# M.Tech Degree

# in

# INDUSTRIAL METALLURGY

SYLLABUS

FOR

CREDIT BASED CURRICULUM

(For the students admitted in the year 2024)

DEPARTMENT OF METALLURGICAL AND MATERIALS ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
TIRUCHIRAPPALLI - 620 015

TAMIL NADU, INDIA

## VISION OF THE INSTITUTE

- To be a university globally trusted for technical excellence where learning and research integrate to sustain society and industry.

## MISSION OF THE INSTITUTE

- To offer undergraduate, postgraduate, doctoral and modular programmes in multi-disciplinary / inter-disciplinary and emerging areas.
- To create a converging learning environment to serve a dynamically evolving society.
- To promote innovation for sustainable solutions by forging global collaborations with academia and industry in cutting-edge research.
- To be an intellectual ecosystem where human capabilities can develop holistically.

## VISION OF THE DEPARTMENT

To evolve into a globally recognized department in the frontier areas of Metallurgical and Materials Engineering.

## MISSION OF THE DEPARTMENT

- To produce Metallurgical and Materials Engineering graduates having professional excellence.
- To carry out quality research having social & industrial relevance.
- To provide technical support to budding entrepreneurs and existing industries

## PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

| | |
|---|---|
| **PEO1** | Choose their careers as practicing metallurgist in manufacturing and service industries. |
| **PEO2** | Enable them to make consistent progress towards a higher degree in Metallurgical engineering and allied fields. |
| **PEO3** | To work and participate in multidisciplinary environments as well as to develop entrepreneur skills |

## PROGRAMME OUTCOMES (POs)

| | |
|---|---|
| **PO1** | An ability to independently carry out research /investigation and development work to solve practical problems |
| **PO2** | An ability to write and present a substantial technical report/document |
| **PO3** | Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program |

CURRICULUM FRAMEWORK / FLEXIBLE CURRICULUM / NEP 2020 / M.Tech

| **Components** | **Number of Courses** | **Number of Credits** | **Senate Suggestions** |
|---|---|---|---|
| Programme Core (PC) | 3 / Semester (6 / Year) | 44 | 4 or 3 credits can be the combination of Programme Core (PC) and Programme Elective (PE) |
| Programme Elective (PE) | 3 / Semester (6 / Year) | | |
| Essential Laboratory Requirements (ELR) | 2 / Year | 4 | 2 Credits / ELR (If the department opts for 2 Essential Laboratory Requirements (ELR) per year, totaling 4 credits, the remaining 2 credits can be allocated to PC or PE courses) |
| Internship / Industrial Training / Academic Attachment (I/A) | 1 | 2 | - |
| Open Elective (OE) / Online Course (OC) | 2 | 6 | Open Elective (OE) / Online Course (OC) can be completed between 1 – 4 Semester |
| Project Phase-I | 1 | 12 | - |
| Project Phase-II | 1 | 12 | - |
| **Total** | **20** | **80** | **-** |

## CURRICULUM

### SEMESTER I

| Code | Course of Study | Credit |
|---|---|---|
| MA613 | Programme Core 1: Engineering Mathematics | 4 |
| MT641 | Programme Core 2: Foundry Technology | 4 |
| MT643 | Programme Core 3: Welding Technology | 4 |
| | Programme Elective I | 4 |
| | Programme Elective II | 3 |
| | Programme Elective III /Online (NPTEL) | 3 |
| MT649 | Laboratory I: Microstructure characterization and Material Testing Laboratory | 2 |
| | | **24** |

### SEMESTER II

| Code | Course of Study | Credit |
|---|---|---|
| MT642 | Programme Core 4: Industrial Heat treatment | 4 |
| MT644 | Programme Core 5: Foundry Metallurgy | 4 |
| MT646 | Programme Core 6: Metal Forming | 4 |
| | Programme Elective IV | 4 |
| | Programme Elective V | 3 |
| | Programme Elective VI /Online (NPTEL) | 3 |
| MT650 | Laboratory II: Advanced Materials Processing Laboratory | 2 |
| | | **24** |

### SUMMER TERM (evaluation in the III semester)

| Code | Course of Study | Credit |
|---|---|---|
| MT656 | Internship / Industrial Training / Academic Attachment (I/A) (6 weeks to 8 weeks) | **2** |

### SEMESTER III

| Code | Course of Study | Credit |
|---|---|---|
| MT657 | Project Work (Phase I) | **12** |

### SEMESTER IV

| Code | Course of Study | Credit |
|---|---|---|
| MT658 | Project Work (Phase II) | **12** |

### SEMESTER I-IV

| Code | Course of Study | Credit |
|---|---|---|
| | Open Elective I | 3 |
| | Open Elective II | 3 |
| | | **6** |

**PROGRAMME ELECTIVES (PE)**

| Sl. No. | Code | Course of Study | Credit |
|---|---|---|---|
| **PE courses for all three specializations** | | | |
| 1. | MT661 | Physical Metallurgy | 4 |
| 2. | MT662 | Testing, Inspection and Characterization | 4 |
| 3. | MT663 | Mechanical Behavior of Materials | 3 |
| 4. | MT664 | Corrosion Engineering | 3 |
| 5. | MT665 | Computational Techniques | 3 |
| 6. | MT666 | Metallurgical Failure Analyses | 3 |
| 7. | MT667 | Surface Engineering | 3 |
| 8. | MT668 | Modeling in Materials processing | 3 |
| 9. | MT669 | Automotive Materials | 3 |
| 10. | MT670 | Nanomaterials and Technology | 3 |
| 11. | MT671 | Advanced Electrochemical Techniques | 3 |
| 12. | MT672 | Developments in Iron-Making and Steel-Making | 3 |
| 13. | MT673 | Additive Manufacturing | 3 |
| 14. | MT674 | Phase Transformations | 3 |
| 15. | MT675 | Crystallography | 3 |
| 16. | MT676 | Particulate Technology | 3 |
| 17. | MT677 | Process Modeling | 3 |
| 18. | MT678 | Advanced Material Characterization Techniques | 3 |
| 19. | MT679 | Non-Destructive Testing | 3 |
| **PE courses for IM specialization** | | | |
| 1. | MT741 | Stainless steel technology | 3 |
| 2. | MT742 | Design of castings & weldments | 3 |
| 3. | MT743 | Advanced materials processing | 3 |
| 4. | MT744 | Special Casting Processes | 3 |
| 5. | MT745 | Special topics in metal forming | 3 |
| 6. | MT746 | Thermodynamics of Solidification | 3 |
| 7. | MT747 | Modeling and Simulation for Metal Processing | 3 |

**OPEN ELECTIVES (OE) / ONLINE COURSE (OC) (To be completed between I to IV semester)**

| Sl. No. | Code | Course of Study | Credit |
|---|---|---|---|
| 1. | MT761 | Design and Selection of Materials | 3 |
| 2. | MT762 | Statistical Quality Control and Management | 3 |
| 3. | MT763 | Intellectual Property Rights | 3 |
| 4. | MT764 | Innovation and Product Development | 3 |
| 5. | MT765 | Energy Storage Systems | 3 |
| 6. | MT766 | Artificial Intelligence in Materials Engineering | 3 |
| 7. | MT767 | Molecular Modeling of Materials | 3 |
| **OE for MSE and/or WE** | | | |
| 1. | MT741 | Stainless steel technology | 3 |
| 2. | MT742 | Design of castings & weldments | 3 |
| 3. | MT743 | Advanced materials processing | 3 |
| 4. | MT744 | Special Casting Processes | 3 |
| 5. | MT745 | Special topics in metal forming | 3 |
| 6. | MT746 | Thermodynamics of Solidification | 3 |
| 7. | MT747 | Modeling and Simulation for Metal Processing | 3 |

# Syllabus

| | | |
|---|---|---|
| **Course Code** | **:** | **MA613** |
| **Course Title** | **:** | **ENGINEERING MATHEMATICS** |
| **Type of Course** | **:** | PC |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 4 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| CLO1 | To make the students mathematically strong for solving engineering and scientific problems |
| CLO2 | To train students with mathematical aspects so as to comprehend, analyse, design and create novel products and solution for the reallife problems. |
| CLO3 | To familiarize the students with Euler-Lagrange's equation and fundamental concepts in calculus of variations. |

**Course Content**

- Partial Differential equations – basic concepts – One dimensional heat flow equation - Two-dimensional heat flow equation in steady flow in Cartesian and Polar coordinates.
- Calculus of variations - Euler's equation - Variational problems in parametric form - Natural boundary condition – Conditional Extremum - Isoperimetric problems.
- Numerical Solution of ODE's – Euler's, Taylor's and Runge Kutta methods – Milne's and Adams' predictor-corrector methods.
- Finite difference scheme for elliptic, parabolic, and hyperbolic partial differential equations.
- Introduction to Finite Element Method - Rules for forming interpolation functions - Shape functions - Application to fluid flow and heat transfer problems.

**References**


| | |
|---|---|
| 1. | *Desai, C.S. and Abel, J. P., Introduction to Finite Element Method, Van NostrandReinhold.* |
| 2. | *Elsegolts, L., Differential Equations and the Calculus of Variations, Mir Publishers.* |
| 3. | *Grewal, B.S., Higher Engineering Mathematics, Khanna Publishers.* |
| 4. | *Reddy, J.N., Introduction to Finite Element Method, Mcgraw Hill.* |
| 5. | *Jain, M.K., Iyengar, S.R. and Jain, R.K., Numerical Methods for Scientific and Engineering Computation, Wiley Eastern, 2010* |
| 6. | *Veerarajan, T., Numerical Methods, Volume III, Tata McGraw Hill Edition, New Delhi, 2009.* |


**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | To identify, formulate and solve engineering problems such as one dimensional and two-dimensional heat transfer problems. |
| **CO2** | Formulate and solve variational problems in parametric form, Ostrogradsky equation and isoperimetric problems |
| **CO3** | Compute numerical solution of ordinary differential equations using various numerical techniques |
| **CO 4** | Discretize and solving the partial differential equations associated with general engineering problems using finite difference scheme. |
| **CO5** | Apply advanced numerical method such as finite element method to solve heat transfer problems. |

| Course Code | Course Title | CO | Course outcomes<br>At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MA613 | Engineering Mathematics | CO1 | To identify, formulate and solve engineering problems such as one dimensional and two-dimensional heat transfer problems. | H | L | H |
| | | CO2 | Formulate and solve variational problems in parametric form, ostrogradsky equation and isoperimetric problem | H | L | H |
| | | CO3 | Compute numerical solution of ordinary differential equations using various numerical techniques | H | L | M |
| | | CO4 | Discretize and solving the partial differential equations associated with general engineering problems using finite difference scheme. | H | L | H |
| | | CO5 | Apply advanced numerical method such as finite element method to solve heat transfer problems | H | L | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT641** |
| **Course Title** | **:** | **Foundry Technology** |
| **Type of Course** | **:** | Program core |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 4 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | Gain knowledge of the concepts, operating procedures, applications, advantagesand limitations of various furnaces used in foundry shop. |
| **CLO2** | To know various metals casting process |
| **CLO3** | To understand the casting design |
| **CLO4** | To know various casting defects, its causes and remedies |

**Course Content**

Understanding concepts of Solidification of metal casting. Types, design of patterns, Allowances material selection, manufacture of patterns

Classification of moulding proesses, mould materials, basic requirement of mould sands, preparation of mould sands, bonds formed in moulding aggregates, Resin binder processes, Sand mouldings – Bonded sand moulds and unbonded sand moulds. Core making processes, plaster moulding processes, ceramic moulding processes, investment casting processes, graphite moulding processes, permanent mould casting processes, die casting processes, types of centrifugal casting processes, continuous casting processes, new casting processes – Squeeze casting, semi solid metal casting, directional solidification processes, CLA process, Thixocasting and Rheocasting processes.

Construction use and operation of electric arc furnace [Direct and Indirect Arc], resistance furnace - core and core less induction, cupola, rotary and crucible furnaces.

Layout, mechanization and automation, fettling, inspection and pollution control.

Casting design and simulation, methoding, Gating and Risering calculations, improvement of yield and efficiency, simple problems in gating and risering for steels and cast irons. Solidification and simulation of metal casting, Phase field modeling, Casting defects Identification, analysis and Remedies

**References**


| | |
|---|---|
| 1. | *Heine R. W., Loper C. R., Rosenthal P. C., ‘ Principles of Metal Casting’,2nd Edition, Tata McGraw Hill Publishers, 1985* |
| 2. | *Jain P. L., ‘ Principles of Foundry Technology’, 3rd Edition, Tata McGraw Hill, 1995* |

**Course Outcomes (CO)**

Upon completion of this class, students are expected to

| | |
|---|---|
| **CO1** | Know the furnaces used in the production of metals and alloys |
| **CO2** | Understand melting practice that takes place in the different furnaces |
| **CO3** | Describe different types of molding, casting and solidification processes |
| **CO4** | Differentiate between the different casting processes and their end products |
| **CO5** | Develop designs for engineering components produced via against defects |

| **Course Code** | **Course Title** | **CO** | **Course outcomes At the end of the course, students will be able** | **PO1** | **PO2** | **PO3** |
|---|---|---|---|---|---|---|
| MT641 | Foundry Technology | CO1 | know the furnaces used in the production of metals and alloys | H | L | M |
| | | CO2 | Understand the melting practice that takes place in the different furnaces | H | L | M |
| | | CO3 | Describe different types of molding, casting and solidification processes | M | L | M |
| | | CO4 | Differentiate between the different casting processes and their end products | H | L | H |
| | | CO5 | Develop designs for engineering components produced via against defects | M | L | M |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT642** |
| **Course Title** | **:** | **Industrial Heat treatment** |
| **Type of Course** | **:** | Program core |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 4 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To know the principles of heat treatment processes |
| **CLO2** | Gain knowledge on various heat treatment processes |
| **CLO3** | To know the applications of various heat treatment processes for ferrous and non-ferrous alloys |
| **CLO4** | To gain knowledge on various heat treatment defects, its causes, and remedies |

**Course Content**:

Principles of Heat treatment**:** Purpose of alloying, effect of alloying elements on ferrite, cementite, Fe-Fe3C system, tempering and TTT Curves, Austenitic Transformation, Pearlitic Transformation, Bainitic Transformation, Martensitic Transformation
Chemical and Thermo mechanical heat treatment**:** Annealing, Normalizing, Hardening, mechanism of heat removal during quenching, quenching media, size and mass effect, hardenability, tempering, austempering. Carburizing, cyaniding, plasma nitriding, flame and induction hardening, residual stresses, deep freezing, thermo mechanical treatments: HTMT, LTMT, Ausforming, Isoforming, Cryoforming.

