M. Tech Degree

IN

WELDING ENGINEERING

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

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

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	Select their profession as Welding Engineer in Industries as well as in expanding areas of materials, power and energy-related fields.
PEO2	Practice effectively in the emerging and modern Industrial environment with lead role and make timely development toward an establishing newer technology in welding related fields or business.
PEO3	Pursue their careers in academia and develop entrepreneur skill

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. / M. Arch.

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 semesters
Project Phase-I	1	12	Third Semester
Project Phase-II	1	12	Fourth Semester
Total		**80**	**-**

CURRICULUM

SEMESTER I

Code	Course of Study	Credit
MA613	Engineering Mathematics	4
MT601	Design of Weldments	4
MT603	Joining of Materials – I	4
	Programme Elective I	4
	Programme Elective II	3
	Programme Elective III	3
MT609	Metallography, Materials Testing and Characterization Laboratory	2
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SEMESTER II

Code	Course of Study	Credit
MT602	Welding Metallurgy	4
MT604	Welding Codes and Standards	4
MT606	Joining of Materials – II	4
	Programme Elective IV	4
	Programme Elective V	3
	Programme Elective VI	3
MT610	Welding Laboratory	2
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SUMMER TERM (evaluation in the III semester)

Code	Course of Study	Credit
MT612	Internship / Industrial Training / Academic Attachment (I/A) (6 weeks to 8 weeks)	2

SEMESTER III

Code	Course of Study	Credit
MT613	Project Work (Phase I)	12

SEMESTER IV

Code	Course of Study	Credit
MT614	Project Work (Phase II)	12

OPEN ELECTIVES (can be completed between 1 – 4 Semesters)

Code	Course of Study	Credit
MTXXX	Open elective / online course - 1	3
MTXXX	Open elective / online course - 2	3
	TOTAL CREDITS	**80**

PROGRAMME ELECTIVES (PE)

Sl. No.	Code	Course of Study	Credit
1.	MT661	Physical Metallurgy	4
2.	MT662	Testing, Inspection and Characterization	4
3.	MT663	Mechanical Behaviour of Materials	3
4.	MT664	Corrosion Engineering	3
5.	MT665	Computational Techniques	3
6.	MT666	Metallurgical Failure Analysis	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
PROGRAMME SPECIFIC ELECTIVES			
20.	MT701	Electrical Aspects of Welding	3
21.	MT702	Welding Application Technology	3
22.	MT703	Repair Welding and Reclamation	3
23.	MT704	Life Assessment of Welded Structures	3
24.	MT705	Welding Economics and Management	3
OPEN ELECTIVES			
25.	MT761	Design and Selection of Materials	3
26.	MT762	Statistical Quality Control and Management	3
27.	MT763	Intellectual Property Rights	3
28.	MT764	Innovation and Product Development	3
29.	MT765	Energy Storage Systems	3

30.	MT766	Artificial Intelligence in Materials Engineering	3
31.	MT767	Molecular Modeling of Materials	3

Syllabus

Course Code	:	**MA613**
Course Title	:	**Engineering Mathematics**
Type of Course	:	PC
Prerequisites	:	NIL
Contact Hours	:	4 (3 L, 1 T)
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 to comprehend, analyze, design, and create novel products and solution for the real-life 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. MATLAB tutorials.

References

1.	*Grewal, B.S., Higher Engineering Mathematics, Khanna Publishers, New Delhi, India, 2012.*
2.	*Elsgolts, L., Differential Equations and the Calculus of Variations, Mir Publishers, MOSCOW, 1977*
3.	*Jain, M.K., Iyengar, S.R., and Jain, R.K., Numerical Methods for Scientific and Engineering Computation, New Age International (P) Limited, New Delhi, India, 2019.*
4.	*Veerarajan, T., Numerical Methods, Volume III, Tata McGraw Hill Edition, New Delhi, 2009.*
5.	*Reddy, J.N., Introduction to Finite Element Method, Mcgraw Hill, Hightstown, New Jersey, 1993.*
6.	*Desai, C.S. and Abel, J. P., Introduction to Finite Element Method, CBS Publishers & Distributors Pvt Ltd, New Delhi, India, 2005.*

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 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	:	**MT601**
Course Title	:	**Design of Weldments**
Type of Course	:	PC
Prerequisites	:	NIL
Contact Hours	:	4 (3 L, 1 T)
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Design weld joins operating under static and dynamic loading conditions.
CLO2	Analyse and predict the life of weld joints using the concepts of fracture mechanics and identifying the effects of stress concentration build up.
CLO3	Learn the various types of stresses & distortions induced in a component as a result of Welding

Course Content

- Weld joints, weld symbols, and joint design principles. Weld design for static loading: Designing for strength and rigidity, Material – section properties, design under different loading.
- Weld design for dynamic loading: Design for fluctuating and impact loading - dynamic behavior of joints - stress concentrations - fatigue analysis - fatigue improvement techniques - permissible stress- life prediction. Principles and methods and practical approach for crack arresting
- Concept of stress intensity factor - LEFM and EPFM concepts - brittle fracture- transition temperature approach - fracture toughness testing, application of fracture mechanics to fatigue, weldments design for high temperature applications.
- Welding residual stresses - causes, occurrence, effects, and measurements - thermal and mechanical relieving; types of distortion - factors affecting distortion - distortion control methods - prediction - correction, jigs, fixtures, and petitioners.

