 3 |

**Correlation levels 1, 2 or 3 as defined below:**

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

<table>
<tr><td colspan="8">Department of Metallurgical & Materials Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MME612</td><td>Production of Ferroalloys</td><td>PCR</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))</td></tr>
<tr><td colspan="2">MMC-302: Metallurgical Thermodynamics and Kinetics</td><td colspan="6">CT+MT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">• CO1: Apply thermodynamic knowledge to understand the fundamentals of Ferro alloys production and their use<br>• CO2: Acquire the knowledge of reaction mechanism and the process technology of production of different ferroalloys<br>• CO3: Learn to analyze the different design and operation aspects of submerged arc furnace</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Introduction to ferroalloys, Classification, quality requirement and application of ferroalloys. Thermodynamic principles - Ellingham diagram, direct and indirect reduction, Equilibrium gas composition, smelting temperature, Energy requirement, Thermal decomposition, Alloy grade and impurities, carbide formation etc, Functions of carbonaceous materials, Types of carbonaceous materials and basis of choosing carbonaceous materials [8]<br>Arc Furnace - principles, types – Direct, Indirect and submerged arc furnace, DC arc furnace and AC Arc furnace,Equipment and accessories of SAF – Transformer, Bus Bar, Flexi Cable, Electrode, Cooling water jacket, Furnace control system, tapping electrode; Soderberg electrode – raw materials, working principle, quality requirement, Prebaked graphite electrode – raw materials, calcination, crushing, Kneading,Moulding parameters, Baking, Impregnation, Secondary Baking, Graphitization – types of furnace used, Mechanical processing, Property check; Design of submerged arc furnace – Power, current and voltage calculation, Electrode diameter, Hearth dimension - bath volume, Furnace shape [10]<br>Production of Ferromanganese - Resources and Reserves of Manganese ore,Thermodynamic fundamentals of manganese oxide reductions, High Carbon FeMn production in BF, High Carbon FeMn production in SAF,Discard slag practice, high slag practice, Production of silicomanganese, Medium and low carbon ferromanganese production [8]<br>Production of ferrochrome - Raw materials, Resources and reserves, Thermodynamics of Reduction of chromium oxide, High carbon and low carbon ferrochrome production [6]<br>Ferrosilicon production - Ores, Resources and reserves, Raw materials and its quality, fundamentals of SiO2 reduction, Operational practice, Reaction mechanism, Origin and Control of impurities [6]<br>Application of Ferroalloys – Deoxidation - Fe-O system, sources of oxygen in liquid steel, Various types of deoxidant used, Thermodynamic fundamentals of deoxidation, Deoxidation constant and its importance, Alloying - Mechanism of dissolution of ferroalloys in liquid steel, Addition methods. [6]<br>Case studies. [6]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Suggested Text Books:<br>1. Handbook of Ferroalloys Theory and Technology, M. Gasik, Elsevier Science, 2013<br>2. The Complete Book on Ferroalloys by B.P Bhardwaj, NIIR PROJECT, CONSULTANCY SERVICES Publisher, 2014.<br>3. Production of ferroalloys: electrometallury, V. P. Elîu`tin, State Scientific and Technical Pub. House for Literature on Ferrous and Nonferrous Metallurgy, 1957.<br>Suggested Reference Books:<br>1. Production of ferroalloys, by M. Riss, Y. Khodorovsky, Mir Publishers, 1967.<br>2. Production of ferroalloys : electrometallurgy, by V.P. Elyutin, Israel Program for Scientific Translation, 1961.</td></tr>
</table>

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO2** | 3 | 3 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 3 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Correlation levels 1, 2 or 3 as defined below:**

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

<table>
<tr><td colspan="7">Department of Metallurgical and Materials Engineering</td></tr>
<tr><td rowspan="2">Course code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Elective (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MME613</td><td>Nano Science and Technology</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">Pre-requisites</td><td colspan="4">Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))</td></tr>
<tr><td colspan="3">MMC301: Introduction to Metallurgy and Materials</td><td colspan="4">CT+MT+EA</td></tr>
<tr><td>Course outcomes</td><td colspan="6">CO1: To gain fundamental knowledge about the nanomaterials and their properties<br>CO2: To learn about various techniques of the synthesis and characterization of nanomaterials<br>CO3: To explore the various applications of nanomaterials</td></tr>
<tr><td>Topics covered</td><td colspan="6">5. BasicsofNanoscaleMaterials:Wave-particleduality,Quantumsizeeffect -Schrödinger wave equation, Particle in a box problem, Formation of bands in solids,Density of states [6h]<br>6. Introduction to Nanoscale Materials:History of nanotechnology, Natural nanomaterials, Classification of nanomaterials, Sizedependent properties of nanomaterials - Physical, Mechanical, Electrical, Semiconducting, Magnetic and Opticalproperties, Advantages of nanomaterials [7h]<br>7. SynthesisofNanomaterials:Physical methods - High energy ballmilling, Melt mixing, Physical vapour deposition, Laser ablation, Laser pyrolysis, Sputter deposition, Chemical vapour deposition and Electric arc deposition<br>Chemical methods – Colloidal route, Microemulsion method, Sol-gel method, Hydrothermal synthesis and Microwave synthesis [8h]<br>8. Characterization of Nanomaterials: XRD, SEM, TEM, DLS, EDS, UV-Vis, UV-Vis-NIR, FTIR, AFM, XPS, PL, Nanoindentation, etc. [3h]<br>9. CarbonNanostructuresandNanocomposites:Fullerenes, Carbon nanotubes - Classification,Synthesis,PropertiesandApplications, Graphene - Classification,Synthesis,PropertiesandApplications, Nanocomposites – Types, Synthesis, Properties and Applications [6h]<br>10. ApplicationsofNanomaterials:Optoelectronicapplications - Hybridsolarcells,LED,Nano-sensors.Photo-catalysis,Fuelcells,Nanofluids,Electrochemicalenergy storage systems, Spintronics, MEMS and NEMS. Applications in medicalfield(drugdelivery),foodprocessingandagriculture [6h]</td></tr>
</table>

| | |
|---|---|
| Text books and/or reference materials | 1) SulabhaKKulkarni,Nanotechnology - PrinciplesandPractices, Capital Publishing Company,2007.<br>2) T.Pradeep,Nano:TheEssentials,TataMcGrawHillEducationPvt.Ltd.,2013.<br>3) JamesMurday,TextbookofNanoscienceandNanotechnology,University Press-IIM, 2012.<br>4) Charles.P.PooleandF.J.Owens,IntroductiontoNanotechnology,John Wiley&Sons Inc.,2003.<br>5) P.MukhopadhyayandR.K.Gupta,Graphite,GrapheneandtheirPolymer Nanocomposites.CRCPress,Taylor&FrancisGroup,2012.<br>6) Materials Science and Engineering: An Introduction - William D. Callister, Jr., John Wiley & Sons, Inc., 2007<br>7) Nanomaterials, Nanotechnologies and Design – D.L. Schodek, P. Ferreira, M.F. Ashby, Butterworth-Heinemann, 2009 |

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 3 | 2 | 1 | - | - | - | 1 | 1 | - | 3 |
| **CO2** | 3 | 3 | 3 | 3 | 3 | 2 | 1 | - | 1 | 1 | - | 3 |
| **CO3** | 2 | 2 | 1 | 2 | 1 | 3 | 3 | - | 1 | 1 | - | 3 |

**Correlation levels 1, 2 or 3 as defined below:**

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

| Department of Metallurgical & Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MME614 | Ceramic Technology | PEL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| Introduction to Metallurgy and Materials (MMC 301) | | CT+MT+EA | | | | | |
| Developer | | Dr. Manab Mallik | | | | | |
| Course Outcomes | CO1: Describes generic classification of ceramics and their specific engineering applications.<br>CO2: Learn various techno-economic aspects of ceramics<br>CO3: Learn structure-property relationships, and solve problems of fabrication of high performance ceramic parts | | | | | | |
| Topics Covered | **Introduction**: Knowledge of different ceramic materials [4 hours]<br>**Structures of ceramics:** Atomic structure, crystal structures, oxide structure, silicate structure, other structures and polymorphism. [6 hours]<br>**Structural imperfections:** Frankel defects, schottky defects, nonstoichiometryetc [4 hours]<br>**Microstructure of ceramics:** Microstructure of different ceramic materials: Oxides, Carbides, Nitrides, Silicides, Borides, etc. Glass and Glass-ceramics [6 hours]<br>**Properties of ceramics:** Physical, Mechanical, Electrical, Thermal and Magnetic properties of ceramics<br>**Applications and processing of ceramics:** Glasses and glass ceramics, refractoties, and abrasives [6 hours]<br>**Advanced and nanostructured ceramics:** Structure, properies and applications [4 hours]<br>**Bioceramics:** Fundamentals of bioceramics and their applications [6 hours] | | | | | | |

| | |
|---|---|
| Text Books, and/or reference material | Text Books:<br>1. Yet-Ming Chiang, Dunbar P. Birnie, W. David Kingery: Physical Ceramics: Principles for Ceramic Science and Engineering, John Wiley and Sons., 1996.<br>Reference Books:<br>2. D.W. Richerson: Modern Ceramic Engineering, , CRC Press, Third Edition, 2005. |