Heat treatment of Ferrous alloys: Heat treatment of Plain carbon, Alloy and structural steels and Cast Iron

Non-ferrous metals and alloys: Precipitation hardening, aging treatment, study of copper, aluminum, Mg and nickel and their alloys Furnaces: Heat treatment furnaces and their design, atmosphere control vacuum heat treatment etc.
Defects in Heat treatment and their remedies, Economics of heat treatment

**References**


| | |
|---|---|
| 1. | Heat Treatment Principle and Techniques by Rajan,Sharma |
| 2. | Principles of Heat treatment of steels by R C Sharma, New Age International, 2007 |
| 3. | The steel Handbook by AlokNayar, McGraw-Hill Education, 2001 |


**Course Outcomes**:
Upon completion of this class, students are expected to

| | |
|---|---|
| **CO1** | Understand the principle of heart treatment processes |
| **CO2** | Understand the types heat treatment processes |
| **CO3** | Understand the effect heat treatment on microstructure and mechanical properties of ferrous and non-ferrous alloys |
| **CO4** | Know the use of various heat treatment furnaces |
| **CO5** | Understand various heat treatment defects, causes, and remedies |

| Course Code | Course Title | CO | Course outcomes At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT642 | Industrial Heat treatment | CO1 | Understand the principle of heat treatment processes | M | L | H |
| | | CO2 | Understand the types heat treatment processes | H | L | H |
| | | CO3 | Understand the effect heat treatment on microstructure and mechanical properties of ferrous and non-ferrous alloys | H | L | H |
| | | CO4 | Know the use of various heat treatment furnaces | M | L | M |
| | | CO5 | Understand various heat treatment defects, causes, and remedies | M | L | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT643** |
| **Course Title** | **:** | **Welding Technology** |
| **Type of Course** | **:** | Program core |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 4 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To know the concepts of different materials joining technology and emphasis on underlying science and engineering principle of every processes. |
| **CLO2** | To understand the weldability of different alloys |
| **CLO3** | To know various welding defects, its causes and remedies |
| | |

**Course Content:**

Classification of welding processes, energy sources used in welding, working principle, advantages, limitations of arc welding processes –MMAW, GTAW, GMAW, SAW, ESW & EGW

Working principle, advantages and limitations of solid-state welding processes. - Friction,friction stir, explosive, diffusion and ultrasonic welding.

Working principle, advantages and limitations of power beam processes: Plasma arc welding, electron beam & laser beam welding.
Principles of operation, process characteristics, types and applications – Resistance welding, Gas welding, brazing, soldering and joining of non-metallic materials.

Welding metallurgy: Introduction, thermal cycles, prediction of peak temperature, pre heat and cooling rate, PWHT. Weldability of carbon steel, stainless steel & aluminum. Hot & cold cracking phenomenon, weld defects, causes and their remedies

**References**


| | |
|---|---|
| 1. | Parmer R. S., ‘Welding Engineering and Technology’, Khanna Publishers, 1997 |
| 2. | *Robert W Messler, Jr. “Principles of welding, Processes, physics, chemistry and metallurgy”, Wiley,2004.* |
| 3. | *Larry Jeffus, “Welding Principles and Applications” Fifth edition, Thomson, 2002* |


**Course Outcomes (CO)**

Upon completion of this class, students are expected to

| | |
|---|---|
| **CO1** | Understand the working principle, merits and demerits of different joining processes |
| **CO2** | Understand the working principle and importance of welding allied processes |
| **CO3** | Solve welding heat flow related problems |
| **CO4** | Learn weldability and welding related problems of different materials |

| Course Code | Course Title | CO | Course outcomes<br>At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT643 | Welding Technology | CO1 | Understand the working principle, merits and demerits of different joining processes | M | L | M |
| | | CO2 | Understand the working principle and importance of welding allied processes | M | L | M |
| | | CO3 | Solve welding heat flow related problems | M | L | L |
| | | CO4 | Learn weldability and welding related problems of different materials | H | L | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT644** |
| **Course Title** | **:** | **Foundry Metallurgy** |
| **Type of Course** | **:** | Program core |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 4 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To understand the metallurgy of various types of cast iron |
| **CLO2** | To understand various specifications for ferrous systems |
| **CLO3** | To comprehend the basic principles of physical metallurgy of ferrous and non-ferrous alloys and apply those principles for engineering applications |
| **CLO4** | Apply the basic principles of physical metallurgy for developing new ferrous and non-ferrous alloys |

**Course Content**

Types of cast iron – Effect of normal elements in cast iron. Influence of composition and cooling rate. Cast iron production methods, SG Iron production – Degree of Nodularising – Malleable iron production, CG Iron, Austempered Ductile iron and Alloy Cast iron-Inoculation and Inoculating practices
Specifications for steels and alloy cast irons as per IS,BS and ASTM- Metallurgical aspects of gating and risering of ferrous alloys, fluidity of ferrous alloys.

Typical non-ferrous casting alloys(such as aluminium, magnesium, copper and other commercially important non-ferrous alloys), specifications, properties, industrial applications, melting and composition control, deoxidation, gating and risering techniques.
Solidifications of ferrous and non –ferrous metals. Directional solidification of ferrous metals and its alloys, modeling of solidification for both ferrous and non-ferrous metals

**References**


| | |
|---|---|
| **1** | *Heine, Loper and Rosenthal, “Principles of Metal Casting”, Tata McGraw Hill, PublishingCo,1995* |
| **2** | *Flinn RA., “Fundamental Metal Casting”., Addison-Wesley,1963.* |
| **3** | *John R.Brown, “FOSECO Ferrous Foundry Man’s Hand Book”, Butterworth, 2000.* |
| **4** | *ASM Hand Book, Vol. 15, Casting, ASM Hand Book Committee, 1998.* |
| **5** | *John R.Brown, “FOSECO Non Ferrous Foundry Man’s Hand Book”, Butterworth, 2000.* |
| **6** | *Murphy,A.J.,Ed.,"Non Ferrous Foundry Metallurgy",Pergamon,USA,1984* |


**Course Outcomes**:
Upon completion of this class, students are expected to

| | |
|---|---|
| **CO1** | Understand the casting aspects of ferrous and non-ferrous alloys. |
| **CO2** | Identify the phases present in different alloy systems. |
| **CO3** | Understand the structure-property correlation in different ferrous and non-ferrous alloys |
| **CO4** | Apply the basic principles of ferrous foundry metallurgy for selection of materials for specificapplications |
| **CO5** | Apply the basic principles of non-ferrous foundry metallurgy for selecting materials forspecific applications |

| Course Code | Course Title | CO | Course outcomes<br>At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT644 | Foundry Metallurgy | CO1 | Understand the casting aspects of ferrous and non-ferrous alloys. | M | L | M |
| | | CO2 | Identify the phases present in different alloy systems. | H | L | M |
| | | CO3 | Understand the structure-property correlation in different ferrous and non-ferrous alloys | H | L | H |
| | | CO4 | Apply the basic principles of ferrous foundry metallurgy for selection of materials for specificapplications | H | L | M |
| | | CO5 | Apply the basic principles of non-ferrous foundry metallurgy for selecting materials forspecific applications | H | L | M |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT646** |
| **Course Title** | **:** | **Metal Forming** |
| **Type of Course** | **:** | Program core |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 4 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To know the concepts of metal forming and associate technologies |
| **CLO2** | To apply the concepts of conventional and advanced materials manufacturing for various structural applications |
| **CLO3** | To gain knowledge on metal forming defects, causes, and remedies |
| **CLO4** | To know various special forming techniques |

**Course content**

Yielding criteria of von Mises and Tresca. Levy-Von Mises equations and Prantl Reuses equations for ideal plastic and elastic plastic solids respectively. Yield Locus. Methods of load calculation including slab method, slip line field theory, FEM, upper and lower bound methods.

Texture effects. Metallurgical factors affecting recrystallization temperature and grain size. Effect of temperature, strain rate, hydrostatic pressure, Microstructure. Residual stresses, Friction and lubrication mechanisms. Lubricants in rolling, forging, extrusion, wire drawing, sheet metal forming. Tool design

Types of rolling mills, Geometrical factors and forces, Factors affecting rolling load and minimum thickness, Roll pass design, wheel and tyre production. Rolling defects,Processes and equipment, Forgeability, effect of various factors, definitions. Selection of equipment, die design, parting line, flash, draft, tolerance. Defects, causes and remedies.

High velocity forming methods, superplastic forming, hydroforming, isothermal forging. Incremental forming, fine blanking, Principles and processes. FLD and LDR, CAD, CAM in forming use of softwares like OPTRIS, DEFORM, etc. Workability.

Sol-gel and other processes for powders. Slip casting, extrusion injection moulding, HIP and CIP (Isostatic pressing), sintering. Blow moulding,Blow and Injection Moulding. Compression and transfer Moulding, Pultrusion. Filament Moulding. Resin Transfer Moulding.

**References**


| | |
|---|---|
| **1** | Dieter, G.E., “Mechanical Metallurgy”, McGraw Hill, 2001. |
| **2** | ASM “Metals Handbook, Vol. 14, Forming & Forging”, ASM, Metals Park, Ohio, USA, 1998. |
| **3** | Kurt Lange, “Handbook of Metal Forming”, Society of Manufacturing Engineers,Michigan, USA, 1985. |
| **4** | Belzalel Avitzur, “Metal Forming- Processes and Analysis”, Tata McGraw Hill, 1977. |
| **5** | Pat.L.Manganon, “Principles of Materials Selection for Engineering Design”,Prentice Hall Int. Inc,1999 |
| **6** | Knigery,W.D., Ceramic Fabrication Processes, John Urley, 1950. |
| **7** | ASM, “Metals Handbook, Vol. I”, Properties and selection, McGraw Hill, 2001. |

**Course outcomes**:

At the end of this course, the students would be able to:

| | |
|---|---|
| **CO1** | Apply the concept of plastic deformation for metals and alloys to convert them in to usefulshapes for intended engineering applications |
| **CO2** | Differentiate the various metal forming technology and choose the appropriate one for requiredengineering applications |
| **CO3** | Provide the successful solution to the various materials design and selection criteria fordemanding engineering applications. |
| **CO4** | Analyze various operational and materials parameters influencing the metal forming quality. |
| **CO5** | Classify various metal forming technology (forging, rolling, extrusion etc.) and associatedforming equipments |
| **CO6** | Define various secondary forming procedures like stretch forming, deep drawing blanking andassociated equipments |

| **Course Code** | **Course Title** | **CO** | **Course outcomes At the end of the course, students will be able** | **PO1** | **PO2** | **PO3** |
|---|---|---|---|---|---|---|
| MT646 | Metal Forming | CO1 | Apply the concept of plastic deformation for metals and alloys to convert them in to useful shapes for intended engineering applications | H | L | H |
| | | CO2 | Differentiate the various metal forming technology and choose the appropriate one for requiredengineering applications | H | L | M |
| | | CO3 | Provide the successful solution to the various materials design and selection criteria for demanding engineering applications. | H | L | H |
| | | CO4 | Analyze various operational and materials parameters influencing the metal forming quality. | M | L | H |
| | | CO5 | Classify various metal forming technology (forging, rolling, extrusion etc.) and associatedforming equipment | M | L | M |
| | | CO6 | Define various secondary forming procedures like stretch forming, deep drawing blanking and associated equipment | M | L | M |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT649** |
| **Course Title** | **:** | **Microstructure characterization and Material Testing Laboratory** |
| **Type of Course** | **:** | Laboratory |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To learn the principles of material testing and characterization and to apply them for various engineering applications. |

**LIST OF EXPERIMENTS:**

1. Study of metallurgical microscope and sample preparation
2. Microscopic examination of ferrous alloys (plain carbon steels, stainless steels, maraging steels and tool steels and cast irons).
3. Microscopic examination of non-ferrous materials (Magnesium alloys, Aluminum alloys, Titanium alloys, Copper alloys, Super alloys).
4. Tensile Testing using Hounsfield and UTM
5. Hardness Measurements (Rockwell, Vickers and Brinell)
6. Impact Testing (Izod and Charpy)
7. Determination of crystal structure and lattice parameters from XRD data
8. Crystallite size determination of materials using XRD
9. Fractography using scanning electron microscope

**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | Prepare the specimens for metallographic examination with best practice, can operate the optical microscope and understand, interpret, analyze the microstructure of materials. |
| **CO2** | Classify the different mechanical testing methods with their inherent merits andlimitations |
| **CO3** | Apply various test methods for characterizing physical properties of materials |
| **CO4** | Recommend materials testing techniques based upon desired results, perform basic statistical analysis on data, and summarily present test results in a concise written format |

| Course Code | Course Title | CO | Course Outcomes At the end of the course student will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT649 | Microstructure characterization and Material Testing Laboratory | CO1 | Prepare the specimens for metallographic examination with best practice, can operate the optical microscope and understand, interpret, analyze the microstructure of materials | H | M | H |
| | | CO2 | Classify the different mechanical testing methods with their inherent merits andlimitations. | M | M | M |
| | | CO3 | Apply various test methods for characterizing physical properties of materials | H | M | H |
| | | CO4 | Recommend materials testing techniques based upon desired results, perform basic statistical analysis on data, and summarily present test results in a concise written format | M | H | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT650** |
| **Course Title** | **:** | **ADVANCED MATERIALS PROCESSING LABORATORY** |
| **Type of Course** | **:** | Laboratory |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To provide an insightfor the latest developments in materials processing. |

**LIST OF EXPERIMENTS:**

1. Fabrication of nanostructured coatings by plasma electrolytic processing
2. Mechanochemical synthesis of nanostructured compounds
3. Microwave synthesis of nanosized ceramic powders
4. Diffusion bonding of Materials
5. Equichannel angular processing of materials
6. Cryorolling of materials
7. Vacuum arc melting of materials
8. Spark plasma sintering of materials
9. Microwave sintering of materials
10. In-situ synthesis of metal matrix composites by casting
11. Arc-welding practice

**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | Understands the working principles of different advanced processes |
| **CO2** | Synthesize nanostructured materials by advanced processing methods. |
| **CO3** | Perform experiments with best practices and understands the advantages andlimitations of different processes |
| **CO4** | Interpret and analyze the data and present the results in a concise written format |
| **CO5** | Recommend a suitable process for modifying the material properties. |

| Course Code | Course Title | CO | Course Outcomes<br>**At the end of the course student will be able** | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT650 | Advanced Materials Processing Laboratory | CO1 | Understands the working principles of different advanced processes | M | M | M |
| | | CO2 | Synthesize nanostructured materials by advanced processing methods. | H | M | H |
| | | CO3 | Perform experiments with best practices and understands the advantages and limitations of different processes | H | M | H |
| | | CO4 | Interpret and analyze the data and present the results in a concise written format | M | H | H |
| | | CO5 | Recommend a suitable process for modifying the material properties. | M | M | M |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT657** |
| **Course Title** | **:** | **PROJECT WORK PHASE –I** |
| **Type of Course** | **:** | Project Work |
| **Prerequisites** | **:** | |
| **Contact Hours** | **:** | |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To know in depth exploration of a topic of special interest and to explain, applyrelevant theories and laws in the chosen area. |