References

1.	*Parmer. R. S. "Welding Engineering and Technology", Khanna Publications, 1999*
2.	*J Hicks, 2000, Welded Design, Theory and Practice, Elsevier*
3.	*Gray T. G. E. 'Rational Welding Design', Butterworths, 1982*
4.	*Hertzberg R.W., 'Deformation and Fracture of Mechanics of Engineering Materials', John Wiley, 1996*
5.	*Dieter G., 'Mechanical Metallurgy', Tata McGraw Hill, 1988*
6.	*Bhattacharya, 'Weldment Design', Association of Engineers,1991*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Design weld joints for strength and rigidity under static loading conditions.
CO2	Design weld joints for dynamic loading and high temperature applications.
CO3	Analyse and predict the life of weld joints subjected to fatigue and evaluate the effect ofstress concentration on fatigue life of such joints.
CO4	Estimate the ductile to brittle transition temperatures based on fracture toughness testing and understand the LEFM and EPFM concepts in Fracture Mechanics to propose solutions for improvements to fatigue life.
CO5	Identify the various types of stresses and distortions to a component during welding andtakes measures to minimize or eliminate such effects.

Course Code	Course Title	CO	Course outcomes At the end of the course, students will be able	PO1	PO2	PO3
MT601	Design Of Weldments	CO1	Design weld joints for strength and rigidity under static loading conditions.	H	M	H
		CO2	Design weld joints for dynamic loading and high temperature applications.	H	L	H
		CO3	Analyse and predict the life of weld joints subjected to fatigue and evaluate the effect of stress concentration on fatigue life of such joints.	H	L	H
		CO4	Estimate the ductile to brittle transition temperatures based on fracture toughness testing andunderstand the LEFM and EPFM concepts in Fracture Mechanics to propose solutions for improvements to fatigue life.	H	L	H
		CO5	Identify the various types of stresses and distortions to a component during welding and takes measures to minimize or eliminate such effects.	H	M	H

Course Code	**:**	**MT603**
Course Title	**:**	**Joining of Materials - I**
Type of Course	**:**	PC
Prerequisites	**:**	NIL
Contact Hours	**:**	4 (3 L, 1 T)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand working principles of the various manual and automated fusion welding processes.
CLO2	Gain knowledge of the concepts, operating procedures, applications, advantages and limitations of various welding processes

Course Content

- Arc Physics, Power Sources, Manual metal arc welding: Concepts, types of electrodes and their applications, Gas tungsten arc welding: Concepts, processes, and applications; gas metal arc welding, Concepts, processes and applications, types of metal transfer, CO2 welding, pulsed and synergic MIG welding, FCAW.
- Submerged arc welding, advantages and limitations, process variables and their effects, significance of flux-metal combination, modern developments, narrow gap submerged arc welding, applications; electro slag and electro gas welding.
- Plasma welding; Concepts, processes and applications, keyhole and puddle-in mode of operation, low current and high current plasma arc welding and their applications; Magnetically impelled arc butt (MIAB) welding.
- Resistance welding, Concepts, types and applications, Flash butt welding, Stud welding and under water welding.

References

1.	*Parmer R. S., 'Welding Engineering and Technology', Khanna Publishers, 1997*
2.	*Cary, Howard, "Modern Welding Technology', prentice Hall, 1998*
3.	*John Norrish, Advanced welding processes Technologies and process control, Woodhead Publishing Limited, 2006*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Understand working principle of various welding processes.
CO2	Select appropriate power source, fluxes, and shielding gases according to the materials to join and the applications.
CO3	Correlation of welding parameters with the various factors.
CO4	Explain the advantages, limitations and practical applications of various processes.

Course Code	Course Title	CO	Course outcomes At the end of the course, students will be able	PO1	PO2	PO3
MT603	Joining of Materials – I	CO1	Understand working principle of various welding processes.	H	L	H
		CO2	Select appropriate power source, fluxes, and shielding gases according to the materials to join and the applications	H	M	H
		CO3	Correlation of welding parameters with the various factors.	H	M	H
		CO4	Explain the advantages, limitations and practical applications of various processes.	H	M	H

Course Code	**:**	**MT609**
Course Title	**:**	**Metallography, Materials Testing and Characterization 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.

<u>LIST OF EXPERIMENTS</u>:

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.
10. Chemical Composition analysis using spectroscopy.