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

| POs / COs | PO1 | PO2 | PO 3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 1 | 3 | 2 | 1 | 1 | 1 | 1 | 3 | 1 | 1 |
| **CO2** | 3 | 3 | 1 | 3 | 1 | 2 | 3 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 3 | 3 | 1 | 3 | 2 | 1 | 3 | 1 | 3 | 1 | 3 | 1 |

**Correlation levels 1, 2 or 3 as defined below:**

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

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MME615 | Solidification Phenomena | PER | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| MMC405: Manufacturing Processes | | CT+MT+EA | | | | | |
| Course Outcomes | • CO1: Understand solidification theories to industrial processes<br>• CO2: Predict microstructures as a function of process parameters.<br>• CO3: Understand solidification of alloys in different industrial conditions | | | | | | |
| Topics Covered | Properties of metals and alloys before and during solidification. Surface phenomena. (2)<br>Basic terms: surface energy, surface tension, Wetting angle. Wetting speed. Classification and influence of wetting. (4)<br>Rapid solidification processes (RSP). Classification of high cooling rates. Conventional and unconventional effects. (2)<br>Under cooling and recalescence. Amorphous state. Glaze-ability. (1)<br>Processing of alloys in the semi-solid state. Rheology. Newton's law of viscosity. Newtonian and non-Newtonian materials. (3)<br>Distribution of non-Newtonian materials, physical models of materials and their rheograms. The apparent viscosity. Thixotropy.. Submersible rotational viscometry. (3)<br>High-speed mixing. The intensity of the flow and its significance for the primary crystallization. The materials in the semi-solid state - SSM (Semi-Solid Metals). (2)<br>Theories of solid solution morphology spheroidization. Types of alloys suitable for SSM. Case studies of selected castings. (4)<br>Pressure solidification processes (PSP). Effect of pressure on the primary crystallization, change the thermo-physical properties, cooling rate and the force induced solidification flow.<br>Alloys used in PSP. (3)<br>Practical use of the rheological behavior of the alloys in the solidification processes and its importance. Case studies of selected castings. (4) | | | | | | |
| Text Books, and/or reference material | Suggested Text Books:<br>1. Principles of Solidification by Laurens Kagerman<br>2. Modelling the Flow and Solidification of Metals by T. A Smith<br>3. Physical Metallurgy- Principles and Practise by A Raghavan<br>Suggested Reference Books:<br>Kirkwood, D.H. – Suéry, M. – Kapranos, P. – Atkinson, H.V. – Young,K.P. Semi-solid processing of Alloys. Springer. | | | | | | |

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

| PO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO2** | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 3 | 3 | 3 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Correlation levels 1, 2 or 3 as defined below:**

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

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MME616 | Metal Joining Processes | PEL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| MMC405: Manufacturing Processes | | CT+MT+EA | | | | | |
| Course Outcomes | CO1: Indicate which types of joining processes are suited for production.<br>CO2: Determine various gas, arc, solid state, thermo chemical welding processes with their process parameters.<br>CO3: Identify the various Weld Joints & Metallurgy | | | | | | |
| Topics Covered | Principles and theory, mechanism and key variables of different joining processes. (5)<br>Soldering, brazing and welding processes types of tooling and equipment and consumables in welding. (6)<br>Microstructures of fusion and HAZ: Carbon and alloy steels, corrosion resistance materials: stainless steels, aluminium alloys. Welding stresses. Heat flow in welding, chemical reactions in welding. Pre and post treatments advantages and disadvantages. (8)<br>Weld joint consideration testing and inspection of weld joints. (6)<br>Welding standard and specification. (5)<br>Weldability field of application of the welding w.r.to gas welding, submerged arc welding, gas-tungsten arc welding, shielded metal arc welding, Plasma arc welding, flux core arc welding, electron beam welding, electro-slag welding, spot welding, laser welding, diffusion welding. (10) | | | | | | |
| Text Books, and/or reference material | Text Books:<br>1. Foundation of Welding Technology, K. S. Ghosh, PHI Learning, 2022.<br>2. Fabrication, Welding & Metal Joining Processes: A Textbook for Technicians and Craftsmen, C.R. Flood, Butterworths, 1981.<br>3. An introduction to Welding - R S Parmar<br>4. Principles of welding technology – L M Gourd, Edward Arnold / ELBS, London, 1980.<br>Reference Books:<br>1. Welding for Engineers – H. Udin, E. R. Funk and J Wulff, John Wiley, New York.<br>2. Welding Engineering, B. E. Rossi, McGraw Hill New York<br>3. Welding Metallurgy, Sindo Kou, A John Wiley and Sons Incorporation Publication. | | | | | | |

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 2 | 1 | 2 | 1 | 2 | 1 | 3 | 2 | 1 | 1 | 1 |
| **CO2** | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 3 | 1 | 2 | 2 | 1 |
| **CO3** | 1 | 1 | 2 | 2 | 2 | 3 | 1 | 3 | 1 | 2 | 2 | 2 |

**Correlation levels 1, 2 or 3 as defined below:**

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

<table>
<tr><td colspan="8">Department of Metallurgical & Materials Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MME 617</td><td>Experimental Techniquesin Metallurgy</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="3">PHC 01: Engineering Physics<br>MMC 403: Materials Characterisation</td><td colspan="5">Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))</td></tr>
<tr><td colspan="3">Engineering Physics</td><td colspan="5">CT+MT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: To understand the principle and theory of different experimental techniques<br>CO2: To understand the mechanisms, science and technological in different techniques<br>CO3: To learn methods of different experimental techniques used for industrial applications</td></tr>
<tr><td>Topics Covered</td><td colspan="7">OpticalMethods:Fundamentalofimageformation,Differentaberrationsinoptical systems, Opticalmicroscopy,characteristics of the microscope, and differentconditionsof imageformation suchas brightfield,darkfield, and obliqueillumination. Special TechniquesinMetallography:Polarizedbeam,Phase Contrast,Differential Interference Microscopy,Fluorescent microscopy,Principles of above techniques andtheirapplications.QuantitativeMetallurgy andImageanalysis,Applications Developments forQuantitativeImage analysis in Metallurgy. [10 hrs]<br>BasicprinciplesofScanningElectronMicroscopy (SEM),TransmissionElectron Microscopy (TEM),secondary electron,backscatteredelectron,Diffractionpattern analysis,energy dispersiveX-ray spectroscopy(EDS),Wavelengthdispersive spectrometeranalysis(WDS),electron back-scattered diffraction(EBSD), electron probe microanalysis(EPMA).FundamentalofAtomic Force Microscopy,Basic theory,Imageformationand its applications.[8 hrs.]<br>Techniquesfor chemical analysis:Atomic absorption spectrometer,Emission spectroscopy&directreadingspectrometer, Mass spectrometer. Principle of temperature measurement by using thermocouples and radiation pyrometers. [4 hrs.]<br>Thermalanalysisofphase transformations: Thermal Analysis techniques: Principle, Working andapplicationofDTA,TGA,DSCandThermo-MechanicalAnalysis, Principles, and Applications. [2 hrs.]<br>Principle of magneticcharacterization, characterization of soft magnetand hard magnets.Application. [4 hrs.]<br>NDT:BasicprincipleofDye Penetranttesting,Typesofdyemethodsand application,Developer applicationandInspection,Magneticparticletesting,Basic theory ofmagnetism,Magnetizationmethods,Fieldindicators,Particleapplication, Inspection.Eddy currenttesting,Basicprinciple;Faraday'slaw,Inductance, Ultrasonic testing:Basicsofultrasonicwaves,Pulseandbeamremarks, Radiographictesting,Basics,differentisotopesanddifferenttechniquestoidentify the flaws. [10 hrs.]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Suggested Text Books:<br>1. ExperimentalTechniquesinPhysicalMetallurgy,V.T.Cherepin&A.K. Malik, I.I.T., Bombay.<br>2. Thermal Analysis byBernhard WiindrelichAcademic Press.<br>3. ImageAnalysis &Metallography.(MicrostructuralScienceVol.-17)ASTM 1989.<br>4. 1.F.Weinberg,Editor,Tools&TechniquesinPhysicalMetallurgy,Vol.I& Vol.II, MarcelDekker, 1970.</td></tr>
</table>

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 2 | 2 | 2 | 3 | 1 | 2 | 2 | 2 | 1 | 2 |
| **CO2** | 3 | 2 | 2 | 3 | 1 | 2 | 0 | 1 | 2 | 2 | 2 | 3 |
| **CO3** | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 3 | 1 |