**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | Interpret theories and doctrines and give recommendations where appropriate. Knowledge on the chosen topic and apply the knowledge, experience, and skillslearned. |
| **CO2** | Acquire knowledge on the chosen topic and apply the knowledge, experience, and skills learned |
| **CO3** | Produce a thesis of publishable quality. Effectively present and defend research orally. |
| **CO4** | Effectively present and defend research orally. |

| **Course Code** | **Course Title** | **CO** | **Course Outcomes**<br>**At the end of the course student will be able** | **PO1** | **PO2** | **PO3** |
|---|---|---|---|---|---|---|
| MT657 | Project Work Phase -I | CO1 | Interpret theories and doctrines and give recommendations where appropriate. Knowledge on the chosen topic and apply the knowledge, experience, and skills learned. | H | M | H |
| | | CO2 | Acquire knowledge on the chosen topic and apply the knowledge, experience, and skills learned | M | M | M |
| | | CO3 | Produce a thesis of publishable quality. | H | H | H |
| | | CO4 | Effectively present and defend research orally. | H | M | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT658** |
| **Course Title** | **:** | **PROJECT WORK PHASE –II** |
| **Type of Course** | **:** | Project Work |
| **Prerequisites** | **:** | |
| **Contact Hours** | **:** | |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To know in depth exploration of a topic of special interest and to explain, applyrelevant theories and laws in the chosen area. |

**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | Interpret theories and doctrines and give recommendations whereappropriate. |
| **CO2** | Acquire knowledge on the chosen topic and apply the knowledge, experience, and skills learned |
| **CO3** | Produce a thesis of publishable quality |
| **CO4** | Effectively present and defend research orally. |

| **Course Code** | **Course Title** | **CO** | **Course Outcomes**<br>**At the end of the course student will be able** | **PO1** | **PO2** | **PO3** |
|---|---|---|---|---|---|---|
| MT658 | Project Work Phase -II | CO1 | Interpret theories and doctrines and give recommendations where appropriate. | H | M | H |
| | | CO2 | Acquire knowledge on the chosen topic and apply the knowledge, experience, and skills learned | M | M | M |
| | | CO3 | Produce a thesis of publishable quality | H | H | H |
| | | CO4 | Effectively present and defend research orally. | H | M | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT661** |
| **Course Title** | **:** | **PHYSICAL METALLURGY** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 4 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To develop an understanding of the basis of physical metallurgy and correlate structure of materials with their properties for engineering applications. |

**Course Content**

- Introduction to structure (atomic structure, micro and macrostructure) and their importance to relate with properties and processing. Overview of engineering alloys and their applications. Details on transformations: Liquid to solid and Solid to solid transformation and their importance in fine tuning the properties of engineering alloy and processing
- Diffusion, energetic of solidification Nucleation and growth-dealing homogeneous and heterogeneous nucleation and growth of solids, dendritic growth in pure metals, constitutional super cooling and dendritic growth in alloys.
- Phase diagrams – solid solution –types, Hume –Rothery rule. Phase diagrams – Binary-types – Lever rule. Solidification of different types of solid solutions – Iron-Carbon diagram – Effect of alloying element on Iron- carbon diagram. Ternary phase diagrams- Understanding of isotherms and isopleths.
- Strengthening mechanisms strengthening by grain-size reduction, solid solution Strengthening, strain hardening, dispersion hardening and other recent modes of hardening. Heat treatment of ferrous alloys; Annealing, Normalising, TTT and CCT diagrams, Hardening – hardenability measurements, tempering. Thermo mechanical treatments. Heat treatment furnaces – atmospheres – quenching media – case hardening techniques.
- Engineering alloys: Types, composition and processing and their structure -property correlation. Metallurgy of newer alloys (High entrpy alloys, intermetallic compounds-Aluminides, silicides,etc)

**References**


| | |
|---|---|
| 1. | *Avner, S. H., "Introduction to Physical Metallurgy", second edition, McGraw Hill, 1985.* |
| 2. | *William F. Hosford, Physical Metallurgy, Taylor & Francis Group, 2008* |
| 3. | *Raghavan, V., "Physical Metallurgy", Prentice Hall of India, 1985* |
| 4. | *Donald R Askland and Pradeep P Phule "Essentials of Materials Science and Engineering, Baba Barkha NathPrinters, Delhi.* |
| 5. | *Willam D. Callister, Jr. Materials Science and Engineering, Wiley India Pvt. Ltd.,2018* |
| 6. | *Vijendra Singh, Physical Metallurgy, Standard Publishers distributors, 1999.* |


**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | Understand the structures of various engineering alloys and relate to their properties and processing. |
| **CO2** | Learn the transformation kinetics and apply in developing microstructure-controlled engineering alloys |
| **CO3** | Design and scheduling of heat treatment process for various engineering in order to meet the industrial requirements |
| **CO4** | Tailor the engineered alloy with the help suitable strengthening methods |
| **CO5** | Know the various newer alloys and their applications and suitably place in different engineering structures |

| Course Code | Course Title | CO | Course outcomes<br>At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT661 | Physical Metallurgy | CO1 | Understand the structures of various engineering alloys and relate to their properties and processing. | H | M | H |
| | | CO2 | Learn the transformation kinetics and apply in developing microstructure-controlled engineering alloys. | H | M | H |
| | | CO3 | Design and scheduling of heat treatment process for various engineering in order to meet the industrial requirements. | H | M | H |
| | | CO4 | Tailor the engineered alloy with the help suitable strengthening methods. | H | M | H |
| | | CO5 | Know the various newer alloys and their applications and suitably place in different engineering structures. | H | M | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT662** |
| **Course Title** | **:** | **TESTING, INSPECTION, AND CHARACTERIZATION** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | **To provide an understanding of the basic principles of various testing, Inspection and characterization tools and use those tools to analyze metallurgical components.** |

**Course Content**

Purpose and importance of destructive tests – Concepts, and method of Tensile, hardness, bend, torsion, fatigue and creep testing; Adopting these testing methods as per standards and analysing the outcome of the testing

Purpose and limitations of NDT, Concepts, operating principles, advantages, limitations of liquid penetrant testing and magnetic particle inspection, eddy current testing, ultrasonic testing, radiography. Comparison of NDT methods and selection of NDT methods. Identifying suitable method(s) and analysing the outcome of the testing.

Light optical microscopy, basic principles and special techniques. X-ray diffraction and its applications in materials characterization. Identifying suitable method(s) and analysing the outcome of the testing.

Electron microscopy, Construction, operation and applications of scanning electron microscope (SEM), transmission electron microscope (TEM) along with their attachments like energy dispersive spectroscopy, wavelength dispersive spectroscopy, electron back scattered diffraction. Analysis of the imaging and diffraction results; tomography.

Thermal analysis: Thermo gravimetric analysis, differential thermal analysis, differential scanning calorimetry and dilatometry.

**References**


| | |
|---|---|
| 1. | *Suryanarayana A.V.K., 'Testing of Metallic Materials', 2nd edition, B S Publications, 2018* |
| 2. | *Non-destructive testing*, B.Hull And V.John, Macmillan, 1988. |
| 3. | *Modern Physical Metallurgy and Materials Engineering*, R. E. Smallman, R. J. Bishop, sixth edition, Butterworth-Heinemann, 1999. |
| 4. | Materials Characterization, P.C.Angelo, Elsevier (India) Pvt. Ltd, Haryana, 2013, |

**Course Outcomes (CO)**
At the end of the course student will be able

| | |
|---|---|
| **CO1** | Know various destructive testing methods of materials and analysing its results |
| **CO2** | Know various non-destructive testing methods of materials and analysing its results |
| **CO3** | Understanding the basic characterization techniques like OM and XRD and also understanding which technique can be used in a specific requirement |
| **CO4** | Understanding the advanced microscopic characterization techniques SEM, TEM, EBSD and also understanding which technique can be used in a specific requirement |
| **CO5** | Evaluate the specimen by thermal analysis and dilatometry |

| Course Code | Course Title | CO | Course outcomes At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT662 | Testing, Inspection, and Characterization | CO1 | Know various destructive testing methods of materials and analyzing its results. | M | H | H |
| | | CO2 | Know various non-destructive testing methods of materials and analysing its results. | M | H | M |
| | | CO3 | Understanding the basic characterization techniques like OM and XRD and also understanding which technique can be used in a specific requirement. | H | H | H |
| | | CO4 | Understanding the advanced microscopic characterization techniques SEM, TEM, EBSD and also understanding which technique can be used in a specific requirement. | H | H | H |
| | | CO5 | Evaluate the specimen by thermal analysis and dilatometry. | H | H | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT663** |
| **Course Title** | **:** | **MECHANICAL BEHAVIOUR OF MATERIALS** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 4 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To understand the concepts on materials failure and fracture analysis of materials and to design new materials that can with stand catastrophic failures at different environment. |

**Course Content**

- Definition of stress, strain, transformation of coordinate systems, tensor notations, relationship between stress and strain in elastic materials, concept of principal stress and principal strain, stress invariants, modulus, Hook's law and understanding of stiffness and compliance tensors, elastic anisotropy,
- Yield criteria, equivalent stress and plastic strain, Theoretical shear of perfect crystal, Mohs circle, concept of dislocations and dislocation theory, edge and screw dislocations, dislocation interactions, kink and jog, sessile and glissiles, partial dislocations, dissociation of dislocations, Thomson tetrahedral, Lomer-Cottress barriers.
- Strengthening mechanisms, work hardening, solid solution strengthening, grain boundary strengthening, particle hardening, polymer elasticity and viscoelasticity, types of reinforcements and their influence, types of composites, high temperature degradation, creep and stress rupture, deformation mechanism maps, superplasticity and hot working.
- Hardness, types of hardness measurements, comparison among hardness methods and scales, nanoindentation, compression testing, comparison between tension and compression studies of materials, shear testing, shear modulus, torsion and twist.
- Fatigue of materials, S-N curves, life data presentation, influence of stress, linear elastic fracture mechanics in fatigue, crack growth studies, Paris law, metallurgical aspects of fatigue failures, concepts of remedial measures, creep-fatigue interaction, theoretical strength, Griffith equation, Brittle fracture, ductile fracture, fracture maps.

**References**


| | |
|---|---|
| 1. | *Dieter G. E., 'Mechanical Metallurgy', 3rd Edition, McGraw Hill, 1988* |
| 2. | *Suryanarayana, 'Testing of Metallic Materials', Prentice Hall India, 1979.* |
| 3. | *Rose R. M., Shepard L. A., Wulff J., 'Structure and Properties of Materials', Volume III, 4th Edition, John Wiley,1984* |
| 4. | *Thomas H. Courtney, "Mechanical Behavior of Materials", 2nd Edition, 2013, Overseas Press India Private Limited, ISBN : 81-88689-69-6* |
| 5. | *Norman E. Dowling, "Mechanical Behavior of Materials", International Editirion (4th), Contributed by K.Sivaprasad and R. Narayanasamy, 2013, Pearson Education Limited. ISBN : 13:978-0-273-76455-7* |

**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | Understand the relationship between stress and strain |
| **CO2** | Understand the yielding behavior and dislocation influence on plastic deformation |
| **CO3** | Understand the various strengthening mechanisms and high temperature deformation |
| **CO4** | Understand testing methods like hardness, compression, and fatigue |

| Course Code | Course Title | CO | Course outcomes At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT663 | Mechanical Behaviors of Materials | CO1 | Understand the relationship between stress and strain. | H | L | H |
| | | CO2 | Understand the yielding behaviour and dislocation influence on plastic deformation. | H | L | M |
| | | CO3 | Understand the various strengthening mechanisms and high temperature deformation. | H | L | H |
| | | CO4 | Understand testing methods like hardness, compression, and fatigue. | H | L | M |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT664** |
| **Course Title** | **:** | **CORROSION ENGINEERING** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To provide a practical knowledge about corrosion and its prevention in engineering field. |

**Course Content**

Principles of corrosion phenomenon: Thermodynamics and kinetics: emf/galvanic series, Pourbaix diagram, exchange current density, passivity, Evans diagram, flade potential.

Different forms of corrosion: atmospheric/uniform, pitting crevice, intergranular, stree corrosion, corrosion fatique, dealloying, high temperature oxidation-origin and mechanism with specific examples.

Corrosion testing and monitoring: Non-Elecrochemical and Electrochemical methods: weight loss method, Tafel Linear polarization and Impedance techniques, Lab, semi plant & field tests, susceptibility test.

Corrosion prevention through design, coatings, inhibitors, cathodic, anodic protection, specific applications, economics of corrosion control.

Corrosion & its control in industries: Power, Process, Petrochemical, ship building, marine and fertilizer industries. Some case studies-Corrosion and its control in different engineering materials: concrete structures, duplex, super duplex stainless steels, ceramics, composites and polymers.Corrosion auditing in industries, Corrosion map of India.

**References**



| | |
|---|---|
| 1. | *Fontana. M.G., Corrosion Engineering, Tata McGraw Hill, 3rd Edition, 2005.* |
| 2. | *Jones. D.A. Principles and Prevention of Corrosion, 2nd Edition, Prentice Hall, 1996.* |



**Course Outcomes (CO)**
At the end of the course student will be able

| | |
|---|---|
| **CO1** | Do electro and electroless plating of Cu, Al alloys |
| **CO2** | Determine the corrosion rate by weight loss method, electrical resistance method, potentiostatic polarization experiment and atmospheric corrosion using color indicator method |
| **CO3** | Analyze galvanic corrosion, pitting corrosion and stress corrosion cracking |
| **CO4** | Estimate the corrosion resistance by IGC susceptibility test, salt spray test and coating thickness |

| Course Code | Course Title | CO | Course outcomes At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT664 | Corrosion Engineering | CO1 | Do electro and electroless plating of Cu, Al alloys. | H | L | H |
| | | CO2 | Determine the corrosion rate by weight loss method, electrical resistance method, potentiostatic polarization experiment and atmospheric corrosion using colour indicator method. | M | H | M |
| | | CO3 | Analyze galvanic corrosion, pitting corrosion and stress corrosion cracking | H | M | H |
| | | CO4 | Estimate the corrosion resistance by IGC susceptibility test, salt spray test and coating thickness. | H | H | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT665** |
| **Course Title** | **:** | **COMPUTATIONAL TECHNIQUES** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To become familiar with experimental design and analysis of variance |
| **CLO2** | To understand finite difference method to solve complex heat transfer problems |
| **CLO3** | To learn the finite element method to simulate various manufacturing processes |
| **CLO4** | To learn the basics of machine learning techniques and how to use it in materials engineering |

**Course Content**

- Computational Techniques: Introduction, importance, applications; Various techniques, Modeling and simulation, Introduction to ICME (integrated computational materials engineering)
- Design of Experiments: Introduction, Basic Concepts, Analysis of Variance (ANOVA), Factorial Design, Taguchi, Response Surface Methodology
- Finite Difference Method: Introduction, Mathematical formulation, Solving steady state and transient one dimensional and two-dimensional heat transfer problems
- Finite Element Method: Introduction, fundamentals, applications; solving heat transfer and fluid flow problems. Simulation of manufacturing processes.
- Machine learning: Introduction, fundamentals, supervised learning – classification and regression, unsupervised learning, semi-supervised learning; usage of machine learning techniques in materials engineering

**References**


| | |
|---|---|
| 1. | *Jiju Antony, Design of Experiments for Engineers and Scientists, 3rd Edition, Elsevier, 2023.* |
| 2. | *Douglas C. Montgomery, Design and Analysis of Experiments, 8th edition, John Wiley & Sons, Inc., 2012* |
| 3. | *S.V. Patankar, Numerical Heat Transfer and Fluid Flow, CRC Press, 2009.* |
| 4. | *Tirupathi Chandrupatla, Ashok Belegundu, Introduction to Finite Elements in Engineering, 5th Edition, Cambridge University Press, 2022.* |
| 5. | *John D. Kelleher, Brian Mac Namee, and Aoife D'Arcy, Fundamentals of Machine Learning for Predictive Data Analytics, 2nd edition, MIT Press, 2022* |