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, analyse the microstructure of materials.
CO2	Classify the different mechanical testing methods with their inherent merits and limitations.
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, students will be able	PO1	PO2	PO3
MT609	Metallography, Materials testing, and Characterization 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	H	M
		CO2	Classify the different mechanical testing methods with their inherent merits andlimitations.	H	H	M
		CO3	Apply various test methods for characterizing physical properties of materials	H	H	M
		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.	H	H	H

Course Code	**:**	**MT602**
Course Title	**:**	**Welding Metallurgy**
Type of Course	**:**	PC
Prerequisites	**:**	NIL
Contact Hours	**:**	4 (3 L, 1 T)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To gain understanding of heat flow and temperature distribution on weld components based on weld geometry
CLO2	To understand the solidification structure, growth morphology and formation of microstructures of weld and Heat Affected Zone (HAZ).
CLO3	Learn the weldability of ferrous and non-ferrous materials
CLO4	Understand the various weld cracking mechanisms and learn the various weldability testing methods

Course Content

- Heat flow - temperature distribution-cooling rates - influence of heat input, joint geometry, plate thickness, preheat, significance of thermal severity number.
- Epitaxial growth - weld metal solidification - columnar structures and growth morphology- effect of welding parameters - absorption of gases - gas/metal and slag/metal reactions
- Phase transformations- weld CCT diagrams - carbon equivalent-preheating and post heating- weldability of low alloy steels, welding of stainless steels use of Schaffler and Delong diagrams, welding of cast irons
- Welding of Cu, Al, Ti, and Ni alloys – processes, difficulties, microstructures, defects, and remedial measures
- Origin - types - process induced defects, - significance - remedial measures, Hot cracking - cold cracking -lamellar tearing - reheat cracking - weldability tests - effect of metallurgical parameters.

References

1.	*Sindo kou, "Welding Metallurgy", John Wiley & Sons, 2003*
2.	*Linnert G. E., 'Welding Metallurgy', Volume I and II, 4th Edition, AWS, 1994*
3.	*Robert W Messler Jr, Principles of Welding, Processes, Physics, Chemistry and Metallurgy, Wiley-VCH, 2004.*
4.	*Granjon H., 'Fundamentals of Welding Metallurgy', Jaico Publishing House, 1994*
5.	*Kenneth Easterling, 'Introduction to Physical Metallurgy of Welding', 2nd Edition, Butterworth Heinmann, 1992*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Explain the influence of heat input and temperature distribution across a welded structure based on weld geometry.
CO2	Correlate the solidification behaviour and solidification structure of weld zone with the welding parameters.
CO3	Analyse and predict the weldability of various ferrous and nonferrous materials.
CO4	Identify the origin and types of process induced defects and conduct weldability tests.

Course Code	**Course Title**	**CO**	**Course outcomes** **At the end of the course, students will be able**	**PO1**	**PO2**	**PO3**
MT602	Welding Metallurgy	CO1	Explain the influence of heat input and temperature distribution across a welded structure based on welded geometry.	H	M	H
		CO2	Correlate the solidification behaviour and solidification structure of weld zone with the welding parameters.	H	M	H
		CO3	Analyse and predict the weldability of various ferrous and nonferrous materials.	H	M	H
		CO4	Identify the origin and types of process induced defects and conduct weldability tests.	H	M	H

Course Code	**:**	**MT604**
Course Title	**:**	**Welding Codes and Standards**
Type of Course	**:**	PC
Prerequisites	**:**	NIL
Contact Hours	**:**	4 (3 L, 1 T)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand the various codes and standards on welding applications.
CLO2	Gain knowledge to apply a specific code for a given welding application

Course Content

- Design requirements, allowable stress values, workmanship and inspection, introduction to welding codes and standards, AWS D1.1
- Process and product standards for manufacturing of pipe - welding procedure and welder qualification, field welding and inspection, API 1104 and API5L
- Design requirements, fabrication methods, joint categories, welding and inspection, post weld heat treatment and hydro testing, ASME II -C, V, VIII and IX
- Welding procedure specification, procedure qualification records, performance qualification, variables
- Introduction to materials standards and testing of materials, consumables testing and qualification as per ASME/AWS requirements.

References

1.	*AWS D1.1 Structural Welding Code*
2.	*API 5L*
3.	*API 1104*
4.	*ASME Section VIII - Division 1*
5.	*ASME Section IX*
6.	*ASME Section II Part A and C*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Identify various design requirements and applicability of AWS D 1.1.
CO2	Apply API 1104 and AP15L for pipe welding applications.
CO3	Apply ASME II, V, VIII and IX for boiler fabrication.
CO4	Understand and apply WPS, PQR and performance qualification variables for a specific welding application.
CO5	Understand different materials standard, testing methods and consumable testing.