**Correlation levels 1, 2 or 3 as defined below:**
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

<table>
<tr><td colspan="7">Department of Metallurgical and Materials Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MME618</td><td>Secondary Steel Making</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT), mid-term (MT), and end assessment (EA))</td></tr>
<tr><td colspan="2">MMC302: Metallurgical Thermodynamics Kinetics, MMC401: Transport Phenomena in Metallurgical Processes and MMC501: Modelling and Simulation of Metallurgical Processes</td><td colspan="5">CT+MT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="6">CO1: Learn fundamentals of physico-chemical principles of Secondary steel making.<br>CO2: Apply laws of thermodynamics and kinetics for producing clean steel.<br>CO3: Design process route for economical production of steel.</td></tr>
<tr><td>Topics Covered</td><td colspan="6">A brief review of fluid flow, thermodynamics and primary steel making processes, composition of the crude steel, need for secondary refining, the objective of secondary steel making, physico-chemical principles of Secondary steel making, Slag basicity and capacities, secondary steel making equipment and processes, preheating and recycling of ladles. (8)<br>Furnace tapping operations; Phenomena during furnace tapping; carry over slag and slag detection devices; slag making in ladles and de-oxidation: common de-oxidisers and requirement of de-oxidisers; addition methodology; melting and dissolution of deoxidisers; de-oxidation thermodynamics and kinetics; simple vs. complex de-oxidation; De-oxidation products; Elementary de-oxidation calculations. (5)<br>Inert Gas Stirring in Ladles (objectives, Devices, gas flow regimes, stirring energy and stirring intensity); Temperature and Composition Control in Ladles (arcing, alloying addition, and aluminium wire feeding). (3)<br>Degassing and Decarburization in liquid steel: Introduction, Principles and thermodynamics of reactions in vacuum degassing, equipment's and degassing Methods and their relative merits and demerits; slag eye area and re-oxidation, fluid flow and mixing in vacuum degassing, rates of vacuum degassing and decarburization, decarburization for Ultra-low carbon (ULC), stainless steel making. (8)<br>Desulfurization in secondary steelmaking: Introduction, thermodynamics aspects, desulfurization with only top slag, injection metallurgy for Desulfurization. (3)<br>Clean steel, Types of inclusions, Morphology, Properties of inclusions, Inclusion assessment, sources of inclusions, control of inclusions, Inclusion modification, Calcium Treatment (cored wire injection. objectives and devices reactions, calcium recovery and inclusion morphology and composition). (6)<br>Teeming speed, Gas absorption during tapping and teeming form surrounding, Temperature changes of molten steel during secondary Steel making, phosphorus control in secondary steel making, Nitrogen control in steel making, application of Magnetohydrodynamics, Modeling of secondary steelmaking processes. (6)</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="6"><u>Suggested Text Books:</u><br>1. Principles and Practices in Iron and Steelmaking – A. Ghosh, and A. Chatterjee.<br>2. Secondary Steelmaking – A. Ghosh<br><br><u>Suggested Reference Books:</u><br>3. Making, Shaping and Treating of Steel (Steelmaking and Refining), 10th Edition, 1985, AISE, Pittsburgh</td></tr>
</table>

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO2** | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 3 | 2 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Department of Metallurgical & Materials Engineering

**Correlation levels 1, 2 or 3 as defined below:**

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| Department of Metallurgical & Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MME619 | Coatings and Thin Film Technology | PEL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| Engineering Physics (PHC01) Introduction to Metallurgy and materials (MMC301) | | CT+MT+EA | | | | | |
| Course Outcomes | CO1: Describes generic approaches to thin film depositions and the basic principle associated with appropriate deposition techniques.<br>CO2: Learn structure-property relationships, and its important in thin film engineering.<br>CO3: To learn technology aspect of coatings and thin films on different engineering application | | | | | | |
| Topics Covered | Introduction: Definitions; Historical perspective of thin films; Reasons for using thin films. [2]<br>Thin film depositions: Evaporation methods, sputtering and chemical methods. [6]<br>Film structure: Structural morphology of films and coatings; crystallographic structure of films; amorphous thin films [6]<br>Characterization of thin films: Film thickness, Structural characterization; Chemical characterization [6]<br>Mechanical properties of thin films [4]<br>Growth and Synthesis of Nanostructured Thin Films [3]<br>Applications of Functional Thin Films and Nanostructures in Gas Sensing [3]<br>Gas sensing applications of zinc oxide [3]<br>Applications of Functional Thin Films for Mechanical Sensing [3] | | | | | | |
| Text Books, and/or reference material | Suggested Text Books:<br>1. Thin Film Phenomena- K. L. Chopra, Robert E Krieger Publishing Company, Florida, 1985<br>2. Lecture Notes and Published Papers<br>Suggested Reference Books:<br>1. Materials Science of Thin Films – Milton Ohring, Academic Press, San Diego; USA, 2002 | | | | | | |

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 2 | 1 | 3 | 2 | 1 | 1 | 1 | 1 | 3 | 1 | 1 |
| **CO2** | 3 | 3 | 1 | 3 | 1 | 2 | 3 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 3 | 3 | 1 | 3 | 2 | 1 | 3 | 1 | 3 | 1 | 3 | 1 |

**Correlation levels 1, 2 or 3 as defined below:**

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

<table>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MME620</td><td>Stainless Steel: Technologies & Applications</td><td>PEL</td><td>3</td><td>1</td><td>0</td><td>52</td><td>4</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))</td></tr>
<tr><td colspan="2">MMC 402: Phase Transformation and Phase Equilibria<br>MMC 503: Mechanical Behaviors of Materials<br>MMC: 504: Steelmaking</td><td colspan="5">CT+MT+EA</td></tr>
<tr><td colspan="2">Developer</td><td colspan="5">JSL & Arup Kumar Mandal</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">CO1: Fundamental understanding of phase transformation and manufacturing of stainless steel.<br>CO2: Acquire detailed knowledge of different processes like AOD, LF, VD and continuous casting.<br>CO3: Learn to analyze physical, chemical, and mechanical properties for suitable industrial applications of different stainless grades.</td></tr>
<tr><td>Topics Covered</td><td colspan="7">1. Introduction: Definition, Alloying elements in Stainless Steels and their functions. Effect of alloying elements on properties of Stainless Steels. Classification of Stainless Steels. Cost implications of alloy additions and substitutes. Stainless steel production in India and in the world. [3L]<br>2. Making and Processing: Raw materials, Electric Arc Furnace, Induction furnace, plasma furnace, Argon oxygen decarburisation, Ladle Refining, Vacuum Oxygen Decarburisation, Vacuum degassing, Ingot casting vis-à-vis Continuous casting, casting defects, inclusion control. Hot Rolling, Hot Forging, Annealing & Pickling, Cold Rolling, Final Annealing and Pickling, Skin Pass Mill, Strip Grinding Line. Finishing of Stainless Steels. Colour Coating of Stainless Steels [8L]<br>3. Phase Transformations and Heat treatments: Relevance of Nickel equivalent and Chromium equivalent, Inadequacy Fe-Fe3C diagram for stainless steels, Role of alloying elements in ferrite and austenite stabilisation, Role of deformation on phase transformation. Heat treatment of stainless steels-ferritic, martensitic, austenitic, duplex, precipitation hardenable grade stainless steels. Precipitation reaction in stainless steels, [4L]<br>4. Mechanical Behaviuor and Properties: Deformation behaviour of stainless steel. Role of precipitates on mechanical properties. Mechanical properties of different grades of stainless steels-tensile, hardness, impact, fatigue [4L]<br>5. Fabrication: Cold roll forming (CRF) processes, Forging, Extrusion, Deep Drawing, Coin blanking, machining, Cutting of Stainless Steels, Welding of Stainless Steels- Welding, Brazing, Soldering and Overlaying, Common welding techniques, welding consumables and precautions required. Fusion Welding processes- Shielded Metal Arc Welding (SMAW), Gas Tungsten AW, Gas Metal AW (Inert/active gas), Flux-cored AW, Plasma AW, Submerged AW, Electro-slag Welding, EBW, LBW. Solid State Welding – All variations of Resistance welding e.g. Spot, Seam, Projection, Flash, Upset, High frequency, Percussion. Friction stir welding. Specific difficulties associated with welding of – Martensitic-, Ferritic-, Austenitic-, Duplex, Precipitation Hardened-, Martensitic, Semiaustenitic-, Austenitic- precipitation hardened stainless steels. Welding of dissimilar metal combinations with stainless steels. Sensitization/Weld decay: Causes, mechanisms, remedies, High temperature sensitization, 475oC embrittlement, α' phase transformation, Distortion-Causes, mechanisms, remedies, Effect of alloying elements on weldability of Stainless Steels, Schaeffler De Long diagram interpretations. Tools and Equipment. Issues faced during fabrication of stainless steels and their solutions. [8L]<br>6. Testing, Handling and Storage of Stainless steel: PMI technique, XRF, Ultrasonic testing, Magnetic Particle testing, Dye penetrant, Portable hardness, Surface roughness measurement, Surface Reflectivity measurement, Recommended procedures for storage. [3L]<br>7. Corrosion: Types of corrosion, Galvanic corrosion-Mechanism and prevention, Pitting Corrosion-Mechanism and prevention, Interpretation of PREN, Crack propagation mechanisms-Inter-granular, Trans-granular, Crevice Corrosion, Stress Corrosion Cracking (SCC), Microbiologically Induced Corrosion (MIC), Erosion Corrosion. High temperature corrosion, Different corrosion testing procedures. Role of precipitates on corrosion, Corrosion resistance of stainless steels [5L]<br>8. Applications: Automotive, Railways & Transport, Architecture, Building & Construction, Reinforcement bars, Roofing sheets, utensils, Furnitures, Material Handling applications, Process Industries, Biomedical applications. Life Cycle Cost Analysis. [4L]<br>9. Plant visit: 2 days plant visit at any one of JSL's manufacturing units at Hisar (Haryana) or Jajpur (Odisha).</td></tr>
</table>