**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | To choose a suitable computational technique for solving different engineering problems |
| **CO2** | To use analysis of variance and design of experiments for any engineering applications |
| **CO3** | To solve heat transfer problems using finite difference method |
| **CO4** | To perform manufacturing simulations using finite element method |
| **CO5** | To identify the suitable machine learning techniques for solving materials engineering related problems |

| Course Code | Course Title | CO | Course outcomes At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT665 | Computational Techniques | CO1 | To choose a suitable computational technique for solving different engineering problems. | H | M | H |
| | | CO2 | To use analysis of variance and design of experiments for any engineering applications. | H | M | H |
| | | CO3 | To solve heat transfer problems using finite difference method. | H | M | H |
| | | CO4 | To perform manufacturing simulations using finite element method. | H | M | H |
| | | CO5 | To identify the suitable machine learning techniques for solving materials engineering related problems. | H | M | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT666** |
| **Course Title** | **:** | **METALLURGICAL FAILURE ANALYSIS** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| CLO1 | To understand the concepts on materials failure and fracture analysis of materials and to design new materials that can with stand catastrophic failures at different environment. |

**Course Content**

- Aims of failure analysis, general procedures of failure analysis. Important factors causing the premature failure of metallic components and structures., classification of failure sources: Design deficiencies, material deficiencies, processing deficiencies, assembly errors, service conditions, neglect and improper operation. Methods and equipment for failure analysis, Sample selection and treatment, equipment for materials examination, materials analysis equipment for failure analysis, commonly used NDT methods.
- Fractography. Types of failures: ductile, brittle, fatigue, creep, corrosion, wear. Fatigue failures, fractography, effect of variables: part shape, type of loading, stress concentration, metallurgical factors, etc. Wear failures, adhesive, abrasive, erosive, corrosive wear. Corrosion failures, types of corrosion: uniform, pitting, selective leaching, intergranular, crevice, etc. Elevated temperature failures, creep, thermal fatigue, microstructural instability, oxidation.
- Failure mechanisms. Embrittlement phenomena. Environmental effects.
- Failures due to faulty heat treatments. Failures in metal forming and welding.
- Case studies in failure analysis and prevention of failures.

**References**


| | |
|---|---|
| 1. | Failure Analysis of Engineering Materials, 1st Edition - Charles R. Brooks, Ashok Choudhury, published by Mc Graw-Hill Professional, 2001. |
| 2. | Metallurgical Failure Analysis: Techniques and Case Studies, 1st Edition Kannadi |
| 3. | Palankeezhe Balan, published by Elsevier, 2018. |
| 4. | Failure Analysis: Fundamentals and Applications in Mechanical Components - Jose Luis |


**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| CO1 | The ability to identify the types of failures in engineering components under service. |
| CO2 | Able to determine fracture toughness of ductile and brittle materials. |
| CO3 | Knowledge of the tools and techniques to perform failure analysis. Ability to perform fractographic analysis after various failures. |
| CO4 | Ability to perform fractographic analysis after various failures. |
| CO5 | The ability to identify different failure mechanisms resulting from manufacturing Processes. |
| CO6 | Able to analyze the failures with the help of case studies and suggest prevention methods for failure. |

| Course Code | Course Title | CO | Course outcomes At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT666 | Metallurgical Failure Analysis | CO1 | The ability to identify the types of failures in engineering components under service. | L | M | H |
| | | CO2 | Able to determine fracture toughness of ductile and brittle materials. | M | H | L |
| | | CO3 | Knowledge of the tools and techniques to perform failure analysis. Ability to perform fractographic analysis after various failures. | L | H | M |
| | | CO4 | Ability to perform fractographic analysis after various failures. | H | M | L |
| | | CO5 | The ability to identify different failure mechanisms resulting from manufacturing Processes. | H | L | M |
| | | CO6 | Able to analyze the failures with the help of case studies and suggest prevention methods for failure. | M | L | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT667** |
| **Course Title** | **:** | **SURFACE ENGINEERING** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| CLO1 | To analyse the various concepts of surface engineering and comprehend the design difficulties. |

**Course Content**

- Introduction tribology, surface degradation, wear and corrosion, types of wear, roles of friction and lubrication- overview of different forms of corrosion, introduction to surface engineering, importance of substrate
- Chemical and electrochemical polishing, significance, specific examples, chemical conversion coatings, phosphating, chromating, chemical colouring, anodizing of aluminium alloys, thermochemical processes -industrial practices
- Surface pre-treatment, deposition of copper, zinc, nickel and chromium - principles and practices, alloy plating, electrocomposite plating, electroless plating of copper, nickel-phosphorous, nickel-boron; electroless composite plating; application areas, properties, test standards (ASTM) for assessment of quality deposits.
- Definitions and concepts, physical vapour deposition (PVD), evaporation, sputtering, ion plating, plasma nitriding, process capabilities, chemical vapour deposition (CVD), metal organic CVD, plasma assisted CVD, specific industrial applications
- Thermal spraying, techniques, advanced spraying techniques - plasma surfacing, D- Gun and high velocity oxy-fuel processes, laser surface alloying and cladding, specific industrial applications, tests for assessment of wear and corrosion behaviour, weld surfacing techniques

**References**



| | |
|---|---|
| 1. | *Sudarshan T S, 'Surface modification technologies - An Engineer's guide', Marcel Dekker, Newyork, 1989* |
| 2. | *Varghese C.D, 'Electroplating and Other Surface Treatments - A Practical Guide',TMH, 1993* |



**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | Define different forms of processing techniques of surface engineering materials |
| **CO2** | Know the types of Pre-treatment methods to be given to surface engineering |
| **CO3** | Select the Type of Deposition and Spraying technique with respect to the application |
| **CO4** | Study of surface degradation of materials |
| **CO5** | Asses the surface testing methods and comprehend the degradation properties |

| Course Code | Course Title | CO | Course outcomes At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT667 | Surface Engineering | CO1 | Define different forms of processing techniques of surface engineering materials. | H | L | H |
| | | CO2 | Know the types of Pre-treatment methods to be given to surface engineering. | H | L | H |
| | | CO3 | Select the Type of Deposition and Spraying technique with respect to the application. | H | L | H |
| | | CO4 | Study of surface degradation of materials. | | | |
| | | CO5 | Asses the surface testing methods and comprehend the degradation properties. | H | H | M |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT668** |
| **Course Title** | **:** | **Modeling in Materials Processing** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To learn principles of physical and mathematical modeling |
| **CLO2** | To gain experience in solving simple non-linear equations |
| **CLO3** | To gain hands-on experience in using software packages |
| **CLO4** | To familiarize with various modeling methods and strategies |

**COURSE CONTENT**

- Overview of Physical and Mathematical modeling principles, advantages and limitations
- Physical modeling pricinples – Similarity criteria, Hot and Cold models, Pilot scale models, Dimensional Analysis, case studies related to steelmaking processes.
- Mathematical modeling principles – Static vs dynamic models, Goals and Strategies, Turbulent and multiphase flows, coupled phenomena, Governing equations, boundary conditions, overview of solution methodologies, Boussinesq approximation, convergance criteria, numerical stability criteria, steady and transient problems, heating of slab example.
- Introduction to CFD software (ANSYS Fluent and open source software) – CAD geometry building, solution and postprocessing exercises – Practise problems – 2D laminar pipe flow and 2D plane channel turbulent flow, near wall treatment, validation with benchmark cases
- Mathematical modeling of industrial processes – Mixing behavior in Ladle (batch process), Residence time distribution in tundish (continuous process), Continuous casting process complexities, Alloy melting, Mass balance model of a gas circuit in DR process, Kinetic modeling of ladle refining process, Thermal and Mechanical Simulation of welding processes.

**References**


| | |
|---|---|
| 1. | Szekely J., Themelis N. J., ‘Rate Phenomena in Process Metallurgy’, Wiley, 1971 |
| 2. | Dipak Mazumdar and James W. Evans, ‘Modeling of Steelmaking Processes’, CRC Press, 2009 |
| 3. | S. K. Dutta, ‘Fundamental of Transport Phenomena and Metallurgical Process Modeling’, Springer, 2021 |
| 4. | ‘CFD Modeling and Simulation in Materials Processing’, Proceedings of Symposium held during TMS 2012, Annual Meeting and Exhibition, Orlando USA. |

**COURSE OUTCOMES (CO)**

At The End of The Course Student will be able.

| | |
|---|---|
| **CO1** | To assess the similarity criteria to build valid physical models |
| **CO2** | To formulate the appropriate building blocks of mathematical models |
| **CO3** | To solve set of non-linear equations iteratively without and with the use of softwares |
| **CO4** | To visualise modeling of complex industrial scale processes in material processing |

| Course Code | Course Title | CO | Course outcomes<br>At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT668 | Modeling in Materials Processing | CO1 | To assess the similarity criteria to build valid physical models | M | L | M |
| | | CO2 | To formulate the appropriate building blocks of mathematical models | H | M | H |
| | | CO3 | To solve set of non-linear equations iteratively without and with the use of software. | M | L | M |
| | | CO4 | To visualize modeling of complex industrial scale processes in material processing | H | H | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT669** |
| **Course Title** | **:** | **Automotive Materials** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | Nil |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous and End Assessment |

Course Learning Objectives (CLO)

| | |
|---|---|
| **CLO1** | To impart the knowledge in auto mobile materials and to equip the students to meet the demands of automobile engineering. |

**Course Content**

Otto cycle, diesel cycle, working principle and constructional details of two stroke and four stroke engine, carburetor, fuel feed systems, mechanical and electrical pumps. Petrol injection. Working principle of compression ignition engine, diesel injection systems, recent trends in engine technology

Engine cylinder: Structure and functions, types, cylinder blocks materials and manufacturing processes, improving engine components with surface modifications, Piston: Structures and functions, types, piston materials, piston manufacturing processes

Structure, function and materials for piston rings, camshaft, valves and valve seats, valve springs, connecting rod, crankshaft, turbocharger and exhaust manifold; ULSAB initiative from steel industry; tailor welds.

Types of chassis layout and chassis materials, vehicle frames, materials used for car body, front axle and steering system, drive line, propeller shaft, universal joints, wheels and suspension system.

Environmental impact of emissions from IC engines, Catalyst: catalysts for petrol engines, structures and functions, catalyst to reduce NOx, controlling pollution at cold start, On-board diagnosis. Exhaust gas treatment for diesel engine: particulate filters, regenerative methods, expendable catalyst additive, deNox catalyst.

**References**


| | |
|---|---|
| 1. | Ganesan.V, Internal Combustion Engines, Tata-McGraw Hill Publishing Co., New Delhi, 1994. |
| 2. | Hiroshi Yamagata, The Science and Technology of Materials in Automotive Engines, Woodhead Publishing in Materials, 2005. |
| 3. | Hajra Choudhury, Elements of Workshop Technology, Vol-I and Vol-II Asia Publishing House, 1996. |

**Course Outcomes (CO)**

At the end of the course, students will be able to

| | |
|---|---|
| **CO1** | Understand the fundamentals of automobile engineering and different components in automobile |
| **CO2** | Describe the importance and reasons for using different types of material used in automobiles |
| **CO3** | Understand future challenges and expectations in automobile engineering. |

| Course Code | Course Title | CO | Course outcomes<br>At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT669 | Automotive Materials | CO1 | Understand the fundamentals of automobile engineering and different components in automobile | H | L | H |
| | | CO2 | Describe the importance and reasons for using different types of material used in automobiles | H | H | H |
| | | CO3 | Understand future challenges and expectations in automobile engineering. | H | L | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT670** |
| **Course Title** | **:** | **NANOMATERIALS AND TECHNOLOGY** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | Nil |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous and End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To know the fundamental concepts of nanomaterials, synthesizing methods, their properties at nanoscale and possible technological applications in various fields of science and engineering |

**Course Content**

Concept of nano materials – scale / dimensional aspects, Top-down and bottom-up approaches for preparing nano materials
Advantages and limitations at the nano level – thermodynamic aspects at the nano level, health and environmental issues.
Characterization of nano materials and nano structures, important characterization techniques for nano size measurement.
Overview of properties of nano materials, Introduction to nano composites, processing of nanocomposites.
Applications in different areas such as semiconductors, sensors, nanostructured bio ceramics and nanomaterials for drug delivery, Energy related, fuel cells, Photocatalysis applications

**References**


| | |
|---|---|
| 1. | Pradeep T "Nano: The Essentials", Mc Graw Hill Publishing Co. Ltd., 2007 |
| 2. | Mick Wilson et al, "Nanotechnology", Overseas Press (India) Pvt. Ltd., 2005. |
| 3. | Charles P. Poole, Jr., Frank J. Owens, "Introduction to nano technology", Wiley, 2003. |
| 4. | Gunter Schmid, "Nanoparticles: From Theory to Applications", Wiley-VCH Verlag GmbH & Co., 2004. |


**Course Outcomes (CO)**

At the end of the course, students will be able to

| | |
|---|---|
| **CO1** | Understand the concepts of nanomaterials and their properties |
| **CO2** | Learn different routes of synthesizing methods of nanomaterials |
| **CO3** | Know the change in properties at the nanoscale level and their applications |
| **CO4** | Understanding the risks on producing nanomaterials and safety precautions. |

| Course Code | Course Title | CO | Course outcomes At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT670 | Nanomaterials and technology | CO1 | Understand the concepts of nanomaterials and their properties | H | L | H |
| | | CO2 | Learn different routes of synthesizing methods of nanomaterials | H | M | M |
| | | CO3 | Know the change in properties at the nanoscale level and their applications | H | L | H |
| | | CO4 | Understanding the risks on producing nanomaterials and safety precautions | M | L | M |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT671** |
| **Course Title** | **:** | **Advanced Electrochemical Techniques** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | Nil |
| **Contact Hours** | **:** | 3 hours |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To learn basic concepts of electrodes, electrolytes, electrode potentials and reference electrodes |
| **CLO2** | To learn fundamental principles of electrode-electrolyte interface and electrode kinetics |
| **CLO3** | To learn and understand DC and AC electrochemical techniques |
| **CLO4** | To learn underlying mechanisms, applications of different electrochemical techniques |

**Course Content**

Thermodynamic and Transport properties of electrolytes - aqueous and molten; solution models: Debye-Hückel (aqueous), Temkin (molten salts); electrode potentials (the underlying physics, i.e., electron excess or electron deficiency on the electrode); emf series (aqueous and molten salts); reference electrodes (thermodynamics and kinetics)

Fundamental aspects of electrochemical processes – Electrode-electrolyte interface, nature of the double layer; kinetics of electrode processes, charge transfer at the electrode/electrolyte interface, cell potential, current distribution and analytical techniques

DC methods such as cyclic voltammetry, linear sweep voltammetry, intermittent titration techniques, potentiodynamic polarization, chronopotentiometry, chronoamperometry, galvanostatic cycling with potential limitation

AC methods, i.e., AC voltammetry and electrochemical impedance spectroscopy, including fitting and analysis of equivalent circuits.