Course Code	**Course Title**	**CO**	**Course outcomes** **At the end of the course, students will be able**	**PO1**	**PO2**	**PO3**
MT604	Welding Codes and Standards	CO1	Identify various design requirements and applicability of AWS D 1.1.	L	H	H
		CO2	Apply API 1104 and AP15L for pipe welding applications.	L	H	H
		CO3	Apply ASME II, V, VIII and IX for boiler fabrication.	L	H	H
		CO4	Understand and apply WPS, PQR and performance qualification variables for a specific welding application.	M	H	H
		CO5	Understand different materials standard, testing methods and consumable testing.	M	H	H

Course Code	**:**	**MT606**
Course Title	**:**	**Joining of Materials - II**
Type of Course	**:**	PC
Prerequisites	**:**	NIL
Contact Hours	**:**	4 (3 L, 1 T)
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	Understand the various manual and automated welding processes available.
CLO2	Gain knowledge of the concepts, operating procedures, applications, advantages and limitations of various solid-state welding processes

Course Content

- Friction welding: Concepts, types, and applications. Friction stirs welding: Metal flow phenomena, tools, process variables and applications and induction pressure welding: Process characteristics and applications.
- Explosive, diffusion and ultrasonic welding, principles of operation, process characteristics and applications
- EBW: Concepts, types, and applications. LBW: Physics of lasers, types of lasers, operation of laser welding setup, advantages and limitations, applications
- Soldering: Techniques of soldering, solders, phase diagram, composition, applications Brazing: Wetting and spreading characteristics, surface tension and contact angle concepts, brazing fillers, role of flux and characteristics, atmospheres for brazing, adhesive bonding
- Cladding, Surfacing and Cutting, Hybrid welding, Automation and Robotics in welding.

References

1.	Nadkarni S.V., ‘Modern Arc Welding Technology’, Oxford IBH Publishers, 1996
2.	David H. Phillips, 2023, Welding Engineering: An Introduction John Wiley & Sons publication
3.	Christopher Davis, ‘Laser Welding - A Practical Guide’, Jaico Publishing House, 1994
4.	Parmar R S, Welding Engineering and Technology, Khanna Publishers, 1997
5.	Mishra. R.S and Mahoney. M.W, Friction Stir Welding and Processing, ASM,2007

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

CO1	Explain the principle of friction welding and its variants.
CO2	Explain the process, advantages, limitations and practical applications of explosive welding, electron beam welding and laser welding.
CO3	Explain the concepts, various operating procedures and applications of soldering and brazing.
CO4	Explain the concepts and applications of various types of cladding, surfacing and cutting.

Course Code	Course Title	CO	Course outcomes At the end of the course, students will be able	PO1	PO2	PO3
MT606	Joining of Materials - II	CO1	Explain the principle of friction welding and its variants.	H	M	H
		CO2	Explain the process, advantages, limitations and practical applications of explosivewelding, electron beam welding and laser welding.	H	M	H
		CO3	Explain the concepts, various operating procedures and applications of soldering and brazing.	H	M	H
		CO4	Explain the concepts and applications of various types of cladding, surfacing andcutting.	H	M	H

Course Code	**:**	**MT610**
Course Title	**:**	**Welding Laboratory**
Type of Course	**:**	Laboratory
Prerequisites	**:**	Nil
Contact Hours	**:**	3
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	**To gain knowledge on practical aspects of different welding processes and able to apply them for various engineering applications.**

LIST OF EXPERIMENTS

1. Arc striking practice.
2. Bead-on-plate welding.
3. Wire arc additive manufacturing using CMT.
4. Effect of welding parameters on weld bead by
   - GTA welding
   - GMA welding
   - Submerged arc welding
5. Microstructural observation of weldments
   - Carbon steel
   - Stainless steel
   - Aluminum alloy
   - Titanium alloy
   - Dissimilar joints
6. Practice for preparation of welding procedure specification.
7. Practice for preparation of procedure qualification record.

Course Outcomes (CO)

At the end of the course student will be able

CO1	Gain knowledge in practical aspects of MMAW, GTAW, GMAW and SAW.
CO2	Gain knowledge on welding of carbon steel, stainless steel, aluminium, titaniumand dissimilar joints.
CO3	Able to write WPS and PQR for MMAW and GTAW

Course Code	**Course Title**	**CO**	**Course outcomes** **At the end of the course, students will be able**	**PO1**	**PO2**	**PO3**
MT610	Welding Laboratory	CO1	Gain knowledge in practical aspects of MMAW, GTAW, GMAW and SAW.	H	M	H
		CO2	Gain knowledge on welding of carbon steel, stainless steel, aluminium, titaniumand dissimilar joints.	H	M	H
		CO3	Able to write WPS and PQR for MMAW and GTAW.	H	M	H

Course Code	**:**	**MT613**
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	Produce a thesis of publishable quality. Effectively present and defend research orally.
CO3	Interpret theories and doctrines and give recommendations where appropriate. Knowledge on the chosen topic and apply the knowledge, experience, and skillslearned.
CO4	Produce a thesis of publishable quality. Effectively present and defend research orally.