| | |
|---|---|
| Text Books, and/or reference material | **Text Books:**<br>1. Corrosion Engineering, MG Fontana, 3rd Edition, McGraw-Hill Book Company, New York, 1987<br>2. Phase Transformation in Metals and Alloys, David A Porter, K.E.Esterling,CRC press, Taylor and francis group, 3rd Edition, 2009, .<br>3. Alloys: Preparation, Properties, Applications, FathiHubashi, *Wiley* VCH; 1 edition, 2008<br>4. Fundamental of Steelmaking by E. T. Turkdogan, The Institute of Materials, London, 1996,<br>5. Fundamental of Steelmaking Metallurgy by Brahma *Deo*; Rob *Boom*, Prentice Hall International, 1993. 6. Steel Making by V. Kudrin, Moscow: Mir Publishers ; Boca Raton : CRC Press, 1985<br>7. Steel and its Heat Treatment by K. E. Thieling, Butterworth-Heinemann, 1967<br>8. The Physical Metallurgy of Steels by William C. Leslie, Hempisphere Pub. Corp., 1981<br>9. Stainless Steel and Their Properties by Bela Lafler<br><br>**Reference Books:**<br><br>1. Physical metallurgy of Stainless Steel Development, F B Pickering, International Materials Reviews, Volume 21, 1976 , ASM international<br>2. 100 years of Stainless Steel by BSSA (UK), 2013<br>3. Handbook of Stainless Steel: Donald Peckner, Irving Melvin Bernstein, Macgraw-hill books, 1977<br>4.Alloy Digest Source Book: Stainless Steel, Joseph R. Davis, ASM international, 1994<br>5.ASM speciality handbook stainless steel, Joseph R. Davis, ASM international<br>6.Outokompu Stainless Steel Handbooks, 2009<br>7.Technical Handbook of Stainless steel: The Atlas Steels, 2013 |

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

| CO | PO 1 | PO 2 | PO 3 | PO 4 | PO5 | PO 6 | PO7 | PO 8 | PO 9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 2 | 3 | 3 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 3 |
| **CO2** | 3 | 3 | 3 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 3 |
| **CO3** | 3 | 3 | 3 | 3 | 2 | 1 | 1 | 1 | 3 | 1 | 2 | 3 |

**Correlation levels 1, 2 or 3 as defined below:**

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

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MME621 | Green Steel Making | PCR | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| MMC-504: Iron Making | | CT+MT+EA | | | | | |
| Course Outcomes | CO1: Understand the fundamentals of physicochemical principles of green steel-making process<br>CO2: Acquire knowledge of the different routes of the steel-making process<br>CO3: Analyze the benefits and shortcomings of different Green steel-making routes in industrial applications | | | | | | |
| Topics Covered | 1. Introduction to Green Steel Making: Definition and importance, Environmental impact of traditional steel-making [2]<br>2. Fundamentals of Steel Making: Iron ore reduction and smelting, Steel production processes (BOS, EAF, etc.) [2]<br>3. Decarbonization Strategies: Challenges/Options facing Steel Producers , Energy efficiency and optimization, Fuel switching (e.g., to natural gas, biomass, hydrogen), Carbon capture, utilization, and storage (CCUS), Recycling and circular economy approaches [2]<br>4. Green Steel Making Technologies: Hydrogen Fundamentals: Production, Combustion & Reduction, Hydrogen usage in Blast Furnace and DRI Processes, Decarbonisation Options Outside Hydrogen Reduction, Carbon capture and utilization, Biomass based Steel making, Hydrogen-based steel | | | | | |

| | |
|---|---|
| | making; Electric arc furnace (EAF) steel-making, Impact on Steelmaking Operations [12]<br>5. Sustainable Raw Materials: Recycling and reuse of steel scrap, Alternative iron ore reduction methods [4]<br>6. Energy Efficiency and Renewable Energy; Energy optimization in steel production, Integration of renewable energy sources (solar, wind, etc.) [4]<br>7. Environmental Impact Assessment: Life cycle assessment (LCA) of green steel production, Environmental footprint reduction strategies [2]<br>8. Case Studies and Industry Examples: Successful implementation of green steel making technologies, Challenges and opportunities in the industry [2]<br>9. Zero-Waste Business Models: Principles of zero-waste manufacturing, Strategies for developing value-added products from steel by-products, Examples of value-added products in the industry, Economic and environmental benefits [2]<br>10. Policy and Regulatory Framework: International agreements and initiatives (Paris Agreement, etc.), National and local regulations supporting green steel making [2]<br>11. Future Directions and Research Opportunities: Emerging technologies and innovations (HDRI-BOF/ HDRI-EAF/HDRI-SR/ Hydrogen Plasma Smelting route, Ammonia based steelmaking, Research and development priorities in green steel making [6] |
| Text Books, and/or reference material | Suggested Text Books:<br>1. Ghosh, A. and Chatterjee, A., Principles and Practices in Iron and Steel making, Prentice Hall of India, New Delhi, 2008<br>2. R.C.Gupta: Energy and Environmental Management in Metallurgical Industries, PHI Learning<br>3. H.S.Ray. B.P.Singh, S.Bhattcharya, V.N.Misra,. Energy in Mineral and Metallurgical Industries, Allied Publisher<br>4. Ian Cameron, MitrenSukhram , Kyle Lefebvre & William Davenport, Blast Furnace Ironmaking: Analysis, Control, and Optimization, (Published by Elsevier, 2020)<br>Suggested Reference Books/ Documents:<br>1. Pasquale Cavaliere, Clean Ironmaking and Steelmaking Processes: Efficient Technologies for Greenhouse Emissions Abatement (Published by Springer, 2019)<br>2. Pasquale Cavaliere, Ironmaking and Steelmaking Processes:Greenhouse Emissions, Control, and Reduction(Published by Springer, 2016)<br>3. K. Rechberger, A. Sasiain Conde, A. Spanlang, I. Kofler, K1-MET GmbH, Linz, Austria; H. Wolfmeir, C. Harris, T. Buergler, Green Hydrogen for Low-Carbon Steelmaking<br>4. Max Åhmana ,OlleOlssonb ,Valentin Vogla ,BjörnNyqvistb ,Aaron Maltaisb ,Lars J Nilssona, Karl Halldingb ,Kristian Skånbergb, MånsNilssonb, Hydrogen steelmaking for a low-carbon economy(2018) |

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

| PO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| **CO2** | 3 | 3 | 2 | 3 | 1 | 1 | 2 | 1 | 3 | 3 | 1 | 2 |
| **CO3** | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |

**Correlation levels 1, 2 or 3 as defined below:**

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

| Department of Metallurgical & Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MME622 | Metallurgical Waste Management | PCR | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| MMC504 Iron Making<br>MMC303 Non - Ferrous Process Metallurgy | | CT+MT+EA | | | | | |
| Course Outcomes | CO1: Identify the various kinds of wastes produced during metallurgical processing<br>CO2: Learn to select suitable treatment method for the waste<br>CO3: Select a suitable methods to recycle the wastes | | | | | | |
| Topics Covered | Various kind of wastes and their classification. Environmental and health impacts of Mining and Metallurgical waste. Principles of waste management. Mining and Beneficiation waste production. [6]<br><br>Waste Production and Utilization of nonferrous metal extraction.[6]<br><br>Recycling and reuse of blast furnace ironmaking slags, steel making dusts and sludges. [6]<br><br>Utilization of steel making dusts and slags [6]<br><br>Ferroalloys Waste Production and Utilization [4]<br><br>E-waste and recovery of metals and useful things from e-waste. [6]<br><br>Waste management and utilization options: zero waste process approach, synergy between residue produces and residue end users. Future outlook. [6] | | | | | | |
| Text Books, and/or reference material | Suggested Text Books:<br>Ndlovu, S., G.S. Simate and E. Matinde, Waste production and utilization in the Metal Extraction Industry, CRC Press, 2017<br>Ramachandra Rao, Resource recovery and recycling from metallurgical wastes, Elsevier, 2006<br>K. Hieronymi, R. Kahhat, E. Williams, E-waste Management: From waste to resource, Routledge, New York,2013 | | | | | | |

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| CO2 | 3 | 3 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 |
| CO3 | 3 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 |

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MMS651 | Mechanical Working of Materials Lab | PCR | 0 | 0 | 3 | 3 | 1.5 |
| Pre-requisites | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| MMC301: Introduction to Metallurgy and materials, MMC503: Mechanical | | CT+EA | | | | | |

| | |
|---|---|
| Behaviour of Materials | |
| Developer | Dr. Madan Mohan Ghosh and Dr. Manab Mallik |
| Course Outcomes | CO1: To know about the methods of rolling, forging under different conditions<br>CO2: To learn the parameters needed to be controlled in rolling, forging processes<br>CO3: To assess and understand the factors affecting the quality of the products |
| Topics Covered | 1. Studying the open-die forging operation by hydraulic press and evaluation of hardness and microstructural changes of the forged product<br>2. Study of the effect of specimen size (h/D ratio) on load vs deformation curve of a ductile materials<br>3. Upset Ring Test using hydraulic press forging to determine interface friction factor (m).<br>4. To study the effect of friction and lubrication on strain energy in open-die forging operation<br>5. Closed-die forging operation by hydraulic press and evaluation of hardness and microstructural changes of the forged product<br>6. Studying the effects of cold working and annealing on the hardness and microstructure of ductile materials.<br>7. Hot forging of a ductile material and evaluation of hardness and microstructural variations<br>8. To study the effect of hammer (drop) forging on the hardness and microstructure of ductile materials.<br>9. Cold rolling to produce sheet from plate using plain barreled rolls and evaluating changes in microstructure and hardness, and estimation of angle of contact, no-slip angle, forward slip, interfacial frictional coefficient and rolling load |
| Text Books, and/or reference material | • Mechanical Metallurgy, SI Metric Edition, *George E. Dieter,* McGraw-Hill Book Company (UK) Limited, 1988<br>• The Rolling of Strip, Sheet and Plate, 2nd Edition, *E.C. Larke,* Chapman and Hall, Ltd., London, 1963 |