Electrochemical mechanisms involved in electrocatalysis, general & localized corrosion and energy systems. Application of techniques in various fields – corrosion & surface engineering, energy conversion & storage devices like fuel cells, supercapacitors, batteries etc., electrochemical processing of materials such as winning, refining, plating, synthesis and electrochemical recycling.

**References:**


| | |
|---|---|
| 1. | Bard, A. J., and L. R. Faulkner. Electrochemical Methods. 2nd Edition. New York: Wiley, 2004. |
| 2. | Fontana. M.G., Corrosion Engineering, Tata McGraw Hill, 3rd Edition, 2005. |
| 3. | Crompton R.G., Batchelur-Mculey C., Dikinson E. J. F., Understanding Voltammetry. Imperial College Press, 2012. |
| 4. | Barsoukov E., McDonald J.R., Impedance Spectroscopy Theory, Experiment, and Applications, Wiley-Interscience, 2nd Edition, 2005. |
| 5. | Shriram S, Kandler S, Jeremy N, Gi-Heon K, Ahmad P, Matthew K, Design and Analysis of Large Lithium-Ion Battery Systems, Artech House, 2014. |

**Course Outcomes (CO)**

At the end of the course student will be able.

| | |
|---|---|
| **CO1** | Asses electrode & electrolyte properties, electrode potentials and distinguish different reference electrodes |
| **CO2** | Explain importance of electrode-electrolyte interface and kinetics occurring at the interfaces |
| **CO3** | Analyze and apply different DC and AC electrochemical techniques |
| **CO4** | Explain mechanisms involved and applications of different electrochemical techniques |

| Course Code | Course Title | CO | Course outcomes At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT671 | Advanced Electrochemical Techniques | CO1 | Asses electrode & electrolyte properties, electrode potentials and distinguish different reference electrodes | H | L | M |
| | | CO2 | Explain importance of electrode-electrolyte interface and kinetics occurring at the interfaces | H | M | H |
| | | CO3 | Analyse and apply different DC and AC electrochemical techniques | H | H | M |
| | | CO4 | Explain mechanisms involved and applications of different electrochemical techniques | M | L | M |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT672** |
| **Course Title** | **:** | **DEVELOPMENTS IN IRON MAKING AND STEEL MAKING** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | **To study the concepts and various processing techniques involved in the field of iron and steel making.** |

**Course Content**

- Principles of ferrous process metallurgy; review of related concepts from metallurgical thermodynamics and kinetics; sequence of operations in steel plants; basic aspects of furnaces, refractories and fuels; differences between the production of carbon steels and highly alloyed steels
- Overview of iron making, steel making, refining and continuous casting processes; indicative process calculations; environmental considerations; quality issues in steel plant operations
- Modifications of steel making converter operations; developments such as sub lance and dynamic control of steel making, secondary treatment including ladle metallurgy and injection metallurgy; continuous steel making; illustrative numerical problems
- Modifications of continuous casting process; developments such as flow control devices in tundish, sequence casting, high speed casting, detection / prevention of caster breakouts, electromagnetic stirring, thin slab casting; strip casting; illustrative numerical problems
- Current research on metallurgical slags, measurement of critical properties, use of process modeling; design and selection of slags and refractories; discussion on related binary and ternary phase diagrams

**References**


| | |
|---|---|
| 1. | *Current literature on related topics.* |
| 2. | *Tupkary R.H., 'Introduction to Modern Steel Making', Khanna Publishers, 2004 (primary text).* |
| 3. | *Bashforth G.R, 'Manufacture of Iron and Steel', Volume I - IV, Asia Publications, 1996.* |
| 4. | *B. Deo, R. Boom, 'Fundamentals of steel making metallurgy', Prentice Hall International, New York,1993 (primary reference).* |
| 5. | *Continuous casting – Vol. 1, 'Chemical and Physical Interactions during transfer operations', Iron andSteel Society, Warrendale, PA, USA, 198.* |


**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | Understand the basics of metallurgy involved in iron and steel making |
| **CO2** | Describe the overview of processing of iron and steel |
| **CO3** | Understand the recent developments, modifications, and applications in the iron and steel making process and apply them in real time problems associated with the making of iron and steel industry |

| Course Code | Course Title | CO | Course outcomes At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT672 | Developments In Iron Making and Steel Making | CO1 | Understand the basics of metallurgy involved in iron and steel making. | H | L | H |
| | | CO2 | Describe the overview of processing of iron and steel. | M | H | M |
| | | CO3 | Understand the recent developments, modifications, and applications in the iron and steel making process and apply them in real time problems associated with the making of iron and steel industry. | H | M | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT673** |
| **Course Title** | **:** | **ADDITIVE MANUFACTURING** |
| **Type of Course** | **:** | OE |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To know the principal methods, areas of usage, possibilities and limitations as well as environmental effects of the Additive Manufacturing technologies |
| **CLO2** | To be familiar with the characteristics of the different materials those are used in Additive Manufacturing. |

**Course Content**

- Overview – History – Need-Classification -Additive Manufacturing Technology in product development-Materials for Additive Manufacturing Technology – Tooling – Applications.
- Basic Concept – Digitization techniques – Model Reconstruction – Data Processing for Additive Manufacturing Technology: CAD model preparation – Part Orientation and support generation – Model Slicing –Tool path Generation – Softwares for Additive Manufacturing Technology: MIMICS, MAGICS.
- Classification – Liquid based system – Stereolithography Apparatus (SLA) - Principle, process, advantages and applications – Solid based system –Fused Deposition Modeling Principle, process, advantages and applications, Laminated Object Manufacturing, Wire Arc Additive Manufacturing
- Selective Laser Sintering – Principles of SLS process – Process, advantages and applications, Three-Dimensional Printing – Principle, process, advantages and applications- Laser Engineered Net Shaping (LENS), Electron Beam Melting.
- Customized implants and prosthesis: Design and production. Bio-Additive Manufacturing- Computer Aided Tissue Engineering (CATE) – Case studies

**References**


| | |
|---|---|
| 1. | *Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing, 2nd Ed. (2015), Ian Gibson, David W. Rosen, Brent Stucker* |


**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | Upon completion of this course, the students can able to compare different methods and discuss the effects of the Additive Manufacturing technologies |
| **CO2** | Analyse the characteristics of the different materials in Additive Manufacturing |
| **CO3** | Select the appropriate techniques according to the applications |

| Course Code | Course Title | CO | Course outcomes At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT673 | Additive Manufacturing | CO1 | Upon completion of this course, the students can be able to compare different methods and discuss the effects of the Additive Manufacturing technologies. | H | L | H |
| | | CO2 | Analyse the characteristics of the different materials in Additive Manufacturing. | M | H | H |
| | | CO3 | Select the appropriate techniques according to the applications. | M | L | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT674** |
| **Course Title** | **:** | **Phase transformations** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | Physical Metallurgy |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To become familiar with various phase transformation processes and their influence on structure-property correlations |
| **CLO2** | To understand the classical nucleation theory and different modes of solidification |
| **CLO3** | To develop a comprehensive understanding on Fe-Fe3C Phase diagram and Time–Temperature Transformation diagram and study their structural transformation with varying temperature |
| **CLO4** | To study the kinetics and mechanism of solid-solid phase transformation and understand the structure –property relation |

**Course Content**

Introduction to phase transformations & classification. Diffusion in solids: phenomenological approach and atomistic approach. Nucleation and growth theories of vapour to liquid, liquid to solid, and solid to solid transformations, Partitionless solidification

Homogeneous and heterogeneous strain energy effect during nucleation; Thermodynamics of solidification, evolution of microstructures in pure metals and binary alloys.

Precipitation from solid solution: types of precipitation reactions, crystallographic description of precipitates, precipitation sequence and age hardening, Precipitate coarsening, spinodal decomposition.

Iron-carbon system: Thermodynamics of peritectic, eutectic, and eutectoid transformations. nucleation and growth of equilibrium phases and non-equilibrium transformations. Diffusion less transformation.

Interface-controlled growth and diffusion-controlled growth;Kolmogorov-Johnson-Mehl-Avrami (KJMA) kinetics, TTT and CCT diagrams, precipitate coarsening

**References**


| | |
|---|---|
| 1. | Porter, D.A, Easterling, K.E., and Sherif, M.A., Phase transformations in metals and alloys, 3rd Ed,<br>CRC press, 2017. |
| 2. | Reza Abbaschian, Robert E. Reed-Hill, Physical Metallurgy Principles, Cengage Learning, 2008 |
| 3. | Lakhtin Y., ‘Engineering Physical Metallurgy’, 2nd Edition, University Press of the Pacific, 2000 |
| 4. | Prabhu Dev K. H., ‘Handbook of Heat Treatment of Steel’, McGraw Hill Education, 2003 |

| | |
|---|---|
| 5. | Avner S.H., 'Introduction to Physical Metallurgy', 2nd edition, Tata McGraw Hill, 1984 |


**Course Outcomes (CO)**

At the end of the course student will be able.

| | |
|---|---|
| **CO1** | To understand the nucleation and growth theories relevant to phase transformation |
| **CO2** | To understand the evolution of microstructures in pure metals and binary alloys. |
| **CO3** | To understand the different mechanisms of phase transformation (diffusion, diffusionless, massive, spinodal decomposition). |
| **CO4** | To apply the TTT and CCT diagrams to design a heat treatment cycle for a given alloy. |

| **Course Code** | **Course Title** | **CO** | **Course outcomes** **At the end of the course, students will be able** | **PO1** | **PO2** | **PO3** |
|---|---|---|---|---|---|---|
| MT674 | Phase Transformation | CO1 | To understand the nucleation and growth theories relevant to phase transformation | H | L | M |
| | | CO2 | To understand the evolution of microstructures in pure metals and binary alloys. | H | L | H |
| | | CO3 | To understand the different mechanisms of phase transformation (diffusion, diffusion less, massive, spinodal decomposition). | H | L | H |
| | | CO4 | To apply the TTT and CCT diagrams to design a heat treatment cycle for a given alloy. | H | H | L |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT675** |
| **Course Title** | **:** | **Crystallography** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | Nil |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To become familiar with basics of crystal systems and lattices. |
| **CLO2** | To get adapted with various crystallographic symmetries, point groups and space groups and also understand the correlation between symmetry and properties |
| **CLO3** | To get acquainted with different types of solid solutions and other compounds |
| **CLO4** | To become familiar with crystallographic defects and their interactions and understand how defects determine the properties |

**Course Content**

Motif, lattices, lattice points, lattice parameter, Crystal systems, 14 Bravais lattices, Coordination number, number of atoms per unit cell, packing factor, Miller indices of planes directions, repeat distance, linear density packing factor along a direction, planar density, planar packing fraction

Symmetry and crystallography. Symmetry in crystals. Rotational symmetry, stereographic projections. Crystallographic point groups, micro translations, symmetry of reciprocal lattice, systematic absences, space groups special position.

Radius ration for coordination number 2,4,6,8. Interstitial solid solution, Interstitial compounds. AX, AX2, AB03 A 2B04 crystal structures.

Frenkel- Schottky ionic defects, Ionic defect concentration, solute incorporation, electronic defect electronic defect concentration

Band Gap, density of states, defects. Defects and chemical reaction.

**References**



| | |
|---|---|
| 1. | Christopher Hammond, The Basics of Crystallography and Diffraction, Oxford Science Publications, third edition, 2009 |
| 2. | Donald R. Askeland and Pradeep phule, The science and Engineering Materials.Thmson,2003 |
| 3. | Cullity B.D., Elements of X-ray diffraction, Addison-Wesley Publishing company 1956 |

**Course Outcomes (CO)**

At the end of the course student will be able.

| | |
|---|---|
| **CO1** | To distinguish different crystal structure and their characteristics |
| **CO2** | To understand the different symmetry in the crystal systems and their importance |
| **CO3** | To identify and characterize the various ionic and electronic defects in crystal structure |
| **CO4** | To demonstrate the importance of band gap and density of states in material properties. |

| Course Code | Course Title | CO | Course outcomes At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT675 | Crystallography | CO1 | To distinguish different crystal structure and their characteristics | H | L | H |
| | | CO2 | To understand the different symmetry in the crystal systems and their importance | H | L | H |
| | | CO3 | To identify and characterize the various ionic and electronic defects in crystal structure | H | H | L |
| | | CO4 | To demonstrate the importance of band gap and density of states in material properties. | H | M | M |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT676** |
| **Course Title** | **:** | **Particulate Technology** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | **To introduce the importance non-conventional processing routes for different materials and its importance for advanced materials manufacturing.** |

**Course Content**

- **Introduction to particulate /powder processing:** Historical development, merits and limitations of this process over other conventional manufacturing methods and applications of particulate processing. Stages of powder metallurgy process in design and manufacturing of full shape components
- **Attributes of powders:** Chemical purity, microstructure, size & distribution, shape, surface area, bulk properties (powder density: apparent density, tap density, flow rate, compressibility, Standards for powder characterizations, procedure and analysis of powder characteristics, Relate the powder attributes in components manufacturing
- **Particulates / powders fabrication methods:** Mechanical methods, Chemical methods and Physical methods., Customizing process parameters to tailor the powders, Advances in powder manufacturing methods. Powders for specific engineering applications such as additive manufacturing, automobile, magnetic materials, etc.
- **Shaping and Compaction:** Binder assisted pressure less compaction (Slip & slurry casting, extrusion and injection moulding), precursor preparation and mould design
- Pressure assisted compaction: Selection of press and die design, pressure selection upon density, selection of lubrications (both internal and externals) Understanding compaction mechanism and measure the green density and strength, relate green density with pressure and strength. Compaction methods: Die compaction, high velocity compaction, warm compaction, powder rolling, Alternative new pressing technologies, Pressure and temperature assisted powder consolidation: Hot pressing, spark plasma sintering, etc.
- **Sintering:** Fundamental, Sintering theory, sintering diagrams, Effect of compaction on sintering, Sintering types and variables, Solid state sintering, Liquid phase sintering, Sintering equipment and practical sintering operations, Full density methods, Spray forming methods
- **Finishing operation / post-sintering processes:** Repressing, machining, heat treatment, etc. Inspection methods and characterization of sintered components (microstructure, porosity, density, mechanical properties, etc.)
- **Applications:** Structural components, Friction materials, Wear resistant materials, Magnetic materials, etc.
- New development in particulate technology

**References**


| | |
|---|---|
| 1. | *German R.M., 'Powder Metallurgy Science', Metal Powder Industries Federation, New Jersey, 1994* |
| 2. | *Kuhn H. A. and Alan Lawley, 'Powder Metallurgy Processing - New Techniques and Analysis', OxfordIBH, Delhi, 1978.* |