Course Code	**Course Title**	**CO**	**Course outcomes** **At the end of the course, students will be able**	**PO1**	**PO2**	**PO3**
MT613	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	H	H
		CO2	Produce a thesis of publishable quality. Effectively present and defend research orally.	H	H	H
		CO3	Interpret theories and doctrines and give recommendations where appropriate. Knowledge on the chosen topic and apply the knowledge, experience, and skills learned.	H	H	H
		CO4	Produce a thesis of publishable quality. Effectively present and defend research orally.	H	H	H

Course Code	**:**	**MT614**
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** **At the end of the course, students will be able**	**PO1**	**PO2**	**PO3**
MT614	Project work Phase –II	CO1	Interpret theories and doctrines and give recommendations where appropriate.	H	H	H
		CO2	Acquire knowledge on the chosen topic and apply the knowledge, experience, and skills learned	H	H	H
		CO3	Produce a thesis of publishable quality	H	H	H
		CO4	Effectively present and defend research orally.	H	H	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, Normalizing, 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 entropy alloys, intermetallic compounds- Aluminides, Silicide, 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, BabaBarkha Nath Printers, Delhi.*
5.	*Willam D. Callister, Jr. Materials Science and Engineering, Wiley India Pvt. Ltd.*
6.	*Vijendra Singh, Physical Metallurgy, Standard Publishers.*

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 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	**:**	4
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 Characterisation, 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	**:**	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

- 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-Cottrell 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, super plasticity 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 Behaviour of Materials", 2nd Edition, 2013, Overseas Press India PrivateLimited, ISBN: 81-88689-69-6*
5.	*Norman E. Dowling, "Mechanical Behaviour of Materials", International Edition (4th), Contributed by K.Siva Prasad 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 behaviour 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, Evan's diagram, Flade potential.
- Different forms of corrosion: atmospheric/uniform, pitting crevice, intergranular, stress corrosion, corrosion fatigue, dealloying, high temperature oxidation-origin and mechanism with specific examples.
- Corrosion testing and monitoring: Non-Electro chemical 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, potentionstatic polarization experiment and atmospheric corrosion using colour indicator method.
CO3	Analyse galvanic corrosion, pitting corrosion and stress corrosion cracking.
CO4	Estimate the corrosion resistance by IGC susceptibility test, salt spray testand 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, potentionstatic polarization experiment and atmospheric corrosion using colour indicator method.	M	H	M
		CO3	Analyse galvanic corrosion, pitting corrosion and stress corrosion cracking	H	M	H
		CO4	Estimate the corrosion resistance by IGC susceptibility test, salt spray testand 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, Modelling 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 Palankeezhe Balan, published by Elsevier, 2018.
3.	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 aluminum alloys, thermochemical processes -industrial practices.
- Surface pre-treatment, deposition of copper, zinc, nickel, and chromium - principles and practices, alloy plating, electro composite 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 behavior. Weld Surfacing.

References

1.	*Sudarshan T S, 'Surface modification technologies - An Engineer's guide', MarcelDekker, New York, 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 principles – 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, convergence 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 – Practice 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 Modelling', 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 software.
CO4	To visualize modeling of complex industrial scale processes in material processing

Course Code	Course Title	CO	Course outcomes 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 modelling 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 engines: particulate filters, regenerative methods, expendable catalyst additive, deNo$_x$ 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 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 Assessment, 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 semi-conductors, 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, Potentio dynamic 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. Introduction to Concrete corrosion technologies, Corrosion in Hydrogen Generation and Storage devices.

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-Inter science, 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 aswell 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 – Software 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 be 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 Transformation**
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, Partition less 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, 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, diffusion less, 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, A2B04 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 explain the crystal structure of interstitial compounds and solid solution
CO4	To identify and characterize the various ionic and electronic defects in crystal structure
CO5	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', Oxford IBH, 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 materialsto meet the demand of the research and industrial needs.
CO2	Characterize the various powders (materials) based on the engineeringapplications Differentiate the processing routes for various powders (materials) and associated technology.
CO3	Define modern day processing routes and apply them successfully to materials 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-conventionalmaterials 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 materialsto 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 tomaterials processing.	H	M	H
		CO4	Apply the powder metallurgy concepts to design new materials for advancedengineering 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. Ghoshdastidar, "Computer Simulation of Flow and Heat Transfer", TataMcGraw Hill, New Delhi, 1998

Course Outcomes (CO)

At the end of the course student will be able

CO1	Understand the capabilities provided by various modelling 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 Modelling	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	**:**	OE
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.
- Ultra sonic 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 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	**:**	**MT701**
Course Title	**:**	**Electrical Aspects of Welding**
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	3
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To gain understanding of static and dynamic characteristics of the electric arc and its associatedpower characteristics.
CLO2	To learn the basic principles, methods and circuit components that control operating power and thevolt-ampere characteristics in electric resistance and arc welding
CLO3	To gain knowledge of the operating principles of Alternators, D.C. generators and motors used forwelding.
CLO4	To understand the operation and regulation of wire feed system and controlling or arcs through theuse of NC and computer controlled welding machines.