**CO-PO Mapping**

| **COs** | **POs** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **PO1** | **PO2** | **PO3** | **PO4** | **PO5** | **PO6** | **PO7** | **PO8** | **PO9** | **PO10** | **PO11** | **PO12** |
| **CO1** | 3 | 2 | 1 | 2 | 3 | | 1 | | 2 | 1 | 1 | 1 |
| **CO2** | 3 | 3 | 3 | 3 | 2 | 1 | 1 | | 3 | 2 | 1 | 2 |
| **CO3** | 2 | 3 | 1 | 2 | 2 | 2 | 1 | 1 | 3 | 3 | 1 | 2 |

**Correlation levels 1, 2 or 3 as defined below:**

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

| Department of Metallurgical & Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MMS652 | Manufacturing Processes Lab - II | PCR | 0 | 0 | 3 | 3 | 2 |
| Pre-requisites | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| MMC403: Materials Characterisation and MMC405: Manufacturing Processes | | CT+EA | | | | | |
| Developer | | Dr. Manab Mallik | | | | | |
| Course Outcomes | CO1: Learn science and technological aspects of the Powder production and characterization<br>CO2: To study the effect of compaction pressure on densification and learn various sintering techniques to produce net shape product<br>CO3: Explore powder-processing-property relationship through laboratory assignment. | | | | | | |

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| Topics Covered | Exp 1: Demonstration of ball milling, compaction unit, dynamic light scattering technique and tube furnace [3 hours]<br>Exp 2: Synthesis of nano powders by Chemical reduction [3 hours]<br>Exp 3: Particle reduction by Ball milling [3 hours]<br>Exp 4: Characterization of nano and milled powders [3 hours]<br>Exp 5: Particle size analysis by different techniques [3 hours]<br>Exp 6: Conventional die compaction of powders [3 hours]<br>Exp 7: Solid state sintering [3 hours]<br>Exp 8: Liquid phase sintering [3 hours]<br>Exp 9: Microstructural characterization and phase analysis of sintered products [3 hours]<br>Exp 10: Hardness measurement of sintered products [3 hours] |
| Text Books, and/or reference material | TEXT BOOKS:<br>1. Powder Metallurgy – A Upadhyaya and G S Upadhyaya.<br>2. Powder Metallurgy Science – R. M. German, 2nd Edition, MPIF, 1994<br><br>REFERENCE BOOKS:<br>1. Powder metallurgy: principles and applications, Fritz V. Lenel, Metal Powder Industries Federation, 1980<br>2. Powder Metallurgy Technology, Cambridge International Science Publishing, 2002 |

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

| CO ↓ | ← PO → | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **PO1** | **PO2** | **PO3** | **PO4** | **PO5** | **PO6** | **PO7** | **PO8** | **PO9** | **PO10** | **PO11** | **PO12** |
| **CO1** | 3 | 1 | 1 | 1 | | | 1 | 1 | 2 | 1 | | 1 |
| **CO2** | 3 | 3 | 3 | 3 | 1 | 2 | 1 | 2 | 3 | 2 | 2 | 2 |
| **CO3** | 2 | 3 | 1 | 2 | 2 | | 1 | 2 | 3 | 3 | 1 | 2 |

**Correlation levels 1, 2 or 3 as defined below:**

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

# SEVENTH SEMESTER

| Departmentof ManagementStudies | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Titleofthecourse | Program Core(PCR)/ Electives(PEL) | TotalNumberofcontacthours | | | | Credit |
| | | | Lecture(L) | Tutorial(T) | Practical(P) | TotalHours | |
| **MSC731** | **PRINCIPLESOF MANAGEMENT** | PCR | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | CourseAssessmentmethods(Continuousassessment(CA)andEndAssessment(EA)) | | | | | |
| | | CA+EA | | | | | |

| | |
|---|---|
| **CourseOutcomes** | • CO1:Tomakebuddingengineersawareofvariousmanagementfunctionsrequiredforanyorganization<br>• CO2:Toimpartknowledgeonvarioustoolsandtechniques appliedbytheexecutivesofan organization<br>• CO3:Tomakepotentialengineersawareofmanagerialfunctionsothatitwouldhelpfortheir professional career<br>• CO4:Toimpartknowledgeonorganizationalactivitiesoperationalandstrategicbothinnature<br>• C05: To impart knowledge on each functionalarea ofmanagementlikeMarketing,Finance,Behavioral Science,QuantitativeTechniquesandDecisionScience |
| **TopicsCovered** | **UNITI:**ManagementFunctionsandBusinessEnvironment:Businessenvironment-macro,Business environment -micro; Porter's five forces, Management functions – overview,Different levels and roles of management, Planning- Steps, Planning and environmentalanalysis with SWOT,ApplicationofBCGmatrixin organization**(12)**<br>**UNIT II:** Quantitative tools and techniques used in management: Forecasting techniques,Decisionanalysis**(6)**<br>**UNITIII:**Creatinganddeliveringsuperiorcustomervalue:Basicunderstandingofmarketing,Consumerbehavior-fundamentals,Segmentation,Targeting&Positioning,ProductLifecycle.**(8)**<br>**UNITIV:**Behavioralmanagementofindividual:Motivation,Leadership,Perception,Learning. **(8)**<br>**UNITV:**Professionalethics:IntroductiontoProfessionalethics,Morals,valuesandEthics,Ethicsin Business**. (2)** |
| **Text Books,and/orreferencematerial** | Text Books:<br>1. MarketingManagement15thEdition,PhilipKotlerandKelvinKeller,PearsonIndia<br>2. ManagementPrinciples, Processes andpractice, first edition, AnilBhat and AryaKumar,Oxford Highereducation<br>3. OrganizationalBehavior,13thedition,StephenPRobbins,PearsonPrenticehallIndia<br>4. Operations Management, 7th edition (Quality control, Forecasting), Buffa & Sarin,Willey<br>5. A.C.Fernando:BusinessEthics&CorporateGovernance,PearsonEducation 2ndedition |

| CO-PO mapping | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Course** | **POs COs** | **PO1** | **PO2** | **PO3** | **PO4** | **PO5** | **PO6** | **PO7** | **PO8** | **PO9** | **PO10** | **PO11** | **PO12** |
| **MS731** | CO1 | - | - | - | - | - | - | **2** | | **2** | **1** | **1** | **3** |
| | CO2 | - | - | - | - | - | - | **1** | | **1** | | | **3** |
| | CO3 | - | - | - | - | - | - | **1** | **2** | **2** | **2** | **2** | **3** |
| | CO4 | - | - | - | - | - | - | **1** | **2** | **2** | **1** | **1** | **3** |
| | CO5 | - | - | - | - | - | - | **2** | **2** | **2** | **2** | **1** | **3** |

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MMC701 | Steel Making | PCR | 3 | 1 | 0 | 4 | 4 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| MMC-301: Metallurgical Thermodynamics and Kinetics | | CT+MT+EA | | | | | |
| Course Outcomes | • CO1: Understand fundamentals of physicochemical principles of steel making<br>• CO2: Understand the design & operational aspects of steel making technology.<br>• CO3 :Understand the design & operational aspects of Continuous Casting | | | | | | |
| Topics Covered | Historical Perspective, An Overview of Modern Steel making. (2)<br>Steelmaking Fundamentals - Chemical Reactions Equilibria, Steel Making Slag (6)<br>LD Steelmaking process - Design aspects of Converter and Lance ; LD Shop Layout, Charge Calculations ;Raw Materials ; Blowing Curve and theories of LD Steelmaking. (6)<br>Bottom Blown Steelmaking - Distinctive Features and combined blow (4)<br>Steelmaking in Electric Arc Furnaces (EAF) - Construction of an Arc Furnace ; Operation ; Developments in EAF steelmaking Technology. Alloy Steelmaking and stainless steel making 6)<br>Refractory in steelmaking - Requirements and various types of refractory Material (2)<br>Secondary Steelmaking: Types of Deoxidation and Deoxidation Kinetics and Products. Vacuum Degassing - Principles - Degassing Techniques (4)<br>Ladle Metallurgy : V.A.D ; V.O.D ; R H (4)<br>Ingot Casting and its Defects (2)<br>Continuous Casting - Process description - Continuous Casting Products (5)<br>Near net shape Casting (1) | | | | | | |
| Text Books, and/or reference material | Suggested Text Books:<br>1. Ghosh, A. and Chatterjee, A., Principles and Practices in Iron and Steel making, Prentice Hall of India, New Delhi, 2008.<br>2. Steel Making - By R.H. Tupkary<br>3. Steel Making - By A Chakroborty.<br>Suggested Reference Books:<br>1. Turkdogan, E.T., A Text Book of Steelmaking, Academic Press, London, 1997.<br>2. Ghosh, A., Secondary Steelmaking, CRC Press, Boca Raton, 2000. | | | | | | |

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

| PO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 3 |
| **CO2** | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 3 |
| **CO3** | 3 | 3 | 3 | 3 | 2 | 1 | 1 | 1 | 3 | 1 | 1 | 3 |