**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | Describe the basic mechanism of powder production for variety of materials to meet the demand of the research and industrial needs |
| **CO2** | Characterize the various powders (materials) based on the engineering applications Differentiate the processing routes for various powders (materials) and associated technology |
| **CO3** | Define modern day processing routes and apply them successfully tomaterials processing |
| **CO4** | Apply the powder metallurgy concepts to design new materials for advanced engineering materials |
| **CO5** | Apply the concepts of particulate processing to produce non-conventional materials which are difficult to produce other techniques |

| Course Code | Course Title | CO | Course outcomes At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT676 | Particulate Technology | CO1 | Describe the basic mechanism of powder production for variety of materials to meet the demand of the research and industrial needs. | H | L | H |
| | | CO2 | Characterize the various powders (materials) based on the engineering applications Differentiate the processing routes for various powders (materials) and associated technology. | H | H | M |
| | | CO3 | Define modern day processing routes and apply them successfully to materials processing. | H | M | H |
| | | CO4 | Apply the powder metallurgy concepts to design new materials for advanced engineering materials. | M | L | H |
| | | CO5 | Apply the concepts of particulate processing to produce non-conventional materials which are difficult to produce other techniques. | M | L | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT677** |
| **Course Title** | **:** | **PROCESS MODELING** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | **To provide an understanding of the basic principles of modeling and use those methods to analyze and solve metallurgical Processes.** |

**Course Content**

- Mathematical modeling, physical simulation, advantages and limitations; process control, instrumentation and data acquisition systems
- Review of transport phenomena, differential equations & numerical methods; concept of physical domain and computational domain, assumptions and limitations in numerical solutions, introduction to FEM & FDM, examples
- Introduction to software packages– useful websites and generic information about different products - ANSYS, Thermocalc, CFD; usage of expert systems, artificial intelligence and robotics; demonstration of some software packages
- Physical modeling – cold and hot models; case studies of water models, use of computers for the construction of phase diagrams, alloy design, crystallography, phase transformations and thermo chemical calculations.
- Case studies from literature – pertaining to modeling of solidification / heat transfer, fluid flow, casting, welding and liquid metal treatment

**References**


| | |
|---|---|
| 1. | Szekely J., Themelis N. J., 'Rate Phenomena in Process Metallurgy', Wiley, 1971 |
| 2. | P.S. Ghosh Dastidar, "Computer Simulation of Flow and Heat Transfer", Tata McGraw Hill, New Delhi, 1998 |


**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | understand the capabilities provided by various modeling methods |
| **CO2** | analysis methods and apply the appropriate ones to solve real problems |
| **CO3** | gain hands-on experience in using software packages |

| **Course Code** | **Course Title** | **CO** | **Course outcomes At the end of the course, students will be able** | **PO1** | **PO2** | **PO3** |
|---|---|---|---|---|---|---|
| MT677 | Process Modeling | CO1 | Understand the capabilities provided by various modeling methods. | H | L | M |
| | | CO2 | Analysis methods and apply the appropriate ones to solve real problems. | H | M | H |
| | | CO3 | Gain hands-on experience in using software packages. | M | L | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT678** |
| **Course Title** | **:** | **Advanced Material Characterization Techniques** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | Nil |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

## Course Learning Objectives (CLO)

| | |
|---|---|
| **CLO1** | To become familiar with advanced microscopy techniques |
| **CLO2** | To understand application of various advanced microscopy techniques in materials engineering |
| **CLO3** | To understand the post processing of results from various advanced characterization techniques |

## Course Content

Electron back scattered diffraction –working principle, imaging, post-processing and orientation analysis, application
Transmission kikuchi diffraction -working principle, imaging, post-processing analysis, application, TKD vs EBSD, TKD vs TEM, TKD vs APT
Aberration-corrected Transmission electron microscopy –basic principle, construction and operation, high resolution imaging, applications
X-ray microscopy -principle, construction and operation, sample preparation, application and limitations, X-ray tomography
Atom probe tomography –principle, construction and operation, sample preparation, IVAS software, post processing and 3D construction, application and limitations

## References


| | |
|---|---|
| 1. | Micheal K Miller Richard G. Forbes, Atom probe tomography: The local electrode atom probe, Springer New York, 2014. |
| 2. | Chris Jacobsen, X ray Microscopy, Cambridge University Press, 2019 |
| 3. | Adam J. Schwartz, Brent L. Adams, Mukul Kumar, Electron Back Scattered diffraction in Material Science, 2nd Edition, Springer 2010 |
| 4. | Glenn C. Sneddon, Patrick W. Trimby, Julie M. Cairney, Transmission Kikuchi diffraction in a scanning electron microscope: A review, Material Science and Engineering R: Reports, 2016 |
| 5. | C. Barry Carter and David B Williams, Transmission Electron Microscopy: Diffraction, Imaging and spectrometry, Springer 2016 |


## Course Outcomes (CO)

At the end of the course student will be able

| | |
|---|---|
| **CO1** | To understand the working principle of various advanced characterization techniques |
| **CO2** | To choose a characterization technique to analyze various features of materials at sub-micro scale |
| **CO3** | To interpret results of advanced characterization techniques |

| Course Code | Course Title | CO | Course outcomes At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT678 | Advanced material characterization techniques | CO1 | To understand the working principle of various advanced characterization techniques | H | L | H |
| | | CO2 | To choose a characterization technique to analyze various features of materials at sub-micro scale | H | L | H |
| | | CO3 | To interpret results of advanced characterization techniques | H | L | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT679** |
| **Course Title** | **:** | **NON-DESTRUCTIVE TESTING** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| CLO1 | To impart knowledge in Non-Destructive Testing and understand the practical importance of Non-Destructive testing methods in engineering with appropriate case studies. |

**Course Content**

- Visual Inspection- tools, applications and limitations. Liquid Penetrant Inspection - principles, types and properties of penetrants and developers. Advantages and limitations of various methods of LPI. Magnetic particle inspection- principles, instrumentation, applications, advantages and limitations.
- Ultrasonic testing (UT) - Nature of sound waves, wave propagation - modes of sound wave generation - Various methods of ultrasonic wave generation, types of UT, Principles, instrumentation, applications, advantages, limitations, A, B and C scan - Time of Flight Diffraction (TOFD).
- Radiography testing (RT) – Principles, instrumentation, applications, advantages and limitations of RT. Types and characteristics of X ray and gamma radiation sources, Principles and applications of Fluoroscopy/Real-time radioscopy - advantages and limitations - recent advances.
- Eddy current testing - Principles, types, instrumentation, applications, advantages and limitations of eddy current testing.
- Acoustic emission testing - Principles, instrumentation, types of signals and noises, applications, advantages and limitations of acoustic emission testing.
- Thermography - Principles, types, applications, advantages and limitations. Optical & Acoustical holography- Principles, types, applications, advantages and limitations. Case studies: weld, cast and formed components.
- Application of Industrial Internet of Things (IIoT) on NDT inspections.

**References**


| | |
|---|---|
| 1. | *Practical Non – Destructive Testing, Baldev raj, Narosa Publishing House (1997).* |
| 2. | *Non-Destructive Testing, B.Hull and V.John, Macmillan (1988)* |
| 3. | *Krautkramer, Josef and Hebert Krautkramer, Ultrasonic Testing of Materials, 3rd edition, New York, Springer-Verlag (1983).* |


**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | Understand the basics of Non-destructive testing |
| **CO2** | Describe the overview of Non-destructive testing methods |
| **CO3** | Understand the recent developments, modifications, and applications in Non-destructive testing and apply them in real-time problems associated with failure analysis and regular quality testing for industries |

| Course Code | Course Title | CO | Course outcomes<br>At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT679 | Non-Destructive Testing | CO1 | Understand the basics of Non-destructive testing. | H | L | H |
| | | CO2 | Describe the overview of Non-destructive testing methods. | H | H | L |
| | | CO3 | Understand the recent developments, modifications, and applications in Non-destructive testing and apply them in real-time problems associated with failure analysis and regular quality testing for industries. | H | M | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT741** |
| **Course Title** | **:** | **STAINLESS STEEL TECHNOLOGY** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To introduce the importance of metallurgical aspects for various types of steel and its importance for advanced manufacturing methods |

**Course Content**

Metallurgy and Properties of Wrought Stainless Steels, Metallurgy and Properties of Cast Stainless Steels, melting practice in special steel and stainless steel technology, Powder Metallurgy of Stainless Steels, Stainless Steel Cladding and Weld Overlays, Melting and Refining Methods, Recycling Technology.

Atmospheric and Aqueous Corrosion, Stress-Corrosion Cracking and Hydrogen Embrittlement, High-Temperature Corrosion, Corrosion of cast Stainless Steels, Corrosion of Weldments. ASTM and EN standards on corrosion resistance testing.

Forming, Forging and Extrusion, Heat Treatment, Machining, Welding, Brazing, Soldering and Adhesive Bonding. Surface Engineering.

Metallographic Practices for Wrought Stainless Steels, Microstructures of Wrought Stainless Steels, Metallography and Microstructure of Cast Stainless Steels, PhaseDiagrams.

Physical Properties, Low-Temperature Properties, Elevated-Temperature Properties, Tribological Properties, Duplex stainless steels and Martensitic stainless steels – Manufacture, Heat Treatment, Corrosion behavior and welding, applications of stainless steels

**References**


| | |
|---|---|
| 1. | J.R.Davis, “Stainless steels”, ASM speciality Hand Book ASTM International, 1996 |
| 2. | *ASM, “Source Book of Stainless Steel”, ASM Publisher, 1977* |
| 3. | *Peckner.D Bernstein.I.M, “Handbook of Stainless Steel”, McGraw Hill Book Co. New York, 1977.* |


**Course outcomes**:

By successful completion of this course, the student will be able to

| | |
|---|---|
| **CO1** | Review of the selection of stainless steels for use in corrosive environments |
| **CO2** | Describe the practical aspects of forming, heat treating, machining, joining and surface engineering of stainless steel |
| **CO3** | To get the knowledge of phase diagram, metallography and microstructures of various types of stainless steel |

| Course Code | Course Title | CO | Course Outcomes<br>At the end of the course student will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT741 | Stainless steel technology | CO1 | Review of the selection of stainless steels for use in corrosive environments | M | L | M |
| | | CO2 | Describe the practical aspects of forming, heat treating, machining, joining and surface engineering of stainless steel | M | L | M |
| | | CO3 | To get the knowledge of phase diagram, metallography and microstructures of various types of stainless steel | H | L | M |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT742** |
| **Course Title** | **:** | **DESIGN OF CASTINGS & WELDMENTS** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | General rules for designing of economical moulding and coring |
| **CLO2** | Design of gating and risering for various metals used in the casting |
| **CLO3** | Appropriate selection of casting design in economical manner for the manufacturing components in industries |
| **CLO4** | Design weld joins operating under static and dynamic loading conditions. |
| **CLO5** | Analyze and predict the life of weld joints using the concepts of fracture mechanics and identifying the effects of stress concentration build up. |

**Course Content**

Designing for economical moulding – designing for sand moulding – investment castings. Design for economical coring – general rules for designing cored holes. Design problems involving thin sections, uniform sections unequal sections. Considering metal flow, riser location, feed path, mould-metal temperature effect.

Design problems involving junctions, distortion – possible design remedies. Dimensional variations and tolerances – influence of cores – influence of location of cores. Dimensions for inspection and machining. Surface finish ISI specification, effect of mould material, parting line, fillet influences. Design of gating andrisering for ferrous and non-ferrous metals

Types of joints, joint efficiency, edge preparation, types of loads, design for static lading, design for cyclic loading, rigid structures, primary and secondary welds, treating a weld as a line, structural tubular connections, influence of specifications on design, symbols for welding and inspection, estimating and control of welding costs. Residual stresses, causes and effects, methods to measure residual stresses, weld distortion.

Welding procedure specifications, welding procedure qualifications, welder performance qualifications, welding variables, filler metal qualifications, qualification of welding inspectors, welding supervisors and welding engineers, qualification of NDT personnel.

**References:**


| | |
|---|---|
| 1 | “Casting.Design Hand Book” , American Society for Metals,1962 |
| 2 | *Matousek R., “Enginering Design”.,Blackwell Scientific Publications.,1962* |
| 3 | *Heine, Loper and Rosenthal, “Principles of Metal Casting”, Tata McGraw Hill Publishing Co,1995.* |
| 4 | *Harry Peck, “Designing for Manufacture”, Pitman Publications, 1983.* |

**Course outcomes**: By successful completion of this course, the student will be able to

| | |
|---|---|
| **CO1** | Gain knowledge of the function of the different parts of the mold during the manufacture of the cast part. |
| **CO2** | Casting design issues and practices through standards |
| **CO3** | Develop key steps in new casting and can help in reduce the time involved |
| **CO4** | Design problems involving thin sections in various types of castings |
| **CO5** | To improve the casting quality by analyzing the various parameters related to cast product,tooling and process on manufacturability |
| **CO6** | Design weld joints for strength and rigidity under static loading conditions |
| **CO7** | Identify the various types of stresses and distortions to a component during welding and takes measures to minimize or eliminate such effects |

| Course Code | Course Title | CO | Course Outcomes<br>At the end of the course student will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT742 | Design of castings & weldments | CO1 | Gain knowledge of the function of the different parts of the mold during the manufacture of the cast part. | M | L | M |
| | | CO2 | Casting design issues and practices through standards | H | L | H |
| | | CO3 | Develop key steps in new casting and can help in reduce the time involved | M | L | M |
| | | CO4 | Design problems involving thin sections in various types of castings | M | L | M |
| | | CO5 | To improve the casting quality by analyzing the various parameters related to cast product, tooling and process on manufacturability | H | L | H |
| | | CO6 | Design weld joints for strength and rigidity under static loading conditions | H | L | M |
| | | CO7 | Identify the various types of stresses and distortions to a component during welding and takes measures to minimize or eliminate such effects | M | M | M |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT743** |
| **Course Title** | **:** | **ADVANCED MATERIALS PROCESSING** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To introduce the importance non-conventional processing routes for different materials and its importance for advanced materials manufacturing. |

**Course Content**:

Structure of liquid metals, macrostructure of pure metals and alloys-Typical casting alloys, specifications, properties, industrial applications, melting and composition control, deoxidation, gating and risering techniques.

Introduction-structure of nanomaterials- classification of production methods- Nanomaterials-Preparation Techniques-Sol-gel method, combustion synthesis, evaporation and condensation method – Examples. Nanoceramics for electrical, magnetic, mechanical and structural functions-applications.

Pure metals, alloys, intermetallics, immiscible alloy systems and composites; their preparation and applications

Mechanical alloying-processing capabilities-process parameters - Examples of material synthesized - Rapid Solidification Processing - Melt spinning, atomization techniques - examples - Self Propagating High Temperature Synthesis - Process - Advantages - examples.