Course Content

- Physical phenomenon occurring in the arc, potential distribution, static and dynamic arc characteristics; types of forces and metal transfer in the arc; arc blow, power source characteristics; volt-ampere relationship and its measurement,
- Basic principles, different methods of control of volt-ampere characteristics, operation, volt control, slope control, dual control, resistance welding transformers, welding rectifiers, choice of diode materials, use of thyristors, inverters
- Alternators and D.C. generators for welding, three brush generators, setting of power source, characteristics of D.C. motors, synchronous motors.
- Wire-feed system, carriage movement control, crater filling devices, up and down slopes, seam tracking devices, magnetic control of arcs, pulsing techniques, NC and computer-controlled welding machines, controls in resistance welding machines
- Measurements of welding current, voltage, temperature, load and displacement, X-Y and strip chart recorders. CRO, LVDT, arc welding analyzer, resistance welding monitor

References

1.	*Welding Handbook, Volume 2, 7th Edition, American Welding Society.*
2.	*Richardson V. D., 'Rotating Electric Machinery and Transformer Technology', Prentice Hall of India, 1978.*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Explain the physical phenomenon occurring in the arc and the types of forces and metal transfer inthe arc based on measurements of power source characteristics.
CO2	Select the right choice of diode material, thyristors and inverters based on the understanding of the basic principles and methods for controlling the volt-ampere characteristics of the electric welding machines.
CO3	Recognize and list the wire feed systems, carriages control techniques, tracking devices andmagnetically control the arc using NC and computer controlled Welding machines
CO4	Measure the welding current, voltage, temperature, load and displacement using equipment's such as CRO, LVDT, arc welding analyser and resistance welding monitors

Course Code	Course Title	CO	Course outcomes At the end of the course, students will be able	PO1	PO2	PO3
MT701	Electrical Aspects of Welding	CO1	Explain the physical phenomenon occurring in the arc and the types of forces and metal transfer in the arc based on measurements of power source characteristics.	H	M	H
		CO2	Select the right choice of diode material, thyristors and inverters based on the understanding of the basic principles and methods for controlling the volt-ampere characteristics of the electric welding machines.	H	M	H
		CO3	Recognize and list the wire feed systems, carriages control techniques, tracking devices and magnetically control the arc using NC and computer controlled Welding machines.	H	M	H
		CO4	Measure the welding current, voltage, temperature, load and displacement using equipment's such as CRO, LVDT, arc welding analyser and resistance welding monitors.	H	M	H

Course Code	**:**	**MT702**
Course Title	**:**	**Welding Application Technology**
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	3
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To learn the Heat exchanges, power cycles, heating equipment's, materials and process used in making and testing of weld joints
CLO2	To understand the materials, processes, fabrication techniques used in welding of pressure vessels and in automatic welding systems used for automobile industry
CLO3	To gain knowledge of the materials, processes, fabrication, inspection and stringent quality control procedures used in Oil, gas and nuclear industries

Course Content

- Heat exchanges, power cycle piping, super heaters, reheaters, economizer, auxiliary pipes, materials, processes and testing/inspection.
- Materials, processes, fabrication techniques and field welding for pressure vessel applications
- Materials, processes, fabrication and construction, use of automatic welding and systems in automobile industry, automation
- Oil and gas industry, materials, processes, fabrication, inspection and testing, case studies, recent trends and developments.
- Materials, processes, fabrication, inspection and testing, reasons for stringent quality control measures in nuclear industry

References

1.	*American Welding Society, 'Guide for Steel Hull Welding', 1992*
2.	*Gooch T. S., 'Review of Overlay Welding Procedure for Light Water Nuclear Pressure Vessels', American Welding Society, 1991*
3.	*Winter Mark H., 'Materials and Welding in Off-Shore Constructions', Elsevier, 1986*
4.	*Welding Institute Canada,' Welding for Challenging Environments', Pergamon Press,1996*
5.	*Mishra. R.S and Mahoney. M.W, Friction Stir Welding and Processing, ASM,2007*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Explain the Heat exchanges, power cycles, heating equipment's, materials andprocesses used in assembling, welding and testing of weld joints.
CO2	Select the appropriate materials, processes and fabrication techniques for welding ofpressure vessels, automobile components, equipment's used in oil and gas industries,and nuclear power plants.
CO3	Carry out inspection and testing based on case studies, recent trends and developments and adopt stringent quality control measures in nuclear plants.

Course Code	Course Title	CO	Course outcomes At the end of the course, students will be able	PO1	PO2	PO3
MT702	Welding Application Technology	CO1	Explain the Heat exchanges, power cycles, heating equipment's, materials and processes used in assembling, welding, and testing of weld joints.	H	M	H
		CO2	Select the appropriate materials, processes and fabrication techniques for welding ofpressure vessels, automobile components, equipment's used in oil and gas industries,and nuclear power plants.	H	M	H
		CO3	Carry out inspection and testing based on case studies, recent trends and developments and adopt stringent quality control measures in nuclear plants.	H	M	H

Course Code	**:**	**MT703**
Course Title	**:**	**Repair Welding and Reclamation**
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	3
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To acquire knowledge and to solve problems associated with failure and to update personnel on the latest technology to ensure welded structure, pressure vessel, plant and machinery would be maintained in good operating condition and at low maintenance cost.