**Correlation levels 1, 2 or 3 as defined below:**

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

<table>
<tr><td colspan="8">Department of Metallurgical and Materials Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MME711</td><td>Fatigue, Creep and Fracture</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="6">Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))</td></tr>
<tr><td colspan="2">MMC-301: Introduction to Metallurgy and Materials<br>MMC503: Mechanical Behaviour of Materials</td><td colspan="6">CT+MT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="7">I. Learn fundamentals of fatigue, creep and fracture (including fracture mechanics).<br>II. Understand fatigue, creep and fracture in details including mechanisms and methods of testing.<br>III. Solve problems on fatigue, creep, fracture and different design problems to meet contemporary needs (including tutorials).</td></tr>
<tr><td>Topics Covered</td><td colspan="7">Fatigue: Types of stress cycles, S-N diagram and endurance limit, Various failure relations, viz., Goodman, Soderberg, Gerber parabola; Fatigue crack nucleation and propagation; application of fracture mechanics for fatigue cracking cyclic stress strain curve; low cycle fatigue; effect of stress concentration on fatigue; size effect; surface effects; effect of metallurgical variables on fatigue; Increased fatigue life due to surface protection cumulative fatigue damage rule; concept reverse plastic zone; corrosion fatigue; fretting; high temperature fatigue. 11h<br><br>Creep: Materials problem at high temperature; time dependant mechanical behavior; Creep curves, Stress rupture test; Creep mechanisms; Deformation mechanism map; Super plasticity; Creep resistant alloys; Presentation of engineering creep data; Prediction of long time properties; Creep-fatigue interaction. 4h<br>Fracture: Examples of fracture in real components; Different design philosophies; atomic view of fracture; stress concentration effects of flaws;<br>Linear elastic plastic fracture mechanics (LEFM): Griffith's theory of brittle fracture; The energy release rate; R-curve; Different modes of loading; Stress analysis of cracks, crack tip plasticity; concepts of plane stress and plane strain.<br>Elastic plastic fracture mechanics: CTOD, J integral, HRR singularity.<br>Types of fracture in metals; microstructural aspects of fracture; Different toughening mechanisms;<br>Fracture toughness testing of metals: $K_{1C}$, CTOD and $J_{1C}$. 22h</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="7">Text Books:<br><br>1. Anderson, T. L. Fracture Mechanics. 2nd ed. CRC Press, 1995.<br>2. Mechanical Metallurgy by George Dieter<br>3. Suresh, S. Fatigue of Materials. 2nd ed. Cambridge University Press, 1998.<br>4. Elementary engineering fracture mechanics by David Broek, 1982, MartinusNijhoff Publishers<br>5. Fracture Mechanics by M. Janssen, J. Zuidema and R. J. H. Wanhill, 2nd edition, Spon Press, Taylor and Francis group.</td></tr>
</table>

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

| CO ↓ | PO ← | | | | | | | | → | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| I | 3 | 2 | 1 | 2 | 1 | | 1 | 1 | 1 | 1 | | 1 |
| II | 3 | 3 | 2 | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 2 |
| III | 3 | 3 | 2 | 3 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 2 |

**Correlation levels 1, 2 or 3 as defined below:**

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

<table>
<tr><td colspan="7">Department of Metallurgical and Materials Engineering</td></tr>
<tr><td rowspan="2">Course Code</td><td rowspan="2">Title of the course</td><td rowspan="2">Program Core (PCR) / Electives (PEL)</td><td colspan="4">Total Number of contact hours</td><td rowspan="2">Credit</td></tr>
<tr><td>Lecture (L)</td><td>Tutorial (T)</td><td>Practical (P)</td><td>Total Hours</td></tr>
<tr><td>MME-712</td><td>Raw materials preparation for iron and steel making</td><td>PEL</td><td>3</td><td>0</td><td>0</td><td>3</td><td>3</td></tr>
<tr><td colspan="2">Pre-requisites</td><td colspan="5">Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA))</td></tr>
<tr><td colspan="2">MMC-404: Iron making</td><td colspan="5">CT+MT+EA</td></tr>
<tr><td>Course Outcomes</td><td colspan="6">CO1: Understand the concept of preparing raw materials as a burden for different iron and steel-making methods.<br>CO2: Acquire knowledge about the different processing routes for raw materials preparation<br>CO3: Application of knowledge for different raw materials preparation, their characterization and suitable use of various iron and steel-making industries</td></tr>
<tr><td>Topics Covered</td><td colspan="6">Introduction: Need of Raw Material Preparation. [1hr]<br>Ore Preparation: Important minerals and their characteristics; Ore reserves in India and World; Techno - economic appraisal of ore- breaking, crushing and grinding techniques considering sizing operations. [8hrs]<br>Agglomeration: Purpose, technological appraisal of various methods with merits and demerits, bonding mechanism.<br><br>[3hrs]<br>Sintering: Process, mechanism, factors affecting sinter quality, fluxed sinter, sinter mineralogy, sintering machine design, process control. [5hrs]<br>Pelletizing: Process, green ball formation and growth, additives and their effect, pellet drying and hardening (cold and hot), pelletizing machine types, design, pellet firing systems. [6hrs]<br>Briquetting and Nodulizing: Process, additives and hardening methods. Rotary hearth furnace, its operation, future prospective. Techno- economic evaluation of various iron ore feed materials. [4hrs] Coal preparation: Coal washing purpose and methods, use of coal in iron and steel making [6hrs]<br>Coke quality: Stamp charging, coke quality affected by process parameters, coke testing, methods for reactivity, strength etc. [4hrs]<br>Industry status: Agglomeration scenario in India and world, coking coal in India and world, future prospects. [1hr]</td></tr>
<tr><td>Text Books, and/or reference material</td><td colspan="6">Text books:<br>1. O.P. Gupta: Elements of Fuels, Furnaces and Refractories, Khanna Publishers (Delhi).<br>2. J.D. Gilchrist: Fuels, Furnaces and Refractories, Pergamon.<br>3. RC Gupta: Theory and laboratory experiments in ferrous metallurgy,PHI, New Delhi<br>4. R.H. Tupkary: Introduction to Modern Iron Making, Khanna Publishers.<br>5.A. Ghosh, Amit Chatterjee: Ironmaking and Steelmaking: Theory and Practice, PHI, New Delhi<br>Reference books:<br>1. Efficient Use of Fuel, HMSO (London).</td></tr>
</table>

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

| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 |
| **CO2** | 3 | 3 | 2 | 2 | 2 | 3 | 3 | 1 | 1 | 3 | 3 | 3 |
| **CO3** | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 3 |

**Correlation levels 1, 2 or 3 as defined below:**

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

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MME713 | Fuel, Furnace and Refractories | PER | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| MMC-302: Metallurgical Thermodynamics & Kinetics. | | CT+MT+EA | | | | | |
| Course Outcomes | • CO1: Understanding the Conventional and Non- Conventional energy sources<br>• CO2: Understanding the property of Fuel and Refractories.<br>• CO3: Understanding the design of furnace with respect to usage of fuel and Refractories | | | | | | |
| Topics Covered | Definition, Comparative study of solid, liquid and gaseous fuels. Constitution, classification and grading of coal. (4)<br>Testing of fuels like: Grindability, Caking properties, calorific value, Proximate and ultimate analysis, Flash and Fire point, viscosity. (6)<br>Non-conventional Energy Resources like Nuclear fuel, Solar, Wind, Geo-thermal, Bio-mass, Hydrogen (2)<br>Carbonization of coal: Coke making and by-products. (2)<br>Producer gas, Water gas, Natural gas, LPG, Industrial Gases, Gobar Gas. Storage of fuels. (2)<br>Combustion of fuels and problems (2)<br>Definition and Classification of Furnaces, Batch furnaces, Continuous furnaces. (2)<br>Construction and working of furnaces Pit furnace, Rotary furnace, Muffle furnace etc. (4)<br>Evolution of heat and flame temperature. Available heat. Natural, forced, induced and balanced draft. Chimney height, (2)<br>Heat losses in furnaces and minimization. Waste heat recovery. (2)<br>Nature and Type and Properties of Refractories, Manufacture of Common Refractories (4)<br>Furnace Design: Lay out of Refractories in a furnace. (2) | | | | | | |
| Text Books, and/or reference material | Suggested Text Books:<br>1. Elements of Fuels, Furnaces and Refractories, O. P. Gupta, Khanna publication.<br>2. Fuels, Furnaces and Refractories, J. D. Gilchrist<br>3. Fuels, Furnaces, Refractories and Pyrometry,-A.V.K. Suryanarayana, B. S. Publication<br>Suggested Reference Books:<br>Industrial Furnaces - Vol. I & II, W. Trinks and M. H. Mawhiney, Wiley | | | | | | |

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

| PO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO2** | 3 | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **CO3** | 3 | 3 | 3 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Correlation levels 1, 2 or 3 as defined below:**

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

| Department of Metallurgical & Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MME714 | Corrosion Engineering | PEL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| CYC-01: Engineering Chemistry | | CT+MT+EA | | | | | |
| Course Outcomes | CO1: To learn Fundamentals of Corrosion Engineering<br>CO2: Techniques to acquaint with Actual Corrosion Testing<br>CO3: To understand the Principles, Mechanism and Prevention of High Temperature Corrosion | | | | | | |