Consolidation techniques for ceramics and metallic powders-Die compaction -Hotpressing, Cold and Hot Isostatic Pressing, Powder extrusion, Equal Channel Angle Process

**References:**


| | |
|---|---|
| 1 | Nobru.H.Ichinose, "Introduction to Fine Ceramics", Butterworth-Heinman Ltd, NY,1992 |
| 2 | Metals Handbook Vol. 9 "Powder Metallurgy" ASM Metals Park, Ohio, 1991. |


**Course outcomes**: At the end of this course, the students would be able to:

| | |
|---|---|
| **CO1** | Describe the basic mechanism of powder production for variety of materials to meet the demand of the research and industrial needs |
| **CO2** | Characterize the various powders, nanomaterials (materials) based on the engineering applications |
| **CO3** | Differentiate the processing routes for different materials like metallic glass (materials) and associated technology like Rapid Solidification Processing |
| **CO4** | Define modern day processing routes and apply them successfully to new materials processing for aerospace and aeronautical applications |
| **CO5** | Apply the powder metallurgy concepts to synthesis new materials |

| Course Code | Course Title | CO | Course Outcomes<br>At the end of the course student will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT743 | Advanced materials processing | CO1 | Describe the basic mechanism of powder production for variety of materials to meet the demand of the research and industrial needs | H | L | M |
| | | CO2 | Characterize the various powders, nanomaterials (materials) based on the engineering applications | M | L | M |
| | | CO3 | Differentiate the processing routes for different materials like metallic glass (materials) and associated technology like Rapid Solidification Processing | M | L | M |
| | | CO4 | Define modern day processing routes and apply them successfully to new materials processing for aerospace and aeronautical applications | M | L | M |
| | | CO5 | Apply the powder metallurgy concepts to synthesis new materials | M | L | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT744** |
| **Course Title** | **:** | **SPECIAL CASTING PROCESSES** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To increase the production rate, affecting economy and improving the quality of the castings. |
| **CLO2** | To develop components of intricate shape and design by properly selecting the mouldingand casting techniques. |

**Course Content**:

Introduction to special casting techniques-Shell moulding machines - pattern equipment - sands, resins and other materials used in shell moulding - closing of shells - dimensional tolerances -applications of shell moulding - comparison of shell moulding with other competitive methods.

Types of centrifugal casting processes - calculation of mould rotary speeds - techniques and equipment used in production processes - advantages and limitations of centrifugal casting methods.

Introduction - Pattern and mould materials used in investment casting - technique and production of investment moulds and castings - dimensional tolerances - applications of investment casting process - Shaw process - comparison with other processes - full mould process.

Die casting machines - operation details - die materials - materials cast by die casting method. Die design - comparison with other processes. low pressure die casting. Metal Injection Moulding.

Fluid sand process - V Process - Rheo,thixo and compo casting processes - squeeze casting, Magnetic moulding, Hot box process, cold box process. No-bake processes, Graphite moulding process, Plaster moulding process-High Pressure moulding and continuous casting

**References:**


| | |
|---|---|
| 1 | Beeley, P.R., “Foundry Technology”,2nd edition, Butterworths, Heinmann, oxford,2001. |
| 2 | Clegg,A.J.,"Precision Casting Processes",Pergamon Press,London,U.K,1991 |
| 3 | Barton,H.K., “Die Casting Processes”, Odhams Press Ltd,1985. |
| 4 | Dumond,T.C.,"Shell Moulding and Shell Moulded Castings",ReReinhold publishing corporation Inc.,1984 |
| 5 | Doehler,E.h.,"Die casting",McGraw Hil Book Co,Newyork,1991 |
| 6 | Heine, Loper and Rosenthal, “Principles of Metal Casting”, Tata McGraw Hill Publishing Co,1995 |
| 7 | “ASM Handbook”, Vol. 15, Casting, ASM Publication, 1998. |

**Course outcomes**: At the end of this course, the students would be able to:

| | |
|---|---|
| **CO1** | Select the appropriate pattern equipment used for shell moulding |
| **CO2** | Techniques and equipment used in centrifugal casting and its types |
| **CO3** | Reinforce the understanding the concepts of patterns and mould materials used in investmentcasting |

| Course Code | Course Title | CO | Course Outcomes<br>At the end of the course student will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT744 | Special Casting Processes | CO1 | Select the appropriate pattern equipment used for shell moulding | M | L | M |
| | | CO2 | Techniques and equipment used in centrifugal casting and its types | M | L | M |
| | | CO3 | Reinforce the understanding the concepts of patterns and mould materials used in investment casting | H | L | M |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT745** |
| **Course Title** | **:** | **SPECIAL TOPICS IN METAL FORMING** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To become familiar with forming processes apart from the conventional forming techniques. |

**Course Content:**

High velocity forming – comparison with conventional forming – Explosive forming - explosives – detonation velocity of explosives – energy transfer media – safety circuit – process parameters – application of explosive forming

Petro forge system – rubber pad forming – electromagnetic forming coil requirements – effect of work

piece dimensions and conductivity - applications – electro hydraulic forming – types of electrodes – applications

Superplastic forming – superplasticity – definition - components – mechanism of superplastic deformation – diffusion bonding – superplastic forming and diffusion bonding – methods of forming Severe plastic deformation – ECAP -types- microstructural variations with processing route – cryo rolling – process- types – stress strain distribution

Severe plastic deformation by mechanical alloying – types – equipment – compaction – sintering – mechanism of sintering

**References:**


| | |
|---|---|
| 1 | Hosford W.F and Caddell, ‘ Metal forming mechanics and metallurgy” Prentice Hall, 1983 |
| 2 | Explosive forming process and techniques – A.A.Ezra, Prentice Hall, 1980 |
| 3 | ASM metals Handbook, Volume 5, 1984 |
| 4 | Padmanabhan K A and G.J.Davis, Superplasticity, Springer Verlag, Berlin Heidberg, NY, 1980. |
| 5 | Mahmood Aliofkhazraei (Editor) “Handbook of Mechanical Nanostructuring” Wiley-VCH Verlag GmbH & Co, Germany, 2015 |


**Course outcomes**: At the end of this course, the students would be able to:

| | |
|---|---|
| **CO1** | Understand the non-conventional metal forming methods |
| **CO2** | Select the appropriate technique for forming components |
| **CO3** | Understand superplastic forming techniques |
| **CO4** | Understand top-down approaches in severe plastic deformation |
| **CO5** | Understand bottom-up approaches in severe plastic deformation |

| Course Code | Course Title | CO | Course Outcomes<br>At the end of the course student will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT745 | Special topics in metal forming | CO1 | Understand the non-conventional metal forming methods | M | L | M |
| | | CO2 | Select the appropriate technique for forming components | M | L | M |
| | | CO3 | Understand superplastic forming techniques | M | L | M |
| | | CO4 | Understand top-down approaches in severe plastic deformation | M | L | H |
| | | CO5 | Understand bottom-up approaches in severe plastic deformation | M | L | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT746** |
| **Course Title** | **:** | **THERMODYNAMICS OF SOLIDIFICATION** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | A study of important thermodynamic functions related to solidification of metal in molds involving the characteristics of liquid-solid phase transformations, laws of thermodynamics and other functions. |
| **CLO2** | To analyze solidification processing of engineering materials in terms of the phase equilibrium, transport, and interface phenomena governing microstructure development in liquid-solid transformations. |
| **CLO3** | To apply these principles to industrial solidification processes, with emphasis on microstructural capabilities and limitations. |

**Course Content**:

Introduction and important thermodynamic functions: Laws of thermodynamics-enthalpy, heat capacity, applications of first law to open and closed systems including chemical reactions; entropy, free energy and their interrelationships

Thermodynamics of solidification; Nucleation and growth; Pure metal solidification, Alloy Solidification, Constitutional undercooling, Mullins-Sekerka instability; Single phase solidification: Cellular and Dendritic growth; Multiphase solidification: eutectic, peritectic and monotectic; Modeling of solidification

Heterogeneous systems –equilibrium constants, Ellingham-Richardson diagrams,predominant area diagrams, principles of free energy minimization; energy balance of industrial systems; solutions-chemical potential, Raoult/Henry's law, Gibbs-Duhem equations, regular solutions, quasi chemical theory

Evolution of Phase diagrams -phase rule, free-energy-composition diagrams, solidus-liquidus lines, retrograde solidus; determination of activity and other thermodynamic parameters from phase diagrams, thermodynamic analysis of ternary and multi component systems, interaction parameters

Principles of applications- principles of applications to molten slags and silicate melts; electrochemical methods and applications, aqueous systems; Interfaces-energy,shape, segregation at external and internal interfaces; solid electrolytes; Effect of high pressure on phase transformations; Point imperfections in crystalline solids.

**References:**


| | |
|---|---|
| 1 | Solidification Processing; Fleming, M.C., McGraw-Hill, N.Y., 1974 |
| 2 | Fundamentals of Solidification by Kurz, W. and Fisher, D.J., Trans-Tech Publications, Switzerland, 1989 |

**Course outcome:**

The students will be able to analyze and understand the

| | |
|---|---|
| **CO1** | Thermodynamics of solidification processes and alloys. |
| **CO2** | Thermodynamic modeling of solid-liquid phase change and solutions |
| **CO3** | Kinetics of solidification such as nucleation, growth, and constitutional super cooling |

| Course Code | Course Title | CO | Course Outcomes<br>At the end of the course student will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT746 | Thermodynamics of Solidification | CO1 | Thermodynamics of solidification processes and alloys. | M | L | M |
| | | CO2 | Thermodynamic modeling of solid-liquid phase change and solutions | M | M | M |
| | | CO3 | Kinetics of solidification such as nucleation, growth, and constitutional super cooling | H | L | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT747** |
| **Course Title** | **:** | **Modeling and Simulation of Metal Processing** |
| **Type of Course** | **:** | PE |
| **Prerequisites** | **:** | Nil |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

## Course Learning Objectives (CLO)

| | |
|---|---|
| **CLO1** | To become familiar with importance of modeling and simulation of metal processing |
| **CLO2** | To understand fundamentals of modeling and simulation of casting and solidification processes. |
| **CLO3** | To learn modeling and simulation techniques for metal forming and joining processes |
| **CLO4** | To learn the basics of thermomechanical modeling in metal additive manufacturing |

## Course Content

Metal processing: Introduction, fundamentals of metal processing, modeling and simulation of metal processing, their benefits and future perspectives.

Casting and Solidification: Introduction, fundamentals of modeling and simulation in metal casting, thermomechanical modeling of casting processes.

Metal forming: Introduction, fundamentals of metal forming processes, sheet metal forming, modeling and simulation of forming processes, thermomechanical modeling of metal forming.

Metal Joining: Introduction, fundamentals of modeling and simulation of welding processes, thermomechanical modeling of welding processes

Additive Manufacturing (AM): Introduction, fundamentals of modeling and simulation of additive manufacturing processes, thermal and stress modeling of AM processes

## References


| | |
|---|---|
| 1. | ASM Handbook Volume 22A, Fundamentals of Modeling for Metals Processing, ASM International, 2009. |
| 2. | ASM Handbook Volume 22B, Metals Process Simulation, ASM International, Materials Park, OH, 2010. |
| 3. | R. Beygi, E. Marques, L. F. M. da Silva, Computational Concepts in Simulation of Welding Processes, Springer, 2022 |
| 4. | Patrice Peyre, Éric Charkaluk, Additive Manufacturing of Metal Alloys 1: Processes, Raw Materials and Numerical Simulation, Wiley-ISTE, 2022 |
| 5. | Chris V. Nielsen, Paulo A.F. Martins, Metal Forming: Formability, Simulation, and Tool Design, Academic Press, 2021 |

**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | To perform a thermomechanical modeling of metal solidification during various casting process |
| **CO2** | To choose a suitable simulation technique for modeling and simulation of different metal forming processes. |
| **CO3** | To do thermomechanical modeling of different welding processes to optimize the process parameters. |
| **CO4** | To apply computational tools for thermal and stress modeling of different additive manufacturing processes. |

| Course Code | Course Title | CO | Course Outcomes<br>At the end of the course student will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT747 | Modeling and Simulation of Metal Processing | CO1 | To perform a thermomechanical modeling of metal solidification during various casting process | H | L | H |
| | | CO2 | To choose a suitable simulation technique for modeling and simulation of different metal forming processes. | H | L | H |
| | | CO3 | To do thermomechanical modeling of different welding processes to optimize the process parameters. | H | L | H |
| | | CO4 | To apply computational tools for thermal and stress modeling of different additive manufacturing processes. | H | L | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT761** |
| **Course Title** | **:** | **DESIGN AND SELECTION OF MATERIALS** |
| **Type of Course** | **:** | OE |
| **Prerequisites** | **:** | Metal Forming or Mechanical Behavior of Materials or Physical Metallurgy |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| CLO1 | To know different Principles of selecting materials and processes for engineering applications and methodologies for designing new materials and conceiving hybrid solutions |

**Course Content**

- Engineering materials and their properties - Technologically important properties of materials - Physical, chemical, mechanical, thermal, optical, environmental and electrical properties of materials.
- Material property charts - Modulus – density, strength-density, fracture toughness-strength, etc.
- Strategy for materials selection - Types of design, Design tools and materials data. Materials selection without shape, Materials selection involving multiple constraints and/or conflicting objectives, Methodology for selection of materials – Collection of data on availability, requirements and non-functional things- its importance to the situations – case studies
- Selection of material and shape - Materials and shape – microscopic and micro structural shape factors – limit to shape efficiency Comparison of structural sections and material indices – case studies
- Material processes and process selection - Classifying process- -systematic selection of process – Selection charts - Ranking of processes – case studies - Influence of manufacturing aspects and processing route on properties of materials and its influence on selection of materials – case studies.

**References**


| | |
|---|---|
| 1. | *Michael F. Ashby, "Materials Selection in Mechanical Design" 4$^{TH}$ edition, Butterworth-Heinemann, 2011.* |
| 2. | *Joseph Datsko, Material selection for design and manufacturing: Theory and Practice, 2$^{nd}$ edition, CRC Press, 1997* |
| 3. | *Mahmoud M. Farag, Materials and process selection for engineering design, 2$^{nd}$ edition, CRC press, 2007* |

**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | Approach to the selection of metals, ceramics, polymers, and composites required for the mechanical design |
| **CO2** | Construct and use materials properties chart to identify a small set of materials meeting mechanical, physical and cost requirements |
| **CO3** | Construct a translation table for problems involved in either multiple constraints or conflicting objectives, and systematically identify candidate materials |
| **CO4** | Use material processing charts to select suitable fabrication processes |

| Course Code | Course Title | CO | Course outcomes<br>At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT761 | Design and Selection of Materials | CO1 | Approach to the selection of metals, ceramics, polymers, and composites required for the mechanical design | L | M | H |
| | | CO2 | Construct and use materials properties chart to identify a small set of materials meeting mechanical, physical and cost requirements | M | H | L |
| | | CO3 | Construct a translation table for problems involved in either multiple constraints or conflicting objectives, and systematically identify candidate materials | L | H | M |
| | | CO4 | Use material processing charts to select suitable fabrication processes | H | M | L |

| | | |
|---|---|---|
| **Course Code** | : | **MT762** |
| **Course Title** | : | **STATISTICAL QUALITY CONTROL AND MANAGEMENT** |
| **Type of Course** | : | OE |
| **Prerequisites** | : | NIL |
| **Contact Hours** | : | 3 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | **To learn the concepts of quality control and quality management and their applications related to the manufacture of metallurgical products.** |

**Course Content**

- Quality – philosophy; cost of quality; overview of the works of Juran, Deming, Crosby, Taguchi; quality loss function; PDCA cycle; quality control; quality assurance; quality audit; vendor quality assurance.
- Quality organization; quality management; quality system; total quality management; quality awards; quality certification; typical procedure for ISO 9000, ISO 14000, QS 9000.
- Review of some calculation procedures involving statistics and probability; exposure to some applications of statistics and probability; distribution functions; normal distribution curve.
- Variations; analysis of variance – statistical tools – statistical quality control; control charts; process capability analysis; statistical process control; introduction to six sigma
- Inspection; inspection by sampling; acceptance sampling; statistical approaches; single, double and multiple sampling plans; statistical design of experiments.