Course Content

- Engineering aspects of repair, aspects to be considered for repair welding, techno-economics, repair welding procedures for components made of steel casting and cast iron, half bead, temper bead techniques, usage of Ni base filler metals, Weld surfacing.
- Damaged bends in gas transmission pipeline, heat exchanger repair techniques-explosive expansion, plugging, etc., creep damaged high-temperature components, repair of cracked petroleum pressure vessel/reactor.
- Types of wear, wear resistant materials, selection of materials for various wear applications; reclamation surfacing techniques, selection of welding process for reclamation.
- Integrating repair/maintenance into on-going operations; radiation protection, steam generator repair, plugging
- Various types of hardness tests, NDE of surface coatings, characterization of coatings, photothermal imaging, case histories on selection application/materials combination

References

1.	*Dobly R.E., Kent K.S., „Repair and Reclamation", The Welding Institute, 1986*
2.	*Maintenance Welding in Nuclear Power Plants", American Welding Society, 1988*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Improve the quality of welding which will benefit the industry in terms ofproductivity and savings.
CO2	Understand the types of cracks and implement proper repair method to enhancethe life of welded structures like boiler, pipeline, bridges etc.
CO3	Develop the skills to carry out practical feasible repair techniques maintaining low cost.
CO4	Selection of repair welding and apply techno-economics for practicalproblems.

Course Code	Course Title	CO	Course outcomes **At the end of the course, students will be able**	PO1	PO2	PO3
MT703	Repair Welding and Reclamation	CO1	Improve the quality of welding which will benefit the industry in terms of productivity and savings.	H	M	H
		CO2	Understand the types of cracks and implement proper repair method to enhancethe life of welded structures like boiler, pipeline, bridges etc.	H	M	H
		CO3	Develop the skills to carry out practical feasible repair techniques maintaining lowcost.	H	M	H
		CO4	Selection of repair welding and apply techno-economics for practical problems.	H	M	H

Course Code	**:**	**MT704**
Course Title	**:**	**Life Assessment of Welded Structures**
Type of Course	**:**	PE
Prerequisites	**:**	NIL
Contact Hours	**:**	3
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To acquire knowledge in life assessment of welded structure and ability to analyse and apply fracture mechanics design concepts to welded structures.
CLO2	Ability to apply fitness-for-service methods and standards for design of new andfor life-assessment of in-service welded structures.

Course Content

- Historical evolution and operation of power plants and petrochemical plants-general description, temperature, pressures and materials, failure in plants-definition of failure
- Toughness, DBTT, LEFM, EPFM, temper embrittlement, hydrogen embrittlement, case histories, Strain gauge measurement.
- Mechanisms, parametric extrapolation techniques - LM, OSD, MH, MB and MCM, design rules, cumulative damage, crack growth models, RLA methodology for bulk and localized damages
- High and low cycle fatigue, Coffin-Manson relationship, creep fatigue interaction, failure mechanism maps, thermal fatigue (TF), thermal-mechanical fatigue (TMF), thermal- mechanical fatigue life prediction, crack growth in fatigue
- Materials, damage mechanisms and RLA of boiler tubes, header, steam pipes, rotors, steam casings, valves and steam chests, steam turbine blades, high-temperature bolts. Nondestructive assessment methods.

References

1.	*Viswanathan R. „Damage Mechanisms and Life Assessment of High Temperature Components", American Society for Metals", 1989.*
2.	Das A.K., 'Metallurgy of Failure Analysis', Tata McGraw Hill, 1993.

Course Outcomes (CO)

At the end of the course student will be able

CO1	An ability to select and design welding materials, processes and inspectiontechniques based on application, fabrication and service conditions.
CO2	An ability to develop welding procedures that specify materials, processes and inspection requirements.
CO3	An ability to design welded structures and components to meet application requirements of static and fatigue loading.
CO4	An ability to use the techniques, skills, and modern engineering tools necessaryfor engineering practice.

Course Code	Course Title	CO	Course outcomes At the end of the course, students will be able	PO1	PO2	PO3
MT704	Life assessment of welded structures	CO1	An ability to select and design welding materials, processes and inspectiontechniques based on application, fabrication, and service conditions.	H	M	H
		CO2	An ability to develop welding procedures that specify materials, processes and inspection requirements.	H	M	H
		CO3	An ability to design welded structures and components to meet applicationrequirements of static and fatigue loading.	H	M	H
		CO4	An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	H	M	H

Course Code	:	**MT705**
Course Title	:	**Welding Economics and Management**
Type of Course	:	PE
Prerequisites	:	NIL
Contact Hours	:	3
Course Assessment Methods	:	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

CLO1	To acquire knowledge in welding economics in selection of process,consumables and work piece materials
CLO2	To acquire knowledge in management

Course Content

- Welding design, selection of electrodes, size, type and metal recovery, electrode efficiency, stub thrown away, over welding and joint, fit - up welding position operation factor, jigs, fixtures, positioners, operator efficiency.
- Need for time standards, definition of standard time, various methods of computing standard time, analytical calculation, computerization of time standards.
- Definition of terms, composition of welding costs, cost of consumables, labour cost, costoverheads, formulae for total cost, cost curves for different processes like CO_2, SAW, ESW, etc., mechanization in welding, job shop operation.
- Process vs product layout, construction, service consideration, employees, services, process services, etc., different workstations in shop floor and their arrangements.
- Selection and installation of equipment, safe handling of equipment, production control, planning for welding processes and materials, inventory control; basic aspects of financial management and manpower planning.