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| Topics Covered | Introduction: Definition of corrosion, Cost of Corrosion, corrosion damage, environments, and classification of corrosion. (1)<br>Corrosion Principles: Electrochemical reactions, thermodynamics of corrosion, cell potential, emf and galvanic series, representation of cell / cell diagram, electrode kinetics, exchange current density, polarization - activation, concentration and combined, Pourbaix diagram, Evans diagram, Passivation. (11)<br>Forms of Corrosion: Uniform attack; galvanic or two-metal corrosion; crevice corrosion; pitting corrosion; intergranular corrosion – sensitization and weld decay; Selective leaching - dezincification; erosion corrosion; Stress corrosion cracking (SCC) and hydrogen damage. Case studies of corrosion in industry e.g. steel, chemical, fertilizer and food etc. (11)<br>Corrosion Prevention: Materials selection, alteration of environments, design, inhibitors, cathodic and anodic protection, coatings – electroplating. (5)<br>Corrosion Testing: Purpose, standard expression of corrosion rate, polarization technique – Tafel extrapolation, linear polarization method, AC impedance method, evaluation of pitting damage, Huey and stretcher test for stainless steel, slow strain rate test (SSRT). Corrosion failure analysis. (5)<br>High Temperature Corrosion: Introduction, oxidation, Pilling – Bedworth (PB) ratio, electrochemical and morphological aspects, oxidation kinetics, internal oxidation, corrosion in mixed environments, salt deposited hot corrosion, case studies for high temperature corrosion. (2) |
| Text Books, and/or reference material | Text Books:<br>1. Foundations of Corrosion Science and Engineering, K. S. Ghosh, PHI Learning, 2024<br>2. Corrosion Engineering – Mars G. Fontana, McGraw- Hill Publication, 1987.<br>3. The Fundamentals of corrosion – J. C. Scully<br>Reference books:<br>1. An Introduction of Metallic Corrosion – R. Evans, Eward Arnold (Publishers) Ltd, London.<br>2. Introduction of High Temperature Corrosion – N. Birks and G. H. Meier |

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 1 | 1 | 3 | 1 | 2 | 2 | 1 | 3 | 2 | 2 | 2 | 1 |
| **CO2** | 1 | 1 | 3 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 1 |
| **CO3** | 1 | 1 | 3 | 1 | 1 | 2 | 2 | 2 | 3 | 2 | 1 | 2 |

**Correlation levels 1, 2 or 3 as defined below:**

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

| Department of Metallurgical & Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MME715 | Metallurgical Process Design | PCR | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| MMC302 Metallurgical Thermodynamics and Kinetics<br>MMC504 Iron Making MMC701 Steel Making<br>MMC303 Non - Ferrous Process Metallurgy | | CT+MT+EA | | | | | |
| Course Outcomes | CO1: Apply the knowledge of law of mass action to perform materials balance of metallurgical processes<br>CO2: Apply the knowledge of the thermodynamics to do the energy balance<br>CO3: Learn to analyze reactor design and upscale the process | | | | | | |

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| Topics Covered | Measurement of quantities; Exercises on measurement of quantities; Stoichiometry, Law of mass action, Materials balance in Metallurgical processes. [12]<br><br>Fuels and combustions, Coal and Metallurgical Coke, Gaseous fuels, Liquid Fuels [6]<br><br>Basics of Energy balance, Energy balance in Metallurgical processes. Rist Diagram analysis [12]<br><br>Dimensional analysis, Buckingham's π-theorem, Similarity Criteria, Reactor design, worked out examples [10] |
| Text Books, and/or reference material | Suggested Text Books:<br><br>Engineering Process Metallurgy – R.I. L. Guthrie<br>Fuels, Furnaces and Refractories - J. D. Gilchrist<br>The Iron Blast Furnace: Theory and Practice - J. G. Peacey, ,W. G. DavenportW. Hopkins .D<br>Handbook On Material And Energy Balance Calculations In Materials Processing - Arthur E. Morris, Gordon Geiger, H. Alan Fine<br><br>Suggested Reference Books:<br>R.Schuhman n Jr. Metallurgical engineering, vol.1: Engineering principles |

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| CO2 | 3 | 3 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 |
| CO3 | 3 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 |

Correlation levels 1, 2 or 3 as defined below:
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

| DepartmentofMetallurgical andMaterialsEngineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| CourseCode | Titleofthe course | Program Core(PCR) / Electives(PEL) | TotalNumber of contacthours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MME716 | Composite Materials | PEL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| MMC-301: Introduction to Metallurgyand Materials | | CT+MT+EA | | | | | |
| CourseOutcomes | I. Learnthefundamentalsofcompositematerials,classification, properties and applications<br>II. Metalmatric composites(MMCs)<br>III. Solidand liquidstate synthesisofMMCs, joining of MMCs | | | | | | |

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| TopicsCovered | Course assessment methods: Mid semester examination and End semester examinationIntroduction:Classificationofcompositesonthebasisofmatrix,ex-situorin-situsynthesis,typeofreinforcementetc.;Metalmatrixcomposite,polymermatrixcomposites,ceramicmatrix compositeand carbon-carboncomposite; applicationofdifferentcompositematerials. (8 hours) Differentroutesofcompositesynthesis:castingroute,powdermetallurgyrouteandotherroutes. (4hours) PowdermetallurgyprocessedComposite:highenergymilling,Mechanicalalloying:Fundamentals and parameters; Compaction and Sintering: material dependent routes andprocess parameters; Recent trends- Spark plasma sintering, Equal channel angular pressingetc.;process parameter-structure-propertycorrelation. (12hours) Cast metal matrix composites: different synthesis routes: dispersion process (stir casting,compocasting and screw extrusion)-contact angle, wettability and particle-matrix bonding;Liquid metal impregnation/infiltration (pressure infiltration, squeeze casting and Lanxideprocess)- principle of molten metal infiltration-capillary flow ofmolten metal; Sprayprocess(Ospreyprocessandrapidsolidificationprocess);In-situproductionofdispersoids-XD process; evolved microstructure: structural defects in cast metal matrixcomposites-porosity,particlesegregation(macrosegregationandmicrosegregation),interfacialreactionand particledegradation;structure-propertycorrelation. (12 hours) Joiningofmetalmatrixcomposites,limitationsofconventionalfusionwelding,Applicationoftransientliquidphase(TLP) diffusionbonding,basicmechanismanddifferentstagesofTLPbondingprocessformonolithicandcompositesystem,process parametersofTLPbonding,joint efficiency. (4hours) |
| Text Books, and/or reference material | Text Books:<br>1. MetalMatrix Composites-Chawla and Chawla, Springer, 2006.<br>2.'Joiningofaluminiumbasedmetalmatrixcomposites'-JoydeepMaity,in'Engineered MetalMatrix Composites: Forming Methods, Material Properties and Industrial Applications',Editor:LucaMagagnin,2012,NOVASciencePublishers,Inc.,NewYork, USA,pp 329-354.<br>3.MaterialsScienceandEngineering:AnIntroduction-WilliamD.Callister,Jr.,John Wiley&Sons,Inc., 2007.<br>4.FundamentalsofMetal-MatrixComposites-AndreasMortensenandAlanNeedleman, Butterworth-Heinemann,1993.<br>5.AnIntroductiontoCompositeMaterials–DerekHull,CambridgeUniversityPress, 1981.<br>6.CompositeMaterials–DeborahD.L.Chung,Springer, 2009.<br>7.Metal-Matrixcomposite–P.K.Rohatgi,DefenceScienceJournal,Vol43,No4, October1993,pp 323-349.<br>8.Y. B.Liu, S. C.Lim, L. Lu,M. O. Lai,Recentdevelopment inthefabricationof metal matrix-particulatecomposites usingpowder metallurgy techniques,Journalof MaterialsScience29(1994)1999-2007. |

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 3 | 1 | - | 2 | 2 | 1 | 2 | 2 | 3 | 3 |
| **CO2** | 3 | - | 2 | 2 | - | 3 | 2 | - | - | - | 3 | 3 |
| **CO3** | 3 | 2 | 3 | 2 | 3 | - | - | 1 | 2 | 1 | 2 | 3 |

**Correlation levels 1, 2 or 3 as defined below:**

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

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MME 717 | Advanced Materials Processing | PCL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| MMC 302 Introduction to Metallurgy and Materials<br>MMC 405: Manufacturing Processes | | CT+MT+EA | | | | | |
| Course Outcomes | CO1: To learn the basic concepts related to advanced processing techniques<br>CO2: To understand the structure - properties correlation depends on processing parameters<br>CO3: To learn the latest developments of new advanced processing techniques | | | | | | |
| Topics Covered | Materials and Manufacturing Processes, Classification of Manufacturing Processes, Selection of Manufacturing processes, Conventional Processing of metal and alloys, Problems in conventional processing of materials. Effect of Manufacturing processes on mechanical properties, Specific | | | | | | |