**References**


| | |
|---|---|
| 1. | *Hansen B.L., P.M. Ghare, 'Quality Control and Application', PHI – EEE, 1997.* |
| 2. | *Juran J.M., and F.M.Gryna, 'Quality Planning and Analysis', McGraw Hill, New York, 2nd Edition, 1980* |


**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | Understand the basic concepts in quality control and management |
| **CO2** | Learn the statistics and probability and distribution functions related to qualitymanagement |
| **CO3** | Understand the process of inspection, sampling and their statistical approach in quality management in industry |

| Course Code | Course Title | CO | Course outcomes At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT762 | Statistical Quality Control and Management | CO1 | Understand the basic concepts in quality control and management. | H | L | L |
| | | CO2 | Learn the statistics and probability and distribution functions related to quality management. | H | L | H |
| | | CO3 | Understand the process of inspection, sampling and their statistical approach in quality management in industry. | H | L | M |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT763** |
| **Course Title** | **:** | **INTELLECTUAL PROPERTY RIGHTS** |
| **Type of Course** | **:** | OE |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | **To impart the knowledge in IPR and related areas with case studies.** |

**Course Content**

- Introduction to Intellectual Property Law – The Evolutionary Past - The IPR Tool KitPara - Legal Tasks in Intellectual Property Law – Ethical obligations in Para Legal Tasks in Intellectual Property Law - Introduction to Cyber Law – Innovations and Inventions Trade related Intellectual Property Right.
- Introduction to Trade mark – Trade mark Registration Process – Post registration Procedures – Trade mark maintenance - Transfer of Rights - Inter partes Proceeding – Infringement - Dilution Ownership of Trade mark – Likelihood of confusion - Trademarks claims – Trademarks Litigations – International Trade mark Law
- Introduction to Copyrights – Principles of Copyright Principles -The subjects Matter of Copy right – The Rights Afforded by Copyright Law – Copy right Ownership, Transfer and duration
- Right to prepare Derivative works – Rights of Distribution – Rights of Perform the work Publicity Copyright Formalities and Registrations - Limitions - Copyright disputes and International Copyright Law – Semiconductor Chip Protection Act
- Introduction to Trade Secret – Maintaining Trade Secret – Physical Secrurity – Employee Limitation - Employee confidentiality agreement - Trade Secret Law - Unfair Competation
- Trade Secret Letigation – Breach of Contract – Applying State Law. Geographic indication
- Managing intellectual property in a knowledge-based society. IPR and technology transfer, case studies.

**References**


| | |
|---|---|
| 1. | Debirag E.Bouchoux: “Intellectual Property”. Cengage learning , New Delhi |
| 2. | M.Ashok Kumar and Mohd.Iqbal Ali: “Intellectual Property Right” Serials Pub. |
| 3. | Cyber Law. Texts & Cases, South-Western’s Special Topics Collections |
| 4. | Prabhuddha Ganguli: ‘ Intellectual Property Rights” Tata Mc-Graw –Hill, New Delhi |

**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | Understand the different types of IPR |
| **CO2** | Study the fundamentals of IPR laws |
| **CO3** | Understand scope of patent, copy right, geographic indication and trade secrete |

| Course Code | Course Title | CO | Course outcomes<br>At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT763 | Intellectual Property Rights | CO1 | Understand the different types of IPR | H | L | M |
| | | CO2 | Study the fundamentals of IPR laws | H | L | H |
| | | CO3 | Understand scope of patent, copy right, geographic indication and trade secrete | H | L | L |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT764** |
| **Course Title** | **:** | **Innovation and Product Development** |
| **Type of Course** | **:** | OE |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To understand customer needs and demand for new products. |
| **CLO2** | To train for design thinking for new products |
| **CLO3** | To know various IPR issues in new product development |

**Course Content:**

Understanding Customer Needs, Organizing Product Development, and New Product Strategy and six sigma in new product development, Creating Demand for New Products

Quantitative Methods for materials selection and Cost–Benefit Analysis

Design for Manufacturing (DFM); Role of DFM in product specification and standardization

Introduction to Intellectual Property and IPR issues in new Product Development

Case studies and minor project

**References**


| | |
|---|---|
| 1. | Drew Boyd & Jacob Goldenberg (2013) Inside the Box: The Creative Method that Works for Everyone |
| 2. | Joseph V. Sinfield, Edward Calder, Bernard McConnell and Steve Colson (2012) How to Identify New Business Models, MIT Sloan Management Review Vol. 53, No.2. |
| 3 | Karl T. Ulrich, Steven D. Eppinger, Maria C. Yang (2020) Product Design and Development, 7th Edition |
| 4 | ASTM Design handbook. |


**Course Outcomes (CO)**

Upon completion of this class, students are expected to

| | |
|---|---|
| **CO1** | Understand the customer expectations and requirements for new products |
| **CO2** | Understand the methods of materials selection for new products |
| **CO3** | Solve social problems by new products development |
| **CO4** | Learn for new product development and launch |

| Course Code | Course Title | CO | Course outcomes At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT764 | Innovation and Product Development | CO1 | Understand the customer expectations and requirements for new products | H | M | H |
| | | CO2 | Understand the methods of materials selection for new products | H | M | H |
| | | CO3 | Solve social problems by new products development | H | M | H |
| | | CO4 | Learn for new product development and launch | H | M | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT765** |
| **Course Title** | **:** | **Energy Storage Systems** |
| **Type of Course** | **:** | OE |
| **Prerequisites** | **:** | NIL |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To become familiarize with energy demands |
| **CLO2** | Acquire insights on various energy storage systems |
| **CLO3** | Study mateirals used in various energy storage systems |
| **CLO4** | Gain insights on futuristic technologies viable for commercialization |

**Course Content**

Energy Storage Systems: Introduction - Energy Demand in India and Sources - Renewable Energy Sources - Power Density Vs. Energy Density –Energy Storage Systems Including Batteries, Supercapacitors, Fuel Cells and Hydrogen Storage

Batteries: Primary And Secondary Batteries (Lithium-Ion, Sodium-Ion, Metal-Air/O2/Co2 Batteries) Working Mechanisms - Battery Components (Cathode, Anode, Electrolyte, Casing Materials) - Nanostructured Materials for Batteries (Carbon-Based and Metal Oxide/Metal Sulfide/MOFs/COFs/MXenes)

Supercapacitors - Electrical Double Layer Model - Principles & Design For EDLC And Pseudocapacitors - Material Prospects - Status & Future Trends. Fuel Cells - Principles For Different Fuel Cells and Materials - Issues & Challenges in Fuel Cells. Hydrogen Storage Methods and Materials- Production and Energy Conversion

Prospects - Discussing Viable Technologies for Commercialization with Emphasis on Environmental Impact, Cost, Efficiency, Advantages, Disadvantages, and Applicability - Integration in Electric Vehicle and Smart Grids.

**References**


| | |
|---|---|
| 1. | Braun, A. Electrochemical energy systems: foundations, energy storage and conversion. Walter de Gruyter GmbH & Co KG. (2018) |
| 2. | Paul, Rajib, Vinodkumar Etacheri, Yan Wang, and Cheng-Te Lin, eds. Carbon based nanomaterials for advanced thermal and electrochemical energy storage and conversion. Elsevier, (2019). |
| 3. | Hirose, Katsuhiko. Handbook of hydrogen storage: new materials for future energy storage. John Wiley & Sons, (2010). |
| 4. | Allen J.Bard and Larry R. Faulkner, Electrochemical methods: Fundamentals and Applications, 2ndEdition John Wiley & Sons. Inc (2004) |
| 5. | San Ping Jiang, Qingfeng Li, Introduction to Fuel Cells Electrochemistry and Materials, Springer Singapore (2021) |

**Course Outcomes (CO)**

At the end of the course, students will be able to

| | |
|---|---|
| **CO1** | Learn about energy demands and various energy storage systems |
| **CO2** | Understand various battery chemistries and their future prospects |
| **CO3** | Select and design materials for energy storage systems |
| **CO4** | Understand Hydrogen production and materials used for hydrogen storage |

| Course Code | Course Title | CO | Course outcomes At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT765 | Energy Storage Systems | CO1 | Learn about energy demands and various energy storage systems | H | L | M |
| | | CO2 | Understand various battery chemistries and their future prospects | H | M | L |
| | | CO3 | Select and design materials for energy storage systems | H | M | H |
| | | CO4 | Understand Hydrogen production and materials used for hydrogen storage | H | M | L |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Course Code** | : | **MT766** | | | | |
| **Course Title** | : | **Artificial Intelligence in Materials Engineering** | | | | |
| **Number of Credits** | | 3 | | | | |
| **LTC Breakup** | : | L | T | P | contact hours | C |
| | | 3 | 0 | 0 | 3 | 3 |
| **Prerequisites (Course code)** | : | NIL | | | | |
| **Course Type** | : | OE | | | | |

**Course Learning Objectives**

To explore the scope of artificial intelligence (AI) in materials engineering and research.

**Course Content**

(Considering that AI in Materials Engineering and Research is an emerging field, the following syllabus is intended to provide an outline for the instructor. This syllabus can be suitably navigated to accommodate the recent and relevant advancements.)

Basics of AI – Mathematical Foundation, History and Evolution; Need for AI in Materials Engineering and Research – Data Analysis, Factor Analysis, Image Analysis, Material Discovery

Machine Learning as a subset of AI – Introduction, Types of Data; Supervised Learning – Basics, Regression, Linear and Non-Linear Regression, Gradient Descent, Logistic Regression; Unsupervised Learning – Clustering; Reinforced Learning

Deep Learning – Introduction; Neural Networks – Feedforward, Backpropagation and Parameters; Types – Convolutional and Recurrent Neural Networks; Autoencoders

Quantitative Microstructure Analysis – Computer Vision, Segmentation, Classification, Object Detection and Counting; Data Visualization – Introduction, Types and Techniques

Leading up to Industry 4.0 – Need, Introduction, Significance and Relevance

**Reference Books**

Artificial Intelligence - A Modern Approach, Stuart Russell, Pearson Publication, 3rd Edition, 2015.

Basics of Artificial Intelligence and Machine Learning, Deeraj Mehrotra, Notion Press, 2019.

Artificial Intelligence by Example, Dennis Rothman, Packt Publishing, 2020

| **Course Outcomes** | |
|---|---|
| At the end of the course, students will be able to | |
| CO1 | Understand the mathematical foundation, history, and evolution of AI, and grasp its necessity in materials engineering for tasks such as data analysis, factor analysis, image analysis, and material discovery. |
| CO2 | Gain knowledge of supervised learning, including regression techniques, gradient descent, and logistic regression, as well as unsupervised learning methods like clustering, and understand the basics of reinforced learning, applying these techniques to analyze and interpret data relevant to materials engineering. |
| CO3 | Introduce neural networks, including feedforward and backpropagation, learn about convolutional and recurrent neural networks, and autoencoders, and apply deep learning methods to tasks such as computer vision, segmentation, classification, object detection, and counting. |
| CO4 | Understand the significance and relevance of Industry 4.0 in the context of AI in materials engineering, learn various data visualization techniques to effectively present and interpret data, and be equipped to use AI-driven approaches to enhance materials engineering practices |

| Course Code | Course Title | CO | Course outcomes<br>At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT766 | Artificial Intelligence in Materials Engineering | CO1 | Understand the mathematical foundation, history, and evolution of AI, and grasp its necessity in materials engineering for tasks such as data analysis, factor analysis, image analysis, and material discovery. | H | L | M |
| | | CO2 | Gain knowledge of supervised learning, including regression techniques, gradient descent, and logistic regression, as well as unsupervised learning methods like clustering, and understand the basics of reinforced learning, applying these techniques to analyze and interpret data relevant to materials engineering. | H | L | M |
| | | CO3 | Introduce neural networks, including feedforward and backpropagation, learn about convolutional and recurrent neural networks, and autoencoders, and apply deep learning methods to tasks such as computer vision, segmentation, classification, object detection, and counting. | H | M | M |
| | | CO4 | Understand the significance and relevance of Industry 4.0 in the context of AI in materials engineering, learn various data visualization techniques to effectively present and interpret data, and be equipped to use AI-driven approaches to enhance materials engineering practices | H | L | H |

| | | |
|---|---|---|
| **Course Code** | **:** | **MT767** |
| **Course Title** | **:** | **Molecular Modeling of Materials** |
| **Type of Course** | **:** | OE |
| **Prerequisites** | **:** | Nil |
| **Contact Hours** | **:** | 3 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

To become familiar with the basic concepts electronic scale and atomic scale modeling techniques useful in materials research.

**Course Content**

Quantum Mechanics – Basic concepts, Schrödinger wave equation, assumptions and approximations, brief introduction to first principle/ab initio methods, applications in materials research

Density functional theory – Electron density, energy terms, exchange correlation functionals, Generalized gradient approximation (GGA), Pseudopotential, DFT exercises

Molecular dynamics - Introduction - Classical mechanics, molecular statics, molecular dynamics; interatomic potentials, Solution for Newton's equations of motion – different algorithms.

Molecular dynamics - Initialization and Integration, energy minimization, estimation of thermodynamic properties, structural properties, thermal properties, MD simulations using LAMMPS

Monte Carlo methods - Introduction, ensembles, algorithms, monte carlo for atomic systems, Modified monte carlo methods-Kinetic Monte Carlo method, Applications of Monte Carlo simulations in different material systems, nucleation and grain growth.

**References**


| | |
|---|---|
| 1. | Lesar, R., Introduction to computational materials science: Fundamentals to applications, Cambridge University Press, UK, 2013. |
| 2. | Lee, J.G., Computational Materials Science: An Introduction, CRC Press, Boca Raton, 2017 |
| 3. | Ohno K, Esfarjani k, Kawazoe Y, Computational materials science: From ab-initio to monte carlo methods, 2$^{nd}$ Ed, Springer-Verlag GmbH Germany, 2018 |


**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | To perform density functional theory simulations to obtain various material properties |
| **CO2** | To understand the principles of molecular dynamics simulations and their fundamentals |
| **CO3** | To perform molecular dynamics simulations for obtaining thermodynamic, structural and thermal properties of different materials. |
| **CO4** | To apply the Monte Carlo simulation methods in materials research. |

| Course Code | Course Title | CO | Course outcomes<br>At the end of the course, students will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MT767 | Molecular Modeling of Materials | CO1 | To perform density functional theory simulations to obtain various material properties | M | M | M |
| | | CO2 | To understand the principles of molecular dynamics simulations and their fundamentals | H | L | H |
| | | CO3 | To perform molecular dynamics simulations for obtaining thermodynamic, structural and thermal properties of different materials. | H | M | H |
| | | CO4 | To apply the Monte Carlo simulation methods in materials research. | M | M | M |