References

1	*Bathy J., „Industrial Administration and Management, 1984*
2	*Pendar J. A., „Welding Projects - A Design Approach,1977*
3.	*Welding Institute U.K., „Standard Data for Arc Welding,1994*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Know the importance of effective costing.
CO2	Know the factors influencing welding costs.
CO3	Understand how to reduce welding costs and calculation of cost of a weldingproject.
CO4	Know the meaning, importance, types and characteristics of maintenance systemand organization of a maintenance department.
CO5	Understand and solve problems relating to calculation of welding cost of given projects.
CO6	Apply management skills in details ways for reducing welding cost.

Course Code	Course Title	CO	Course outcomes At the end of the course, students will be able	PO1	PO2	PO3
MT705	Welding Economics and Management	CO1	Know the importance of effective costing.	H	M	H
		CO2	Know the factors influencing welding costs.	H	M	H
		CO3	Understand how to reduce welding costs and calculation of cost of a weldingproject.	H	M	H
		CO4	Know the meaning, importance, types and characteristics of maintenance system and organization of a maintenance department.	H	M	H
		CO5	Understand and solve problems relating to calculation of welding cost of givenprojects.	H	M	H
		CO6	Apply management skills in details ways for reducing welding cost.	H	M	H

Course Code	**:**	**MT761**
Course Title	**:**	**Design and Selection of Materials**
Type of Course	**:**	OE
Prerequisites	**:**	NIL
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 – e.g. Automotive, Nuclear, and Aerospace components.

References

1.	*M.F. Ashby, "Materials Selection in Mechanical Design' – Third edition, Elsevierpublishers, Oxford, 2005.*
2.	*Gladius Lewis, "Selection of Engineering Materials", Prentice Hall Inc, New Jersey,USA, 1995.*
3.	*Charles.J.A. and Crane, F.A.A., "Selection and Use of Engineering Materials",Butterworths, London, UK, 1989*

Course Outcomes (CO)

At the end of the course student will be able

CO1	Understand types of materials and properties.
CO2	Know different methods for materials selection.
CO3	Know different methods for process selection.
CO4	Selection of materials for Specific engineering applications and process.

Course Code	Course Title	CO	Course outcomes At the end of the course, students will be able	PO1	PO2	PO3
MT761	Design and Selection of Materials	CO1	Understand types of materials and properties.	H	L	M
		CO2	Know different methods for materials selection.	H	L	L
		CO3	Know different methods for process selection.	H	L	M
		CO4	Selection of materials for Specific engineering applications and processes.	M	M	H

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 quality management.
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 qualitymanagement.	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 Kit-Para -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 Trademark – Trademark Registration Process – Post registration Procedures – Trademark maintenance - Transfer of Rights - Inter partes Proceeding – Infringement - Dilution Ownership of Trademark – Likelihood of confusion - Trademarks claims – Trademarks Litigations – International Trademark Law
- Introduction to Copyrights – Principles of Copyright Principles -The subjects Matter of Copyright – 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 - Limitations - Copyright disputes and International Copyright Law – Semiconductor Chip Protection Act
- Introduction to Trade Secret – Maintaining Trade Secret – Physical Security – Employee Limitation - Employee confidentiality agreement - Trade Secret Law - Unfair Competition
- Trade Secret Litigation – 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.	Prabuddha 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 secret.

Course Code	**Course Title**	**CO**	**Course outcomes** **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 uunderstand 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 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 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	**:**	**MT 765**
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 materials 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 Sulphide/MOFs/COFs/MXenes)
- Supercapacitors - Electrical Double Layer Model - Principles & Design for EDLC And Pseudo capacitors- 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**
Type of Course	**:**	OE
Prerequisites	**:**	NIL
Contact Hours	**:**	3
Course Assessment Methods	**:**	Continuous Assessment, End Assessment

Course Learning Objectives (CLO)

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

References:

1.	Artificial Intelligence - A Modern Approach, Stuart Russell, Pearson Publication, 3rd Edition, 2015.
2.	Basics of Artificial Intelligence and Machine Learning, Deeraj Mehrotra, Notion Press, 2019.
3.	Artificial Intelligence by Example, Dennis Rothman, Packt Publishing, 2020

Course Outcomes (CO)

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 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 modelling 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, 2nd 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 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