| | |
|---|---|
| | Advantages, Limitations and applications. [6 hrs]<br><br>Advanced Casting Processes: Metal mold casting, Vacuum mould casting, Ceramic shell casting, Stir casting, Principle of stir casting, steps in stir casting process, Factors affecting stir casting process, Continuous casting, squeeze casting, spray casting, Semi solid processing, rheo-casting, and Pressure die casting, Rapid solidification, Rate of solidification, Solidification Contraction; Fluidity, Mould-metal interface reactions. Nucleation and grain growth, Solidification of pure metals, short and long freezing range alloys. macrostructure and microstructure and properties. [14 hrs]<br><br>Advanced Al Alloys: High temperature and high strength Al alloys, Al-Li alloy, Al-Fe V-Si, nanocrystalline Al alloys, etc.; Materials: Synthesis, Structure and Properties. [4 hrs]<br>Advances in Metal Forming:<br>Conventional Processes-High Energy Rate Forming techniques, Electro-magnetic forming, Explosive forming, Electro hydraulic forming, magnetic pulse forming, super plastic forming, rubber forming, flow forming - Principles and process parameters- Advantages -Limitations and Applications. Overview of powder metal forming Technique-Advantages Applications-Powder perform forging- Hot and cold Isostatic pressing powder Rolling-Tooling and process parameters.<br><br>[10 hrs] |
| Text Books, and/or reference material | Suggested Text Books:<br>1. Materials Science and Engineering An Introduction – William D. Callister, Jr., John<br>2. Wiley & Sons, Inc., 2007<br>3. ScropeKalpakjian, “Manufacturing processes for Engineering Materials”, Addision, Wesley, 1997.<br>4. Fundamentals of metal casting technology - P.C. Mukherjee, Oxford and IBH.<br>5. Mechanical Metallurgy, Dieter, Me Graw Hill, Kogakusha<br>6. Casting properties of metals and alloys -V. Korolkove.<br>7. Metal casting-B.Ravi-PHI Physical Metallurgy – Vijendra Singh.<br>Suggested Reference Books:<br>4. Physical Metallurgy of Engineering Materials by N. R. petty, Allen Unwin (1968)<br>5. Light Alloys: Metallurgy of the light Metals by I. J. Polmser-Edwaraedannord.<br>6. The Super alloys by C. T. Sims and W. C. Hegel –Wily-Interscience. |

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

| POs / COs | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 2 | 2 |
| **CO2** | 3 | 3 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 3 |
| **CO3** | 3 | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 3 |

**Correlation levels 1, 2 or 3 as defined below:**
1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High)

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MME-718 | High Temperature Materials | PEL | 3 | 0 | 0 | 3 | 3 |
| Pre-requisites | | Course Assessment methods (Continuous (CT), mid-term (MT) and end assessment (EA)) | | | | | |
| MMC-301: Introduction to Metallurgy and Materials | | CT+MT+EA | | | | | |
| Developer | | Dr. Manab Mallik | | | | | |
| Course Outcomes | CO1: Learn science and technological aspects to selection of high temperature materials.<br>CO2: Emphasis is put on such engineering materials which are important for high temperature applications.<br>CO3: Learn structure-property relationships, as well as processing techniques of materials for high | | | | | | |

| | |
|---|---|
| | temperature structural application |
| Topics Covered | **Introduction:** Need for high temperature materials; Historical development of high temperature materials; Materials requirements for high-temperature structures in the 21st century [4]<br>**Requirements of high temperature materials:** Environmental resistance; Wear, Mechanical and Physical properties [4]<br>**Temperature capability:** Metallic materials; Ceramic materials; Composite materials [2]<br>**Creep resistant Materials:** [2]<br>**Refractory metals and alloys:** Steels; Nickel alloys; Titanium alloys; Cobalt alloys [4]<br>**Intermetallics:** Structure, properties and application [4]<br>**Engineering Ceramics:** Material Selection; Structure; Properties and Applications. [3]<br>**High temperature Composites:** Metal matrix composites; Ceramic matrix composites; Intermetallic matrix composites [3]<br>**Ultra High Temperature Ceramics and Composites:** Classification, $ZrB_2$ and $HfB_2$ based Ultra High Temperature Ceramic Composites, Processing, mechanical behaviour and oxidation resistance [4]<br>**Coatings for high temperature materials:** Corrosion/ Oxidation resistant coatings; Thermal barrier coats [4] |
| Text Books, and/or reference material | Suggested Text Books:<br>1. Materials Science and Engineering An Introduction – William D. Callister, Jr., John Wiley & Sons, Inc., 2007<br>2. Materials; Engineering, Science, Processing and Design – Michael Ashby, Hugh Shercliff and David Cebon<br>3. Engineering Materials: M. F. Ashby and D. R. N. jones, Pergamon press Oxford (1980).<br>4. G.W. Meetham and M.H. Van de Voorde, Materials for High Temperature Engineering Applications, Springer, Berlin (2000).<br>Suggested Reference Books:<br>1. W. O. Soboyejo and T. S. Srivastan (ed.), Advanced Structural Materials: Properties, Design, Optimization and Applications, CRC Press, New York (2007).<br>2. The Super alloys by C. T. Sims and W. C. Hegel –Wily-Interscience.<br>3. Ultra-High Temperature Ceramics Materials for Extreme Environment Applications, Edited by William G. Fahrenholtz, Eric J. Wuchina, William E. Lee and Yanchun Zhou, John Wiley & Sons, Inc., Hoboken, New Jersey (2014)<br>5. Intermetallic Matrix Composites: Properties and Applications by Rahul Mitra, WP, Elsevier, UK, (2018)<br>4. Lecture Notes and Published Papers |

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

| CO ↓ | PO → | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **PO1** | **PO2** | **PO3** | **PO4** | **PO5** | **PO6** | **PO7** | **PO8** | **PO9** | **PO10** | **PO11** | **PO12** |
| **CO1** | 3 | 3 | 3 | 2 | 2 | 2 | 3 | 2 | 1 | 1 | 1 | 1 |
| **CO2** | 3 | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 1 | 1 | 2 | 2 |
| **CO3** | 3 | 3 | 3 | 3 | 3 | 2 | 1 | 2 | 1 | 1 | 3 | 3 |

**Correlation levels 1, 2 or 3 as defined below:**

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

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MMS751 | Ferrous Process Metallurgy Laboratory | PCR | 0 | 0 | 3 | 3 | 1.5 |
| Pre-requisites | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| MMC303: Non- Ferrous Process Metallurgy | | CT+EA | | | | | |
| Course Outcomes | • CO1: Understand the method of agglomeration of iron ore fines by sintering and pelletization<br>• CO2: Study the fluid dynamics in a cold model of B.O.F<br>• CO3: Evaluate the properties of agglomerates | | | | | | |
| Topics Covered | Experiment -1: Sintering of iron ore fines in laboratory Sintering Machine<br>Experiment-2: Pelletization of iron ore fines in a disc pelletizer<br>Experiment -3: Measure the properties of sinter produced<br>Experiment-4: Measure the green and indurated properties of pellets<br>Experiment -5: Briquetting of iron ore fines.<br>Experiment-6: Study the effect of velocity and nozzle diameter and no of nozzles on the diameter and depth of Crater formed in a water model of LD Converter | | | | | | |
| Text Books, and/or reference material | Suggested Text Books:<br>1. Ghosh, A. and Chatterjee, A., Principles and Practices in Iron and Steel making, Prentice Hall of India, New Delhi, 2008.<br>2. F. Habashi, Principles of Extractive Metallurgy, Vol.1, Gordon and Breach, New York | | | | | | |

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

| PO / CO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO1** | 3 | 3 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| **CO2** | 3 | 3 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |
| **CO3** | 3 | 3 | 2 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 |

**Correlation levels 1, 2 or 3 as defined below:**

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

| Department of Metallurgical and Materials Engineering | | | | | | | |
|---|---|---|---|---|---|---|---|
| Course Code | Title of the course | Program Core (PCR) / Electives (PEL) | Total Number of contact hours | | | | Credit |
| | | | Lecture (L) | Tutorial (T) | Practical (P) | Total Hours | |
| MMS752 | Materials Testing Laboratory | PCR | 0 | 0 | 3 | 3 | 2 |
| Pre-requisites | | Course Assessment methods (Continuous (CT) and end assessment (EA)) | | | | | |
| MMC-503: Mechanical Behaviour of Materials | | CT+EA | | | | | |
| Course Outcomes | I. Learn fundamentals and operational aspects of wear, non-destructive and other testing techniques.<br>II. In-hand interpretation of wear and conductivity results of different materials to meet contemporary needs.<br>III. Data analysis and report writing of various experiments. | | | | | | |

| | |
|---|---|
| Topics Covered | **List of Experiments:**<br>1. Non-destructive testing (NDT) using Magnetic particle testing method.<br>2. Non-destructive testing (NDT) using Dye penetrant testing method.<br>3. Non-destructive testing (NDT) using Ultrasonic technique.<br>4. Tribological characterization of different materials using Pin-on-disk wear testing machine.<br>5. Tribological characterization of different materials using High stress abrasive wear testing machine.<br>6. Determination of electrical conductivity of different materials<br>7. Determination of fracture toughness by indentation technique |
| Text Books, and/or reference material | Text Books/Reference:<br>1. Mechanical Metallurgy by George Dieter<br>2. Practical Non-Destructive Testing by by Baldev Raj, M. Thavasimuthu and T. Jayakumar<br>3. ASTM G99-05. Standard Test Method for Wear Testing with a Pin-On-Disk Apparatus, West Conshohocken, 2010, ASTM, PA, USA. |

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

| CO ↓ | PO → | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| I | 3 | 1 | 1 | 1 | | | 1 | 1 | 2 | 1 | | 1 |
| II | 3 | 3 | 3 | 3 | 1 | 2 | 1 | 2 | 3 | 2 | 2 | 2 |
| III | 2 | 3 | 1 | 2 | 2 | | 1 | 2 | 3 | 3 | 1 | 2 |

**Correlation levels 1, 2 or 3 as defined below:**

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